sciendo THE RING 43 (2021) 10.2478/ring-2021-0002

THE EUROPEAN AUTUMN MIGRATION PATTERN OF THE GARDEN WARBLER, *SYLVIA BORIN* – A BASIC ANALYSIS OF ORIENTATION CAGE FIELD DATA

Przemysław Busse

ABSTRACT

Busse P. 2021. *The European autumn migration pattern of the Garden Warbler, Sylvia borin – a basic analysis of orientation cage field data*. Ring 43: 41–86.

The introduction of an effective method for studying the local headings of migrants using 'orientation cages' has made it possible to study the migration patterns of small passerine nocturnal migrants. Numerous papers have been published on varied samples of local data collected using this method. A rough generalization was presented at the 2019 Meeting of the European Ornithologists Union and subsequently published in *The Ring*. Case studies on data collected for the Blackcap have already been published, and further studies on other species were suggested. The presented work is the next study of this kind, on the migration pattern of the Garden Warbler, using data from orientation tests collected in autumn as part of the work of the SEEN (SE European Bird Migration Network). The data comprises 2,593 tests performed at 31 ringing sites in Central/Eastern Europe and the Middle East. The paper continues the discussion of application of the method to present migration patterns in a geographically wide territory. The general data evaluation methods in this work are exactly as described in the earlier papers. The paper discusses azimuths of arrival and departure tracks at every ringing site, their linearity, number relations between departing and arriving headings, and the general pattern of migration streams followed by different groups of migrants.

The hypothesis put forth earlier, stating that the arrival/departure heading axes shown in studies using orientation cages are situated linearly, is once again confirmed and can be used as a general assumption in this type of study. The average deviations are very small and are negligible for drawing general migration patterns. In some cases, however, there were deviations caused by the geographic location of the study site. This problem should be discussed in more detail when more species data become available. Nine migration streams are defined in the study area, which are presented, for simplicity, using different names and colours on maps. Southward and south-eastward streams are dominant and distributed similarly to the streams of the Blackcap. The most pronounced is a stream shown in yellow (*YELLOW stream*), which is directed from the wide area of central and eastern Europe to the Arabian Peninsula. The *BLACK* and *NAVY* streams are the most intriguing (running nearly longitudinally) and require a great deal of attention in further analyses of migration in the Mediterranean. Two styles of presentation of the species migration pattern are discussed, of which the location style of presentation seems to be

more precise. The simpler presentation style that shows only general heading axes could be used to compare the general patterns of different species.

P. Busse, Bird Migration Research Foundation, Przebendowo 3, 84-210 Choczewo, Poland; e-mail: busse@wbwp-fund.eu

Keywords: migration pattern, methods, ringing, orientation cage, autumn migration, passerines, Garden Warbler, *Sylvia borin*, Europe, Middle East

INTRODUCTION

An effective method for studying the migratory patterns of nocturnal passerine migrants by checking their local headings was introduced in 1995 (Busse 1995). The novel standard procedure of the method (only 10 minutes of testing during the daytime) enabled intensive data collection. A new evaluation method was introduced as well (Busse 1995, Busse and Trocińska 1999). Since that time data from more than 43,000 tests on nocturnal migrants have been collected at more than 40 European ringing sites in autumn, mainly by the Operation Baltic and SEEN (SE European Bird Migration Network) (Busse 2019). Evaluation of the test data was discussed in detail by Busse (2018), and the general nocturnal migration pattern of passerines based on the collected data was presented in a subsequent paper by Busse (2019). First, it was found that at every location studied a few migration streams directed towards different destinations could be defined. Before analysing the migration patterns of individual species, a few basic properties of the data were studied and discussed in a case study on the Blackcap, *Sylvia atricapilla*, at the Bukowo/Kopań ringing station in Poland (Operation Baltic/SEEN), as the station whose orientation data set covered the longest period (1995-2010) and where the Blackcap was one of the most commonly tested bird species (Busse 2020). It is well known that most single individuals show multimodal headings in the cage (e.g. Busse 1995; Busse and Trocińska 1999; Muś 2005, 2008; Ożarowska and Muś 2008), and the same is true when we add up these headings to obtain group/sample headings for the test site. In most cases, especially in the group heading patterns, the heading directions were found to be located more or less on opposite sides of the wind rose and were interpreted as *input* (arrival) and *output* (departure) headings. Distributions in the group headings are varied as to their 'power', so we can roughly estimate the numerical shares of groups migrating in different directions.

This paper is an attempt to draw a large-scale autumn migration pattern for another species – the Garden Warbler, *Sylvia borin*, which is systematically very close to the first case species studied, i.e. the Blackcap, but is exclusively a long-distance Europe to southern/southwestern Africa migrant (Moreau 1974, Shirihai *et al.* 2001). Some general findings common to both species could be the basis for evaluations of further species.

MATERIAL

As in the presentation of the overall passerine migration pattern (Busse 2019), the study area (Fig. 1) mainly covers the SE European Flyway, but also includes a few sites located on the Central European Flyway (Croatia, Italy) and sites in Medvedivka and Omsk, which at least partly belong to the Indian Flyway. The list of sites, with years of work and numbers of Garden Warbler individuals tested, is given below in alphabetical order of the station codes used in Figure 1 and elsewhere in the text, tables and figures. In an earlier paper (Busse 2020), the site list includes brief information on the *general location* of the sites and a brief description of the *habitat*. Here this information is added only for study sites that were not listed in that source.

Fig. 1. Geographical distribution of the study sites. After Busse (2019), modified. See *Material section* in the text (p. 43) for list of letter codes.

AA – Aras, Turkey (2006-2007, *N* = 63)
AC – Carpatica, Poland (2000-2002, 2004, *N* = 37)
AH – Ashtoum, Egypt (2010-2011, *N* = 16) – *general location:* southern Mediterranean coast, narrow spit of land between the sea and a huge coastal lagoon; *habitat:* strip of bushes along the coast of the lake, bordering on a strip of recreation housing (two- or three-storey buildings) opposite a road.
AK – Akyatan, Turkey (2003, *N* = 89)
AN – *Antikythira, Greece* (2009, *N* = 64)
AR – Arosio, Italy (2005-2009, *N* = 28)
AS – Siemianówka, Poland (2002-2004, *N* = 82)
AZ – Azraq, Jordan (2002-2003, *N* =82)
BK – Bukowo/Kopań, Poland (1995-2010, *N* = 539)

BR – Burullus, Egypt (2005-2007, *N* = 9) – *general location:* southern part of a huge coastal lagoon in northern Egypt; *habitat:* dams creating a system of fish ponds bordering on reed bed (a few km wide) of a lagoon.
CR – Cernek, Turkey (2002-2004, 2009, *N* = 816)
DH – Dhleil, Jordan (2002, *N* = 39)
DI – Dicle, Turkey (2003-2005, *N* = 67)
DR – Drużno, Poland (1996-2007, *N* = 46)
GU – Gumbaritsy, Russia (2000-2001, *N* = 46)
HA – Haademeeste, Estonia (1996, 2001, *N* = 34)
HY – Hashimyyia, Jordan (2001, *N* = 64)
KB – Karabogaz, Azerbajian (2004, *N* = 73)
KK – Kalimok, Bulgaria (2001, *N* = 6)
KN – Kinburn, Ukraine (2001, *N* =33)
MV – Medvedivka, Russia (1998-2001, *N* = 47)
MW – Mierzeja Wiślana, Poland (1996-2008, *N* = 49)
OL – Olenevka, Ukraine (2006, *N* = 114)
OM – Omsk, Russia (2002, *N* = 118) - *general location:* suburb of Omsk situated within a steppe; *habitat:* teaching and study gardens of the local university with numerous fruit trees and bushes, bordering on a strip of broadleaf trees serving as a windbreak.
PP – Pape, Latvia (2000-2003, *N* = 32)
RA – Rakutowskie Lake, Poland (2010, *N* = 37)
TK+TM – Talitha Kumi + Tulkarem, Palestine (2000, 2015, *N* = 7)
TU – Turov, Belarus (2000, *N* = 7)
UC – Ucka, Croatia (2014, *N* = 15)
WL – Wadi Allaqi, Egypt (2012, *N* = 19) – *general location:* an oasis created several kilometres from the Nile, near Aswan, by a deposit of the town's wastewater in a local desert depression; *habitat:* polders with reed beds and strips of bushes.

There are a few sites where a vast number of birds were tested over several years. Yearly samples at individual sites frequently numbered dozens or even hundreds of tests. At some SEEN sites, however, only a few autumn data are available, or only single or no garden warblers were caught or tested. Therefore there is pronounced variation in the actual value of local directional patterns. Nevertheless, in terms of the number of sites (31) and number of tests performed (2,593) the sample sizes are large enough to provide a general pattern of the movements of this passerine species on a wide geographic scale. The analysis mainly includes data from 26 ringing sites at which at least 15 tests were performed. In a few places five additional sites where fewer tests were carried out are presented.

METHODS

The general data evaluation methods in this work are exactly as described earlier in papers by Busse (2017, 2019, 2020, 2021). Because it is essential to understand the presentation and reasoning used in this work, some parts of the section are exact citations from the previously published papers. If any doubts remain regarding the methods presented here, it is recommended to the consult papers mentioned above for details omitted from this abbreviated description.

"Birds were caught using mist-nets, sexed/aged, measured (wing length, tail length, and wing formula), scored for fatness, and weighed according to Operation Baltic/ SEEN standards (Busse 2000). Individuals were immediately (within 2 hours) tested in Busse's Flat Orientation Cage (Busse 1995, 2000), placed in a wide, open meadow. The test lasted 10 minutes. The total number of Blackcaps caught was much higher than the number tested, as individuals for testing were taken randomly, mainly according to the availability of manpower for running tests.

Basic field data processing has been presented and discussed in detail by Busse (2017). The procedure used assumed the multimodality of distributions at both levels of evaluation: individual bird and group distribution of headings. The individual bird level was based on actual numbers of scratches made by the bird in eight sectors of the cage. The individual distributions of scratches were processed in ORIENT 4.6 software, which gave the individual heading pattern (no significant heading according to the chi-square test, or from one to a maximum of four vectors, which were assigned to one of 16 sectors of the wind-rose). Each vector had its own 'power', i.e. a percentage share in the total number of scratches. The individual heading pattern can be presented as vectors (direction and length illustrating the 'power') on a wind-rose panel. This presentation is rarely used, as the main goal of testing is to obtain the group distribution of headings. At the group level, vectors of all individuals included in a defined sample were added in sectors. The group headings distribution was the distribution of percentage shares (indices of the number of headings) of the above-mentioned sector sums in the total sum of powers. Group distributions are usually presented as polygons in radar graphs on the wind-rose panel..." (Busse 2020). The local heading patterns are presented here as seen in the example in Figure 2 and subsequently, for all sites, in Figure 3.

"According to the procedure of estimation of the main headings, described in detail by Busse (2018), the distribution was interpreted as several estimated headings presenting 'input' (arrival) and 'output' (departure) heading directions". (op. cit.)

A problem that was solved earlier (Busse 2020, 2021) for the Blackcap on the basis of the data from one ringing site – Bukowo/Kopań – and for multiple ringing sites (28) is confirmation of the suspected axiality of arrival and departure headings. *"Thus the axiality of headings is assumed here, and the opposite or quasi-opposite headings found at the various ringing sites are presented in the figures using fixed colours representing axes of migration at a given location. Thus, the RED stream is heading very much westward (traditionally called the Atlantic Flyway), the BLUE stream heads towards the western Mediterranean, GREEN heads SW towards the Chad Lake area (?), ORANGE heads directly to the eastern part of Africa, and YELLOW is directed towards the Middle East/Arabian Peninsula (the last two together are usually called the SE European Flyway), while WHITE heads towards a winter quarters very far eastward. The BLACK heading is surprisingly longitudinal and has never before been described, but mentioned only by Busse (2019)."* In the present paper, an additional *NAVY* stream is defined according to the Garden Warbler data.

"Due to the properties of the field method – an orientation cage wind-rose divided into only eight sectors – the heading vectors will not be very precise, as to either direction or length. Previous estimations suggest that the level of precision of directions determined using estimation procedures can be plus/minus 6-11°, which means one of

32 rose-wind sectors. The estimation procedure, after Busse (2019), takes into account mainly the local maxima of the polygon of distribution of headings... For a more quantitative determination of the heading direction (and its 'power' – the number index of the heading vector) we can use not only the local maximum value in the result vector calculation, but also those closely bordering on it (minus one and plus one sector values), and sum up these three values. The result vector will be more precise than previously, and we will have some information about its power (share of the index in the total distribution). The power values will still be estimated, but they will hereafter be referred to as 'calculated' ... In any general bird migration study the level of precision reached here is high enough for a discussion of migration patterns on a continental scale." (Busse 2020).

In the present work (as in the previous one – Busse 2021), the axiality of the arrival and departure headings is checked at the inter-site level. *"For every study site, headings assigned to a specific stream were compared with respect to the wind-rose sectors they belong to, and deviations from the straight line were determined ('0' = opposite sector, '+' - departure heading shifted clockwise, '–' - shift anti-clockwise). Comparisons were made separately for raw and calculated headings.*

Apart from axiality, another parameter characterizing the departure/arrival number indices was studied: the Departure/Arrival number relations vary at different sites and for different streams of migrants. Two aspects of this parameter were studied – the geographic location of the site and the stream of migration". (Busse 2021)

The geographical description of the Garden Warbler migration pattern is presented using two of the three methods used in the analysis of the Blackcap pattern in the paper by Busse (2021) – the ***graphical*** and ***calculation*** procedures. The third method used for the Blackcap (the *rough graphical* estimation) is not used here, as it was determined to be significantly less precise and thus less informative. The graphical estimation of the pattern used a basic map with the distribution of local headings in geographical space (see Fig. 5). Then the local headings were extended using straight lines in both directions: arrival headings to the north and departure headings to the south (see Fig. 6). Next, the average crossing points of the migration streams with the edge of the map were determined. A summarizing figure (see Fig. 7) presents a general estimation of the axes of the migration of the Garden Warbler and Blackcap populations. In the calculation procedure, the data from stations where the defined heading stream was observed were studied, i.e. the centre of the station's location (average geographic co-ordinates) and average arrival and departure tracks (see Figs 8–9, *Appendix – Maps*).

Some additional parameters, i.e. the number indices of different streams, relations between the departure and arrival number indices, and their relation to the location (geographic co-ordinates), were analysed using *chi-square* and *t*-tests and by means of Pearson's correlation.

RESULTS AND DISCUSSION

Local heading patterns

Evaluation of the local heading patterns began with the standard procedure. An example is shown in Figure 2, according to the style described in earlier papers (Busse 2019, 2020). The results for the sites are presented in Figure 3 and documented in the *Appendix – Sites* table. To facilitate comparison of the results of the analyses for both species, the Garden Warbler and the Blackcap, basic data about the local patterns at each ringing site are given in the same manner: *"(1) classification of the local headings to one of eight migration streams defined in the general passerine migration pattern presented by Busse (2019) and designated with colour names (see Methods, p. 45); (2) heading directions (sectors of the local wind-rose) of arrival and departure; and (3) indices of numbers of birds belonging to the stream groups. Values of derivative parameters used later in a detailed discussion of some aspects of the migration pattern are included. A summary for the migration streams is given in Table 1."* (Busse 2021).

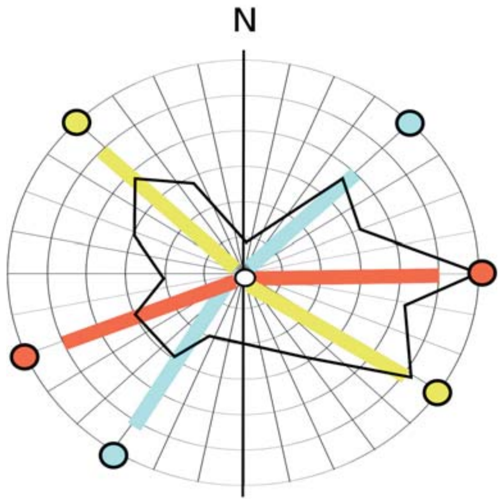


Fig. 2. Example of a local heading pattern after the basic evaluation. Polygon sample distribution of headings; circles and lines – estimated local headings; colours preliminary classification of headings to streams of migration as proposed by Busse (2019).

More than one stream of migration was found at all study sites there (Fig. 3). The most commonly found (Table 1) was the *YELLOW* stream (24 of 31 sites), followed by *ORANGE* (17) and *GREEN* (15). The least common were the *WHITE* (6 sites), *BLACK* (7) and *TEAL* streams (8). This pattern is very similar to that found earlier for the Blackcap (p = 0.92 according to the *chi-square* test). The only visible difference is that here the *BLACK* stream as defined for the Blackcap is split into two streams: *BLACK* and *NAVY*. The *NAVY* stream is more clearly visible for the Garden Warbler data, while the analysis of the Blackcap data raised some doubts, as mentioned in Busse (2021).

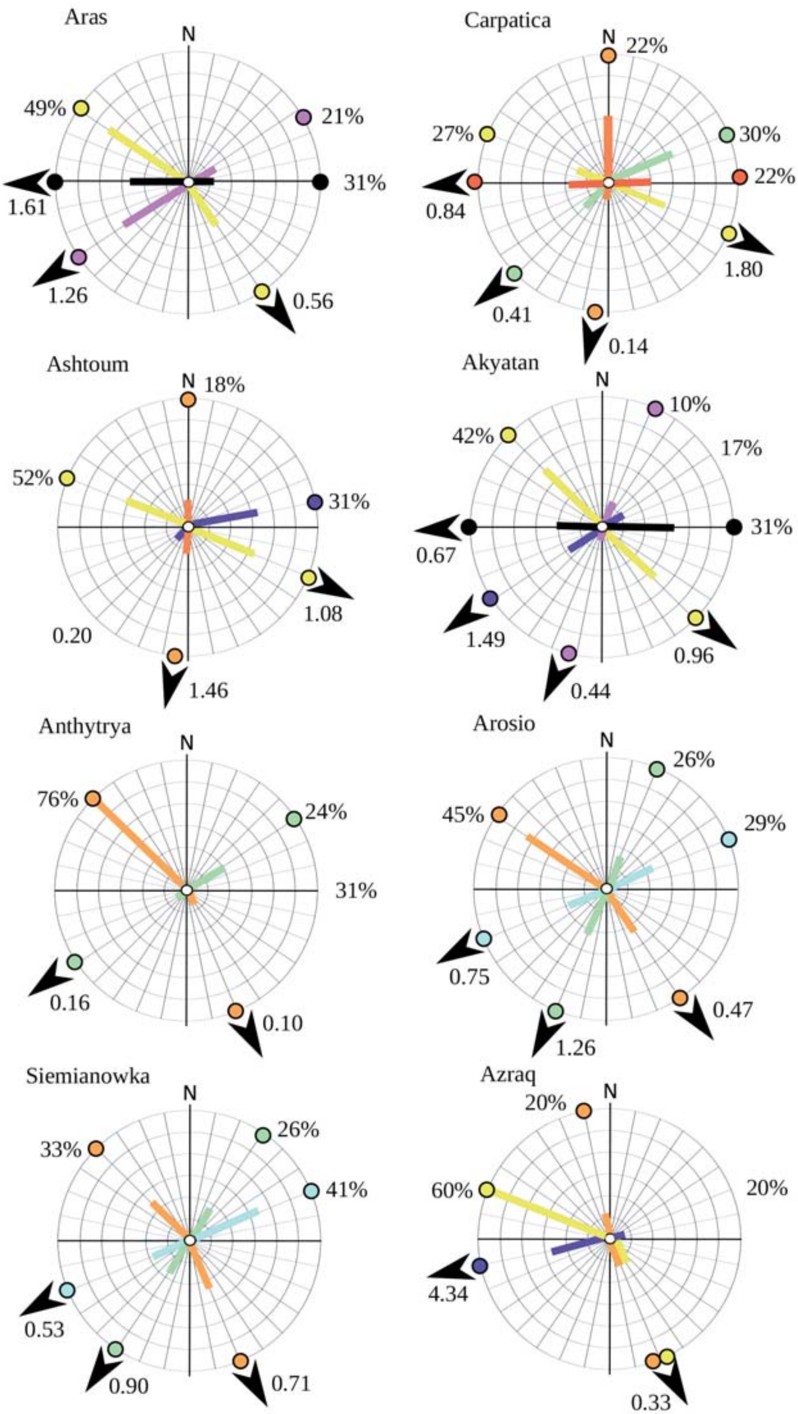


Fig. 3. Local heading patterns at the study sites. For basic legend see Fig. 2. Added here: % numbers – percentage share of the stream (colour) among all headings; arrows and numbers – departure headings with the value of the *Departure/Arrival* heading indices ratio.

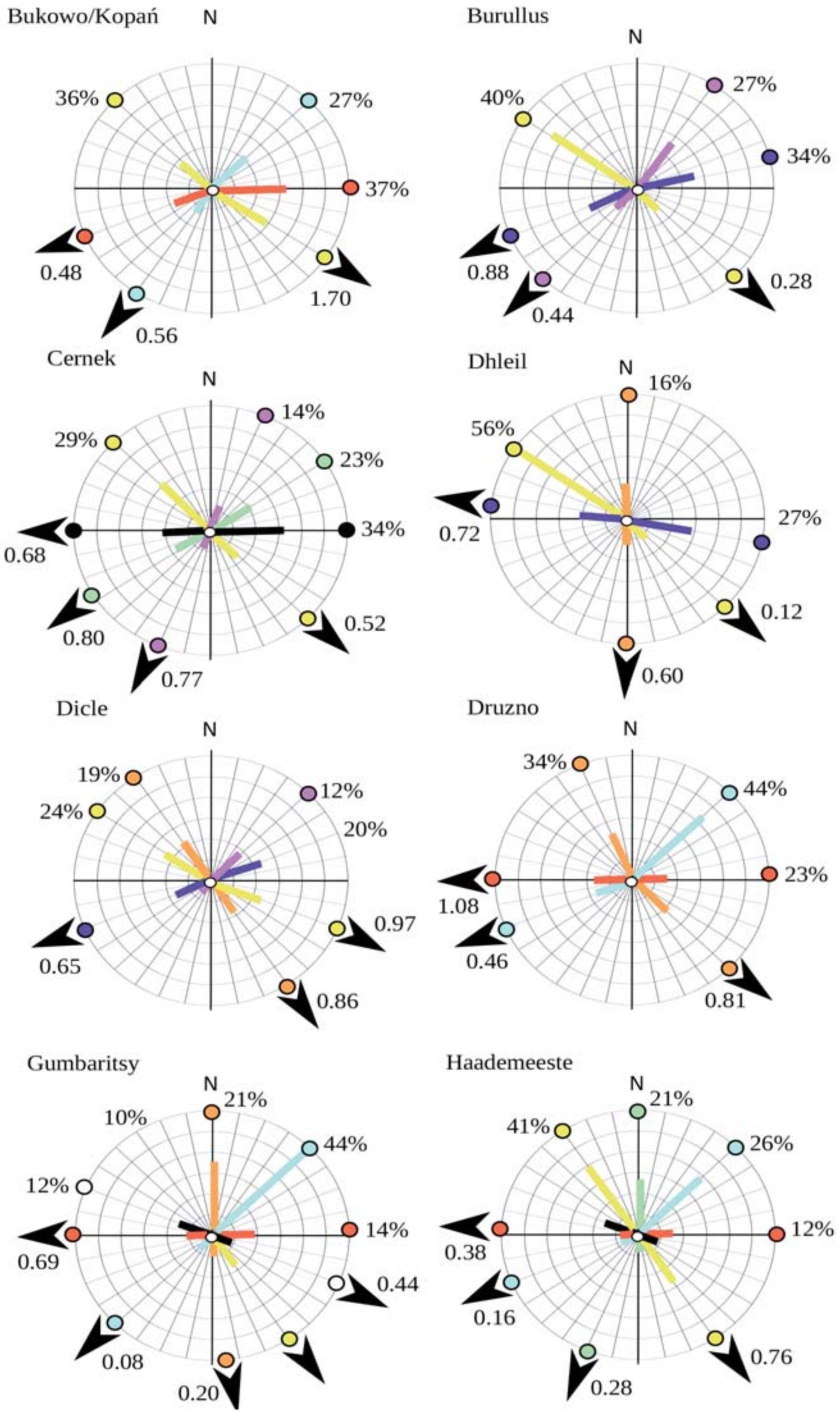
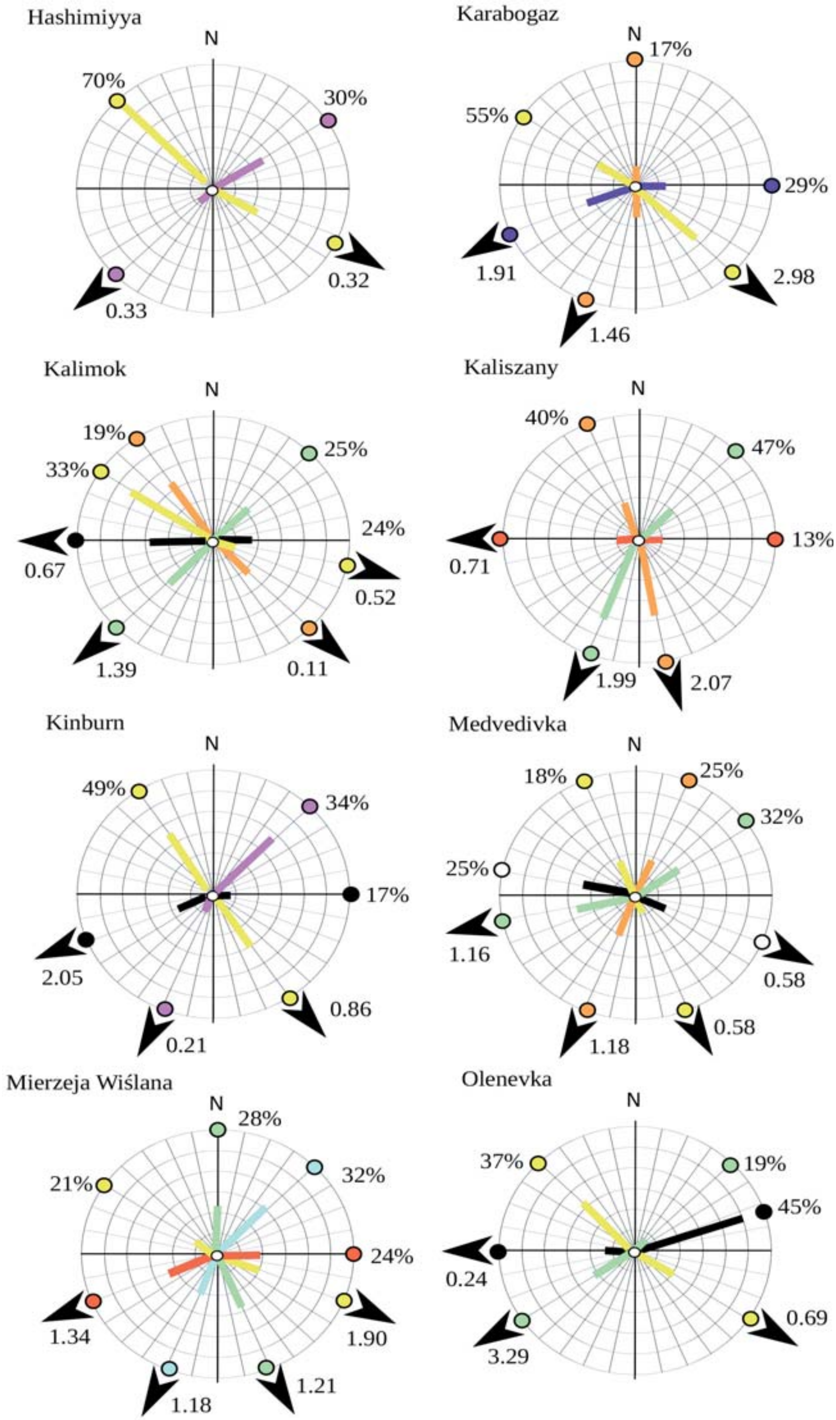

Bukowo/Kopań
N
36%
27%
37%
0.48
0.56
1.70
Burullus
N
40%
27%
34%
0.88
0.44
0.28
Cernek
N
14%
29%
23%
34%
0.68
0.80
0.77
0.52
Dhleil
N
16%
56%
27%
0.72
0.12
0.60
Dicle
N
19%
24%
12%
20%
0.97
0.65
0.86
Druzno
N
34%
44%
23%
1.08
0.46
0.81
Gumbaritsy
N
21%
10%
44%
12%
14%
0.69
0.44
0.08
0.20
Haademeeste
N
21%
41%
26%
12%
0.38
0.16
0.76
0.28

Fig. 3. cont.



Hashimiyya
N
70%
30%
0.32
0.33
Karabogaz
N
17%
55%
29%
1.91
2.98
1.46
Kalimok
N
19%
25%
33%
24%
0.67
0.52
1.39
0.11
Kaliszany
N
40%
47%
0.71
13%
1.99
2.07
Kinburn
N
49%
34%
17%
2.05
0.86
0.21
Medvedivka
N
18%
25%
32%
25%
1.16
0.58
1.18
0.58
Mierzeja Wiślana
N
28%
32%
21%
24%
1.34
1.90
1.21
1.18
Olenevka
N
37%
19%
45%
0.24
0.69
3.29

Fig. 3. cont.

The *Track* (heading patterns) of migration at a site could be studied by both the *estimation* and *calculation* procedures (Table 1), while the number indices (*Index*) could be analysed only by the *calculation* procedure. The relationships between the data were compared in detail for the Garden Warbler.

Table 1
Basic heading parameters for streams of migrants. Track – average heading sector of 32-sector wind-rose; Deviation – deviation of departure heading from straight extension of arrival heading (as number of sectors); Index – average number index of stream heading; Axis – sum of arrival and departure indices; % – percentage share of Axis within total distribution of stream; Dep./Arr. – average ratio of departure to arrival index within the stream distribution.

Stream	N sites		Track			Index				
			Arrival	Departure	Deviation	Arrival	Departure	Axis	%	Dep./Arr.
RED	9	***Avg***	**7.96**	**23.69**	**-0.96**	**10.26**	**7.09**	**17.35**	**20.00**	**0.81**
		SD	0.09	0.92	1.13	4.89	3.67	5.35	9.92	0.46
BLUE	10	***Avg***	**4.80**	**20.68**	**-0.02**	**15.23**	**9.10**	**24.33**	**30.20**	**0.98**
		SD	1.06	1.66	1.49	9.79	5.49	8.52	10.32	0.91
GREEN	15	***Avg***	**5.25**	**19.16**	**0.05**	**11.43**	**9.54**	**20.97**	**26.53**	**1.10**
		SD	7.08	2.39	1.75	6.97	4.95	7.80	9.63	0.79
VIOLET	10	***Avg***	**3.96**	**19.74**	**-0.79**	**9.53**	**8.44**	**17.96**	**23.20**	**3.03**
		SD	1.28	1.56	0.77	6.58	8.30	7.88	10.68	7.72
ORANGE	17	***Avg***	**30.63**	**14.66**	**0.01**	**13.03**	**7.69**	**20.73**	**25.41**	**1.19**
		SD	1.93	2.10	1.66	8.79	4.38	8.63	16.01	1.50
YELLOW	24	***Avg***	**27.61**	**11.77**	**0.18**	**17.76**	**12.87**	**30.63**	**36.96**	**1.03**
		SD	1.27	1.44	1.29	10.57	6.98	10.47	12.80	1.03
WHITE	6	***Avg***	**26.03**	**10.14**	**0.38**	**9.62**	**9.26**	**18.87**	**23.00**	**1.34**
		SD	0.61	1.40	1.55	3.93	3.95	3.81	6.32	1.20
BLACK	7	***Avg***	**7.81**	**23.82**	**0.01**	**12.51**	**12.35**	**24.86**	**31.10**	**1.87**
		SD	0.66	0.71	1.31	7.44	7.23	7.07	**8.24**	**2.25**
NAVY	8	***Avg***	**6.85**	**22.75**	**-0.63**	**9.58**	**9.46**	**19.04**	**23.75**	**1.44**
		SD	1.96	1.26	1.37	4.36	3.24	3.87	7.14	1.21
N headings	106	***Avg***			**-0.20**	**12.11**	**9.53**	**21.64**	**26.68**	**1.42**
N sites	31	*SD*			0.44	2.70	1.82	4.03	4.92	0.64

The arrival and departure headings found at the study sites are defined using the numbers of the sectors where they occur in the distribution of site headings (Fig. 2 and 3). They were determined separately by the two procedures mentioned above (*estimated* and *calculated*) and then compared within migration streams in Table 2 (arrivals) and Table 3 (departures). There were 106 estimated and 108 calculated headings used for arrivals, while 78 estimated and 82 calculated values were used for departures. The differences found vary slightly within streams, but for both procedures the total deviations are less than 0.1 of the 32nd wind-rose sector, which means that the differences are at a level of 1°.

Table 2
Differences between average arrival numbers of migration stream tracks at the sites as determined by the *estimation* and *calculation* procedures

	RED	*BLUE*	*GREEN*	*VIOLET*	*ORANGE*	*YELLOW*	*WHITE*	*BLACK*	*TEAL*		
Estimated											
Min-max	7	4	0		027	26	26	6	5		
sector	8	6	6	4	32	30	30	8	8		
Variation	**1**	**2**	**6**	**4**	**5**	**4**	**4**	**2**	**3**	SD_V =	3.44
n sites	10	11	13	8	16	26	7	8	7	*N* =	106
Avg	7.8	4.6	3.3	3.0	30.3	27.7	27.4	7.5	6.6		
SD	0.40	0.88	2.05	1.41	1.82	1.44	1.76	0.87	1.29	Avg_{SD} =	1.33
Calculated											
Min-max	7.8	3.9	-1.0	2.2	26.9	26.0	25.0	6.2	5.1		
sector	8.1	6.0	5.9	5.0	32.0	31.0	27.1	8.3	8.3		
Variation	**0.3**	**2.1**	**6.9**	**2.8**	**5.1**	**5.0**	**2.1**	**2.1**	**3.2**	SD_V =	3.29
n sites	10	11	14	8	16	26	6	9	8	*N* =	108
Avg	8.0	4.6	3.3	3.6	30.1	27.9	26.0	7.7	6.9		
SD	0.11	0.89	2.29	1.05	1.89	1.55	0.86	0.79	1.30	Avg_{SD} =	1.19
										N =	**9**
Difference	0.2	-0.0	0.0	0.6	-0.2	0.3	-1.4	0.2	0.4	$\mathbf{Avg_D}$ =	**0.00**
										$\mathbf{SD_D}$ =	**0.54**
										p =	**0.57**

Table 3
Differences between average departure numbers of migration stream tracks at the sites as determined by the *estimation* and *calculation* procedures

	RED	*BLUE*	*GREEN*	*VIOLET*	*ORANGE*	*YELLOW*	*WHITE*	*BLACK*	*TEAL*		
Estimated											
Min-max	22	18	18	18	12	10	8	24	22		
sector	24	22	22	22	18	14	12	24	22	Avg_V =	SD_V =
Variation	2	4	4	4	6	4	4	0	0	3.1	1.13
n sites	5	8	10	7	12	23	5	4	4	*N* =	78
Avg	23.2	20.8	19.2	19.7	14.8	11.9	10.4	24.0	22.0		
SD	0.98	1.71	1.40	1.28	2.13	1.19	1.50	0.00	0.00	Avg_{SD} =	1.13
Calculated											
Min-max	22.0	17.9	17.9	17.3	12.1	9.9	8.3	22.1	22.0		
sector	24.1	22.1	23.0	22.9	18.1	15.0	13.0	24.1	22.2	Avg_V =	SD_V =
Variation	2.1	4.2	5.1	5.6	6.0	5.1	4.7	2.0	0.2	3.9	1.38
n sites	5	9	11	8	12	25	4	4	4	*N* =	82
Avg	23.3	20.7	19.7	19.7	14.7	11.7	10.3	23.6	22.0		
SD	1.04	1.74	1.68	1.72	2.18	1.39	1.69	0.85	0.10	Avg_{SD} =	**1.38**
										***N* =**	**9**
Difference	0.1	-0.0	0.5	-0.1	-0.0	-0.1	-0.1	-0.4	0.0	$\boldsymbol{Avg_D}$ =	**-0.02**
										$\boldsymbol{SD_D}$ =	**0.22**
										***p* =**	**1.00**

At this point it would be important to know how the levels of accuracy are related to the actual ability of migrants to reach their destination. This information could be obtained by determining the accuracy of the migration heading of a relatively small population based on the ringing method. An interesting example is presented in Figure 4, based on data from the 'Italian Bird Migration Atlas' (Spina and Volponi 2008). Garden Warblers ringed within a relatively small area in Finland were recovered within a very small area in Italy. The average heading of this group was 206°, while the variation in individual headings was 202-208°, and thus the variation between extremes for this sample was only 6°. It is possible to find more rough estimations of variation in the course of migration, where a single migratory population could be extracted: for the Tree Pipit *Anthus trivialis* and Black Redstart *Phoenicurus ochruros* in the Czech Republic and Slovakia (Cepak *et al*. 2008) – 20°; for the Reed Warbler *Arcocephalus scirpaceus* (adults), in Sweden – 20°; in the same country for two distinct populations of Willow Warbler *Phylloscopus trochilus* – 15° and 18° (Fransson and Karlsson-Hall 2008), and for the Blackcap at Faroes (Hammer *et al*. 2014) – 13° (a few individuals) These values are comparable to the estimations suggested here.

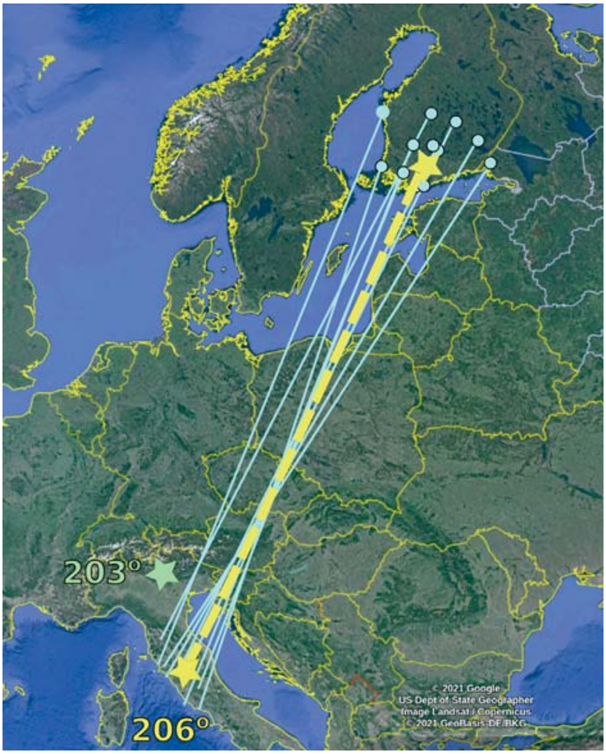


Fig. 4. An example comparison between heading track estimation of the *GREEN* stream at the Italian Arosio study site (green asterisk, 203° azimuth) and the ringing recovery pattern of Garden Warblers ringed within a limited area of Finland and recovered in autumn in Italy. White dots – ringing sites, solid lines – individual tracks to Italy, broken line – connects mean ringing and recovery locations – yellow asterisks, 206° azimuth). Ringing data after Spina and Volponi (2008).

The Italian case is especially interesting in terms of testing data relations versus ringing results: one of the departure headings (*GREEN* stream) at the northern Italian ringing station Arosio (see *Appendix - Sites*) was estimated to be in sector 18 (azimuth 203°), while the calculated average heading of the ringed birds is 206°. This is a highly satisfactory level of agreement.

The arrival and departure sectors of local distributions at the study sites, as determined by both the *estimation* and *calculation* procedures, were highly varied (Table 2 and 3). The differences between the results obtained by these two procedures are negligible. The average heading values for streams do not occur in the same sector. The arrival and departure headings are significantly different when streams are compared in the estimation and calculation procedures (Tables 4 and 5). This finding confirms that the local estimations differentiate streams well. Some doubts may arise from the separation of the *BLUE* stream from the *GREEN* and *VIOLET* ones (*n.s.* differences) as well as for the *BLACK* and *NAVY* streams in relation to the *RED* and *BLUE* ones. However, geographically the *BLACK* and *NAVY* streams are located so differently from the *RED* and *BLUE* ones that they must be discussed separately.

Apart from the distribution of arrival and departure headings, a second parameter – the axiality of the arrival/departure headings – was studied as well (Table 6). The axiality of the arrival-departure headings is defined as the deviation (as the number of sectors) from a straight line following the arrival heading. Differences from the straight line were defined as '0' = opposite sector, '+' – departure heading shifted clockwise, '-' – shifted anticlockwise. The arrival and departure tracks of the streams (from input to output sectors) show high linearity for the average spatial course, with an average deviation of -0.03 for the estimated results and -0.08 for the calculated results for the sector, which means only 1-2° (for 67 lines, all streams and sites included). The average heading lines for separate streams deviate from -1.0 to +1.0 of the sector size in the estimation procedure and from -1.0 to +0.1 of the sector in the calculation procedure – on average -0.13 and -0.21 of the sector, respectively. Variation in deviations within the set of streams is about twice as high as within sites (in both the estimation and calculation procedures). Still, the overall average deviation from the straight line is about 2°, which is negligible from the point of view of the migration pattern study. **This strongly confirms earlier findings (Busse 2019, 2020, 2021) that as a rule arrival and departure tracks are situated linearly.**

Total average stream number indices are fairly balanced with respect to arrival versus departure headings (11.62 for arrival and 9.36 for departure headings), which means that a similar number of birds show a departure heading as an arrival heading at the average site (Table 1). The average departure/arrival ratio is below one (0.80, which is statistically non-significant (p = 0.39). However, it should be noted that this ratio for separate streams varies greatly, from 0.50 (SD = 0.32) for the *VIOLET* stream to 1.90 (with a very high SD = 2.25) for the *BLACK* stream (Table 7). Within the *VIOLET* and *RED* streams, the departure headings are less numerous than the arrival headings (in the data – reverse headings to those of autumn migration) – in the *VIOLET* stream even significantly (p = 0.0002) – while for six others they are more numerous (parameter value from 1.1 to 1.9). The average ratio counted from all headings in the stream values is 1.13 (N = 100, SD = 0.36, p = 0.0003), which means that

Table 4

Differences between average arrival tracks of migration streams at the study sites (see Table 1) as determined by the *estimation* and *calculation* procedures; *p*-values are given. Significant differences are in bold; *n.s.* differences are shaded.

	RED	*BLUE*	*GREEN*	*VIOLET*	*ORANGE*	*YELLOW*	*WHITE*	*BLACK*	*TEAL*
Estimation									
RED	**X**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.24	**0.002**
BLUE		**X**	**0.05**	**0.01**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
GREEN			X	0.69	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
VIOLET				X	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
ORANGE					X	**<0.001**	**0.002**	**<0.001**	**<0.001**
YELLOW						X	0.68	**<0.001**	**<0.001**
WHITE							**X**	**<0.001**	**<0.001**
BLACK								**X**	0.14
TEAL									**X**
Calculation									
RED	**X**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.44	0.06
BLUE		**X**	**0.02**	0.07	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
GREEN			**X**	**0.003**	**<0.001**	**<0.001**	**<0.001**	**0.01**	0.25
VIOLET				**X**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
ORANGE					**X**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
YELLOW						**X**	**<0.001**	**<0.001**	**<0.001**
WHITE							**X**	**<0.001**	**<0.001**
BLACK								**X**	0.16
TEAL									**X**

Table 5

Differences between average departure tracks of migration streams at the study sites (see Table 1) as determined by the *estimation* and *calculation* procedures; *p*-values) are given. Significant differences are in bold; *n.s.* differences are shaded.

	RED	*BLUE*	*GREEN*	*VIOLET*	*ORANGE*	*YELLOW*	*WHITE*	*BLACK*	*TEAL*
Estimation									
RED	**X**	0.008	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.08	0.03
BLUE		**X**	0.05	0.18	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
GREEN			X	0.46	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
VIOLET				X	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
ORANGE					X	**<0.001**	<**0.001**	**<0.001**	**<0.001**
YELLOW						X	0.04	**<0.001**	**<0.001**
WHITE							**X**	**<0.001**	**<0.001**
BLACK								**X**	**<0.001**
TEAL									**X**
Calculation									
RED	**X**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.63	**0.01**
BLUE		**X**	**0.04**	0.20	**<0.001**	**<0.001**	**<0.001**	**0.001**	**0.03**
GREEN			**X**	1.00	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
VIOLET				**X**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
ORANGE					**X**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
YELLOW						**X**	0.13	**<0.001**	**<0.001**
WHITE							**X**	**<0.001**	**<0.001**
BLACK								**X**	**0.009**
TEAL									**X**

Table 6

Deviations from linear axiality of arrival-departure headings in migration streams at the sites as determined by the *estimation* and *calculation* procedures; *p*-values are given. Significant differences are in bold; *n.s.* differences are shaded.

	RED	*BLUE*	*GREEN*	*VIOLET*	*ORANGE*	*YELLOW*	*WHITE*	*BLACK*	All	Streams	Sites
Estimated											
n sites	4	8	9	4	10	20	4	4	N=67	N_{ST}=8	N_{SI}=28
Avg	-0.8	0.1	-0.2	-0.5	0.0	0.3	-1.0	1.0	-0.03	-0.13	0.07
SD	0.83	1.45	1.69	0.87	1.79	1.00	1.00	1.00	1.39	0.36	1.98
p =	0.10	0.85	0.75	0.29	1.00	0.19	0.09	0.09	0.86	0.10	0.79
Calculated											
n sites	**4**	**8**	**10**	**5**	**11**	**21**	**4**	**4**	N=67	N_{ST}=8	N_{SI}=29
Avg	-1.0	-0.0	0.1	-0.8	0.1	0.1	-0.2	0.0	-0.08	-0.21	-0.13
SD	1.13	1.49	1.75	0.77	1.68	1.38	1.69	1.31	1.51	0.31	2.42
p =	0.13	1.00	**0.87**	**0.05**	0.84	0.74	0.82	1.00	0.66	**0.006**	0.99
Difference	0.21	0.15	-0,28	0.29	-0,11	0.17	-0.79	0.99	*Avg*=0.08	*SD*=0.48	*p*=0.64

Table 7
Differences in departure/arrival number ratios between migration streams and sites. Significance of deviation from 1:1 ratio is indicated by ‘<’ and ‘>’

Calculated	**RED**	BLUE	GREEN	**VIOLET**	ORANGE	YELLOW	WHITE	BLACK	TEAL		
Min-max	0.11	0.08	0.16	0.21	0.10	0.12	0.44	0.34	0.20		
sector	1.69	3.06	3.29	1.26	5.73	4.23	3.85	7.18	4.34		
Variation	1.58	2.98	3.13	1.05	5.63	4.11	3.41	6.94	4.14		
										Streams	Sites
n sites	**9**	10	15	**8**	15	21	7	7	8	100	31
Avg	**0.8**	1.0	1.1	**0.5**	1.1	1.1	1.2	1.9	1.4	1.13	0.87
SD	**0.46**	0.91	0.79	**0.32**	1.37	1.04	1.15	2.25	1.21	0.36	0.65
$< p >$	**< n.s.**	=	> n.s.	**>0.001**	> n.s.	> n.s.	> n.s.	> n.s.	> n.s.	**>0.001**	< n.s.

this value is significantly different from an equal distribution. The disagreement in the total average value (Table 1) and '*Streams*' value in Table 7 is caused by differentiated numbers of individuals migrating in different streams. Note that the '*Sites*' value in Table 7 (0.87) is close to the value in Table 1 (0.80). The *SD* is much larger within *Sites* (0.65) than within Streams (0.36). This indicates larger variation of this parameter between streams than between study sites. However, it seems that this variation may not be a special property of streams, but may depend more on the geographic location of the study sites. These discrepancies indicate the need for more extensive studies on this problem when evaluating data for other species.

Spatial analysis of migration pattern

As mentioned above (p. 55), the defined streams of Garden Warbler migration were represented at varying numbers of study sites (Table 1). At sites where they were represented, their shares in the local samples were differentiated as well (Table 1 – *Axis*): the average values for streams usually varied from 20.0 to 26.5, but the highest values were 30.2 (*BLUE*), 31.1 (*BLACK*) and 37.0 (*YELLOW*). The distributions of frequencies of study sites where streams are represented and their local shares in samples are highly similar (*chi-square* test, $p = 0.0002$), and thus they accurately represent the number relations of migrant streams in the study area.

The migration pattern parameters discussed above – headings, deviation from axial relations (arrival-departure), and the number ratios of departure/arrival cohorts – could be related to the geographic locations of the study sites. For this reason they were checked for correlations with the latitude and longitude of the study sites. The results of that analysis are presented in Table 8, and they provide some information about the spatial course of different streams. The number of the arrival sector seems to be correlated with the latitude of the study sites – the correlation coefficient *r* shows a positive correlation with the southern latitude in six of seven streams (two of them statistically significantly), but the coefficient for the one stream with a negative correlation is significant as well. Correlations with the longitudinal axis are both positive and negative (only one, for the *ORANGE* stream, is significantly positive). Departure sector numbers show both positive (dominating) and negative *r-values*. These sector numbers correlate with the longitude mainly positively (6 to 1), but only one *r-value* is significant. Values of arrival and departure indices with co-ordinates show a highly varied pattern, with a few significant values for different streams (two positive and two negative significant values among 36 *r-values* – 19 positive and 17 negative). The *r-values* for two other parameters, deviation and departure/arrival ratio, seem to be inconclusive as well, with one exception, i.e. the correlation of the deviation value with the longitude, where all *r-values* are positive and two of them even significantly. As the possibility of comparison with similar results is very limited (Busse 2021), it is only worth mentioning that in the Blackcap, *deviations* were found to be positively (even significantly) correlated with the longitude, while the *Departure/Arrival* ratio was negatively correlated with the longitude as well. This is an attractive field for further study.

Table 8

Correlation coefficients of the migration parameters of the streams with the geographic location of the sites (S – south latitude, E – east longitude). Included are the numbers of the arrival and departure sectors, values of arrival and departure indices, deviation from axiality, and departure/arrival relation value. Pearson's r-values are given; statistically significant values are in bold (p – given in parentheses). Additionally, results of sign-tests for distribution of positive and negative correlation are presented.

	Arrival sector		Departure sector	
	S	**E**	**S**	**E**
RED	+0.11	+0.02	-0.21	+0.30
BLUE	**+0.82 (0.01)**	-0.47	+0.38	-0.16
GREEN	+0.25	-0.21	+0.36	**+0.80 (0.001)**
VIOLET	+0.32	+0.04	+0.46	+0.09
ORANGE	+0.03	**+0.62 (0.01)**	+0.01	+0.45
YELLOW	**-0.63 (0.01)**	-0.09	-0.27	+0.28
WHITE	**+0.91 (0.01)**	0.00	+0.40	+0.66
BLACK				
NAVY				
S+/E+	**6**	3	**5**	**6**
S-/E-	**1**	3	**2**	**1**
Sign-test	**p=0.01**	p=0.65	p=0.06	**p=0.01**

	Arrival sector		Departure sector	
	S	**E**	**S**	**E**
RED	-0.09	-0.25	+0.22	+0.52
BLUE	**-0.69 (0.05)**	**+0.77 (0.01)**	+0.06	-0.18
GREEN	-0.23	+0.16	-0.11	+0.27
VIOLET	-0.50	+0.48	-0.46	-0.10
ORANGE	-0.20	-0.39	+0.03	+0.13
YELLOW	**+0.73 (0.001)**	+0.20	-0.06	-0.11
WHITE	+0.48	_0.62	-0.15	-0.36
BLACK	+0.29	+0.50	-0.09	**-0.87 (0.05)**
NAVY	+0.25	-0.35	-0.28	+0.48
S+/E+	4	6	3	4
S-/E-	5	3	6	5
Sign-test	p=0.25	p=0.09	p=0.09	p=0.25

	Arrival sector		Departure sector	
	S	**E**	**S**	**E**
RED			-0.22	+0.62
BLUE	**-0.84 (0.01)**	+0.14	-0.25	-0.27
GREEN	+0.14	+0.61	-0.03	+0.12
VIOLET	-0.22	+0.50	0.00	+0.11
ORANGE	-0.17	**+0.62 (0.01)**	**-0.52 (0.05)**	+0.18
YELLOW	+0.35	**+0.45 (0.05)**	+0.35	-0.27

WHITE			+0.16	-0.38
BLACK			+0.33	**-0.88 (0.05)**
NAVY			+0.05	+0.27
S+/E+	2	**5**	4	5
S-/E-	3	**0**	4	4
Sign-test	*p*=0.19	***p*<0.001**	*p*=0.37	*p*=0.26

The starting map for the spatial analyses of headings of the Garden Warbler migration pattern was prepared as described by Busse (2021) and looks like the map in Figure 5. Figure 6 illustrates the next step: the traditional presentation of the local headings (Fig. 5) is transferred to patterns in Figure 6 by extending the local headings far from the site (arrival tracks backwards to the north and departure tracks forwards to the south). This operation is based on the confirmed axiality of the tracks and the

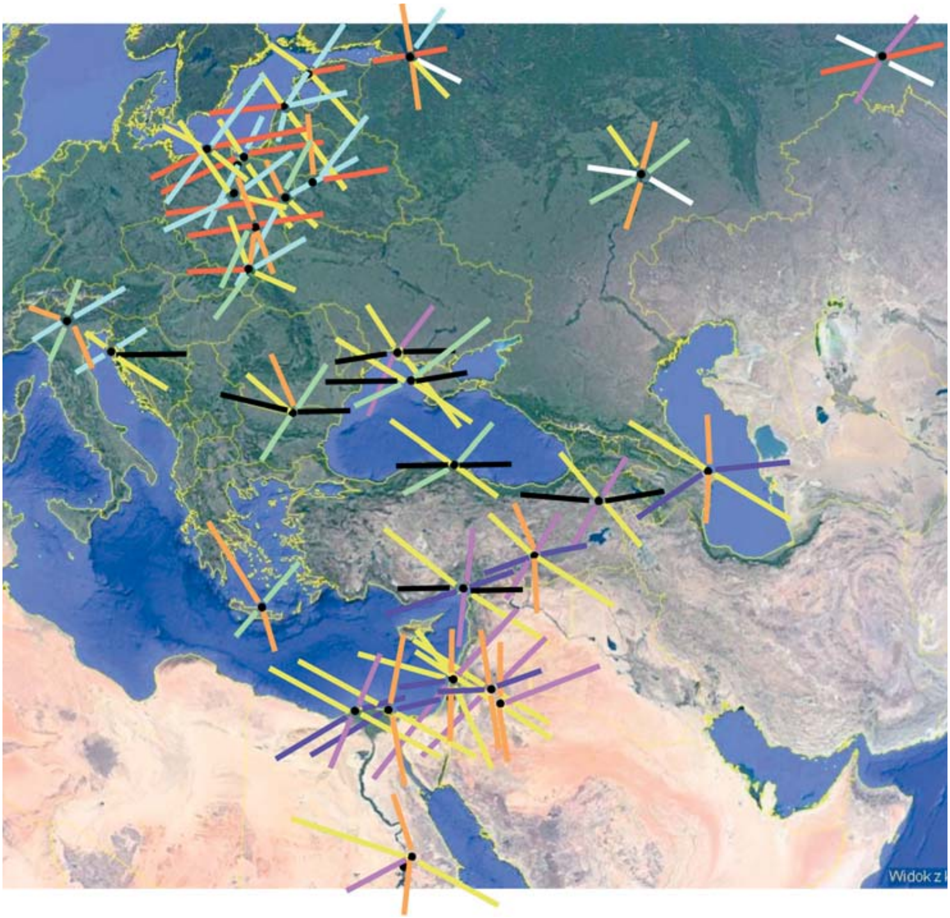


Fig. 5. Graphical presentation of local heading patterns at all study sites. Coloured lines show headings assigned to defined migration streams. Lengths of lines are not determined by the ‘powers’ of local migration streams.

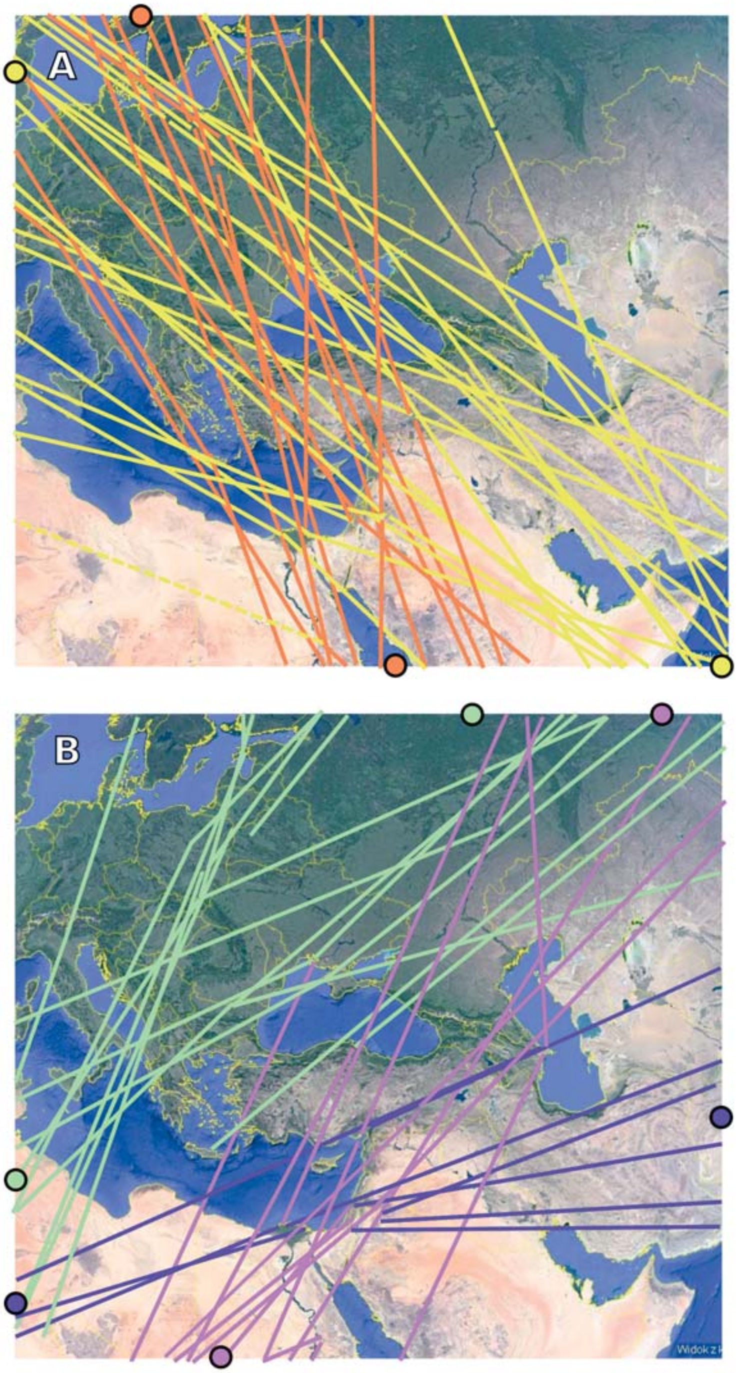


Fig. 6. The next step in the graphical presentation in the general heading patterns estimation method: local lines are extended to the borders of the map, and the average stream heading locations are shown as circles. A. *ORANGE* and *YELLOW* streams, B. *GREEN, VIOLET* and *NAVY* streams. These define the summary pattern shown in Fig. 7.

assumption that these headings are stable over long distances. The tracks are extended to the borders of the map used, and then the average co-ordinates of the points where the tracks cross the edges of the map are calculated and drawn in Figure 7 – upper panel. The lower panel shows an analogous picture already drawn for the Blackcap (Busse 2021). The width of the lines is proportional to the numbers of study sites where the stream was found. The patterns obtained for both species are highly coherent, while only the 'powers' of the streams are slightly differentiated.

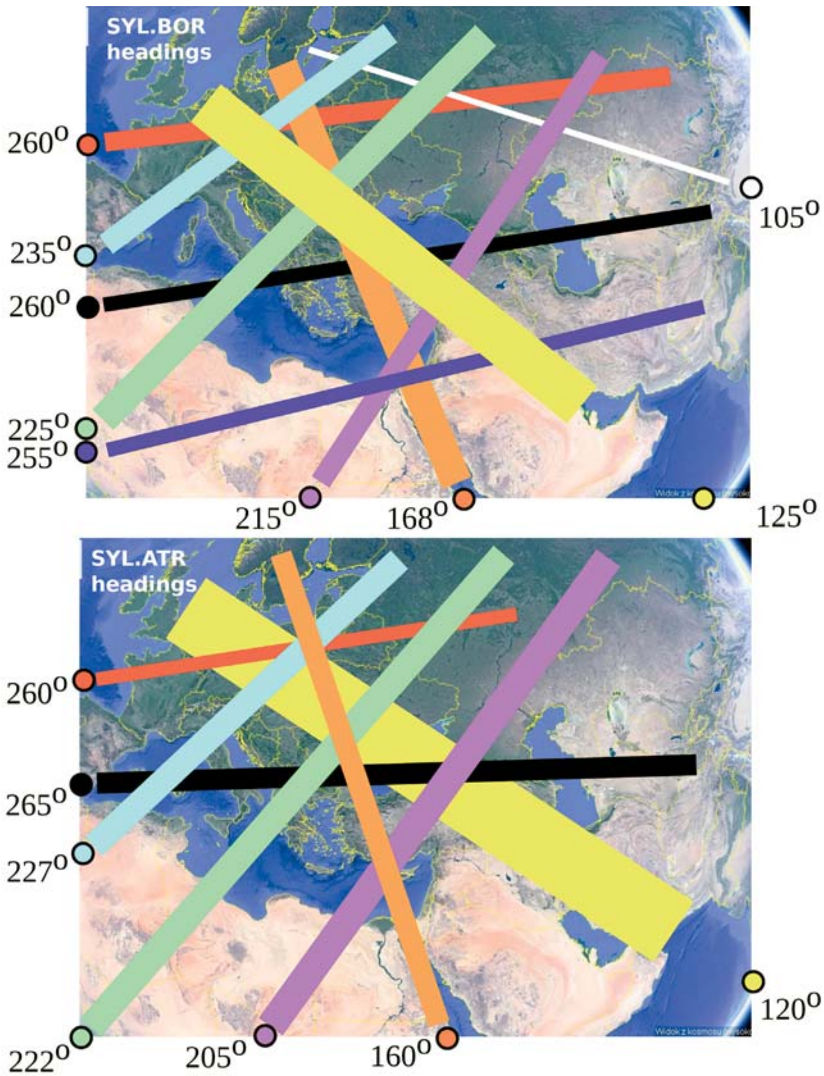


Fig. 7. General stream migration patterns for the Garden Warbler (upper panel) and the Blackcap (lower panel), with a standardized number of sites where each stream was noted (proportional width of lines). Heading azimuths are given at the margins of the maps. The Blackcap panel is after Busse (2021), modified for compatibility with the Garden Warbler picture.

The next procedure, based on some calculations, takes under consideration not only data for local headings at the study sites (*Appendix - Sites*), but the geographic co-ordinates of the sites as well. This locates the pattern more precisely in a geographical space, so the picture presented is more realistic than the pattern shown in Figure 7, where stream azimuths are more certain than their geographic location. Figure 8 is a more detailed presentation of the *GREEN* stream, as an example. The figure shows the average co-ordinates for all sites where the stream was found (designated by site codes within circles). A graphical presentation of the average stream headings (arrival and departure) and number indices (lengths of tracks are proportional to the number index) was added based on the data from Table 1. Additionally, the minimum area of the migration stream is designated with broken lines. Maps for other streams are presented in the *Appendix - Maps*.

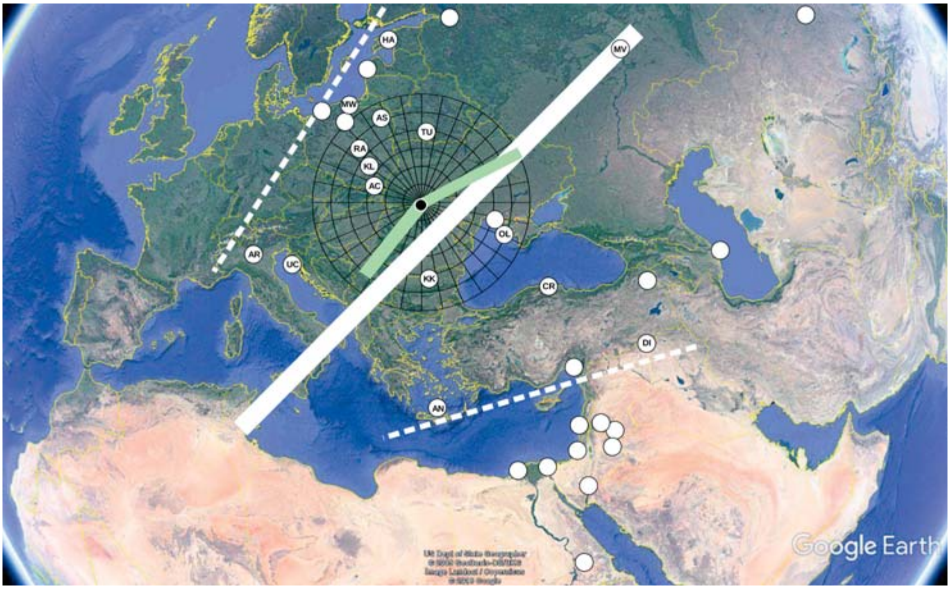


Fig. 8. Example (for the *GREEN* stream) of heading pattern estimation using some calculated migration parameters of the stream: geographic centre of distribution of sites where the stream was noted (average longitude and latitude), average calculated arrival and departure sectors, and number indices of arrival and departure headings (as lengths of coloured lines). Broken lines frame the territory where the stream was noted; number codes are given in circles for sites (other location circles are empty). White line - general heading of the stream as determined using only the estimation method (see Fig. 7). For other stream patterns see: Appendix-Maps.

Figure 9 enables comparison of the patterns of the migration streams of Garden Warbler versus Blackcap. The locations of most of the streams are nearly identical for both species, except the *GREEN* and *BLACK* streams. The location of the *GREEN* stream of the Garden Warbler is similar with respect to the migration track azimuths, but the centre of distribution is shifted a few hundred kilometres to the NW. The *BLACK* stream location in the case of the Garden Warbler is situated more to the north than that of the Blackcap. However, this seems to be due to the fact that no *NAVY* stream was established for Blackcap. Doubts concerning this detail were mentioned above.

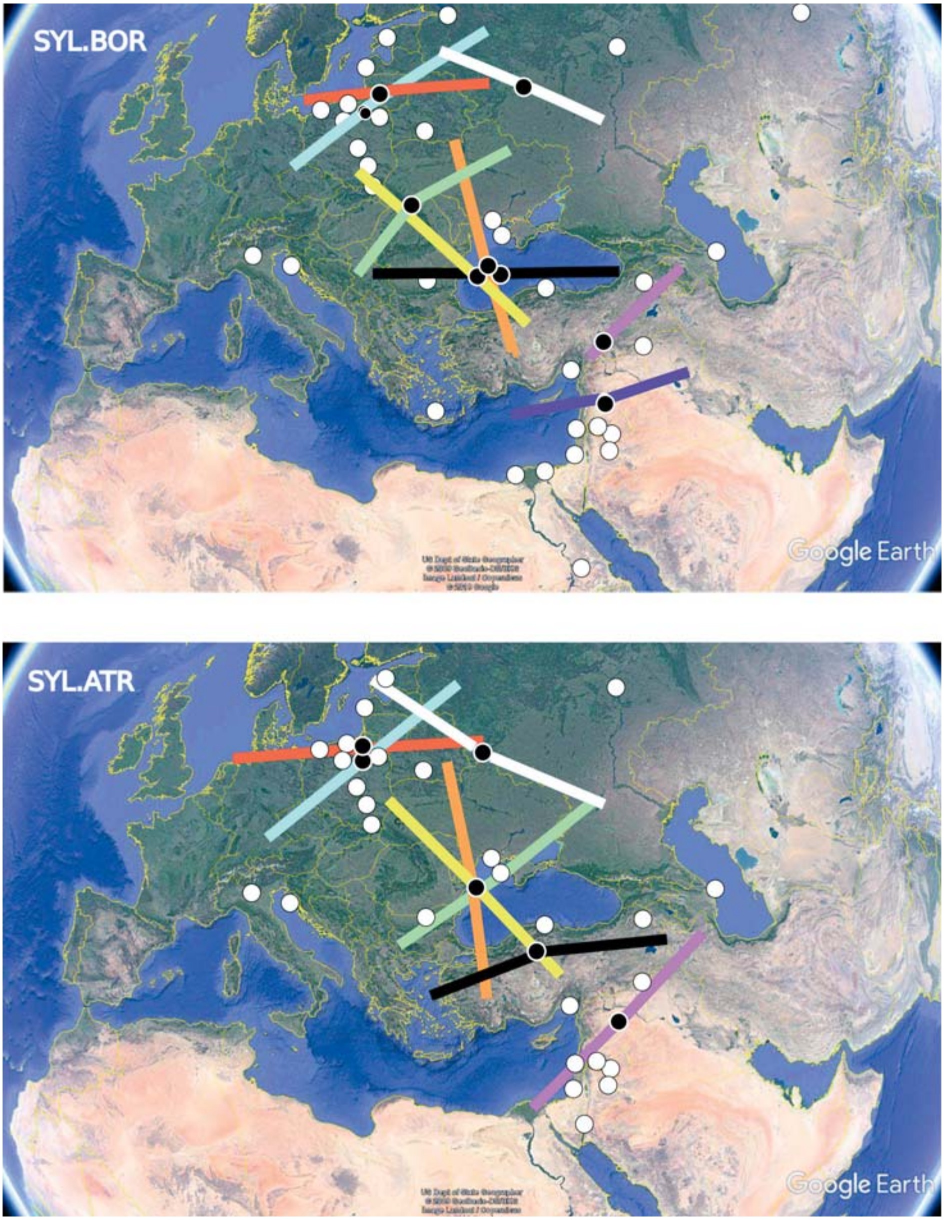


Fig. 9. Comparison of migration patterns of the Garden Warbler (upper panel) and the Blackcap (lower panel) as determined using the calculation method. Pattern for the Blackcap after Busse (2021).

CONCLUSIONS

1. The hypothesis put forth by Busse (2019) that arrival/departure heading axes as shown in studies using orientation cages are situated linearly is once again confirmed and can be adopted as a general assumption in this type of study. The average deviations are very small and are negligible for drawing general bird migration patterns. However, in some cases deviations caused by the geographic location of the study site were found. This problem should be discussed in more detail when more species data become available.

2. The *YELLOW* stream is the most common in the study area in both species. The *BLACK* and *NAVY* streams are the most intriguing and demand much attention in further analyses of migration in the Mediterranean region.

3. The location style of presentation of the species migration pattern seems to be more precise. For comparison between the general patterns of different species, the simpler presentation using only general heading axes could be used.

ACKNOWLEDGEMENTS

The data were collected from 1995 to 2016 during field work at 31 sites in 15 countries by dozens or even hundreds of professionals and volunteers. This makes it impossible to thank them individually, but they should all feel that this paper has been completed thanks to their hard work. We all participated in the network activity, within Operation Baltic, SEEN or individual projects, by collecting the data and discussing the method of application and interpretation of the results during numerous meetings and e-mail contacts. Thank you all, indeed.

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APPENDIX – STREAMS

Basic migration pattern parameters of migration streams at the sites. Tracks – according to the *estimation* procedure, Number indices – according to the *calculation* procedure. Share % – percentage share of the stream within the site.

RED at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Carpatica	7.9	24.1		9.8	8.2	18.0	22	0.84
Bukowo/Kopań	8.0	22.0	-2	16.5	7.8	24.3	37	0.48
Drużno	7.9	24.1	0	7.3	7.9	15.2	23	1.08
Gumbaritsy	7.8	24.2		8.5	5.9	14.4	14	0.69
Hadeemeeste	8.0	24.2		7.2	2.7	9.9	12	0.38
Kaliszany	7.9	24.0		5.1	3.6	8.7	13	0.71
Mierzeja Wiślana	8.1	22.0	-2	8.9	11.9	20.8	24	1.34
Omsk	8.0	24.1	0	7.9	13.4	21.3	29	1.69
Pape	8.0	24.6		21.3	2.3	23.5	26	0.11

BLUE at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Arosio	6.0	22.1	0	12.0	9.0	21.0	29	0.75
Siemianówka	6.0	21.9	0	17.3	9.1	26.4	41	0.53
Bukowo/Kopań	4.1	19.1	-1	11.3	6.4	17.6	27	0.56
Drużno	3.9	21.9	2	20.1	9.2	29.3	44	0.46
Gumbaritsy	4.0	20.1		40.4	3.2	43.5	44	0.08
Hadeemeeste	4.0	21.9	2	18.1	2.9	21.0	26	0.16
Mierzeja Wiślana	3.9	17.9	-2	15.2	8.3	23.6	27	0.55
Pape	4.0	17.9	-2	7.4	22.6	30.0	33	3.06
Rakutowskie	5.0	22.0	1	7.2	14.4	21.5	27	2.01
Ucka	6.9	21.9		3.5	6.0	9.5	10	1.69

GREEN at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Carpatica	5.9	19.0	-3	17.1	7.1	24.2	30	0.41
Anthytrya	4.9	20.9		11.0	1.8	12.7	24	0.16
Arosio	2.0	18.0	0	8.3	10.5	18.9	26	1.26
Siemianówka	3.1	19.1		8.9	8.0	16.9	26	0.90
Cernek	5.0	21.2		10.4	8.2	18.6	23	0.80
Dicle	4.0	22.1	2	11.4	13.8	25.2	25	1.22
Hademeeste	0.0	17.9	2	13.7	3.8	17.4	21	0.28
Kalimok	4.0	20.0	0	10.5	14.6	25.1	25	1.39
Kaliszany	4.0	18.0	-2	10.3	20.5	30.8	47	1.99

Medvedivka	4.8	23.0	2	12.0	13.9	25.9	32	1.16
Mierzeja Wiślana	0.0	14.0	-2	10.7	12.9	23.6	28	1.21
Olenevka	4.0	21.2	1	3.2	10.6	13.8	19	3.29
Rakutowskie	2.0	18.2		5.6	9.5	15.0	19	1.70
Turov	3.9	19.9	0	34.2	5.4	39.6	46	0.16
Ucka	31.0	14.9		4.4	2.5	6.9	7	0.57
VIOLET at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Aras	5.2	21.0		6.2	7.7	13.9	21	1.26
Akyatan	2.2	17.3	-1	5.9	2.6	8.6	10	0.44
Burullus	2.9	19.7		13.8	6.0	19.8	27	0.44
Cernek	2.1	18.1	0	6.1	4.7	10.8	14	0.77
Dicle	3.8	20.5		9.6	2.6	12.2	12	0.27
Hashimiyya	5.0	20.0	-1	13.3	4.4	17.7	30	0.33
Kinburn	4.0	17.9	-2	18.7	3.9	22.5	34	0.21
Omsk	4.0	20.0	0	20.5	8.9	29.5	40	0.44
Talitha Kumi	4.0	20.0		0.0	11.4	11.4	10	x
Wadi Allaqi	6.3	22.9		1.2	32.0	33.2	34	x
ORANGE at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Carpatica	32.0	16.4		15.8	2.1	17.9	22	0.14
Ashtoum	32.0	15.9		4.3	6.3	10.6	18	1.46
Anthytrya	28.1	13.9	2	36.1	3.7	39.7	76	0.10
Arosio	26.9	12.9	2	22.0	10.4	32.3	45	0.47
Siemianówka	28.0	14.0	2	12.3	8.7	21.0	33	0.71
Azraq	31.0	12.0	-3	3.1	12.9	16.0	20	4.12
Dhleil	32.0	16.0	0	8.9	5.3	14.2	16	0.60
Dicle	28.9	12.9	0	10.4	9.0	19.4	19	0.86
Drużno	30.0	12.0	-2	12.6	10.2	22.8	34	0.81
Gumbaritsy	32.0	15.6		17.4	3.5	21.0	21	0.20
Karabogaz	32.0	18.0	2	4.8	7.0	11.9	17	1.46
Kalimok	28.9	12.3		17.8	1.9	19.6	19	0.11
Kaliszany	30.0	15.0	1	8.6	17.9	26.6	40	2.07
Medvedivka	34.1	18.0		9.0	10.7	19.7	25	1.18
Talitha Kumi	29.8	12.1	-2	24.9	13.7	38.6	35	0.55
Turov	32.0	14.0	-2	21.5	4.1	25.6	30	0.19
Wadi Allaqi	33.0	18.1		1.0	5.9	6.9	7	5.73
YELLOW at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Aras	27.0	13.1	2	20.8	11.7	32.5	49	0.56
Carpatica	25.9	10.1		7.8	14.0	21.7	27	1.80

Ashtoum	28.0	10.0	-2	15.1	16.3	31.3	52	1.08
Akyatan	28.0	12.0	0	17.5	16.9	34.5	42	0.96
Azraq	26.0	12.0	2	36.0	12.9	48.9	60	0.36
Bukowo/Kopań	28.0	11.0	-1	8.8	14.9	23.7	36	1.70
Burullus	27.0	12.0	1	22.9	6.3	29.2	40	0.28
Cernek	27.9	12.0	0	15.4	8.0	23.4	29	0.52
Dhleil	27.0	12.0	1	43.8	5.3	49.1	56	0.12
Dicle	26.1	10.0	0	12.4	12.1	24.5	24	0.97
Gumbaritsy	29.0	12.9		0.0	9.6	9.6	10	x
Hadeemeeste	28.9	13.1	0	19.1	14.4	33.6	41	0.76
Hashimiyya	28.0	11.0	-1	31.9	10.3	42.2	70	0.32
Karabogaz	27.1	12.0	1	9.7	29.1	38.8	55	2.98
Kalimok	26.0	9.0	-1	22.1	11.5	33.6	33	0.52
Kinburn	29.0	13.1	0	17.4	14.9	32.3	49	0.86
Medvedivka	30.0	14.2	0	9.2	5.3	14.5	18	0.58
Mierzeja Wiślana	27.0	10.0	-1	6.1	11.7	17.8	21	1.90
Olenevka	27.8	11.0	-1	15.8	10.9	26.7	37	0.69
Pape	29.9	15.0	1	5.6	15.6	21.2	23	2.76
Rakutowskie	29.0	12.9		17.9	2.9	20.8	26	0.16
Talitha Kumi	26.9	12.1	1	32.4	13.7	46.1	42	0.42
Ucka	28.0	9.9	-2	8.3	35.2	43.5	47	4.23
Wadi Allaqi	25.0	12.0	3	30.1	5.4	35.5	37	0.18

WHITE at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/Arrival
Gumbaritsy	25.9	10.0		8.0	3.5	11.5	12	0.44
Medvedivka	25.0	9.9	1	12.6	7.2	19.8	25	0.58
Omsk	27.1	13.0	2	15.9	7.1	22.9	31	0.45
Pape	26.1	9.7		6.2	10.5	16.8	18	1.69
Rakutowskie	26.1	10.0		10.8	11.1	21.9	28	1.02
Turov	26.1	8.3	-2	4.2	16.1	20.3	24	3.85

BLACK at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/Arrival
Aras	8.0	24.3		7.9	12.7	20.6	31	1.61
Akyatan	8.0	24.0	0	15.2	10.2	25.3	31	0.67
Cernek	8.0	24.0	0	16.0	10.9	26.9	34	0.68
Kalimok	8.2	24.2		14.5	9.7	24.2	24	0.67
Kinburn	8.0	22.1	2	3.6	7.4	11.0	17	2.05
Olenevka	6.2	24.1	-2	26.4	6.2	32.6	45	0.24
Ucka	8.3	24.0		4.1	29.4	33.5	36	7.18

NAVY at	Track			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
Ashtoum	6.6			15.6	3.1	18.7	31	0.20
Akyatan		21.2		5.6	8.4	14.0	17	1.49
Azraq		23.0		3.1	13.6	16.7	20	4.34
Burullus			1	13.2	11.6	24.8	34	0.88
Dhleil		24.5		13.9	10.1	24.0	27	0.72
Dicle	6.2			12.3	7.9	20.3	20	0.65
Karabogaz			-2	7.0	13.3	20.3	29	1.91
Talitha Kumi		25.0		5.9	7.7	13.7	12	1.30

APPENDIX – SITES

Basic migration pattern parameters of migration streams at the sites. Tracks – according to the *estimation* procedure, Number indices – according to the *calculation* procedure. Share % – percentage share of the stream within the site.

AA Aras	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET	5.2	21.0		6.2	7.7	13.9	21	1.26
ORANGE								
YELLOW	27.0	13.1	2	20.8	11.7	32.5	49	0.56
WHITE								
BLACK		24.3		7.9	12.7	20.6	31	1.61
NAVY								
N = 63			2	34.8	32.2	67.0	100.0	0.92

AC Carpatica	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	7.9	24.1		9.8	8.2	18.0	22	0.84
BLUE								
GREEN	5.9	19.0	-3	17.1	7.1	24.2	30	0.41
VIOLET								
ORANGE	0.0	16.4		15.8	2.1	17.9	22	0.14
YELLOW	25.9	10.1		7.8	14.0	21.7	27	1.80
WHITE								
BLACK								
NAVY								
N = 37			-3	50.5	31.5	81.9	100.0	0.62

AH Ashtoum	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET								
ORANGE	0.0	15.9		4.3	6.3	10.6	18	1.46
YELLOW	28.0	10.0	-2	15.1	16.3	31.3	52	1.08
WHITE								
BLACK								

NAVY	6.6			15.6	3.1	18.7	31	0.20
N = 16			-2	34.9	25.7	60.6	100.0	0.73

AK Akyatan	Sector			Number indices				
	Arrival	Departu-re	Devia-tion	Arrival	Departu-re	Axis	Share (%)	Departu-re/Arrival
RED								
BLUE								
GREEN								
VIOLET	2.2	17.3	-1	5.9	2.6	8.6	10	0.44
ORANGE								
YELLOW	28.0	12.0	0	17.5	16.9	34.5	42	0.96
WHITE								
BLACK	8.0	24.0	0	15.2	10.2	25.3	31	0.67
NAVY		21.2		5.6	8.4	14.0	17	1.49
N = 89			-1	44.3	38.1	82.4	100.0	0.86

AN Anthytrya	Sector			Number indices				
	Arrival	Depar-ture	Devia-tion	Arrival	Depar-ture	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	4.9	20.9		11.0	1.8	12.7	24	0.16
VIOLET								
ORANGE	28.1	13.9	2	36.1	3.7	39.7	76	0.10
YELLOW								
WHITE								
BLACK								
NAVY								
N = 64			2	47.0	5.4	52.5	100.0	0.12

AR Arosio	Sector			Number indices				
	Arrival	Depar-ture	Devia-tion	Arrival	Depar-ture	Axis	Share (%)	Departu-re/Arrival
RED								
BLUE	6.0	22.1	0	12.0	9.0	21.0	29	0.75
GREEN	2.0	18.0	0	8.3	10.5	18.9	26	1.26
VIOLET								
ORANGE	26.9	12.9	2	22.0	10.4	32.3	45	0.47
YELLOW								
WHITE								
BLACK								
NAVY								
N = 28			2	42.3	29.9	72.2	100.0	0.71

AS Siemianówka	Sector			Number indices				
	Arrival	Depar-ture	Devia-tion	Arrival	Depar-ture	Axis	Share (%)	Departure/ Arrival
RED								
BLUE	6.0	21.9	0	17.3	9.1	26.4	41	0.53
GREEN	3.1	19.1		8.9	8.0	16.9	26	0.90
VIOLET								
ORANGE	28.0	14.0	2	12.3	8.7	21.0	33	0.71
YELLOW								
WHITE								
BLACK								
NAVY								
N = 82			2	38.4	25.8	64.3	100.0	0.67

AZ Azraq	Sector			Number indices				
	Arrival	Depar-ture	Devia-tion	Arrival	Depar-ture	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET								
ORANGE	31.0	12.0	-3	3.1	12.9	16.0	20	4.12
YELLOW	26.0	12.0	2	36.0	12.9	48.9	60	0.36
WHITE								
BLACK								
NAVY		23.0		3.1	13.6	16.7	20	4.34
N = 82			-1	42.3	39.3	81.6	100.0	0.93

BK Bukowo/Kopań	Sector			Number indices				
	Arrival	Depar-ture	Devia-tion	Arrival	Depar-ture	Axis	Shar e (%)	Departure/ Arrival
RED	8.0	22.0	-2	16.5	7.8	24.3	37	0.48
BLUE	4.1	19.1	-1	11.3	6.4	17.6	27	0.56
GREEN								
VIOLET								
ORANGE								
YELLOW	28.0	11.0	-1	8.8	14.9	23.7	36	1.70
WHITE								
BLACK								
NAVY								
N = 539			-4	36.5	29.1	65.7	100.0	0.80

BR Burullus	Sector			Number indices				
	Arrival	Depar-ture	Devia-tion	Arrival	Depa-rture	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								

GREEN								
VIOLET	2.9	19.7		13.8	6.0	19.8	27	0.44
ORANGE								
YELLOW	27.0	12.0	1	22.9	6.3	29.2	40	0.28
WHITE								
BLACK								
NAVY			1	13.2	11.6	24.8	34	0.88
N = 9			2	49.8	24.0	73.8	100.0	0.48

CR Cernek	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	5.0	21.2		10.4	8.2	18.6	23	0.80
VIOLET	2.1	18.1	0	6.1	4.7	10.8	14	0.77
ORANGE								
YELLOW	27.9	12.0	0	15.4	8.0	23.4	29	0.52
WHITE								
BLACK			0	16.0	10.9	26.9		0.68
NAVY								
N = 816			0	47.9	31.9	79.7	100.0	0.67

DH Dhleil	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET								
ORANGE	0.0	16.0	0	8.9	5.3	14.2	16	0.60
YELLOW	27.0	12.0	1	43.8	5.3	49.1	56	0.12
WHITE								
BLACK								
NAVY		24.5		13.9	10.1	24.0	27	0.72
N = 39			1	66.6	20.7	87.3	100.0	0.31

DI Dicle	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	4.0	22.1	2	11.4	13.8	25.2	25	1.22
VIOLET	3.8	20.5		9.6	2.6	12.2	12	0.27
ORANGE	28.9	12.9	0	10.4	9.0	19.4	19	0.86
YELLOW	26.1	10.0	0	12.4	12.1	24.5	24	0.97
WHITE								

BLACK									
NAVY	6.2			12.3	7.9	20.3	20	0.65
N = 67			2	56.2	45.4	101.6	100.0	0.81
DR Drużno	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	7.9	24.1	0	7.3	7.9	15.2	23	1.08
BLUE	3.9	21.9	2	20.1	9.2	29.3	44	0.46
GREEN								
VIOLET								
ORANGE	30.0	12.0	-2	12.6	10.2	22.8	34	0.81
YELLOW								
WHITE								
BLACK								
NAVY								
N = 46			0	40.0	27.3	67.3	100.0	0.68
GU Gumbaritsy	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	7.8	24.2		8.5	5.9	14.4	14	0.69
BLUE	4.0	20.1		40.4	3.2	43.5	44	0.08
GREEN								
VIOLET								
ORANGE	0.0	15.6		17.4	3.5	21.0	21	0.20
YELLOW	29.0	12.9		0.0	9.6	9.6	10	
WHITE	25.9	10.0		8.0	3.5	11.5	12	0.44
BLACK								
NAVY								
N = 14				74.3	25.7	100.0	100.0	0.35
HA Hadeemeeste	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	8.0	24.2		7.2	2.7	9.9	12	0.38
BLUE	4.0	21.9	2	18.1	2.9	21.0	26	0.16
GREEN	0.0	17.9	2	13.7	3.8	17.4	21	0.28
VIOLET								
ORANGE								
YELLOW	28.9	13.1	0	19.1	14.4	33.6	41	0.76
WHITE								
BLACK								
NAVY								
N = 34			4	58.1	23.9	81.9	100.0	0.41

HY Hashimiyya	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET	5.0	20.0	-1	13.3	4.4	17.7	30	0.33
ORANGE								
YELLOW	28.0	11.0	-1	31.9	10.3	42.2	70	0.32
WHITE								
BLACK								
NAVY								
N = 64			-2	45.2	14.7	59.9	100.0	0.33

KB Karabogaz	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET								
ORANGE	0.0	18.0	2	4.8	7.0	11.9	17	1.46
YELLOW	27.1	12.0	1	9.7	29.1	38.8	55	2.98
WHITE								
BLACK								
NAVY			-2	7.0	13.3	20.3	29	1.91
N = 73			1	21.5	49.4	71.0	100.0	2.30

KK Kalimok	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	4.0	20.0	0	10.5	14.6	25.1	25	1.39
VIOLET								
ORANGE	28.9	12.3		17.8	1.9	19.6	19	0.11
YELLOW	26.0	9.0	-1	22.1	11.5	33.6	33	0.52
WHITE								
BLACK		24.2		14.5	9.7	24.2	24	0.67
NAVY								
N = 6			-1	64.8	37.7	102.5	100.0	0.58

KL Kaliszany	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	7.9	24.0		5.1	3.6	8.7	13	0.71
BLUE								

GREEN	4.0	18.0	-2	10.3	20.5	30.8	47	1.99
VIOLET								
ORANGE	30.0	15.0	1	8.6	17.9	26.6	40	2.07
YELLOW								
WHITE								
BLACK								
NAVY								
N = 19			-1	24.0	42.0	66.0	100.0	1.75
KN Kinburn	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET	4.0	17.9	-2	18.7	3.9	22.5	34	0.21
ORANGE								
YELLOW	29.0	13.1	0	17.4	14.9	32.3	49	0.86
WHITE								
BLACK			2	3.6	7.4	11.0	17	2.05
NAVY								
N = 33			0	39.7	26.2	65.9	100.0	0.66
MV Medvedivka	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	4.8	23.0	2	12.0	13.9	25.9	32	1.16
VIOLET								
ORANGE	2.1	18.0		9.0	10.7	19.7	25	1.18
YELLOW	30.0	14.2	0	9.2	5.3	14.5	18	0.58
WHITE	25.0	9.9	1	12.6	7.2	19.8	25	0.58
BLACK								
NAVY								
N = 47			3	42.7	37.1	79.8	100.0	0.87
MW Mierzeja Wiślana	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	8.1	22.0	-2	8.9	11.9	20.8	24	1.34
BLUE	3.9	17.9	-2	15.2	8.3	23.6	27	0.55
GREEN	0.0	14.0	-2	10.7	12.9	23.6	28	1.21
VIOLET								
ORANGE								
YELLOW	27.0	10.0	-1	6.1	11.7	17.8	21	1.90
WHITE								

BLACK								
NAVY								
N = 49			-7	40.9	44.8	85.8	100.0	1.10

OL Olenevka	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	4.0	21.2	1	3.2	10.6	13.8	19	3.29
VIOLET								
ORANGE								
YELLOW	27.8	11.0	-1	15.8	10.9	26.7	37	0.69
WHITE								
BLACK			-2	26.4	6.2	32.6		0.24
NAVY								
N = 114			-2	45.4	27.7	73.1	100.0	0.61

OM Omsk	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	8.0	24.1	0	7.9	13.4	21.3	29	1.69
BLUE								
GREEN								
VIOLET	4.0	20.0	0	20.5	8.9	29.5	40	0.44
ORANGE								
YELLOW								
WHITE	27.1	13.0	2	15.9	7.1	22.9	31	0.45
BLACK								
NAVY								
N = 118			2	44.3	29.4	73.7	100.0	0.66

PP Pape	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED	8.0	24.6		21.3	2.3	23.5	26	0.11
BLUE	4.0	17.9	-2	7.4	22.6	30.0	33	3.06
GREEN								
VIOLET								
ORANGE								
YELLOW	29.9	15.0	1	5.6	15.6	21.2	23	2.76
WHITE	26.1	9.7		6.2	10.5	16.8	18	1.69
BLACK								
NAVY								
N = 32			-1	40.5	51.0	91.5	100.0	1.26

RA Rakutowskie	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE	5.0	22.0	1	7.2	14.4	21.5	27	2.01
GREEN	2.0	18.2		5.6	9.5	15.0	19	1.70
VIOLET								
ORANGE								
YELLOW	29.0	12.9		17.9	2.9	20.8	26	0.16
WHITE	26.1	10.0		10.8	11.1	21.9	28	1.02
BLACK								
NAVY								
N = 37			1	41.5	37.8	79.3	100.0	0.91

TK+TM Talitha Kumi	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET	4.0	20.0		0.0	11.4	11.4	10	x
ORANGE	29.8	12.1	-2	24.9	6.8	6.8	35	0.55
YELLOW	26.9	12.1	1	32.4	6.8	6.8	42	0.42
WHITE							32	
BLACK							39	
NAVY		25.0		5.9	7.7	13.7	12	1.30
N = 7			-1	63.2	32.8	96.0	100.0	0.74

TU Turov	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN	3.9	19.9	0	34.2	5.4	39.6	46	0.16
VIOLET								
ORANGE	0.0	14.0	-2	21.5	4.1	25.6	30	0.19
YELLOW								
WHITE	26.1	8.3	-2	4.2	16.1	20.3	24	3.85
BLACK								
NAVY								
N = 7			-4	59.8	25.6	85.4	100.0	0.43

UC Ucka	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE	6.9	21.9		3.5	6.0	9.5	10	1.69

GREEN	31.0	14.9		4.4	2.5	6.9	7	0.57
VIOLET								
ORANGE								
YELLOW	28.0	9.9	-2	8.3	35.2	43.5	47	4.23
WHITE								
BLACK		24.0		4.1	29.4	33.5	36	7.18
NAVY								
N = 15			-2	20.3	73.0	93.3	100.0	3.60
WL Wadi Allaqi	Sector			Number indices				
	Arrival	Departure	Deviation	Arrival	Departure	Axis	Share (%)	Departure/ Arrival
RED								
BLUE								
GREEN								
VIOLET	6.3	22.9		1.2	32.0	33.2	34	26.16
ORANGE	1.0	18.1		1.0	5.9	6.9	7	5.73
YELLOW	25.0	12.0	3	30.1	5.4	35.5	37	0.18
WHITE	30.0	12.0	-2	15.5	5.4	20.9	22	0.35
BLACK								
NAVY								
N = 19			1	47.8	48.7	96.5	100.0	1.02

APPENDIX – MAPS

Migration patterns for Garden Warbler migration streams. The *GREEN* stream is presented in Figure 8, where all explanations are given.


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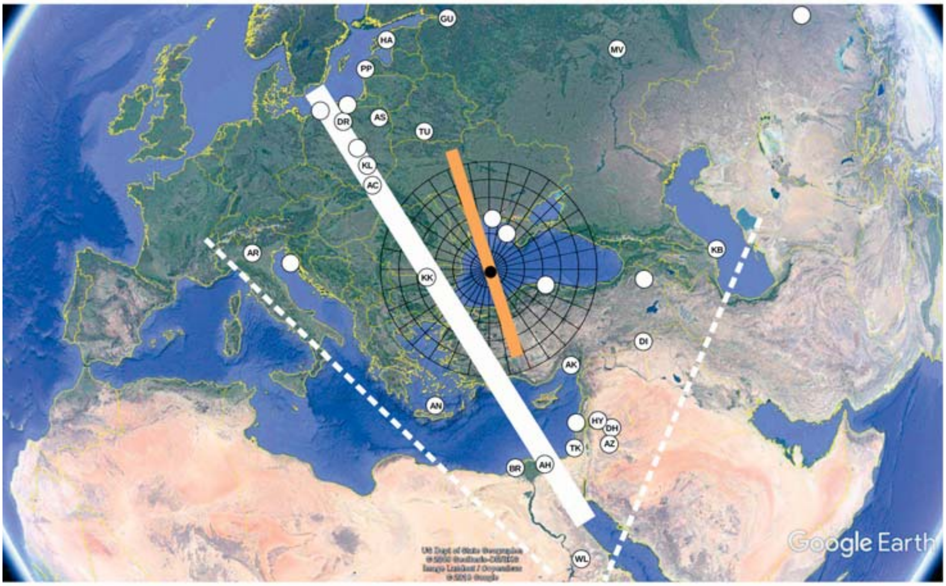
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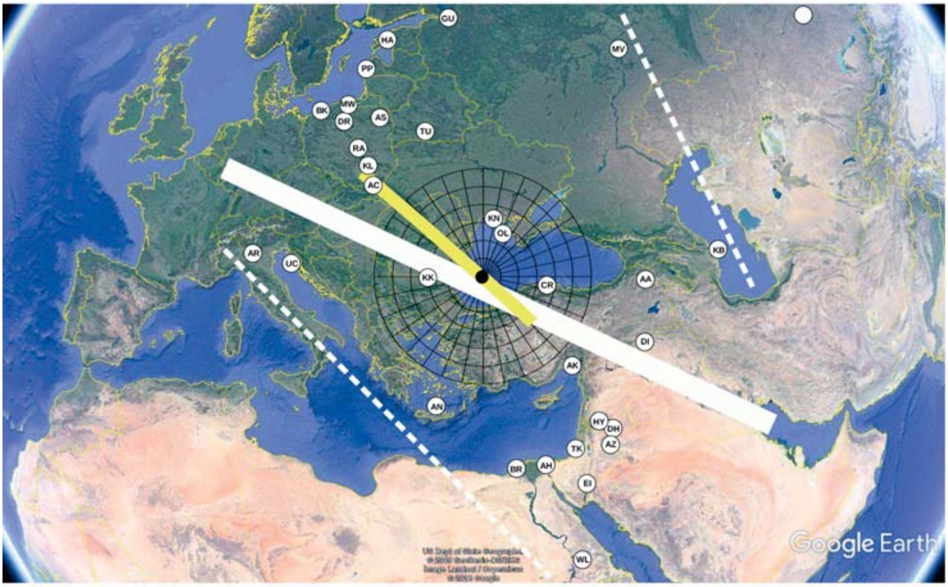
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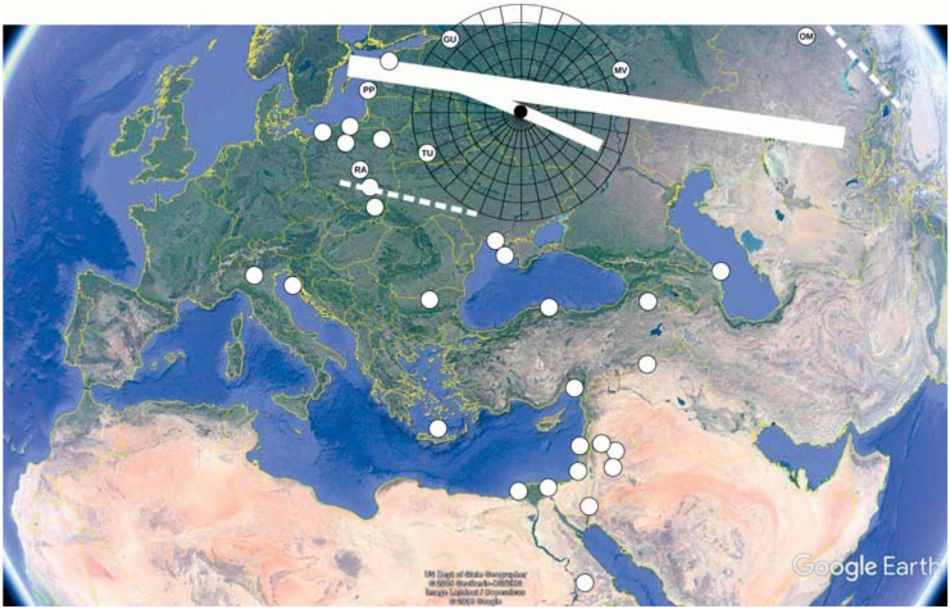
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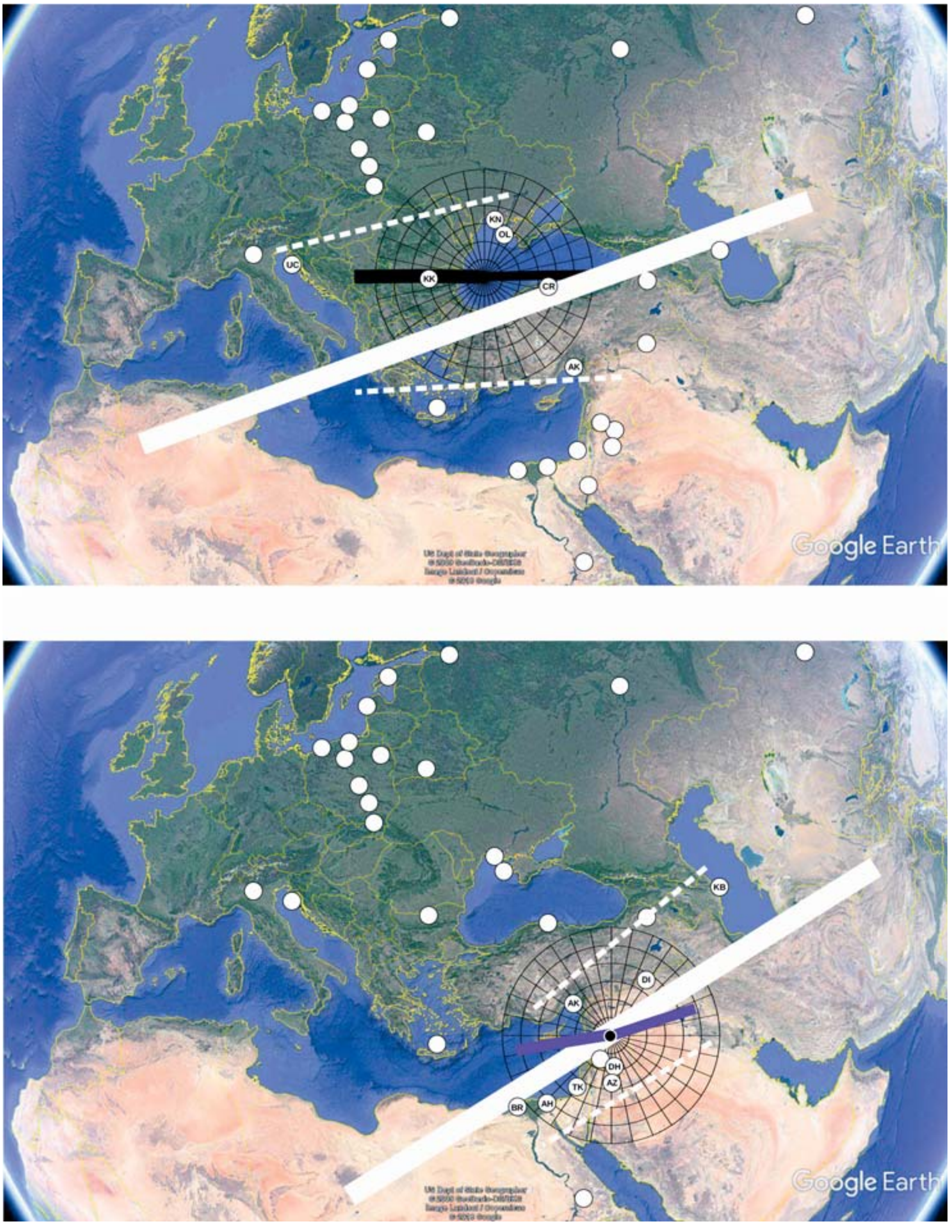
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