CORRELATIVE TOPOGRAPHY BY KRIGGING – A USEFUL METHOD TO STUDY INTRA-GROUP BIOMETRICAL DIFFERENTIATION

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ABSTRACT

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An idea to combine results of some bird measurements in studies on biometrical differentiation of migrating birds is one of the bases of the Operation Baltic working methods. The first attempt to use correlation tables of two measurements has been already published in 1968 (Busse 1968). The method of application of drawing methods originated from the geographical topography was proposed there and it was called „correlative topography". However, calculations required in the analysis were very time consuming, although rather simple. Now appropriate computer software is available. This paper is a presentation of the contemporary possibilities of the method.

The method requires a set of measurements of two bird size parameters, as e.g. wing-length and tail-length, taken from the same individuals. These data arranged into a two-dimension array make the basic data for all following procedures. The basic plane (X and Y coordinates) are measured parameters while the third dimension (Z axis) gives numbers representing defined combination of measurements that are X and Y values. Then these data are presented on the surface as the isolines connecting points with the same values of Z frequencies.

The method enables to study internal biometrical differentiation of groups of birds defined by means of seasonal migration pattern analysis, collected at different ringing stations or selected with the use of other methods of bird migration studies. This method can give, at least, general orientation in size of intra-group differentiation and make aware of unsound assumptions as to homogeneity of samples studied.

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INTRODUCTION

An idea to combine results of some bird measurements in studies on biometrical differentiation of migrating birds was one of the basis of the Operation Baltic working methods. The first attempt to use correlation tables of two measurements was already published in 1968 (Busse 1968). The method of application of drawing methods originating from the geographical topography was proposed there and was called „correlative topography". Wing-length and tail-length measurements of Robin (*Erithacus rubecula*) migrating in spring through Hel and Mierzeja Wiślana bird stations located at the southern Baltic coast were used as an example. Although it was shown that there were well pronounced intra-group and inter-group differentiations the method was not applied in further biometrical studies (with a few exceptions – Busse and Maksalon 1986, Cofta 1986). The main reason was that the calculations required in the analysis were very time consuming, although rather simple. Now, appropriate computer software (e.g. Surfer for Windows) is available. This software allows not only to draw charts with isolines as it was done before, but visualizes biometrical differentiation as three-dimension pictures and „slice cuts" of distributions and their relative volumes.

This paper is a presentation of the contemporary possibilities of the method but is not a biometrical analysis of the data used as an example.

MATERIAL

The examplary data are the wing-length and tail-length measurements of Robins caught in autumn 1997 at two bird ringing stations situated at the southern Baltic coast – Bukowo-Kopań (54°28' N, 16°25' E) and Mierzeja Wiślana (54°21' N, 19°19' E). The total number of Robins caught at Bukowo-Kopań was 873 individuals and at Mierzeja Wiślana – 1101 individuals. Biometrical data used in all examples were taken from immatures only and the numbers of measured individuals were 583 and 487 respectively. At Bukowo-Kopań station there were a few ringers that measured the birds, while at Mierzeja Wiślana measurements were taken by two ringers, but the decided majority of birds was measured by one of them.

THE METHOD

The method requires a set of measurements of two bird size parameters, as e.g. wing-length and tail-length, taken from the same individuals. These data arranged into a two-dimension array make the basic data for all following procedures. The basic plane (X and Y co-ordinates) are measured parameters while the third dimension (Z axis) gives numbers of individuals that have the defined combination of measurements that are X and Y values. Such set of biometrical data is equivalent to topographical data where heights of different points located at the Earth surface describe the relief of the mountains. Then this type of data is presented on the surface as the isolines connecting points located at the same height above sea level. The analogy between geographical application and biometrical use of the method has, however, limited extent as the geographical map of the defined area is a static picture of the Earth surface relief while the biometrical „maps" are dynamic pictures depending on the group from which the data originate. Such biometrical maps for different groups show various patterns despite that the X and Y values are the same. So, in biometry, the pictures obtained by the application of the method depend on the group of birds measured and they can be used for searching of intra-group differentiation.

Technically, the raw data of any studied group must be arranged as three columns in a spreadsheet file – listing X, Y and Z values which describe the array, where X and Y are the values of the studied biometrical parameters (e.g. wing-length and tail-length) and Z values are numbers of individuals representing defined combination of X and Y values. Grid values for correlation charts could be obtained by different calculation procedures used in cartography that give similar results. Here the Krigging method used as a default in SURFER software was applied.

EXAMPLE OF APPLICATION

Typical biometrical one-parameter analysis searches for differences in average values of a studied measurement between two or more groups of defined birds by e.g. time of migration, the station they were caught at, or orientation experiments (Busse 1995). Sometimes differences are statistically significant and a conclusion is that the groups in question are differentiated. Frequently, the averages are not different enough and the null-hypothesis cannot be rejected. The Robin measurements data of autumn 1997, collected at Bukowo-Kopań and Mierzeja Wiślana, could be a good example of the latter case – neither wing-length averages (M_{BK} = 72.10 and M_{MW} = 72.31, while standard deviations SD_{BK} = 1.83 and SD_{MW} = 1.84 and numbers of individuals N_{BK} = 583, N_{MW} = 487) nor tail-length differed significantly (tail-length averages nearly identical, while SD_{BK} = 2.63 and SD_{MW} = 2.09). Nevertheless, one remember the basic limitations of the statistical way of thinking: (1) the possibility to show statistically significant differentiation depends very much on a number of measurements in the samples, and (2) groups which are not homogenous should not be defined as statistically not differentiated even if their parameter average values are the same. In the discussed example, there is suspicion of heterogeneity of at least tail-length measurement because of distribution of this parameter (Fig. 1) and statistically significant (F-test, $p > 0.05$) difference in the tail-length variance. So, one of the principles when studying biometrical differentiation is the knowledge whether the groups in question are uniform or not.

Let's try to make the correlative topography analysis starting from the general data set – all Robin measurements taken at both ringing stations. After performing procedure for all data one obtains a picture shown at Figure 2. In the central part of the chart there is rather regular concentration of isolines representing a „central mountain" and some rather chaotic lines around, being the result of some excep-

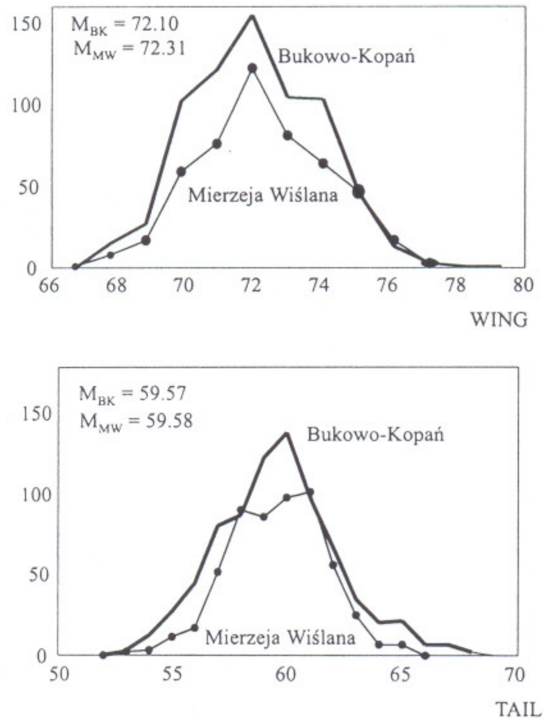

Fig. 1. Distributions of wing-length and tail-length measurements of immature Robins caught in autumn 1997 at Bukowo-Kopań and Mierzeja Wiślana ringing stations. Average values (M_{BK} and M_{MW}) are given for both measurements.

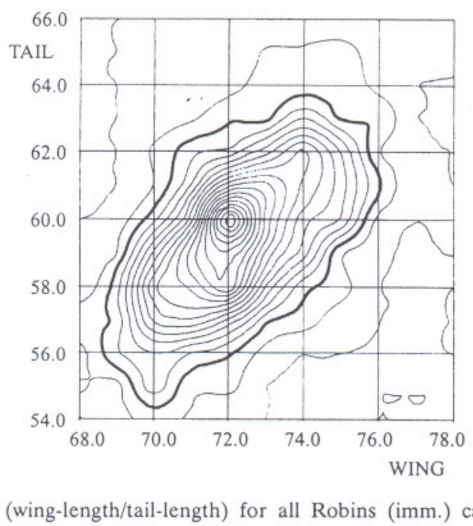

Fig. 2. Correlation chart (wing-length/tail-length) for all Robins (imm.) caught in autumn 1997 at Bukowo-Kopań and Mierzeja Wiślana. Isolines below the thick one are removed from the following Figures.

tional deviations in measurements included into calculations. At least some of them were reading mistakes of measurements and miswriting the data during recording. These lines should be removed as they represent usually nothing more than „information noise". Removement of some „lowland" isolines is possible within the options available in the SURFER programme. After this „cleaning procedure" the main „mountain" could be shown in two aspects – the plane isolines map and three-dimensional graph giving better picture of the group composition (Fig. 3). The second aspect is useful for those who have some problems with three-dimensional interpretation of the isolines' map. This, very general picture, confirms a common belief that wing-length and tail-length are positively correlated (this is generally true for the Robin, but it is not always the case – Busse 1988), but at the same time this distribution seems to be contradictory to data showing that there is

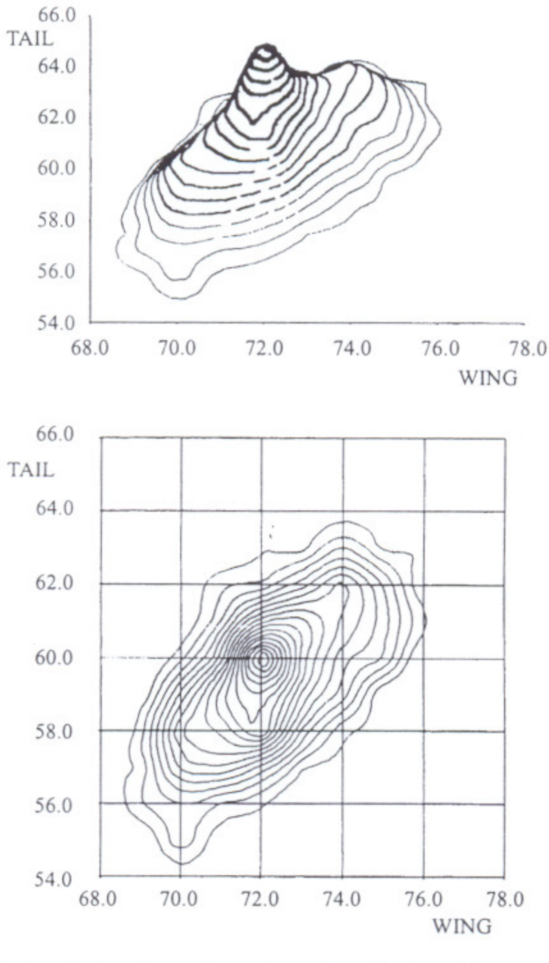

Fig. 3. „Cleaned" correlation chart and three-dimension picture for the total sample presented at Figure 2.

sexual dimorphism in both wing- and tail-length (e.g. Glutz von Blotzheim 1988, Svensson 1992). If there is a sexual dimorphism in measurements, this distribution must contain at least two groups of birds where males belonging to the group of smaller birds are just of size of females originating from the larger-sized birds. Possibility that the size structure is even more complicated should not be excluded.

Next steps of the analysis confirm the last statement of the previous paragraph – when we use correlative topography procedure to the samples of the Robin measurements collected separately at both ringing stations, the pictures (Fig. 4) show clear differentiation of Robins migrating through Bukowo-Kopań and Mierzeja Wiślana. The „mountains" we obtain are of a very different „relief" and the highest peaks are situated in various locations – at Bukowo-Kopań there is one very com-

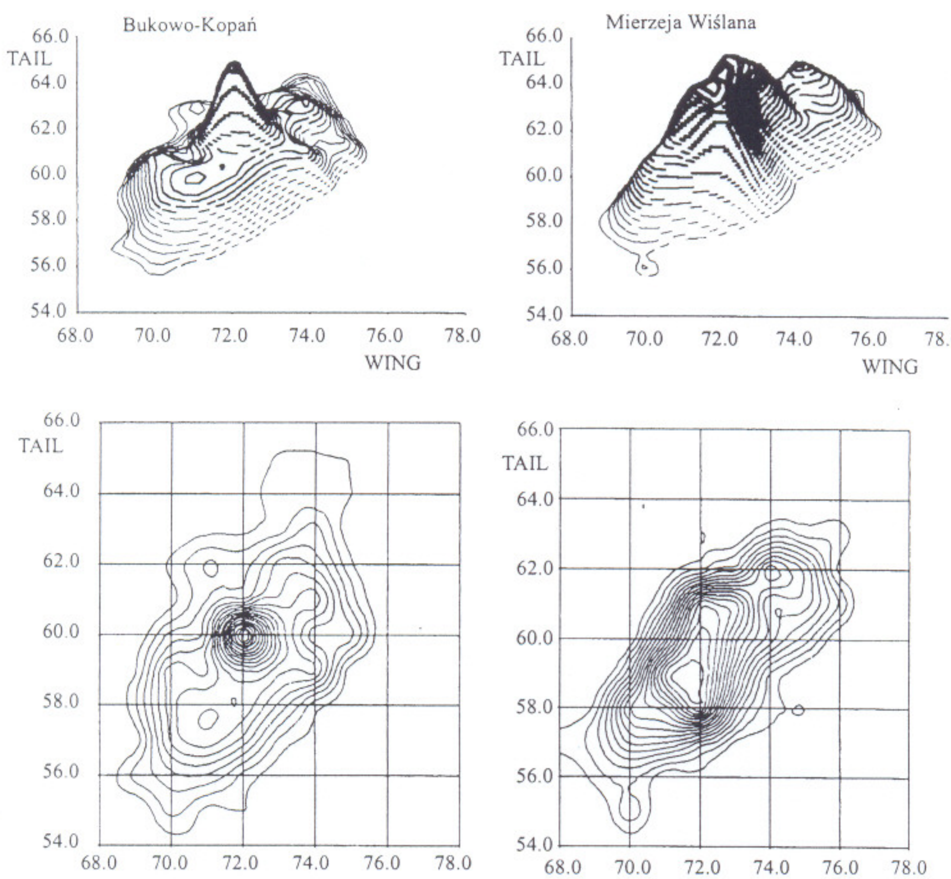

Fig. 4. Correlation charts and their three-dimension presentations for Bukowo-Kopań and Mierzeja Wiślana separately.

pact peak at co-ordinates 72.00 (wing) and 60.00 (tail) while the highest peak at Mierzeja Wiślana is at 72.00-58.00. When one considers supplementary information about seasonal migration patterns at both stations in 1997 (Fig. 5) the biometrical differentiation shown above is not too surprising as the migration pattern suggests that different populations of Robins do pass these two stations. For a more detailed analysis of biometrical structure of migrating Robin populations, the season was divided into three periods of migration as shown at the Figure 5. This is a very rough division of Robins into few groups used in this exemplary analysis and is not equivalent to a real wave division, similar to those used in other biometrical analyses (e.g. Busse 1972, Busse and Maksalon 1978, Maksalon 1983) or analyses of seasonal migration dynamics (Busse 1996, Remisiewicz and Baumanis 1996). Figures 6 and 7 show how well pronounced the differences in wing/tail distributions are if more compact groups of migrants are analysed. Out of the six analysed groups of birds only group II at Mierzeja Wiślana is similar to the general distribution at this station. However, this group divided into two parts according to the migration dynamics (two-days of lower intensity of migration between two distinct peaks – Fig. 5)

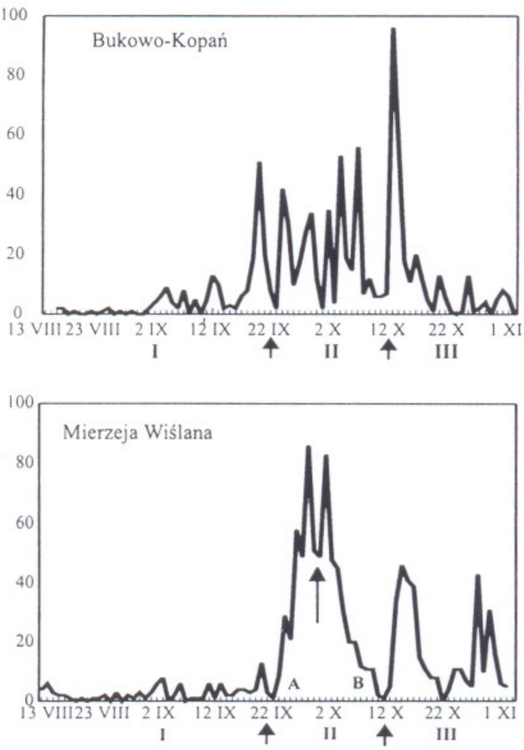

Fig. 5. Migration dynamics of Robins passing Bukowo-Kopań and Mierzeja Wiślana, autumn 1997. Arrows below the X axis show division of the migration time onto three periods. At Mierzeja Wiślana a subdivision of the second period is pointed by the arrow on the graph.

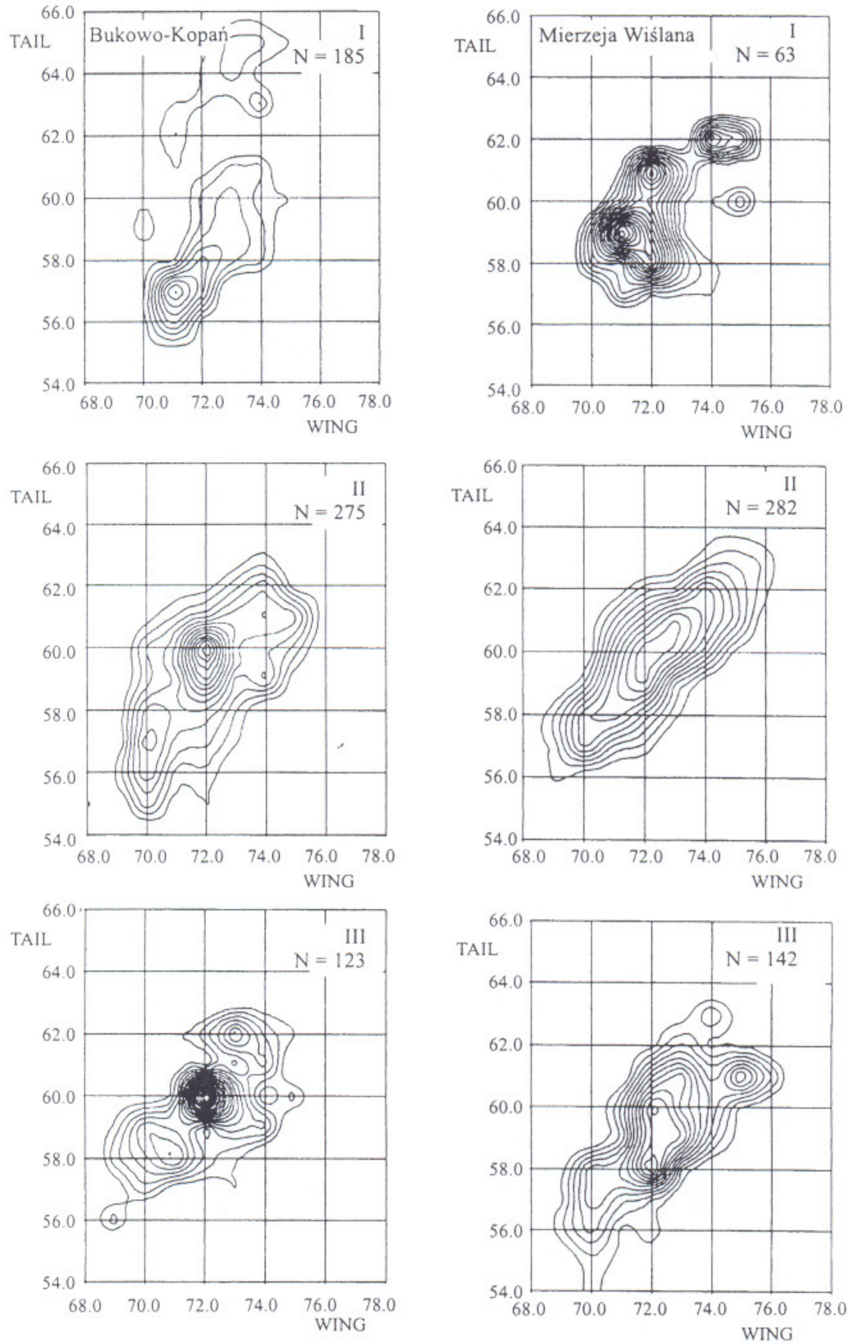

Fig. 6. Correlation charts for three periods of migration (according to division shown at Fig. 5). Numbers of individuals measured are given as N.

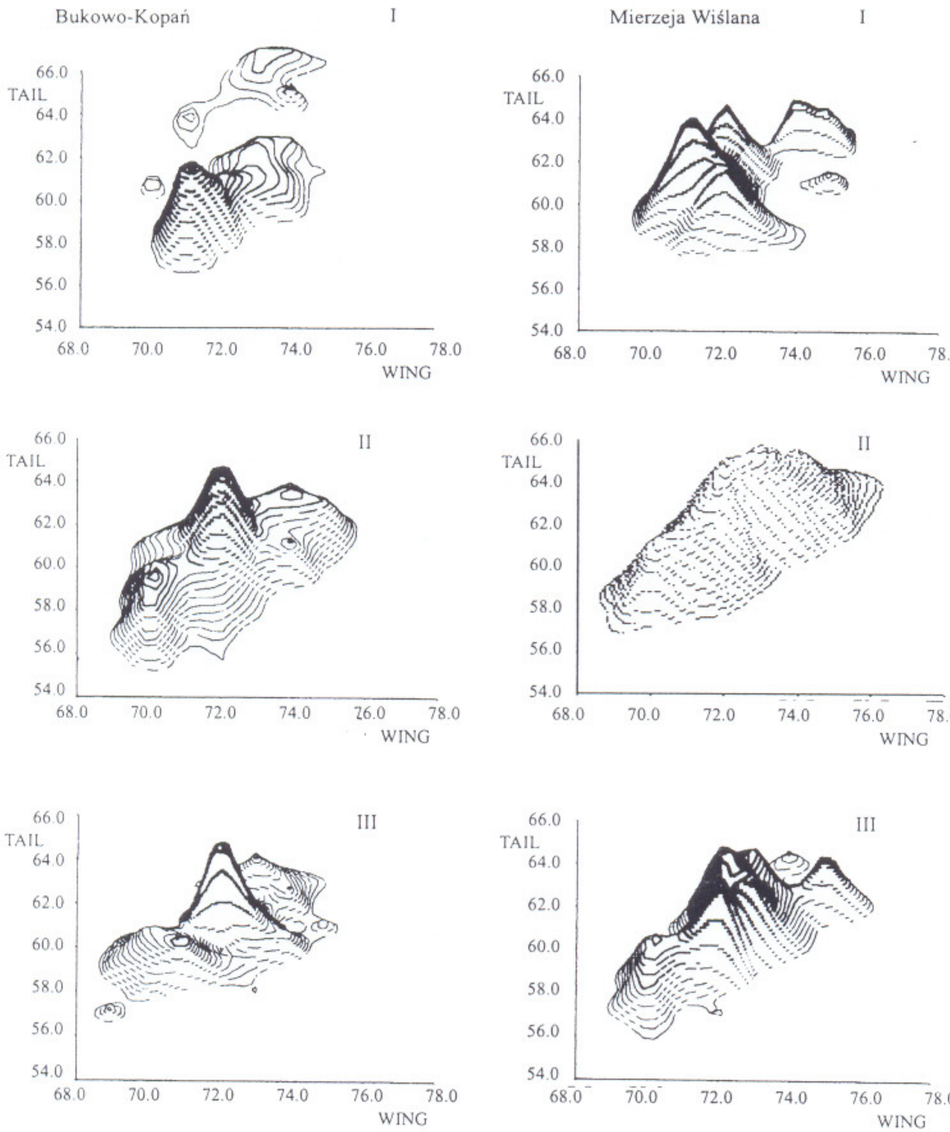

Fig. 7. Three-dimension presentation of the correlation charts shown at Figure 6.

shows that even neighbouring peaks of migration could be differentiated very much (Fig. 8). In this case it is interesting that the first, pronounced peak of migration is more uniform than the following one. The pictures presented above visualize the complexity of the biometrical patterns observed when more detailed analyses are performed. This should convince that a great care is necessary when any assumptions as to uniformity of biometrical data are made.

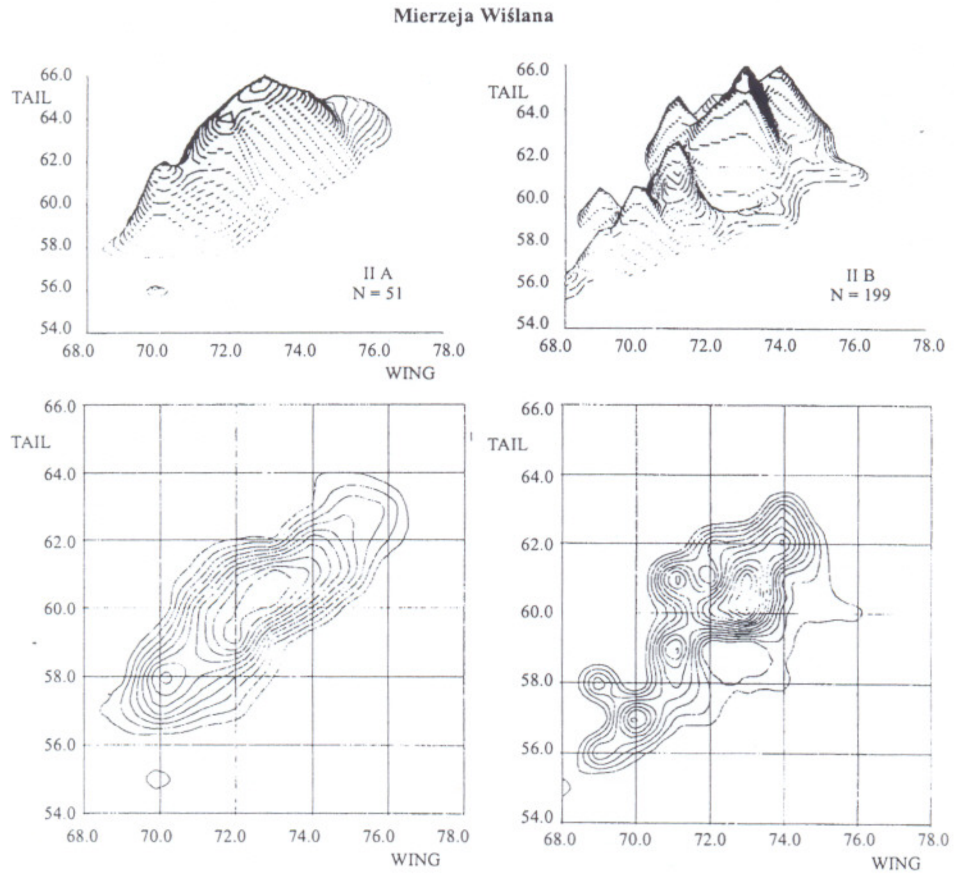

Fig. 8. Correlation charts and their three-dimension presentations for two subsamples (A and B, according to division shown at Fig. 5) of the period II at Mierzeja Wiślana.

Apart from this very general conclusion, the method offers some possibilities to describe the observed patterns more precisely. The software allows to localise local peaks of every group distribution (giving their X and Y co-ordinates and relative height), to define „volume" and surface of the „mountains" above the defined level (Table 1, Fig. 9). If one wants to compare different groups (both at one station and these at different stations) the original, raw distributions should be recalculated to the same number level, e.g. to one thousand of measured birds or to per cent shares. Then resulting distributions must have the same value of the basic isoline (at Figure 9 all distributions were recalculated to one thousand and the basic isolines are equal to 25). The studied distributions can be described by number of peaks and their height, e.g. Bukowo-Kopań I (BK I) group and Mierzeja Wiślana II (MW II) group have only one low peak suggesting the small concentration of measurements. At the same time these two groups are much differentiated as to the total number of birds which measurements fall within the central concentration of the distribution (very small value of „volume" index for BK I and much higher for MW II). Other groups have three peaks each but their heights show large variation as well as their volumes. Surface index seems to illustrate how much differentiated is the relief of distribution „mountains" but it should be interpreted in relation to the volume index. More exact evaluation of these parameters will be possible after more detailed analyses of distribution patterns.

Table 1

Characteristics of wing-length/tail-length distributions of Robins caught at Bukowo-Kopań and Mierzeja Wiślana stations in subsequent waves of migration. Peak's height as well as wave's volume and surface are given in relative values. Main distribution peak within the wave is given in bold.

Wave	Peak	Bukowo - Kopań				Mierzeja Wiślana			
			Wing	Tail	Peak		Wing	Tail	Peak
I	A		**71.00**	**57.06**	**55.9**				
	B						**71.00**	**58.89**	**103.0**
	C						72.00	60.94	76.0
	D						74.00	61.96	60.3
Volume		50.1				288.1			
Súrface		140.2				638.5			
II	A		70.00	57.06	38.7				
	B		**72.00**	**59.91**	**76.7**		**72.00**	**59.91**	**59.4**
	C		74.00	60.93	35.5				
Volume		141.1				228.1			
Surface		329.5				373.8			
III	A		71.00	58.08	47.4				
	B						**72.00**	**58.08**	**67.7**
	C		**72.00**	**59.91**	**119.2**		72.00	59.91	61.5
	D		73.00	61.96	47.5				
	E						75.00	60.94	46.3
Volume		163.7				198.7			
Surface		465.0				394.4			

Another method of analysis of distribution patterns uses the slicing procedure which allows to draw vertical profiles of the „mountains" cut along defined lines. The lines could be arbitrarily selected but slicing through the highest peaks of studied distributions could be recommended. The profile shape depends on the line of cutting – for the same distribution various profiles can differ to a large extent

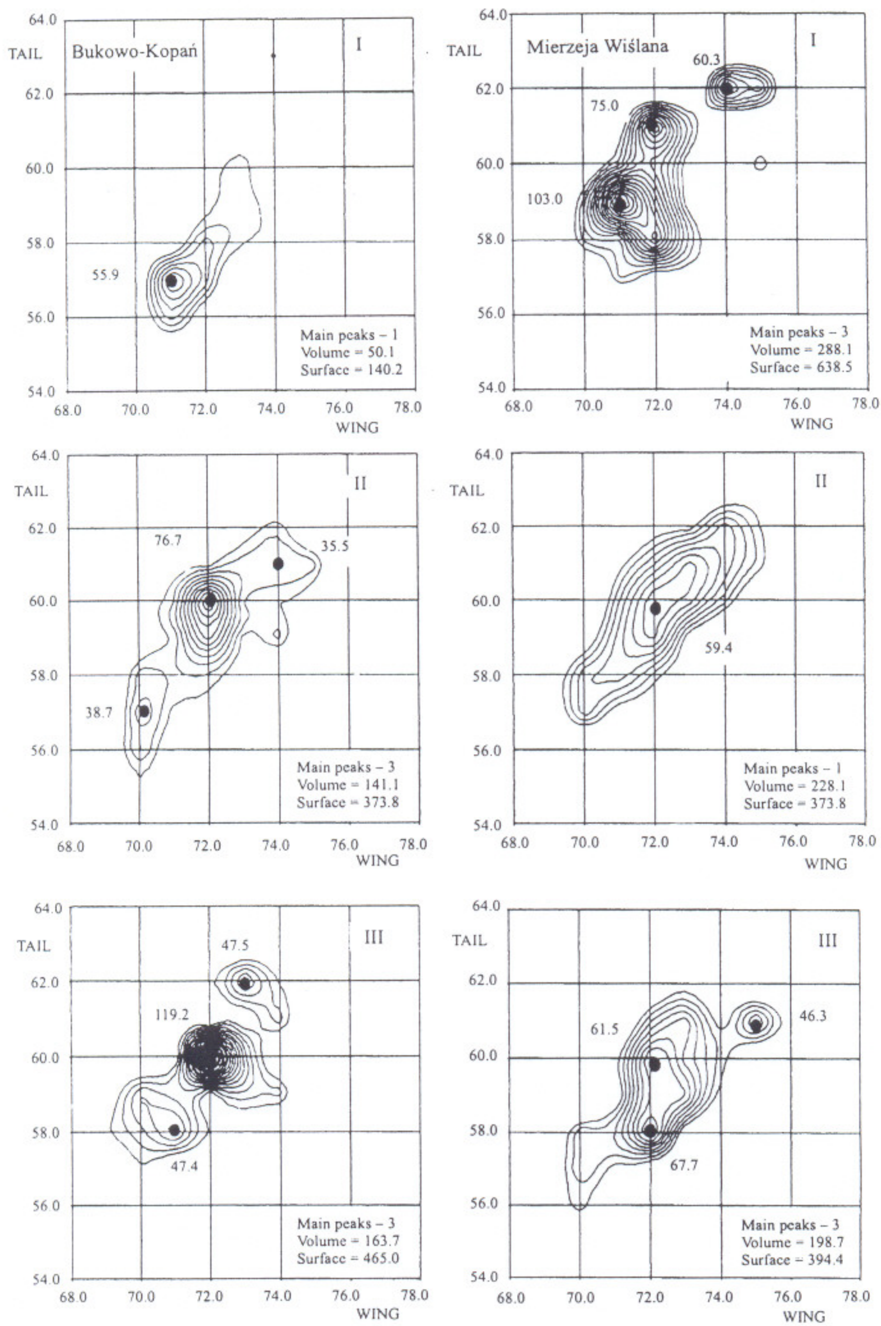

Fig. 9. Standardised correlation charts for three periods at Bukowo-Kopań and Mierzeja Wiślana (common basic level – value 25 isoline). Numbers describe heights of observed peaks. Number of peaks, volume and surface indices are listed for every chart.

(Fig. 10). Despite of this unpleasant feature, drawing profiles could be a useful method when comparisons between some groups are required (Fig. 11). Contrary to the three-dimensional distributions, linear profiles could be easily tested for statistical significance of their differentiation.

Correlative topography analysis should be performed especially if one wants to localise the breeding origin of migrants using the biometrical data. In the description of the method of localising the breeding origin of migrants this problem was already mentioned (Busse 1997).

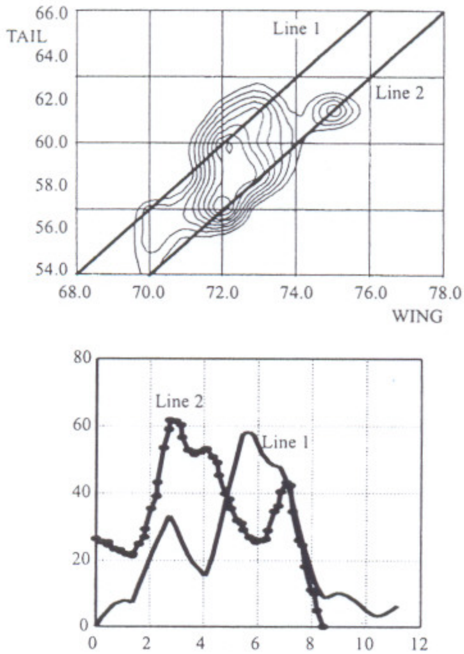

Fig. 10. Example presentation of distribution by slicing method. Results for one correlation chart cut along two lines are shown.

CONCLUSIONS

1. The method gives opportunity to study internal biometrical differentiation of groups of birds defined by means of seasonal migration pattern analysis, collected at different ringing stations or selected using other methods of bird migration studies.
2. The method should be developed by comparing its results with the data collected by ringing and orientation experiments. The combined picture could allow to solve the problem of mixing of different populations on migration or show at least partial isolation of groups that originate from various breeding grounds.

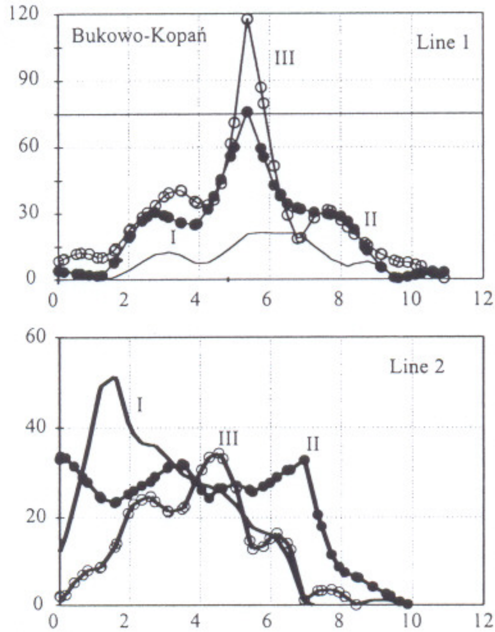

Fig. 11. Distributions obtained by slicing the correlation charts for three periods at Bukowo-Kopań.

B						**72.00**	**58.08**	**67.7**
C		**72.00**	**59.91**	**119.2**		72.00	59.91	61.5
D		73.00	61.96	47.5				
E						75.00	60.94	46.3
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