Problems of pooling migration monitoring data from several bird ringing stations

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A special methodological problem arises when one tries to generalise trends observed at different bird ringing stations with respect to the numerical trend of individual species. How are the numbers changing over the entire source area of migrants? What is the general trend? What is the size of the fluctuations of the overall population? Answers to such questions require summing up partial results obtained at different bird stations into regional totals. Numbers of individuals of the same species caught yearly at different stations show large variations. Numbers vary not only from year to year, but, more importantly, the averages at various stations are also different. Differences in averages can be assumed to be a result of (1) various trapping efficiencies at the bird stations, (2) different numbers of individuals passing (i.e. different average intensities of migration) or (3) both. Different pooling procedures - weighted and unweighted averages - can be applied. The data were extracted from earlier publications in which migration counts (results of catching) were analysed for trends and annual variation in years 1961-1990. Eight species of long-distance migrants were analysed and different pooling procedures compared. It was found that the method of pooling monitoring data considerably influences the results. In the case of regression coefficients, weighted averages always give more positive (or less negative) values, which may affect conclusions derived from such data. The influence of the pooling procedure on the measure of annual fluctuation CF is less clear and the CF seems to be more species dependent. Further studies on effects of pooling procedures are needed.

1. Introduction

Several papers analysing migration monitoring data collected simultaneously at a dozen or so bird ringing stations in Northern and Central Europe have been published (Busse & Marova 1993; Busse 1995; Busse *et al.* 1995). These data refer to species of several Passerines families (shrikes, Laniidae, warblers, Sylviidae, and thrushes, Turdidae). This new level of monitoring studies (in contrary to evaluation of population trends at separate stations [Busse 1973, 1994; Hjort & Lindholm 1978; Svensson 1978; Lindholm *et al.* 1983; Baumanis & Rute 1986; Berthold *et al.* 1986; Busse & Cofta 1986; Pettersson & Hedenström 1986; Payevsky 1990]) yielded results which must be interpreted within a more general than local population dynamics model.

Comparisons between different stations show clear differences as to long-term trends and annual fluctuations. Some stations can be grouped into clusters where population dynamics/fluctuations are similar, but different from other groups (Busse 1995). Trend patterns can be difficult to explain when the background of bird migration patterns has not been studied sufficiently. This is especially clear within Northern and Central Europe, where populations are differentiated as to direction of migration: populations of the same species, sometimes even individuals from the same populations, may migrate to such distant winter quarters as Spain and Balkan Peninsula. In some species (e.g. Blackcap) results suggest that SW and SE migrating birds show different population dynamics (Busse *et al.* 1995). Similarities between population trends/fluctuations of some species have been observed (do they come from the same areas?) and various patterns in closely related species were found (do they come from different areas or do they react differently to the same ecological conditions? Busse & Marova 1993). In species in which periods of high and low population levels can be distinguished, levels of annual variation are often higher in periods of high population size (Busse *et al.* 1995). Which population level is „normal" for the area? Should we alert bird conservationists and a wide audience every time we find a negative trend? Such questions can be asked when the data come from a wide area and from many bird stations.

A special problem of analysis arises when one tries to generalise trends observed at different bird stations and answer the question: how does the numerical status of a species develop in the wider area from which migrants originate? What is the general trend? What is the magnitude of the fluctuations? Answers to such questions require the integration of counts obtained at different bird stations to provide regional totals.

It is well known that the numbers of individuals of the same species caught yearly at bird stations vary greatly (e.g. BUSSE 1990). Numbers vary not only from year to year, but, more importantly, the averages at various stations are also different. Differences in averages can be assumed to be a result of (1) different trapping efficiencies at the bird stations, (2) different numbers of individuals passing through (i.e. different average intensities of migration) or (3) both. If the first assumption is true, general population totals should be calculated as unweighted averages from the station data (the weight of every station is the same independently of the number of individuals caught). When the second assumption is true, the totals must be averaged by weighting for the number of individuals caught at the particular station (i.e. stations with higher ringing totals influence the total trend/fluctuation value more than the others). When both assumptions are true simultaneously, the best trend estimate will result after correcting for the influence of the first factor (catching efficiency). This can be partially reached by relating the number of individuals of the particular species caught at a station to the total number of birds caught there by means of the same catching devices and having similar habitat preferences. The species shares within the bird station totals can define a kind of validation of the station as to its value for migration of that species. Trends at the bird stations with the share of the species higher than the total average can be assumed to be more repesentative for the general population trend than those at the stations, where the species is scarce. A comparison of different methods of pooling count data is discussed in the present paper.

2. Material and Methods

The data used here were extracted from earlier publications in which migration count data (results of catching) have been analysed (BUSSE & MAROVA 1993; BUSSE 1995; BUSSE *et al.* 1995). In those papers the trends and annual variations for the years 1961-1990 were analysed for ten species: Red-backed Shrike, *Lanius collurio*, Great Grey Shrike *L. excubitor* Willow Warbler *Phylloscopus trochilus* Wood Warbler *Phylloscopus sibilatrix* Chiffchaff *Phyll. collybita*,

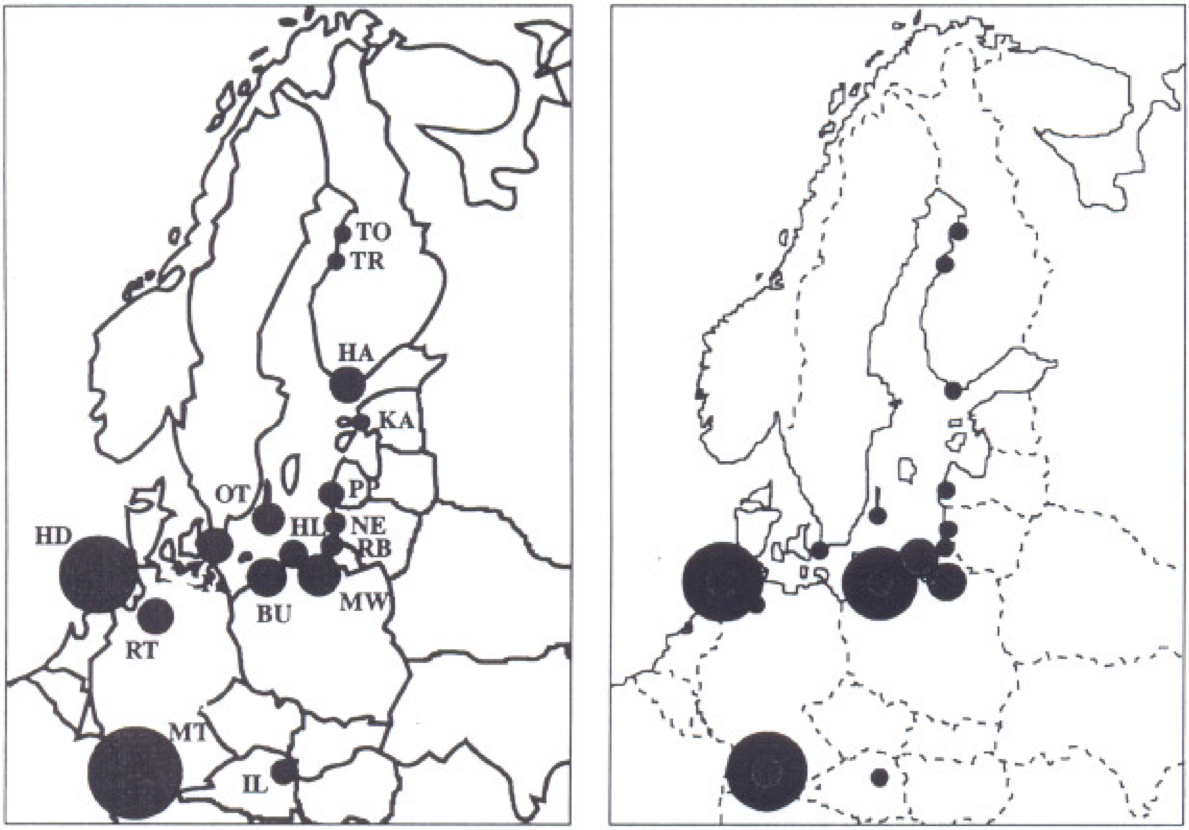

Fig. 1: Bird stations in North-Central Europe (left) and weighting of the stations based on numbers of Blackcap (right). Left: areas of circles proportional to annual average numbers of Blackcaps caught. Right: large circles = station index >150, circles = station index 100-150; dots = station index <100 (compare text).
Stations: BU - Bukowo/Kopan, FA - Falsterbo, HA - Hanko, HD - Helgoland, HL - Hel, IL - Illmitz, KA - Kabli, MT - Mettnau, MW - Mierzeja Wislana, NE - Neringa, OT - Ottenby, PP - Pape, RT - Reit, TO - Tauvo, TR - Tankar.

Garden Warbler, *Sylvia borin*, Blackcap *S. atricapilla*, Whitethroat, *S. communis*, Lesser Whitethroat, *S. curruca*, and Barred Warbler, *S. nisoria*. The present analysis includes a group of eight long-distance migrants (Great Grey Shrike excluded) which are sufficiently numerous (Table 1), i.e. more than 100 individuals are caught per season at six stations (Barred Warbler was less numerous and hence excluded).

Source papers contain the data from 9-15 bird stations depending on availability of station data and their compatibility with other data sets. The raw data are listed in the references along with their working periods and special comments as to the compatibility of the data. In the present paper data from those six stations which had the longest working periods are used (see Fig. 1): Mierzeja Wislana (54.21N, 19.19E), Hel (54.46N, 18.28E), Bukowo/Kopan (54.21N, 16.17E / 54.28N, 16.25E), Helgoland (54.00N, 8.00E), Ottenby (56.12N, 16.24E), Rybatchy (55.09N, 20.52E). At Mierzeja Wislana, Hel and Bukowo the birds were mist-netted, at Ottenby they were caught by mist-netting and in a Helgoland type trap, while Helgoland and Rybatchy data were based on Helgoland traps of quite different size and construction. Four of the stations (Mierzeja Wislana, Hel, Bukowo and Rybatchy) are situated within linear stretches of coastal woodland, where migrants can move during the daytime. Two bird stations (Helgoland and Ottenby) are on islands. These variations in the catching methods and the station location could have an important impact on the trapping efficiencies.

Table 1. Average number of individuals caught per year at various bird stations.

	Mierzeja Wislana	Hel	Bukowo	Helgoland	Ottenby	Rybatchy	Total
L. collurio	12.2	3.1	5.5	2.5	206.1	3.1	232.3
S. atricapilla	122.1	47.1	101.5	464.8	61.5	26.8	823.7
S. borin	83.9	38.1	58.5	572.1	118.1	52.6	923.1
S. curruca	27.2	16.6	20.4	4.6	177.4	58.8	305.1
S. communis	13.3	1.6	6.9	62.1	124.6	17.3	225.8
P. trochilus	395.3	159.2	178.4	315.6	756.6	685.4	2490.5
P. collybita	50.8	17.6	35.5	37.8	42.4	34.8	218.9
P. sibilatrix	6.8	1.3	2.6	1.9	47.9	45.1	105.5
Total	711.6	284.6	409.3	1461.4	1534.6	923.9	

Table 2. Percent share of each species at stations in relation to the total number of individuals belonging to the studied group.

	Mierzeja Wislana	Hel	Bukowo	Helgoland	Ottenby	Rybatchy	Total
L. collurio	1.7	1.1	1.3	0.2	13.4	0.3	4.4
S. atricapilla	17.2	16.5	24.8	31.8	4.1	2.9	15.5
S. borin	11.8	13.4	14.3	39.1	7.7	5.7	17.3
S. curruca	3.8	5.8	5.1	0.3	11.6	6.4	5.7
S. communis	1.9	0.6	1.7	4.2	8.1	1.9	4.2
P. trochilus	55.6	56.1	43.6	21.6	49.3	74.2	46.8
P. collybita	7.1	6.2	8.7	2.6	2.8	3.8	4.1
P. sibilatrix	1.1	0.5	0.6	0.1	3.1	4.9	2.1

Table 3. Relative index values of stations for each species. Percent values of the species' station share (station data from Table 2) in relation to the "Total".

	Mierzeja Wislana	Hel	Bukowo	Helgoland	Ottenby	Rybatchy	Variat. (SD)
L. collurio	39	25	30	5	305	7	106
S. atricapilla	111	106	160	205	26	19	67
S. borin	68	77	83	226	45	33	64
S. curruca	67	102	88	5	204	112	59
S. communis	45	14	40	100	193	45	60
P. trochilus	119	120	93	46	105	159	34
P. collybita	173	151	212	63	68	93	56
P. sibilatrix	50	25	30	5	155	245	86
mean	84	78	92	82	138	89	
SD	43	48	61	83	89	76	

Two statistics are used to describe population variation: long-term trends expressed as a linear regression coefficient (R) and annual variation in the number of the birds caught at the station expressed as a coefficient of fluctuation (CF):

CF = 1/M * ((Xoy - Xy)2/N * 100% where
M = mean value of the population size index for all years
Xy = the value of population size index for year „y"
Xoy = local value of moving average for the year „y"
N = number of years in the sample.

The CF is a measure of variability of yearly values around the smoothed curve of the long-term trend (Busse 1990). It describes annual fluctuations better than a coefficient of variation whenever the long-term trends are more pronounced.

Table 4. Example of the calculation procedures (explanation see text).

Years	Station a		Station b		Total (%)			
	Na	PCa (%)	Nb	PCb (%)	PCsum	PCavg	PCn	PCst
1	360	227	15	105	166		217	205
2	20	13	5	35	24		12	17
3	220	139	24	169	154		127	144
4	92	58	11	77	68		63	61
...								
30	100	63	36	253	158		58	98
SumN	4752		426					
Mx	158.4		14.2					
STx	180		40					
Rx		-2.46		-8.17	-6.91	-5.31	-1.23	-2.85
CFx		27.1		120.1	7.95	73.55	2.36	3.48
	a		b		Tsum	Tavg	Tn	Tst

Na, Nb - number of individuals; SumN -total number;
Mx - station "x" yearly average; STx - station "x" validation index;
Rx - correlation coefficient for the station (or total in the right sector of the table)
CFx - fluctuation coefficient for the station or total;
Tsum - calculation procedure 1.1. in the text,
Tavg - calculation procedure 1.2,
Tn - calculation procedure 2.1,
Tst - calculation procedure 2.2.

All numbers describing population levels (abscissa of figures) and R values are percentages of the average number of individuals of the species caught per year at the particular station in the years 1974-1983. This period was selected as it was a common period of work of most of the stations analysed in earlier publications (op. cit.). Calculations in these papers included, in the first step, conversion of bird numbers into percentages of the standard average number (1974-1983) and then calculations of R and CF values (cf. Table 4, station data). As the present paper is devoted to the methodical considerations, further calculations are explained below.

Table 5. Comparison of weighted and unweighted regression coefficients for species calculated according to different procedures: Unweighted - Tsum (procedure 1.1 in the text), Tavg (procedure 1.2) Weighted - Tn (procedure 2.1), Tst (procedure 2.2).

	N per year	Unweighted		Weighted	
		Tsum	Tavg	Tn	Tst
L. collurio	232.3	-6.91**	-5.31	-1.23**	-2.85**
S. atricapilla	823.7	-1.97**	-1.72	-0.19~	-2.38**
S. borin	923.1	-2.94**	-2.36	-1.46**	-2.52**
S. curruca	305.1	-4.45**	-3.89	-2.79**	-3.96**
S. communis	225.8	-8.76**	-9.33	-2.96**	-4.81**
P. trochilus	2490.5	-1.91**	-1.92	-0.78**	-2.57**
P. collybita	218.9	-2.45**	-2.63	-1.83**	-3.38**
P. sibilatrix	105.5	-3.21**	-3.34	+3.71**	+0.48~
mean		-4.07	-3.81	-0.94	-2.75
r with number		0.48~	0.46~	-0.02~	0.03~

Statistical significance: ** - $p < 0.01$, * - $p < 0.05$, ~ - n.s.

3. Results and Discussion

Assuming that broad front of migration should result in more or less even distribution of migrants, each station's share of a particular species should be the same. The value should be equal to the total species share within a mass of migrants as estimated from all count data pooled. However, data collected show that this is not the case (Table 2). Species differ strongly with respect to their share in the totals for each station. Differences are most pronounced in Wood Warbler (0.1 % at Helgoland, 4.9 % at Rybatchy) and Red-backed Shrike (0.2 % Helgoland, 13.4 % Ottenby). This suggests that some bird stations are located in stopover sites more important to a given species than others. Such areas are distributed according to the migration pattern of the particular species which is frequently poorly known. Thus the weight or "value" with regard to the description of migration pattern and population trends differs between stations. The stations with the species shares higher than average have greater importance for that species than those with shares lower than average. Station indices (Table 3) are calculated as the ratio of a station's percent share relative to the average for all stations. For example: Willow Warbler makes up 55.6 % Mierzeja Wislana and total value for this species is 46.8 % (Table 2), so Mierzeja Wislana gets a station index of 55.6/46.8 = 119 (Table 3). Figure 1 shows index values for Blackcap at 15 stations. The most important stations for this species are not necessarily those with the highest numbers individuals caught (note e.g. high value of Bukowo station).

Among the species studied, the most differentiated station indices for those of Red-backed Shrike, the most stable ones are for Willow Warbler. Ottenby is the most important station for Red-backed Shrike, Whitethroat and Lesser Whitethroat, Helgoland for Blackcap and Garden Warbler, Rybatchy for Willow Warbler and Wood Warbler, while Polish stations Bukowo, Mierzeja Wislana and Hel are most important for Chiffchaff.

Comparison of station indices shows that only Ottenby has clearly higher values for the species studied than other stations, which among themselves are rather even in this respect. Thus Ottenby has a particularly high value for studying Red-backed Shrike, Lesser Whitethroat, Whitethroat and Wood Warbler, while the migration of Blackcap and Garden Warbler is insignificant there. Mierzeja Wislana and Hel are most important for Chiffchaff, Bukowo for Chiffchaff and Blackcap, Helgoland for Blackcap and Garden Warbler and Rybatchy for Wood Warbler and Willow Warbler.

The problem of station evaluation becomes important when one would like to combine results from many stations to form more general indices (e.g. regression coefficients and fluctuation coefficients) which describe population trends across wide breeding areas. There are four possible procedures, which have different pros and contras. This is discussed below, based on an exemplary data from Table 4, where station data are fictitious, but a sector right and down of the Table contains real values of Tsum, Tavg, Tn and Tst for Red-backed Shrike.

1. Unweighted average: every station is assumed to have the same significance for the population studied (broad front migration assumed). Two pooling procedures are possible:

1.1. Tsum: summing up the stations' data and then calculating total values of the population parameters (regression coefficient and CF value).

Calculation procedure: (a) PCsum for every year is an average of PCa, PCb, etc., e.g.(for first row): (227 + 105) / 2 = 166. Note that this procedure is the simplest, but stations where the number of individuals is very low have a relatively strong influence on the pooled value of the parameter: here behind PCa value is 360 individuals against only 15 for PCb value, which are averaged into PCsum. (b) Tsum values for R and CF are calculated as for one station (cf. below).

1.2. Tavg: averaging parameter values calculated for single stations into pooled population value. Tavg values are the averages for R and CF values for stations (Ra, Rb ...., CFa, CFb ...); e.g.: Rarg = (Ra + Rb) / 2; CFarg = (CFa + CFb) / 2.

2. Weighted average: the stations are assumed to be of unequal value for describing total population parameters. Two procedures were used:

2.1. Tn: weighting for the number of individuals caught at the station (N-weighting). Calculation procedure: (a) PCn for every year: PCn = ((PCa * Ma) + (PCb *Mb) + ...)) / Ma + Mb + ..., e.g.: PCn(1) = ((227*158.4) + (105*14.2)) / (158.4 + 14.2) = 217. (b) Tn values are calculated as for one station. This can lead to overemphasising stations with the highest

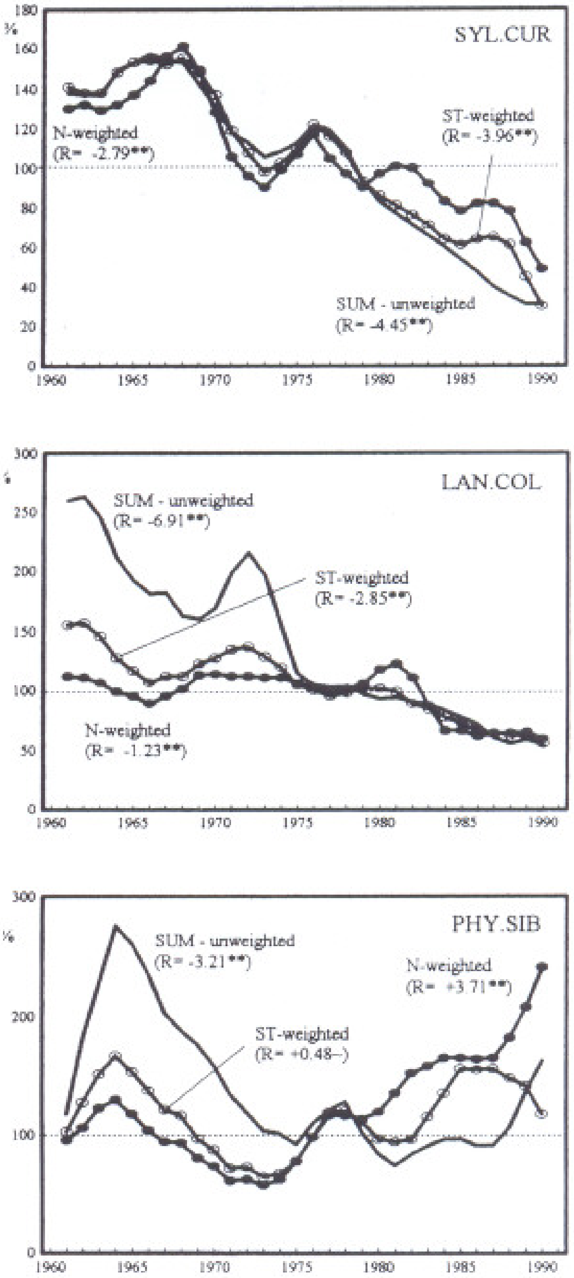

Fig. 2. Examples of population dynamics described by means of different calculation procedures. Unweighted: SUM - procedure 1.1. in the text; weighted: N - procedure 2.1.; ST - procedure 2.2. SYL.CUR - Lesser Whitethroat *Sylvia curruca*, LAN.COL - Red-backed Shrike *Lanius collurio*, PHY.SIB - Wood Warbler *Phylloscopus sibilatrix*.

Table 6. Comparison of weighted and unweighted CF coefficients for species calculated according to different procedures: Unweighted - Tsum (procedure 1.1 in the text), Tavg (procedure 1.2) Weighted - Tn (procedure 2.1), Tst (procedure 2.2).

	N per year	Unweighted		Weighted	
		Tsum	Tavg	Tn	Tst
L. collurio	232.3	7.95	73.55	2.36	3.48
S. atricapilla	823.7	2.55	9.11	3.36	2.35
S. borin	923.1	5.28	15.71	3.48	3.69
S. curruca	305.1	4.03	20.46	6.01	4.66
S. communis	225.8	13.95	67.78	9.91	7.05
P. trochilus	2490.5	4.91	16.37	4.11	4.81
P. collybita	218.9	5.09	17.32	5.46	6.38
P. sibilatrix	105.5	9.58	60.23	9.63	8.66
mean		6.69	35.07	5.54	5.14
r with number		-0.39~	-0.50~	-0.40~	-0.33~

Statistical significance: ** - p < 0.01, * - p < 0.05, ~ - n.s.

numbers of birds caught because of very high catching efficiency (here 217 is much closer to 227 than to 105).

2.2. Tst: weighting for the station value indices („ST-weighting") should theoretically be the best method relating species data to the total catching results. Calculation procedure is much as in „N-weighting", but instead of Mx we use STx values (station validation indices) are used. However, one must be aware that when a particular station is extremely valuable for one or two species, the station validation for others can be negatively biased.

Tables 5 and 6 contain results obtained by means of different pooling procedures for the same raw station data. The general pattern of results for both population parameters clearly shows that different procedures lead to quite different summary statistics. Especially different are weighted and unweighted values of the regression coefficient. In published papers (BUSSE & MAROVA 1993; BUSSE 1995; BUSSE *et al.* 1995), where the unweighted calculation procedure was used, pooled regression coefficients were clearly negative (see Table 5, „Tsum" procedure) for all species and thus the conclusions were rather pessimistic as to the welfare of the species studied. This is especially obvious for Whitethroat and Red-backed Shrike. Application of weighting procedures leads to much more optimistic general conclusions. Weighted procedures applied to Wood Warbler even give a statistically significant positive trend instead of a significant negative trend. Figure 2 shows how strong the influence of the pooling procedure on the description of the overall population trend can be. For Lesser Whitethroat the influence is relatively low as seen both in the population curve and the regression coefficients. Red-backed Shrike and Wood Warbler are examples of strong dependence of the population curve and regression coefficient on the calculation procedure.

Pooled regression coefficients obtained by means of weighted procedures seem to be independent of the num-bers of individuals caught per species at all stations (Table 5). Results of unweighted procedures seem to be positively correlated with numbers of birds caught (but p > 0.05). Does this mean that most common birds are more resistant against changes in the environment?

The influence of the pooling procedure on estimates of annual fluctuations is less clear. The only exception is the unweighted averaging procedure (Table 5). Despite calculation of CF values is very similar to estimation of the variance, which is an additive measure, averaging station CF values (to Tavg) gives very different results than another unweighted procedure (Tsum). As it gives pooled CF values several times higher than other procedures, it cannot be accepted. Second, the unweighted procedure gives a slightly higher average CF value than weighted procedures, but patterns differ between species. All pooled CF values, independently of the procedure used, seem to be negatively correlated with the numbers of individuals caught per species (but p>0.05). CF coefficients seem to be more species-dependent than number-dependent. A similar conclusion on the variation of migration counts was presented by SVENSSON (1978), but very general patterns for passerines and raptors were studied. It seems that the problem needs further detailed studies on many species.

4. Conclusions

1. The method of pooling monitoring data collected at several stations considerably influences the results.
2. For regression coefficients weighted averages give always more positive (or less negative) values, which may affect conclusions derived from monitoring data. It seems that the results obtained at the stations where the species is more numerous are more representative of the overall population trend than those from other stations.
3. The influence of the pooling procedure on an annual fluctuation measure, CF, is less clear and the CF seems to be more species-dependent.
4. Further studies on effects of pooling procedures are needed.

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