ESTIMATION OF ANIMAL POPULATION TRENDS AND ANNUAL INDICES FROM A SURVEY OF CALL-COUNTS OR OTHER INDICATIONS

Paul H. Geissler, Patuxent Wildlife Research Center

The estimation of time trends in the sizes of animal populations provides important information for the management of these species. Reliable annual estimates of the absolute animal population size are often impractical to obtain. Instead some indicator of their abundance such as the number of individuals heard calling on standardized routes is often used. I will use the Mourning Dove Call-Count Survey as an example of the use of such indicators.

Currently the national Mourning Dove Call-Count Survey encompasses more than 1,000 routes. They were selected as a stratified random sample with optimal allocation of routes to physiographic strata. The primary sampling units (PSU) are squares, 20 miles on a side. One cluster subsample in the form of a route along rural roads was selected from each PSU that was included in the sample. The sample routes are used each year without drawing a new sample. Each route has 20 listening stations spaced at 1.6 km (1 mi) intervals. At each station, the number of doves heard calling is recorded during a 3 min period.

The dove population of a PSU (route) is equal to the product of area a and density ($K\,\gamma_{sry}$). Thus

$$P_{sry} = a\ K\ \gamma_{sry} \tag{1}$$

where s indexes strata, r indexes routes (PSUs), y indexes years, and γ_{sry} is the true call-count on the route. The constant K that converts the call-count on a route to a density for the PSU cannot be estimated with the call-count data. It is assumed to be the same for all years and all areas so that it will cancel out of the estimates.

If K were known, the dove population of a stratum in year y, $P_{s.y} = \Sigma_{r=1}^{N_s} P_{sry}$, could be estimated using (1) by

$$\hat{P}_{s.y} = N_s\ \Sigma_{r=1}^{n_s}\ \hat{P}_{sry}/\ n_s$$

$$= A_s\ K\ \Sigma_{r=1}^{n_s}\ \hat{\gamma}_{sry}/n_s \tag{2}$$

where N_s = number of PSUs in stratum, n_s = number of sampled PSUs (routes) in stratum, and $A_s = (N_s\ a)$ = area of stratum.

<u>Estimation of population trends</u>

I will refer to the rate of population change over time as a population trend. I think it is reasonable to define this population trend for a state or management unit (group of states) as the ratio of the total dove population for that area in one year to the population in the preceding year.

$$\beta_{..y} = P_{..(y+1)}/P_{..y} \tag{3}$$

where $P_{..y} = \Sigma_s\ P_{s.y}$ is the total population of the state or management unit. Often one is interested in estimating the average trend over a number of years. This average trend could be estimated from the annual population totals $P_{..y}$. However, if some routes are not run every year, the estimated annual totals are affected by which routes happen to be run in a particular year. Estimating an average trend on each route and then expanding the route trend estimates removes that source of variation and also allows us to use covariables to control observer and disturbance effects.

To illustrate the estimation of trends, consider a simple situation with 3 years and 2 PSU.

Year	1	2	3	Aver. trend	Geom. mean
Population in PSU 1	40	60	90	1.50	60
Population in PSU 2	8	4	2	0.50	4
Total population	48	64	92	1.38	
Annual trend		1.33	1.44		

The annual trends can be estimated by the ratios of the total population in successive years. These trends change each year although the trend in each PSU is constant because the relative sizes of the PSU populations are changing. The average trend in a PSU is estimated using a linear regression on the logarithmic scale. The annual trend for strata and larger areas in the mean year can be estimated by the mean of the PSU average trends, weighted by their geometric mean populations:
(1.50 * 60 + 0.50 * 4) / (60 + 4) = 1.44 .
Although one would like to estimate the trends based on the total population, this is not practical in situations where there are missing counts.

Year	1	2	3	Aver. trend	Geom. mean
Population in PSU 1	40	60	?	1.50	49.0
Population in PSU 2	?	4	2	0.50	2.8
Total population	?	64	?	?	
Annual trend		?	?		

However in this situation, one can still estimate the annual trend in the mean year by the mean of the PSU average trends, weighted by their geometic mean populations
(1.50 * 49.0 + 0.50 * 2.8)/(49.0 + 2.8) = 1.45.

The call-counts on a route are affected by the observer differences and by the amount of disturbance (noise, etc.). These effects can be modeled as

$$c_{sry} = \gamma_{sry}\ \theta_{sri}\ \delta_s^{d_{sry}}\ \epsilon_{sry} \tag{4}$$

where c_{sry} = number of birds heard calling, γ_{sry} = true call-count, θ_{sri} = effect of observer i, δ_s = disturbance coefficient, d_{sry} = observed disturbance (a covariable), and ϵ_{sry} = error term with $\ln(\epsilon_{sry}) = \epsilon'_{sry} \sim N[0, V(\epsilon')]$. Greek letters are used to represent parameters, lower case Roman letters are used to represent estimates and sample values, and capital Roman letters are used to represent population values. Quantities on the logarithmic scale are indicated by a prime to distinguish them from the corresponding quantities on the arithmetic scale.

A multiplicative model is appropriate because the call-counts appear to be lognormally distributed. Multiplicative errors are expected because a change in the hearing radius of the observer will change the proportion of birds that are heard. Taking logarithms, (4) becomes a linear regression.

$$c'_{sry} = \gamma'_{sry}+\theta'_{sri}+\delta'_s\ d_{sry}+\epsilon'_{sry} \quad (5)$$

where $c'_{sry} = \ln(c_{sry}+0.5)$ because the logarithm of zero is not defined.

Caution is required when disturbance is included as a covariable in the model (5). Because disturbance often increases with time, adjusting for disturbance may also adjust out other time trends as well.

The trend on an individual route $\beta_{sry} = P_{sr(y+1)} / P_{sry}$. Substituting (1), $\beta_{sry} = \gamma_{sr(y+1)}/\gamma_{sry}$. If the trend is the same in all years, $\gamma_{sry} = \gamma_{sr\bar{y}}\ \beta_{sr.}^{(y-\bar{y})}$ where $\bar{y}$ is the mean year. Substituting this restriction in (4),

$$c_{sry} = \gamma_{sr\bar{y}}\ \beta_{sr.}^{(y-\bar{y})}\ \theta_{sri}\ \delta_s^{d_{sry}}\ \epsilon_{sry} \quad (6)$$

Taking logarithms

$$c'_{sry} = \gamma'_{sr\bar{y}}+\beta'_{sr.}(y-\bar{y})+\theta'_{sri}+\delta'_s d_{sry}+\epsilon'_{sry} \quad (7)$$

If the trend β_{sry} is not the same in all years, fitting $\hat{\beta}_{sr.}$ will estimate some average trend.

There is probably a long term population trend caused by habitat changes superimposed on short term fluctuations resulting from weather, disease, etc. Here I am interested in estimating the long term trends. Routes with all zero counts are not used because these routes do not have any information about population changes.

Ordinary linear regression provides the best linear unbiased estimate of $\beta'_{sr.}$ from (7). Bradu and Mundlak (1970) have shown that if ϕ' is an estimable linear combination of the regression parameters on the logarithmic scale, then the uniformly minimum variance unbiased estimate of $\phi = \exp(\phi')$ is

$$\hat{\phi}=T(\hat{\phi}')=\exp(\hat{\phi}')g_m[-(m+1)\ \hat{v}(\hat{\phi}')/2m] \quad (8)$$

where m = residual degrees of freedom,

$\hat{v}(\hat{\phi}')$ = estimated variance of $\hat{\phi}'$,

$g_m(t) = \Sigma_{k=0}^{\infty} f_k(t)$, $f_0(t) = 1$, and

$f_{k+1}(t) = [f_k(t)\ m^2\ t] / [(m+2k)(m+1)(k+1)]$

for $k \geq 0$. The summation is continued until $f_k(t) < 1E-9$. If the sequence $f_k(t)$ diverges,

$$\hat{\phi} \cong T(\hat{\phi}') = \exp[\hat{\phi}'-0.5\hat{v}(\hat{\phi}')]$$

is used. $\beta_{sr.}$ is estimated as

$$\hat{\beta}_{sr.} = T(\hat{\beta}'_{sr.}) \ . \quad (9)$$

The call-count in the mean year $\gamma_{sr\bar{y}}$ is estimated by the marginal mean. With observer and disturbance effects in the model (7), $\gamma_{sr\bar{y}}$ is not estimable. An estimated marginal mean (least square mean) is defined as the arithmetic mean of all the cell means for a particular level of a factor with any covariables taken at their mean levels (Searle, Speed, and Milliken 1980; Ray 1982: 177-178)

$$\tilde{\gamma}'_{sr\bar{y}} = \gamma'^{o}_{sr\bar{y}}+\Sigma_{i=1}^{q_{sr}}\theta'^{o}_{sri}/q_{rs}+\delta'^{o}_s\ \bar{d}_{sr} \quad (10)$$

where a super o indicates a solution to the normal equations and where q_{sr} = number of observers and $\bar{d}_{sr.}$ = mean disturbance.

The estimated marginal mean is back transformed (8) as

$$\tilde{\gamma}_{sr\bar{y}} = T(\tilde{\gamma}'_{sr\bar{y}}) \ . \quad (11)$$

Some routes are relocated and others are established or discontinued during the period of interest. In these situations, estimating a marginal mean call-count for the mean year may involve extrapolation beyond the data points along the fitted line, resulting in unstable (unreliable) estimates. In other situations, the route marginal means may not be estimable. In both situations, a geometric mean call-count is used instead of the (geometric) marginal mean. The reduced model

$$c_{sry} = \bar{\gamma}_{sr.}\ \epsilon_{sry} \quad (12)$$

is fitted by taking logarithms

$$c'_{sry} = \bar{\gamma}'_{sr.} + \epsilon'_{sry} \quad (13)$$

and then back transforming as

$$\hat{\bar{\gamma}}_{sr.} = T(\hat{\bar{\gamma}}'_{sr.}) \ . \quad (14)$$

The stratum trend may be viewed as a mean of the route trends, weighted by either the geometric marginal mean or the geometric mean call-counts.

The estimated average trend for a state or management unit from (2) and (3) using the population size at the mean year is

$$\hat{\beta}_{..\bar{y}} = \hat{P}_{..(\bar{y}+1)} / \hat{P}_{..\bar{y}}$$
$$= (\Sigma_s A_s \Sigma_r \hat{\gamma}_{sr(\bar{y}+1)} / n_s)$$
$$/ (\Sigma_s A_s \Sigma_r \hat{\gamma}_{sr\bar{y}} / n_s)$$

According to the model (6) $\gamma_{sr(\bar{y}+1)} = \beta_{sr.}\ \gamma_{sr\bar{y}}$. Then

$$\hat{\beta}_{..\bar{y}} = (\Sigma_s A_s \Sigma_{r=1}^{n_s}\ \hat{\beta}_{sr}\ \tilde{\gamma}_{sr\bar{y}} / n_s)$$
$$/ (\Sigma_s A_s \Sigma_{r=1}^{n_s} \tilde{\gamma}_{sr\bar{y}} / n_s) \ . \quad (15)$$

Estimates of $\beta_{sr.}$ and $\gamma_{sr\bar{y}}$ from (9) and (11) are used.

Route trend estimates often have different variances because the routes are often run for different numbers and patterns of years. The route trend estimates are weighted by the inverse of their variance (relative to the variance of the call-counts), to reduce the variance of the stratum, state, and management unit estimates.

$$\hat{\beta}_{..\bar{y}} = (\Sigma_s A_s \Sigma_{r=1}^{n_s}\ \hat{\beta}_{sr}\ \tilde{\gamma}_{sr\bar{y}} / v_{sr} n_s)$$
$$/ (\Sigma_s A_s \Sigma_{r=1}^{n_s} \tilde{\gamma}_{sr\bar{y}} / v_{sr}\ n_s) \quad (16)$$

where v_{sr} is the variance of $\hat{\beta}_{sr}$ relative to the variance of the call-counts $[\hat{v}(\hat{\beta}_{sr})/\hat{v}(c_{sry})]$. I use v_{sr} instead of $\hat{v}(\hat{\beta}_{sr})$ because $\hat{v}_{sr}$ is not a function of $\hat{v}(c_{sry})$ which is imprecisely estimated.

<u>Estimation of Annual Indices of Abundance</u>

Annual indices are needed to depict dispersion about fitted trends and to show possible systematic departures from these trends. Annual indices can be estimated without assuming a trend if one consideres year to be a classification variable instead of a quantative variable. Unfortunately, year effects are not estimable for individual routes when observers change. However, the year effects can usually be estimated at the stratum level. Modeling the call-counts as the product of a route effect ξ_{sr} and a year effect η_{sy} and substituting the restriction $\gamma_{rsy} = \xi_{sr}\,\eta_{sy}$ into (4) yields the model

$$c_{sry} = \xi_{sr}\,\eta_{sy}\,\theta_{sri}\,\delta_s^{d_{sry}}\,\epsilon_{sry} . \qquad (17)$$

Taking logarithms the model becomes

$$c'_{sry} = \xi'_{sr} + \eta'_{sy} + \theta'_{sri} + d_{sry}\,\delta'_s + \epsilon'_{sry} \qquad (18)$$

Marginal means are estimated for each stratum following (10)

$$\tilde{\eta}'_{sy} = \eta'^{o}_{sy} + \Sigma_{r=1}^{n_s}\xi'^{o}_{sr}/n_s + \Sigma_{i=1}^{q_{sr}}\,\theta'^{o}_{sri}/q_{sr} + \bar{d}_{sry}\delta'^{o}_s \qquad (19)$$

and back transformed (8) as

$$\tilde{\eta}_{.y} = T(\tilde{\eta}'_{sy}) \qquad (20)$$

The marginal means $\tilde{\eta}_{sy}$ are used to estimate the stratum average call-counts in year y. Following (1)

$$\hat{P}_{s.y} = A_s\,K\,\tilde{\eta}_{sy} . \qquad (21)$$

Annual population estimates

$$\hat{P}_{..y} = K\,\Sigma_s\,A_s\,\hat{\eta}_{sy} \qquad (22)$$

involve the constant K which cannot be estimated. However it is reasonable to define the annual indices as

$$\alpha_{.y} = (\Sigma_s\,P_{s.y}) \,/\, (K\,\Sigma_s A_s) \qquad (23)$$

which can be estimated by

$$\hat{\alpha}_{.y} = (\Sigma_s\,A_s\,\hat{\eta}_{sy}) \,/\, \Sigma\,A_s . \qquad (24)$$

These annual indices can be interpreted as the average call-count per route, weighted by the stratum areas.

Confidence intervals

The PSUs (routes) are the only randomly selected element in the sampling design. Counts are repeatedly made on the same routes without selecting a new sample. Years are not independent because the animal population in one year is dependent on the population in the previous year and because the habitat that controls the number of animals in a PSU changes little among years. Therefore variances should be calculated among PSUs not among years.

Percentile confidence intervals (Efron 1982) are used for trend estimates (16). The parameters β_{sr}, and $\gamma_{sr\bar{y}}$ are estimated for each route. A large number, B, of bootstrap samples each with n_s routes are selected with replacement from the n_s routes in each stratum and B bootstrap replicate estimates are made for a state or management unit using the parameter estimates for the selected routes. For percentile confidence intervals, B=1000 bootstrap replications is recommended. The route parameter estimates are not recalculated for each bootstrap sample to reduce the computational cost. This underestimates the variability of the trend estimates because the variation due to the covariable (disturbance) is excluded. If this variance component is thought to be large, it could be included by recalculating the route parameter estimates for each bootstrap sample. The 100α percent percentile confidence intervals consist of the interval between the 100α/2 and the 100(1-α/2) percentage points on the bootstrap cumulative distribution function constructed from the B bootstrap samples. Unlike the usual normal parametric confidence intervals, percentile confidence intervals are useful for non-normal distributions.

The bootstrap trend estimate is reported to reduce the bias of a ratio from order 1/n to order $1/n^2$ (Efron 1982). The median of the bootstrap distribution is reported as the trend estimate instead of the mean because it is a better representative of the center of a skewed distribution and is equal to the mean of a symmetric distribution.

Similar confidence intervals could be placed on the annual indices (24) but they would be of questionable value for comparing years because of the covariance among annual indices. The annual indices are intended to depict the dispersion about the fitted trends and to show any systematic departures from the line. Hypothesized differences among years can be tested by constructing appropriate constrasts among the annual counts on a route and then estimating the contrast following (16). Although confidence intervals on the annual indices are not useful, some indication of their joint variability is helpful. Plotting a few bootstrap replicate sets of annual indices provides an indication of the joint variability that can be expected (Diaconis and Efron 1983).

Example

A small set of data selected from the Mourning Dove Call-count Survey (Tables 1, 2, and 3) are used to illustrate these methods. Route trends and marginal means were estimated for each route using the following SAS statements (Ray 1982).

```
PROC GLM; BY STRATUM; CLASSES ROUTE OBSERVER;
MODEL LOGCOUNT=ROUTE ROUTE*YEAR
  ROUTE*OBSERVER DISTURB/
  NOINT SOLUTION;
LSMEANS ROUTE/ STDERR;
```

The route trend estimates on the logarithmic scale are the coefficients of the ROUTE*YEAR effects and the LSMEANS give the route marginal means. They are back-transformed as indicated above (8) using their estimated standard errors (Table 4). Trend estimates (16) based on the original sample are:

First stratum	2251.0 / 2122.7 = 1.060
Second stratum	2634.5 / 2646.2 = 0.996
Both strata	4885.5 / 4768.9 = 1.024

The trend bootstrap distribution for both strata combined cannot be distinguished from a normal distribution (P>0.15 Kolmogorov-Smirnov test, Fig. 1), but the distributions for individual strata are not normal (P<0.01) and skewed (Fig. 2). The bootstrap trend estimates are:

	Stratum		
	Both	First	Second
Median	1.026	1.055	1.001
Mean	1.027	1.060	1.003
95% percentile conf. int.	1.102	1.152	1.113
	.958	.989	.896
95% parametric conf. int.	1.100	1.142	1.126
	.954	.987	.880

The annual indices (Fig 3) are:

	Stratum		
Year	Both	First	Second
1	17.1	19.2	15.3
2	12.9	19.4	7.5
3	11.1	18.7	4.8
4	19.5	21.4	18.0
5	21.0	27.2	15.9
6	18.8	26.2	12.2
7	21.5	25.9	17.8

The variablity to be expected with the annual indices are illustrated with bootstrap replicates (Fig. 4). Replicates are separated on the graph by successively adding 5 to the successive replicatives.

Summary

Methods were developed to estimate population trend and annual indices from indicators of abundance (Fig. 3). These estimates mimic the regression line and point scatter that could have been obtained from the population totals if each route was run every year. However, the trend and annual index estimates have the following advantages: (1) they can be estimated when some routes are not run every year; (2) they reduces the variance by estimating the trend separately on each route; removing the route to route variability analagus to a paired t-test; (3) they use covariables to control variation due to observers and disturbance; and (4) they calculate the variance among routes, allowing for the repeated measure nature of the observations. Bootstrap trend estimates reduce the bias of the ratio from order $1/n$ to $1/n^2$. Percentile confidence intervals on the trend estimate are not affected by the normality of the trend distribution. Bootstrap annual indices provide an indication of the joint variability of these indices.

Acknowledgements

I appreciate the helpful suggestions of the reviewers, Gary L. Hensler and Christine M. Bunck.

References

Bradu, D. and Y. Mundlak. 1970. Estimation in lognormal linear models. JASA 65: 198-211.

Diaconis, P. and B. Efron. 1983. Computer intensive methods in statistics. Scientific American, May 116-130.

Efron, B. 1982. The jackknife, the bootstrap and other resampling plans. SIAM, Philadelphia

Ray, A. A., ed. 1982. SAS users guide: statistics. SAS Institute, Cary, N. C.

Searle, S. R., F. M. Speed, and G. A. Milliken. 1980. Population marginal means in the linear model: an alternative to least squares means. American Statistician 34: 216-221.

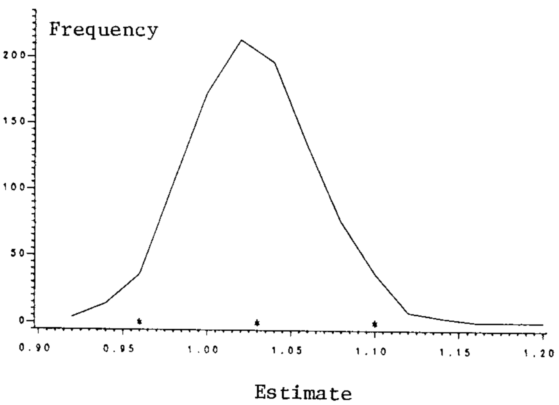

Figure 1. Bootstrap distribution of trend estimates for both strata combined with median and 95% confidence interval (*).

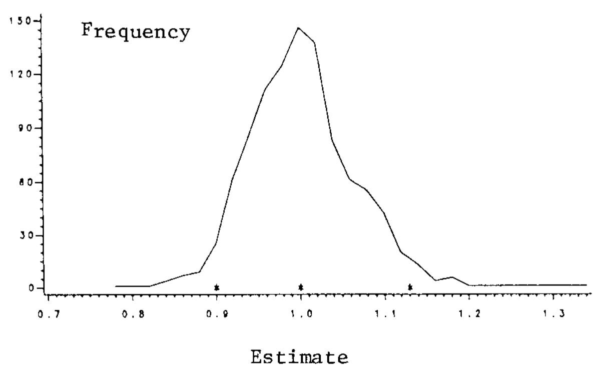

Figure 2. Bootstrap distribution of trend estimates for the second stratum with median and 95% confidence interval (*).

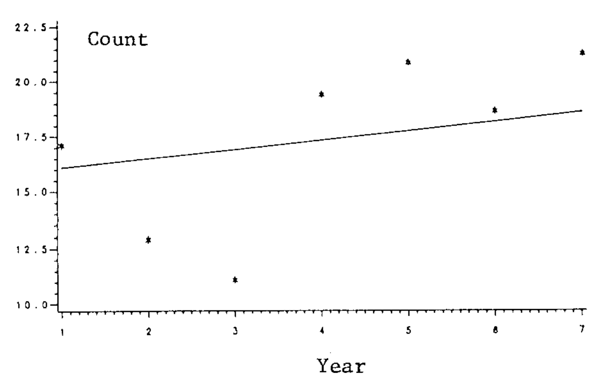

Figure 3. Bootstrap estimates of population trend and annual indices for both strata combined.

Table 1. Call-count data used to illustrate the calculations.

	Year						
Route	1	2	3	4	5	6	7
First stratum (area=20.15)							
1	10	3	25	10	20	19	14
2	45	14	19	75	48	31	56
3	83	55	35	39	43	63	50
4	23	28	21	4	23	41	16
5	23	33	10	46	61	28	34
6	44	20	33	22	29	29	45
7	26	36	67	34	26	28	46
8	69	31	.	.	.	.	.
9	.	.	27	16	36	26	25
10	14	22	41	32	50	28	35
11	9	24	5	26	13	13	12
12	35	26	.	.	.	.	.
13	.	.	24	15	24	29	25
14	7	44	6	56	23	31	25
15	31	10	16	36	47	25	20
16	14	34	3	15	25	10	19
17	19	8	14	17	15	47	46
18	33	30	50	47	58	36	50
19	32	11	19	36	6	.	20
Second stratum (area=24.20)							
20	0	.	5	59	5	4	51
21	61	20	12	28	9	36	61
22	7	.	0	44	12	0	53
23	0	0	0	5	1	0	0
24	12	1	2	54	34	3	5
25	46	.	0	57	17	2	17
26	20	4	4	5	4	22	22
27	18	12	7	16	31	16	23
28	52	9	21	45	36	26	22
29	29	8	10	77	55	16	43
30	26	15	#	7	13	13	.
31	14	20	11	*	52	32	18
32	1	0	0	0	4	14	0
33	6	4	16	7	1	3	14
34	39	24	26	.	30	26	31
35	8	31	.	.	.	.	.
36	.	.	38	53	47	37	24
37	33	61	4	30	35	40	29
38	71	4	5	61	.	55	55
39	70	94	24	71	40	50	47
40	4	9	9	3	4	11	4

Two observers both recorded 0.

* Two observers recorded 52 and 40.

Table 2. Observer identification numbers for call-count data given in Table 1.

	Year						
Route	1	2	3	4	5	6	7
First stratum							
1	55	55	55	38	38	38	38
2	37	53	37	37	37	37	37
3	55	55	55	38	38	38	38
4	55	55	55	38	38	38	38
5	53	37	53	37	37	26	27
6	55	55	55	38	38	38	40
7	14	14	14	49	49	46	46
8	55	55	.	.	.	.	.
9	.	.	55	38	38	38	40
10	29	7	7	4	23	4	5
11	44	5	44	5	5	5	5
12	5	44	.	.	.	.	.
13	.	.	7	4	14	14	14
14	44	44	29	14	3	15	15
15	29	22	29	14	14	15	15
16	9	43	4	49	54	12	12
17	29	29	4	4	3	43	43
18	1	22	1	22	43	43	43
19	22	1	1	22	10	.	6
Second stratum							
20	21	.	50	18	53	18	18
21	34	34	21	21	30	35	35
22	24	.	51	51	51	51	51
23	2	56	30	2	18	18	18
24	19	30	19	21	53	19	19
25	2	.	19	51	19	19	19
26	32	32	32	20	20	20	20
27	52	52	52	52	52	52	52
28	11	11	11	11	3	29	29
29	11	11	11	11	3	4	45
30	41	41	#	41	41	41	.
31	31	3	44	*	41	41	41
32	41	42	33	41	42	42	41
33	13	8	8	8	16	36	8
34	47	47	47	.	39	41	41
35	44	31	.	.	.	.	.
36	.	.	47	31	31	31	15
37	17	48	17	28	28	28	28
38	28	48	17	28	.	17	28
39	28	48	54	28	28	28	28
40	18	18	18	44	25	25	31

The two observers were 33 and 42.

* The two observers were 41 and 44.

Table 3. Disturbance data for call-counts given in Table 1.

	Year						
Route	1	2	3	4	5	6	7
First stratum							
1	.	1	.	1	3	1	15
2	2	0	5	8	11	12	10
3	.	20	.	3	8	10	4
4	.	21	23	4	7	14	11
5	0	2	2	6	0	2	16
6	.	8	6	2	8	6	4
7	40	36	37	20	27	43	39
8	.	16	.	.	.	.	.
9	.	.	.	14	15	35	36
10	6	9	13	3	8	5	13
11	1	3	.	17	21	24	5
12	.	12	.	.	.	.	.
13	.	.	2	6	12	14	6
14	12	23	14	29	15	11	13
15	18	13	25	35	30	23	23
16	.	40	0	5	20	28	3
17	10	3	6	20	6	5	3
18	.	22	12	.	13	.	19
19	.	2	2	.	0	.	24
Second stratum							
20	2	.	.	1	10	5	2
21	3	2	20	0	.	22	22
22	26	.	2	2	6	0	8
23	5	0	.	11	8	9	11
24	3	.	0	2	1	.	.
25	0	.	22	8	.	3	.
26	0	0	0	11	7	16	9
27	6	8	2	9	10	5	10
28	.	0	.	.	19	10	17
29	.	0	.	.	18	16	8
30	29	20	#	27	28	25	.
31	8	0	0	*	8	6	2
32	4	2	2	2	.	.	7
33	.	27	28	25	6	2	15
34	49	48	30	.	34	45	42
35	.	13	.	.	.	.	.
36	.	.	0	9	0	1	0
37	22	6	.	0	0	0	24
38	9	28	26	8	.	25	19
39	0	21	36	20	0	0	15
40	3	2	12	0	12	11	.

Two observers recorded 22 and 0.

* Two observers recorded 18 and 2.

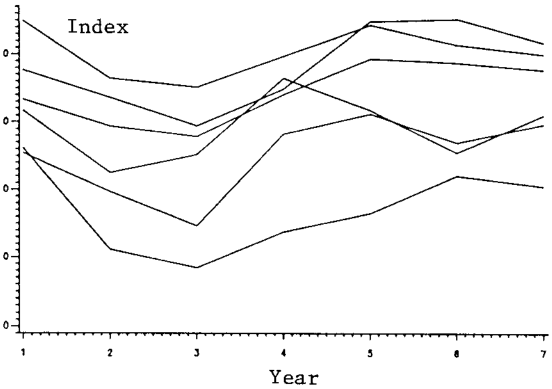

Figure 4. Bootstrap estimates of variability of annual indices for both strata combined.

Table 4. Estimates for each route including trend (b), trend on logarithmic scale (b'), variance of trend on logarithmic scale [v(b')], relative variance of trend (v), route marginal mean (g), route marginal mean on logarithmic scale (g'), variance of route marginal mean on logarithmic scale [v(g')], and degrees of freedom and mean square for error (dfe and mse).

Rt	b	b'	v(b')	v	g	g'	v(g')
First stratum (dfe=28 and mse=0.217)							
1	1.049	0.071	0.048	0.221	7.71	2.091	0.097
2	1.029	0.033	0.010	0.046	25.74	3.292	0.089
3	1.091	0.109	0.043	0.200	52.66	4.004	0.079
4	1.413	0.366	0.042	0.191	21.41	3.087	0.046
5	1.000	0.017	0.033	0.150	29.05	3.399	0.060
6	1.170	0.200	0.087	0.402	28.17	3.384	0.091
7	1.371	0.352	0.072	0.334	28.66	3.434	0.158
8							
9	1.120	0.183	0.139	0.642	13.91	2.834	0.401
10	1.018	0.062	0.087	0.403	30.34	3.434	0.042
11	0.839	-0.168	0.015	0.070	9.94	2.345	0.096
12							
13	0.980	0.035	0.111	0.512	21.51	3.103	0.069
14	1.890	0.751	0.229	1.054	24.72	3.238	0.061
15	0.777	-0.216	0.073	0.336	17.86	2.924	0.083
16	1.552	0.747	0.609	2.806	15.93	2.794	0.051
17	0.739	-0.230	0.145	0.670	19.16	2.975	0.045
18	0.865	-0.089	0.111	0.512	38.57	3.706	0.108
19	1.363	0.528	0.434	2.000	8.60	2.254	0.206
Second stratum (dfe=37 and mse=1.001)							
20	0.710	-0.235	0.215	0.215	3.69	1.457	0.302
21	0.846	0.194	0.714	0.714	29.72	3.492	0.200
22	1.521	0.470	0.101	0.101	8.31	2.335	0.432
23	1.318	0.355	0.157	0.157	0.95	0.059	0.222
24	0.356	-0.781	0.502	0.502	15.05	2.939	0.453
25	1.659	0.637	0.261	0.261	20.59	3.300	0.547
26	1.133	0.197	0.143	0.143	9.39	2.335	0.190
27	1.073	0.089	0.036	0.036	16.43	2.879	0.158
28	0.265	-0.275	2.048	2.047	16.35	3.143	0.691
29							
30	0.852	-0.131	0.058	0.058	1.08	0.233	0.310
31	0.783	-0.144	0.200	0.200	16.32	3.043	0.498
32	0.803	-0.191	0.056	0.056	0.44	-0.639	0.380
33	1.174	0.200	0.078	0.078	2.62	1.122	0.318
34	0.796	0.005	0.465	0.465	9.66	2.928	1.298
35							
36	0.688	-0.114	0.516	0.515	31.43	3.825	0.746
37	0.789	-0.111	0.250	0.250	26.12	3.578	0.625
38	1.080	0.100	0.046	0.046	12.77	2.719	0.342
39	0.887	-0.096	0.048	0.048	32.22	3.673	0.398
40	1.253	0.432	0.411	0.411	6.06	1.924	0.244