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MIGRATION DYNAMICS AND DIRECTIONAL PREFERENCES OF PASSERINE MIGRANTS IN AZRAQ (E JORDAN) IN SPRING 2008

Katarzyna Stępniewska, Ashraf El-Hallah and Przemysław Busse

ABSTRACT

Stępniewska K., El-Hallah A., Busse P. 2011. *Migration dynamics and directional preferences of passerine migrants in Azraq (E Jordan) in spring 2008*. Ring 33, 1-2: 3-25.

Azraq ringing station is located in the Azraq Wetland Reserve in the eastern part of Jordan, on the Eastern Palearctic Flyway. It covers different types of habitat: reedbeds and a dry area with tamarisks (*Tamarix sp.*) and nitre bushes (*Nitraria billardierei*). In total, from 18 March till 28 April 2008, we caught 2767 birds from 64 species. Three species dominated distinctly, constituting 58% of total number of caught birds: the Reed Warbler (*Acrocephalus scirpaceus*) – 570, the Chiffchaff (*Phylloscopus collybita*) – 535 and the Lesser Whitethroat (*Sylvia curruca*) – 488 birds. The catching dynamics reveals the highest numbers of birds in the beginning of the studied period. The total number constantly decreased till 6 April and then subsequently increased. The first high peak of the dynamics at the end of March was due to intensive migration of Chiffchaffs and Lesser Whitethroats. The second one at the end of April was caused by pronounced migration of Reed Warblers and Blackcaps. High numbers of migrants in the beginning and at the end of the catching period reveal that we did not cover the whole migration season in Azraq, so it is necessary to begin the study much earlier and to finish later there.

We performed also 1169 directional preferences tests using Busse's orientation cage, mostly for the Reed Warbler. Directional preferences of tested birds reveal clear dominance of NW headings – towards European breeding grounds. The NE headings towards Asian breeding grounds were also present. There was a low share of reversed headings, especially SE. We suppose that birds showing NW headings could migrate from wintering grounds in Africa across the most southern coasts of the Arabian Peninsula; these flying to the NE seem to have crossed Egypt and then fly along the Arava Valley. Many species presented in this paper, like the Red-backed Shrike (*Lanius collurio*), could show loop-migration, flying in spring more eastern than in autumn.

High numbers of caught and observed birds, including habitat-specialists like numerous *Acrocephalus* warblers, reveal that the Azraq Wetland Reserve is a very important place for Palearctic migrants during their migration through desert areas of the Middle-East.

K. Stępniewska, Bird Migration Research Station, University of Gdańsk, Al. Marszałka Józefa Piłsudskiego 46, PL-81-378 Gdynia, Poland, E-mail: stepniewska.aves@gmail.com; A. El-Hallah, Shoumary Wild Life Reserve, The Royal Society for the Conservation of Nature, North Azraq, Zarqa, Jordan; P. Busse, SE European Bird Migration Network, Przebendowo, PL-84-210 Choczewo, Poland

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INTRODUCTION

The Middle East is a very important area for migratory birds. Twice a year, in spring and in autumn, huge numbers of birds of many Palearctic species fly there between their breeding grounds in Eurasia and wintering grounds in Africa (Moreau 1972, Newton 2008). In addition, this is also the wintering area for some of the medium-distant migrants (Hagemeijer and Blair 1997, Cramp 1998). A major part of the Middle East is covered by deserts or semi-deserts. For this reason birds commonly use there natural oases or anthropogenic places like gardens, plantations, cultivable lands as well as reedbeds by fishponds and sewage farms to rest or stopover (Hasseb *et al*. 2004, Ożarowska *et al*. 2011, Stępniewski *et al*. 2011). One of the best known attractive places for birds in Jordan is Azraq Wetland Reserve, belonging to areas of the Ramsar Convention on Wetlands. This reserve was established in 1978 by the Royal Society for the Conservation of Nature and covers 12 km^2. The oasis is located in a natural depression in the Jordanian Eastern Desert. In the 1960s, water began to be pumped to support Amman (the capital city) booming population. The natural springs dried up, so nowadays there are maintained artificial springs. Nevertheless, this is still a very important place for migrants because of the ponds and luxuriant vegetation. For this reason, in autumn 2002 Azraq Ringing Station was established there as a member of the SE European Bird Migration Network (SEEN).

The main factors affecting migration in the Middle East are the desert conditions and the trade wind system (Bruderer 1999). The knowledge on directional preferences of passerines from the eastern Mediterranean basin and Middle East is still lacking, particularly from the spring passage. Up to now, these issues have been investigated almost entirely in Israel or Egypt (*e.g*. Biebach *et al*. 2001, Bruderer 2001, Komenda-Zehnder 2002, Dinevich and Leshem 2010) using different methods, such as orientation tests, visual observations or radar monitoring. Results from those data allow to fill in gaps in the knowledge about flyway routes through the areas with very low recovery rates (Ożarowska *et al*. 2004). Moreover, we can gain information on the migration routes of birds in respect of big geographical barriers, such as the Mediterranean Sea or the Sahara and Arabian Deserts, and determine if they are similar or different in spring and autumn (Pearson and Lack 1992).

In this paper, we present results of our research in Azraq during spring migration in 2008. The aim of this study was to describe seasonal dynamics of Palearctic mi-

grants and their directional preferences during spring migration with an attempt to indicate their arrival and departure routes.

MATERIAL AND METHODS

Study area and fieldwork

The study was conducted in the Azraq Wetland Reserve (31°50'N, 36°49'E), close to the eastern border of Jordan (Fig. 1), 100 km to the east of the capital of Amman. The data were collected from 18 March to 28 April 2008. Birds were caught in 41 mist-nets (the number was stable during the whole catching season), in three types of habitat: 1) pure reedbeds and reedbeds with admixed tamarisk (*Tamarix sp.*) bushes near natural or ancient-artificial ponds, 2) tamarisk bushes and 3) nitre bushes (*Nitraria billardierei*) in a semi-desert area. Close to the reserve there were orchards with date palms (*Phoenix dactylifera*), peaches (*Prunus persica*) and pomegranates (*Punica granatum*). Around the reserve and Azraq village there is a desert covered with black basalt stones, without or with low shrub vegetation only.

Fig. 1. Location of Azraq in Jordan

Due to high temperatures in the mid-day, nets were opened from dawn till 11.00 *a.m.* / 12.00 *p.m.* and then from 5.00 *p.m.* till dusk.

We applied the standard SEEN methodology including constant mist-netting, ringing, taking standard set of biometric measurements and orientation tests of randomly selected nocturnal migrants in Busse's cage (Busse 1995, 2000). The cage is divided into 8 sectors, covered with a stripe of transparent foil at the side wall and a piece of netting at the top. It is placed inside a higher, non-transparent screen to prevent the bird from seeing any landscape marks. A tested bird is put into the cage for 10 minutes and then released. The activity of the bird is expressed by holes and scratches on the foil, which are counted in each sector immediately after the release of the bird and then noted down in a special form. The stripe of foil is replaced by a new one always before the next test. Test were performed only in the morning hours, up till 11.00 *a.m.*

Data analyses

Seasonal dynamics graphs for the number of species caught per day (see Fig. 2), all caught birds (see Fig. 3) and for the most numerous species were prepared (see Fig. 4). House Sparrows (*Passer domesticus*) were not ringed, so for this species we did not perform any analyses. Seasonal dynamics cover the period from 19 March till 27 April, because the first day of catching (18 March) began in the evening and the last (28 April) was finished before noon. In order to obtain a more general pattern of number dynamics, we smoothed the numbers using a 5-day moving average according to the formula:

$$C_w = (a + 2b + 3c + 2d + e) / 9$$

where:
C_w – moving average of birds' numbers in day c,
a, b, c, d, e – numbers of birds caught in five consecutive days.

The data from orientation tests for the most frequently tested birds were elaborated using a non-standard calculation procedure proposed and improved by Busse and Trocińska (1999). This method is based on accepting multimodal circular distributions of preferred directions by migrants. Calculations were performed using original ORIENT v. 4.6 software (available from the authors). Inactive birds (less than 20 marks in total) and those whose distribution of headings did not differ significantly from randomness (χ^2-test) were excluded from further analyses (47 indiv.). Directional preferences were presented for each species as circular 16-sector radar graphs, prepared in Corel Quattro Pro for raw (see Fig. 5) and reversed data (see Fig. 6). The reversed patterns are based on the assumption of axial behaviour of tested migrants, which means that southern headings in spring are reversed in relation to the normal spring directions, so they should be added to the northern headings – it means adding 180° to the southern vectors (Busse and Trocińska 1999). For the analyses, each graph was divided into four main sectors along the N-S and W-E axes: sector I (around NE directions), II (around SE), III (around SW) and IV (around NW). For each of these sectors (for raw and then for reversed data) a percentage of displayed

directions was calculated (see Table 2). At the end, for each species we calculated the proportion of northern to southern headings on the two axes (see Table 3). Retraps were excluded from all analyses.

RESULTS

Seasonal dynamics

In total, from 18 March till 28 April 2008 we caught 2767 birds from 64 species (Table 1). Three species dominated distinctly, constituting 58% of caught birds: Reed Warbler (*Acrocephalus scirpaceus*), Chiffchaff (*Phylloscopus collybita*) and Lesser Whitethroat (*Sylvia curruca*). For at least several species we identified different subspecies (marked with an asterisk and described in the title of Table 1).

Daily diversity of caught species fluctuated from 7 – in the middle of the catching period till 23 – on 24 April, at the end of the catching period (Fig. 2).

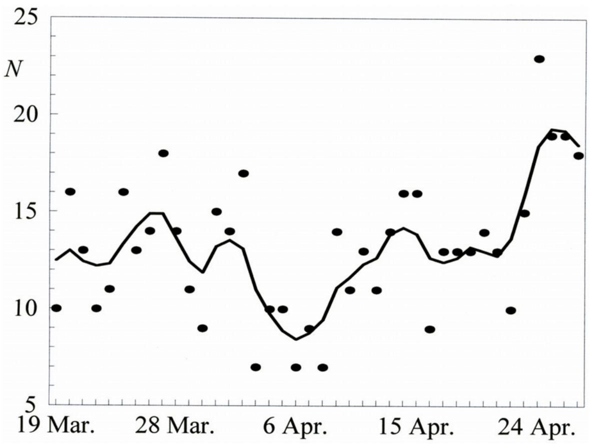


Fig. 2. Dynamics of daily numbers of caught species. Dots – raw data; line – data smoothed once.

A total seasonal dynamics for all species revealed two distinct migration peaks (Fig. 3): higher at the beginning, with the highest daily number of birds – 178 on 19 March, and lower – at the end of the catching period. In the middle of the catching period, on 6 April, there was the lowest number of migrants – only 22 birds; this breakdown is visible at the majority of presented dynamics graphs.

The first peak was constituted mainly by the early migration of particularly two species, *i.e.*: Chiffchaff and Lesser Whitethroat. The Bluethroat (*Luscinia svecica*) and the Spanish Sparrow (*Passer hispaniolensis*) also migrated early (Fig. 4). Afterwards their numbers decreased – slowly for the Lesser Whitethroat, but rapidly and exponentially for the Chiffchaff. These four species migrated at the earliest. The end of migration of the Chiffchaff, Spanish Sparrow and Bluethroat fell within the period of work.

Table 1
List of caught species and their numbers (from 18 March to 28 April). Because the Isabelline Shrike (*Lanius isabellinus*) and the Turkestan Shrike (*L. phoenicuroides*) have been separated only recently and in the field we did not identify the subspecies of each individual, they are presented as one species.

	Number of birds		Number of birds
*Acrocephalus scirpaceus**	570	*Cettia cetti*	5
Phylloscopus colllybita	535	*Lanius isabellinus/phoenicuroides*	5
Sylvia curruca	488	*Oenanthe oenanthe*	5
Sylvia atricapilla	222	*Saxicola maura*	5
*Hirundo rustica**	123	*Irania gutturalis*	4
*Phoenicurus phoenicurus**	84	*Otus scops*	4
Passer domesticus	83	*Turdus merula*	4
Lanius collurio	82	*Erithacus rubecula*	3
Acrocephalus schoenobaenus	68	*Sylvia borin*	3
Riparia riparia	52	*Sylvia cantillans*	3
*Phylloscopus trochilus**	41	*Sylvia rueppeli*	3
*Sylvia communis**	39	*Anthus trivialis*	2
Luscinia megarhynchos	38	*Buteo buteo*	2
Jynx torquilla	32	*Cecropsis daurica*	2
*Luscinia svecica**	32	*Oenanthe hispanica*	2
Acrocephalus arundinaceus	31	*Phylloscopus sibilatrix*	2
Passer hispaniolensis	27	*Remiz pendulinus*	2
Phylloscopus orientalis	16	*Streptopelia senegalensis*	2
Acrocephalus palustris	14	*Upupa epops*	2
Luscinia luscinia	14	*Accipiter brevipes*	1
Pycnonotus leucotos	14	*Acrocephalus melanopogon*	1
Lanius nubicus	12	*Alcedo atthis*	1
Iduna pallida	10	*Anthus campestris*	1
Sylvia crassirostris	9	*Ficedula hypoleuca*	1
*Sylvia melanocephala**	8	*Hippolais icterina*	1
Sylvia nisoria	8	*Ixobrychus minutus*	1
Turdus philomelos	8	*Oenanthe cypriaca*	1
Cercotrichas galactotes	7	*Oenanthe isabellina*	1
Locustella luscinioides	7	*Phoenicurus ochruros*	1
Lanius senator	6	*Rhodospiza obsoleta*	1
Muscicapa striata	6	*Saxicola rubicola*	1
Saxicola rubetra	6	*Streptopelia decaocto*	1

An asterisk (*) marks species for which there were identified different subspecies, *i.e.*: Reed Warbler (*Acrocephalus scirpaceus*) – nominative and *fuscus*; Barn Swallow (*Hirundo rustica*) – nominative and *transitiva*; Redstart (*Phoenicurus phoenicurus*) – nominative and *samamisicus*; Willow Warbler (*Phylloscopus trochilus*) – nominative and *yakutensis*; Whitethroat (*Sylvia communis*) – nominative and *icterops*; Bluethroat (*Luscinia svecica*) – nominative and *cyanecula*; Sardinian Warbler (*Sylvia melanocephala*) – nominative and *momus*.

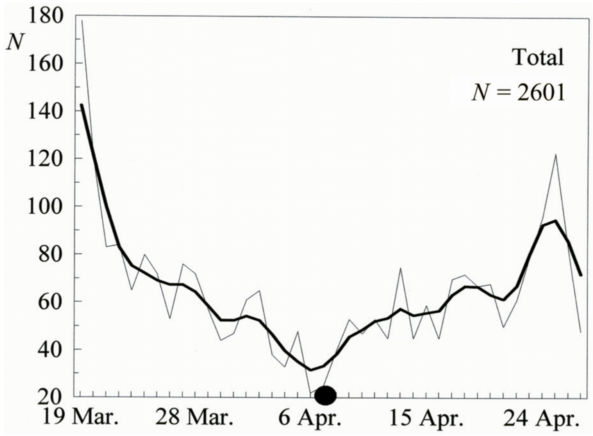


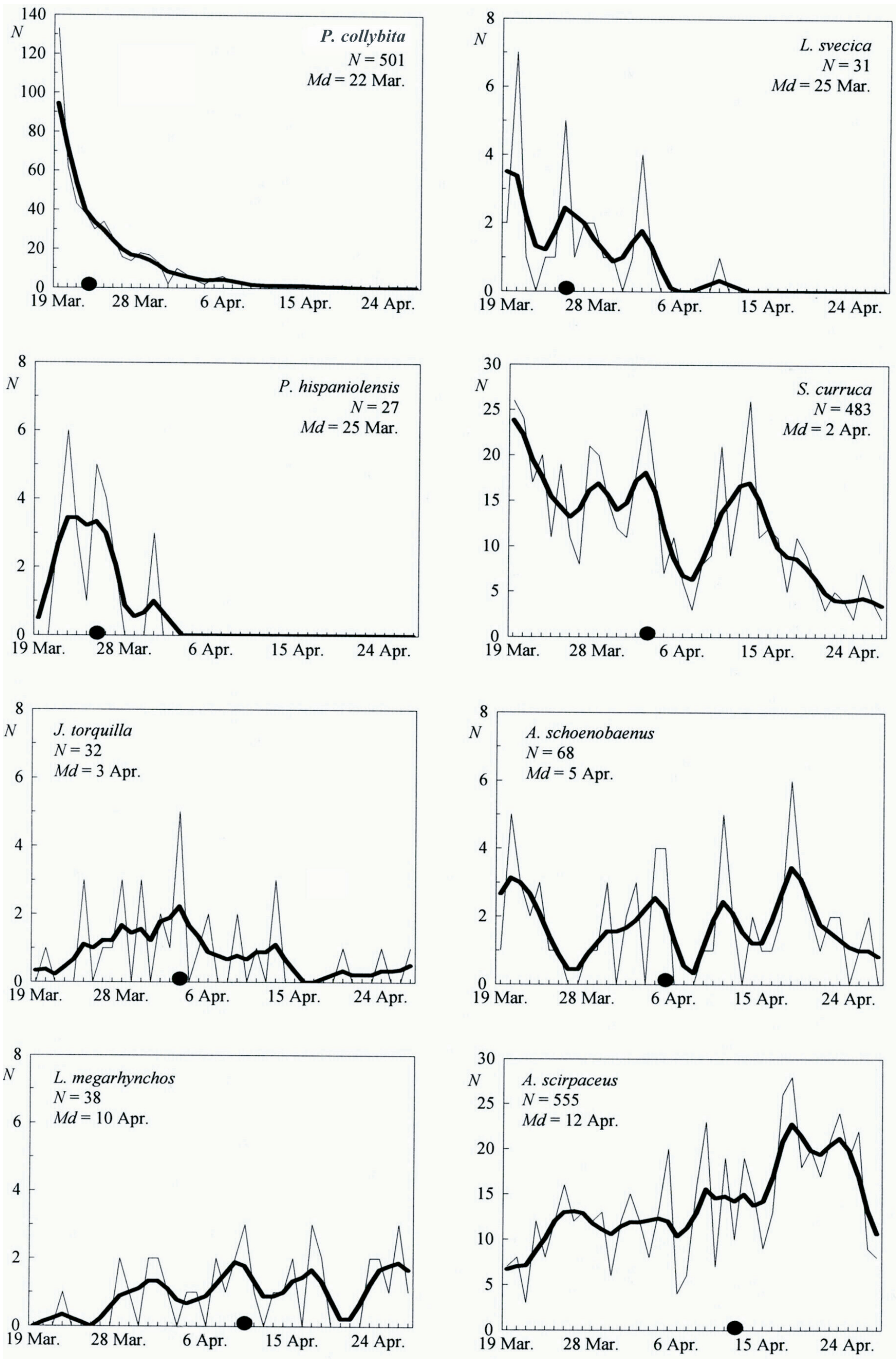
Fig. 3. Total seasonal dynamics, excluding the House Sparrow (*Passer domesticus*). Median date marked by black dot. Thin line – raw data; thick line – data smoothed once.

For the Blackcap (*Sylvia atricapilla*) and especially for the Reed Warbler, we covered neither the beginning nor the end of their migration. Their numbers increased through the catching period – gradually for Reed Warbler and rapidly for Blackcap (after 6 April), with the peak at the same time around 20 April; then decreased – either slightly (Reed Warbler) or rapidly (Blackcap).

Passage of the Sedge Warbler (*Acrocephalus schoenobaenus*) was the most prolonged, without the main peak, but there were four almost equal waves of migration. We did not cover either distinct beginning nor end of its migration. Because of equal peaks, the migration dynamics of the Nightingale (*Luscinia megarhynchos*) resembled the one for the Sedge Warbler, but it seems that we covered only the beginning of its passage.

We caught the beginning of migration, but not the end, of the remaining species: Barn Swallow (*Hirundo rustica*), Great Reed Warbler (*Arcocephalus arundinaceus*), Redstart (*Phoenicurus phoenicurus*), Willow Warbler (*Phylloscopus trochilus*), Sand Martin (*Riparia riparia*), Whitethroat (*Sylvia communis*) and Red-backed Shrike (*Lanius collurio*). Their numbers increased gradually (like Great Reed Warbler) or rapidly (like Red-backed Shrike) through the study period. Together with the Reed Warbler, these species affected also the second peak of the total seasonal dynamics.

We could also compare dynamics within larger groups. The most distinct differences were visible in the genus *Phylloscopus* – the Chiffchaff migrated much earlier with a difference of one month between its and the Willow Warbler's median date of passage. In the genus *Sylvia*, the Lesser Whitethroat migrated first. The migration dynamics of the Blackcap and Whitethroat were more similar; the Whitethroat migrated as the last one. In the genus *Acrocephalus*, similar dynamics were visible for the Reed Warbler and Great Reed Warbler. The Sedge Warbler migrated first and the Great Reed Warbler – last. In the genus *Luscinia*, the Bluethroat migrated earlier than the Nigtingale. In swallows, there were similar dynamics with a small difference between median dates of their passage.


P. collybita
N = 501
Md = 22 Mar.
L. svecica
N = 31
Md = 25 Mar.
P. hispaniolensis
N = 27
Md = 25 Mar.
S. curruca
N = 483
Md = 2 Apr.
J. torquilla
N = 32
Md = 3 Apr.
A. schoenobaenus
N = 68
Md = 5 Apr.
L. megarhynchos
N = 38
Md = 10 Apr.
A. scirpaceus
N = 555
Md = 12 Apr.
N
19 Mar.
28 Mar.
6 Apr.
15 Apr.
24 Apr.

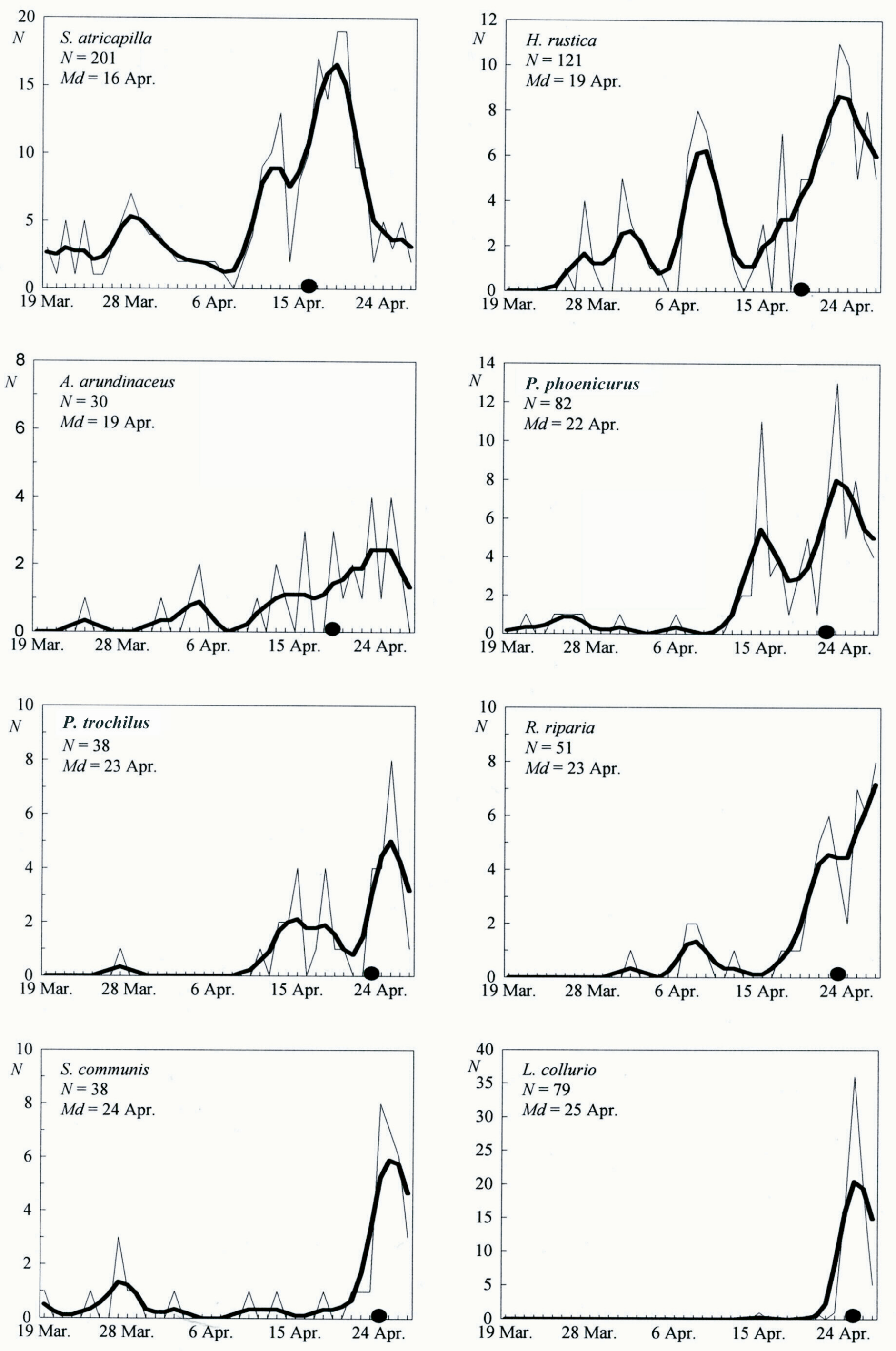
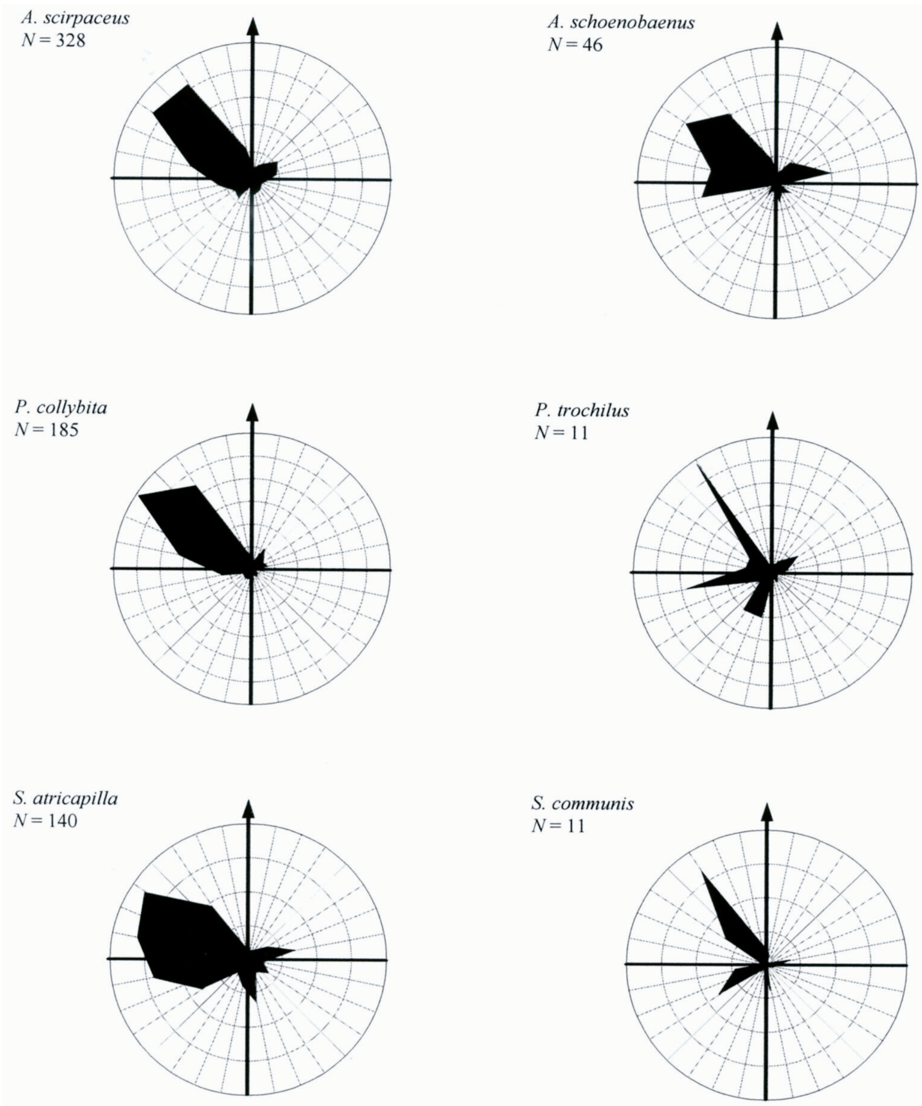


Fig. 4. Seasonal dynamics of the most numerous species. Thin line – raw data, thick line – data smoothed once. Median date marked by black dot. Charts arranged according to the median date of passage (from the earliest).

To sum up, the Chiffchaff migrated in Azraq as the earliest (median date – 22 March) and the Red-backed Shrike as the latest (median date – 25 April). Probably only for one species – the Wryneck (*Jynx torquilla*), almost the whole passage was covered. For almost all of presented species we could observe distinct waves of their passage and common low intensity of passage about 6 April.

Directional preferences

Altogether, we performed 1169 orientation experiments (1344 including retraps) on 34 species. The most frequently tested were: Reed Warbler, Chiffchaff and Lesser Whitethroat (Fig. 5 and 6). They constituted 74% of the tested birds.



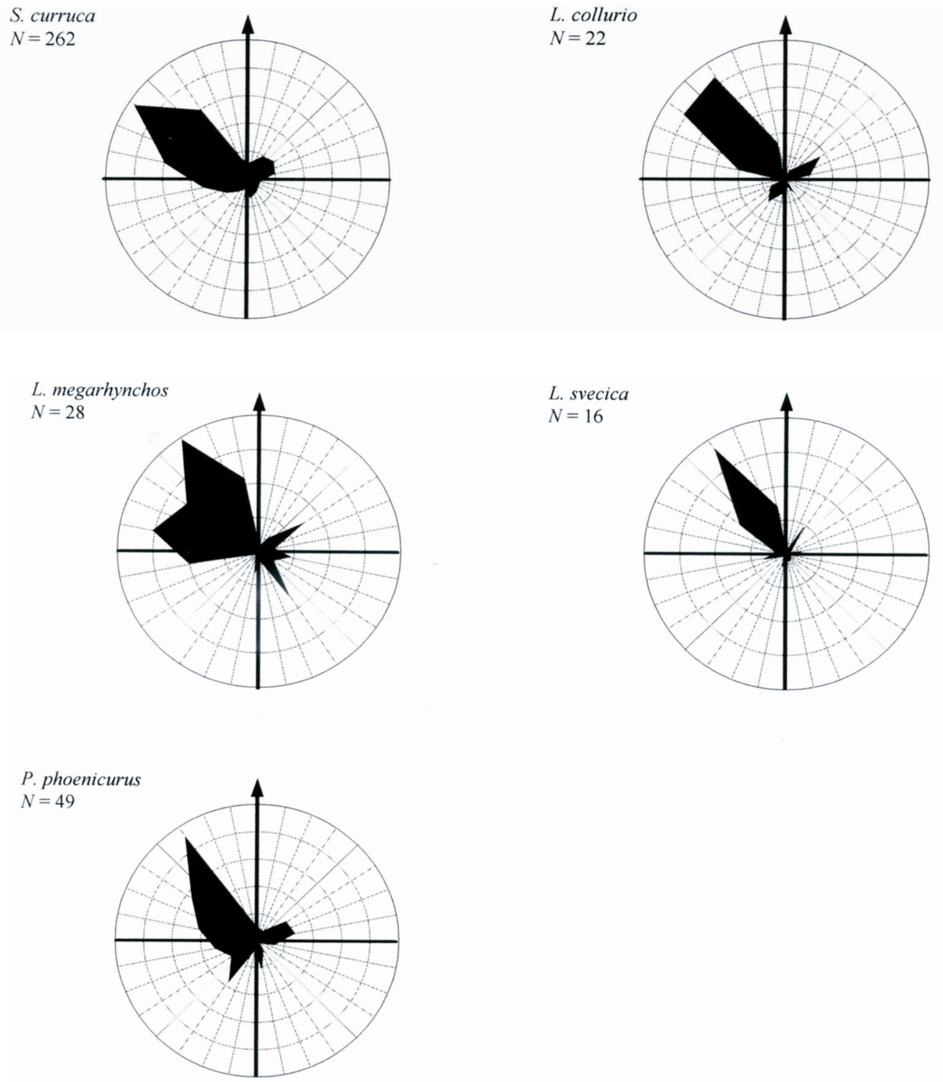
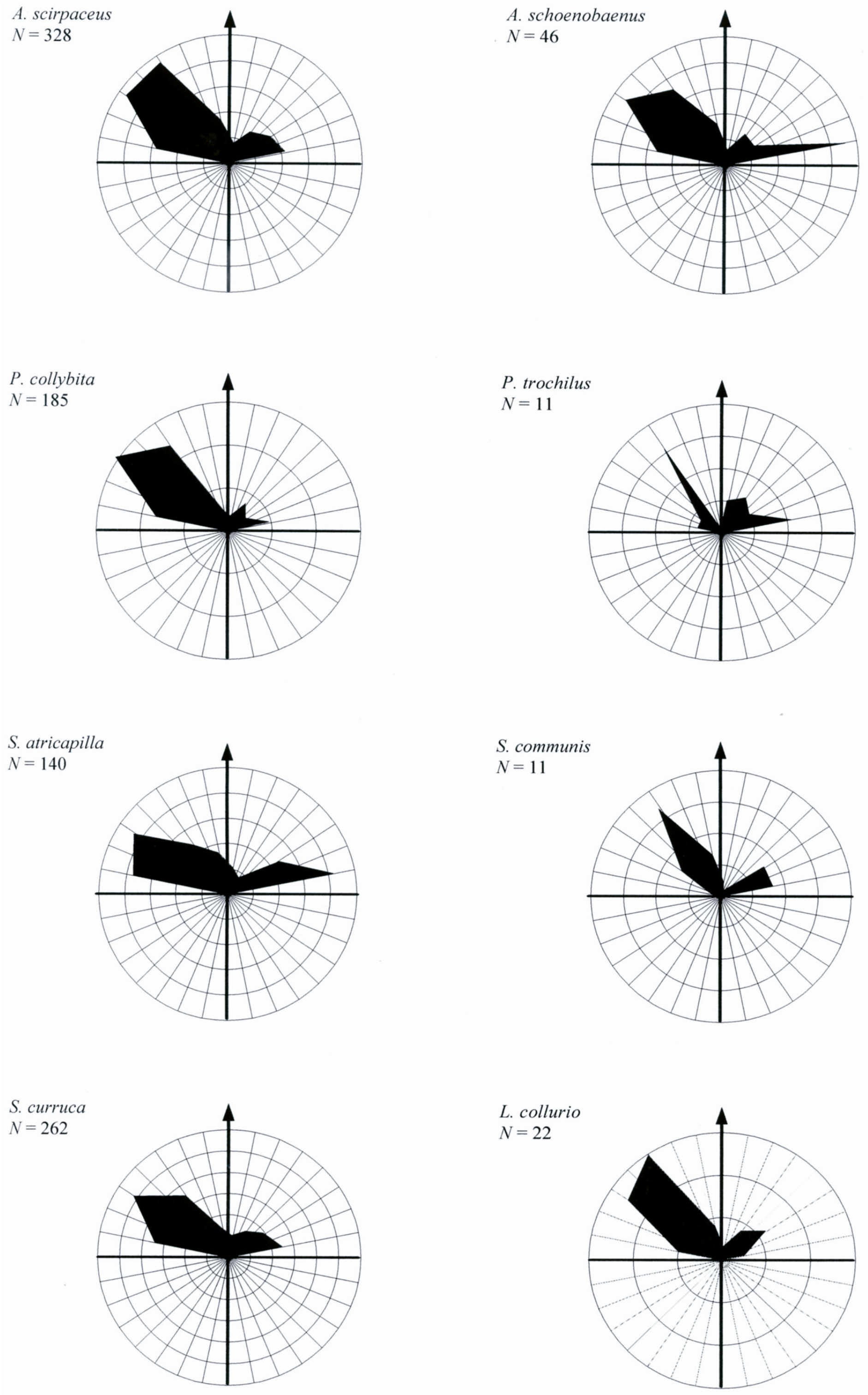


Fig. 5. Distributions of directional preferences of the most numerous tested species – raw data

For all presented species there was a striking similarity of directional preferences, with a distinct presence of NW headings (Fig. 5 and 6). Excluding the Willow Warbler, they dominated in each species (Table 2) and reached the largest share (70%) for the Chiffchaff. The second preferred were SW headings, with the largest share (41.5%) for the Willow Warbler, and third – NE, reaching the highest value (21.8%) for the Sedge Warbler. Headings to the SE had the least share of overall percentage.

Generally, the shares of opposite directions to the normal spring migration headings were low. It refers mostly to SE headings – they were the lowest for the Chifchaff, Bluethroat, Willow Warbler and particularly for the Red-backed Shrike (only 3.1%). It is worth noting that for the same species there were also the least


A. scirpaceus
N = 328
A. schoenobaenus
N = 46
P. collybita
N = 185
P. trochilus
N = 11
S. atricapilla
N = 140
S. communis
N = 11
S. curruca
N = 262
L. collurio
N = 22

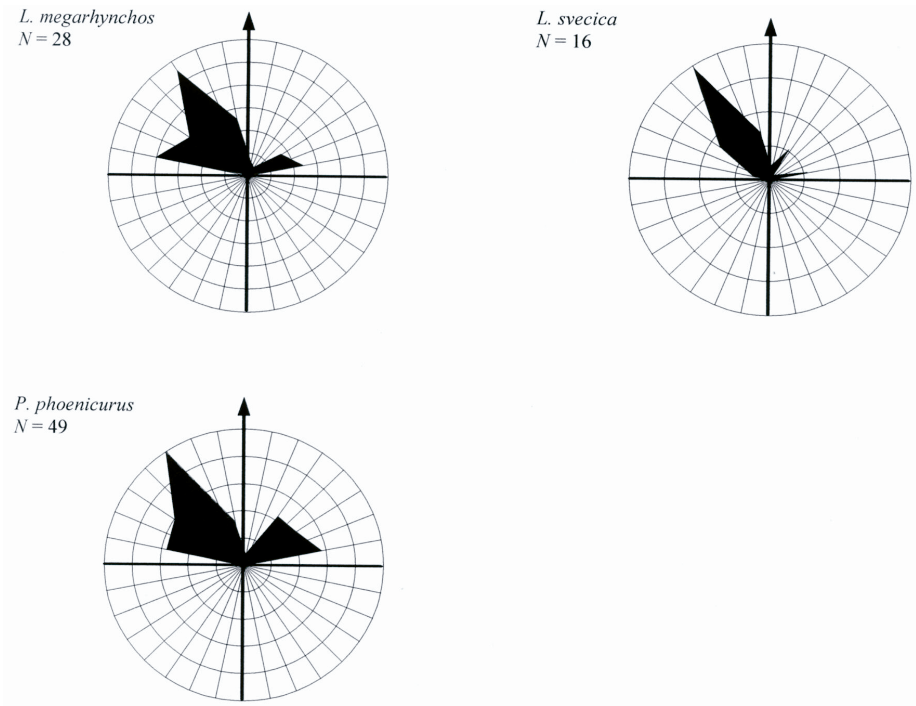


Fig. 6. Distributions of directional preferences of the most numerous tested species – reversed data

shares of SW headings – except for the Willow Warbler, for which this share was the largest among all of 11 presented species. For the reversed radar graphs there was, similarly to the raw data, a clear predominance of NW headings over NE ones in all cases – from 54.5% (Willow Warbler) till 75.0% (Chiffchaff).

It should be emphasized, that there was a distinct disproportion of northern and southern headings present on the NW-SE and NE-SW axes (Table 3). The share of northern headings for the NW-SE axis, contrary to the second one, was several times higher than that of southern directions for every species. The largest disproportion could be seen for the Red-backed Shrike (the share of NW headings is twenty two times as much as of the opposite SE headings) and the least – for the Blackcap (only three times). For the second axis, on the other hand, there was only slight predominance either of northern (particularly in the Red-backed Shrike and Bluethroat) or southern (particularly in the Willow Warbler and Whitethroat) directions.

In order to obtain a more general picture of migration we should also analyse the overall directional preferences of birds in Azraq (Fig. 7). This image is similar as the ones for individual species. There is the same, clear presence of NW headings (*cf*. Table 2). For the reversed data there is the highest share of NW headings, which is twice as much as NE headings. There is also a distinct disproportion of headings on the NW-SE and NE-SW axes. For the first one, the share of NW headings is almost six as much as the opposite SE headings. For the second axis the proportion of headings is very similar (Table 3).

Table 2
Share of directional preferences of tested birds in each of four main sectors in radar graphs. The largest value for each species is in bold.

Species	*N* of tests	Raw data Sector (%)				Reversed data Sector (%)	
		NW	SW	SE	NE	NW	NE
A. scirpaceus	328	**59.2**	15.2	9.9	15.4	**69.1**	30.9
S. curruca	262	**55.7**	15.8	10.6	17.9	**66.3**	33.7
P. colllybita	185	**70.0**	12.1	5.0	12.9	**75.0**	25.0
S. atricapilla	140	**44.7**	27.8	14.2	13.2	**58.9**	41.1
P. phoenicurus	49	**50.3**	23.2	11.3	15.2	**61.6**	38.4
A. schoenobaenus	46	**51.2**	17.8	9.2	21.8	**60.4**	39.6
L. megarhynchos	28	**58.1**	14.1	16.0	11.8	**74.1**	25.9
L. collurio	22	**68.8**	11.9	3.1	16.2	**71.9**	28.1
L. svecica	14	**69.5**	10.5	4.9	15.2	**74.3**	25.7
P. trochilus	11	40.8	**41.5**	4.7	12.9	**54.5**	45.5
S. communis	11	**52.6**	27.9	9.9	9.6	**62.5**	37.5
Total	1169	**57.2**	17.7	9.7	15.4	**66.9**	33.1

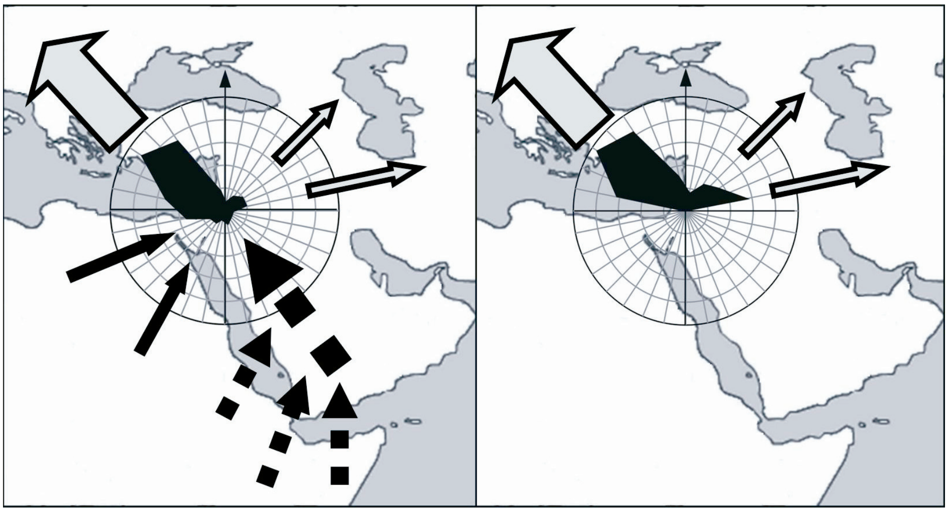


Fig. 7. Overall picture of directional preferences of all tested birds (N = 1169) for raw (left) and reversed (right) data. Presumable pattern of **arrival directions** (black solid arrows – based on the orientation results in Ibrahim (2011), black dashed arrows – based on the literature data, *e.g.* Pearson and Lack 1992) and **departure directions** (light grey arrows) of migrants are given.

Table 3
Proportion of northern to southern headings on two axes: NW-SE and NE-SW. Values calculated according to the raw data from Table 2

Species	**NW**-SE	**NE**-SW
A. scirpaceus	6.0	1.0
S. curruca	5.3	1.1
P. colllybita	14.0	1.1
S. atricapilla	3.1	0.5
P. phoenicurus	4.5	0.7
A. schoenobaenus	5.6	1.2
L. megarhynchos	3.6	0.8
L. collurio	22.2	1.4
L. svecica	14.2	1.4
P. trochilus	8.7	0.3
S. communis	5.3	0.3
Total	**5.9**	**0.9**

Species observed in the field

Except 64 ringed species, we also observed 58 other species in the area of Azraq Wetland Reserve. These observations were made only occasionally – we did not make detailed counts, so below only a list of species without numbers is given: Grey Heron (*Ardea cinerea*), Purple Heron (*A. purpurea*), Great Egret (*A. alba*), Little Egret (*Egretta garzetta*), Cattle Egret (*Bubulcus ibis*), Squacco Heron (*Ardeola ralloides*), Night Heron (*Nycticorax nycticorax*), Bittern (*Botaurus stellaris*), White Stork (*Ciconia ciconia*), Glossy Ibis (*Plegadis falcinellus*), Garganey (*Anas querquedula*), Shoveler (*A. clypeata*), Osprey (*Pandion haliaetus*), Honey Buzzard (*Pernis apivorus*), Black Kite (*Milvus migrans*), Egyptian Vulture (*Neophron percnopterus*), Short-toed Eagle (*Circaetus gallicus*), Marsh Harrier (*Circus aeruginosus*), Hen Harrier (*C. cyaneus*), Pallid Harrier (*C. macrourus*), Long-legged Buzzard (*Buteo rufinus*), Golden Eagle (*Aquila chrysaetos*), Booted Eagle (*A. pennata*) – light and dark form, Hobby (*Falco subbuteo*), Quail (*Coturnix coturnix*), Moorhen (*Gallinula chloropus*), Coot (*Fulica atra*), Black-winged Stilt (*Himantopus himantopus*), Collared Pratincole (*Glareola pratincola*), Black-winged Pratincole (*G. nordmanni*), Spur-winged Lapwing (*Vanellus spinosus*), Common Snipe (*Gallinago gallinago*), Greenshank (*Tringa nebularia*), Green Sandpiper (*T. ochropus*), Wood Sandpiper (*T. glareola*), Common Sandpiper (*Actitis hypoleucos*), Ruff (*Philomachus pugnax*), Little Stint (*Calidris minuta*), Temminck's Stint (*C. temminckii*), Common Tern (*Sterna hirundo*), White-winged Tern (*Chlidonias leucopterus*), Rose-ringed Parakeet (*Psittacula krameri*), Nightjar (*Caprimulgus europaeus*), Egyptian Nightjar (*C. aegyptius*), Alpine Swift (*Apus melba*), Common Swift (*Apus apus*), Pied Kingfisher (*Ceryle rudis*), Blue-cheeked Bee-eater (*Merops persicus*), Bee-eater (*M. apiaster*), Crested Lark (*Galerida cristata*), Temminck's Lark (*Eremophila bilopha*), Crag Martin (*Ptyonoprogne rupestris*), Common House Martin (*Delichon urbica*), Yellow Wagtail (*Motacilla flava*) – probably *feldegg* and *thunbergii* subspecies,

White Wagtail (*M. alba*), Ortolan Bunting (*Emberiza hortulana*), Sinai Rosefinch (*Carpodacus synoicus*), Golden Oriole (*Oriolus oriolus*).

DISCUSSION

Seasonal dynamics

In Azraq we caught large numbers of transient birds. The most common family was *Sylviidae*, as in previous ringing seasons in Azraq (Al-Omari *et al*. 2005, Al-Omari *et al*. 2007). The most numerous species were the same as in previous five spring seasons in 2002-2005 and 2007: Reed Warbler, Lesser Whitethroat, Chiffchaff and Blackcap (Al-Omari *et al*. 2005, Al-Omari *et al*. 2007). Except the Blackcap, the remaining species were the most abundant spring migrants also in Egypt (Ibrahim 2011).

Spring migration in Azraq is intensive, much more than in autumn (Al-Omari *et al*. 2005, Al-Omari *et al*. 2007), which is a general rule in the Middle East (Yom-Tov 1984, Shirihai 1996, Morgan and Shirihai 1997, Ibrahim 2011, Ożarowska *et al*. 2011). It is worth mentioning that the most numerous species ($N > 30$, see Table 1) have their breeding grounds spread widely in Europe, often reaching Siberia and western Asia (Harrison 1982, Hagemeijer and Blair 1997, Cramp 1998). Except for the Chiffchaff and Bluethroat, which can also winter in the Middle East (Porter *et al*. 1996, Shirihai 1996, Cramp 1998), these are generally the species whose wintering grounds are located mainly or exclusively in Africa. From more southern species (Mediterranean, Middle-Eastern or central-western Asiatic), the most numerous was the Spanish Sparrow; the remaining species from this group were caught rarely. This is clear evidence that the Middle East is an important area for many species during their migration between wintering and breeding grounds.

Fieldwork was started too late especially for the Chiffchaff. This is confirmed by the catching results from the previous spring seasons in Azraq (Al-Omari *et al*. 2005, Al-Omari *et al*. 2007), from Eilat in Israel located quite nearby (Morgan and Shirihai 1997) and from Egypt (Ibrahim 2011). Despite the early start of study in Azraq in 2005 (on 1 March), the peak of migration occurred exactly at the beginning of catching, so we do not know if the main peak of migration was caught. The passage of Chiffchaffs in Eilat starts in early February, with rapid growth in the middle of the month and the peak in the first half of March, so even later than in Azraq in 2005. Two things are similar and repeatable for dynamics in these two places – a rapid decrease of migration as the season advances and the end of passage in similar time frames (only single birds after 15 April). In Israel, this species is more abundant in the eastern part of the country (Shirihai 1996), which could mean that the spring passage could be strong eastwards, through Jordan. In Egypt, the Chiffchaff is also an early migrant, commencing its migration in mid-February and peaking in March (Goodmann and Meininger 1989). Nevertheless, the spring passage of this species in Egypt is less intensive than in Jordan – maximum daily number was only 19 (Hurghada – Ibrahim 2011), while 133 in Azraq.

Beside the Chiffchaff, also the Spanish Sparrow, Lesser Whitethroat and Bluethroat migrated through Azraq early. Contrary to the data from Israel, the last migrants of the Spanish Sparrow were caught at the end of March, while in Israel usually at the end of May, with three peaks of passage through mid-February till the end of April (Shirihai 1996). In Israel, the first to migrate is the eastern subspecies *transcaspicus* before the nominative one, migrating closer to the Mediterranean Sea, so it is possible that we caught only birds from the eastern populations.

Probably we did not cover the peak of migration also for the Lesser Whitethroat, although in previous seasons in Azraq this species peaked much later – at the end of March 2004 and 2005 (but in 2004 the second high peak appeared also after mid-April – Al-Omari *et al.* 2005). Migration of Lesser Whitethroats in Israel starts in the second half of February with a peak in the second half of March in Eilat. It seems that the pattern of migration of Lesser Whitethroats is changeable between years. In Egypt, it is the most numerous in March (Ibrahim 2011). Distinct waves of the seasonal dynamics could reflect different time of migration either of sex groups or maybe even subspecies (Shirihai 1996), which were not identified by us due to too high similarity among them (Svensson 1992, Shirihai 1996).

In the case of the Bluethroat, we could miss the main peak of its migration – the major wave of the passage of Bluethroats in Israel falls into the second week to the end of March (Morgan and Shirihai 1997). The passage of this species weakened gradually, but with distinct waves, till total expiring before mid April.

For the Sedge Warbler and Nightingale there were no visible predominant peak of their passage (in Eilat they peak at the end of March and beginning of April, respectively – Shirihai 1996). These quite equal intensities of passage through the whole catching season resemble the spring migration of the Sedge and Reed Warbler in Egypt (Ibrahim 2011, Ożarowska *et al.* 2011).

The Reed Warbler is the most common migrant species in the migration season in Azraq (Al-Omari *et al.* 2005, Al-Omari *et al.* 2007). It also breeds in the Middle East; we caught a few females with a brood patch or with an egg in the oviduct. The nominative and *fuscus* subspecies occur in the Middle East (Shirihai 1996, Morgan and Shririhai 1997, Cramp 1998) – we caught the first *fuscus* on 20 April. In previous spring seasons double-peaked dynamics, similar to the one in Israel, occurred (Al-Omari *et al.* 2005, Al-Omari *et al.* 2007). Shirihai (1996) and Morgan and Shirihai (1997) suggested that this is not due to the differentiation in timing between sex groups, but rather due to the migration of at least two discrete populations at a different time. It is interesting that one of these peaks in the spring of 2008 occurred in the same time (16-20 April) as in spring 2004 and 2005. We are not sure if we covered the highest peak of the Reed Warbler migration in the season – in 2005, when the study was conduced till mid May, it fell at the beginning of this month (Al-Omari *et al.* 2005, Al-Omari *et al.* 2007).

The migration of the Blackcap started with a small group of birds, what could be seen also for the Whitethroat, Redstart and Sand Martin. More intensive migration appeared much later. Morgan and Shirihai (1997) found that there are two distinct peaks in the migration of Blackcaps at Eilat – the first one in mid-April and the second in early May. They pointed at the migration of two, unrelated populations of

Blackcaps through Eilat – it is possible that the same phenomenon occurred also in Jordan. In comparison to the spring 2004 and 2005 in Azraq, we discovered the same pattern for the migration of Blackcaps in 2008: low daily numbers up to the beginning of April and then rapid growth with the peak exactly in the same time, between 16 and 20 April. It means that the pattern of migration for this species is repeatable like in the case of the Chiffchaff. In Eilat, similarly, Blackcaps were noted in the highest densities at the turn of April (Shirihai 1996). In Egypt, on the other hand, this migrant was scarce in spring (Ibrahim 2011). This could mean that this species in majority probably flies eastwards through the Arabian Peninsula.

The most common swallow in Azraq – the Barn Swallow, appeared at the end of March and showed distinct waves with higher and higher numbers through the season. It formed large flocks at dusk and roosted commonly in reedbeds in the reserve. Because in Israel it is a common migrant from the end of March till the third week of May, we probably missed a major part of its passage (Morgan and Shirihai 1997). A gradual increase in numbers of migrating Barn Swallows resembles the situation in Hurghada (Ibrahim 2011). The second quite numerous species, the Sand Martin, appeared later in Azraq. The main passage of this species in Israel begins in the third week of April and maximum numbers fall in the beginning of May (Shirihai 1996). A rapid increase of passage from mid April was also noted at coastal Egyptian stations – Hurghada and Wadi Gemal (Ibrahim 2011).

The passages of the Willow Warbler and Redstart were similar, with a smaller peak about mid-April and then growth at the end of April. They are quite similar to the results from Hurghada, with main passage in the second half of April (Ibrahim 2011). In the case of the Willow Warbler, there is a clear difference in timing of migration as compared to the closely related Chiffchaff – *i.e.* the spring migration of Willow Warblers through the Middle East occurs later, which is also the rule in Europe (Shirihai 1996, Cramp 1998).

The Whitethroat was one of the latest spring *Sylvia* species. Single individuals appeared during almost the whole catching period. Just at the end of April, there followed a rapid increase in their numbers, resembling the passage in Hurghada; however, this species was scarce at the other inland stations in Egypt (Ibrahim 2011). It is surprising why Whitethroats were caught in Azraq and Hurghada so late, if in Israel they migrated much earlier, with a peak in the second half of March (Shirihai 1996).

The Red-backed Shrike, on the other hand, is a very late migrant also in Israel (with a peak in mid-May). In Azraq, these birds appeared rapidly and in high numbers at the end of April during days with very hot SE winds from the Arabian Peninsula. This species is known from performing the loop migration – it crosses in spring Africa and the Middle East further east than in autumn (Pearson and Lack 1992, Morgan and Shirihai 1997, Cramp 1998).

It seems probable that only for the Wryneck we caught almost the whole passage. This species migrates through Israel mainly between the third week of March and the third week of April (Shirihai 1996).

The migration of the majority of presented species is characterized by distinct waves. Some of these waves were common for many species – this could reflect influence of the same factor during their migration. The most distinct and also common

decrease occurred on 6 and 7 April; it was caused by bad weather during these days (strong NE and then NW wind). This stopped the migration of the majority of species presented here. For the latest migrants there was a common increase of their numbers around 24 April, probably also caused by weather, bringing a new wave of migrants. Waves could also reflect differentiation in timing of migration between populations, as well as age and sex groups, which was proved generally for many Palearctic species, also in the Middle East (Shirihai 1996, Morgan and Shirihai 1997).

Directional preferences

Despite differentiation between seasonal dynamics, the directional preferences of the presented species were surprisingly similar to each other with a clear dominance of NW headings towards Europe. Moreover, they were multimodal, suggesting that the stream of migrants consisted of birds migrating into different wintering quarters and breeding grounds (Busse 1987, Busse 2001, Formella and Busse 2002, Ibrahim 2011). Tested birds showed also axial behaviour; reversed (southern) headings, opposite to the northern, were interpreted as directions from which they come to Azraq (Formella and Busse 2002, Zehtindjiev *et al.* 2003).

The strong share of north-western headings suggests routes towards European breeding grounds through Cyprus, Balkans and Turkey (Fig. 7). This could be an evidence against the commonly accepted phenomenon that spring migration towards Europe leads mainly around the eastern Mediterranean coast than across the sea (*e.g.* Shirihai 1996). Directions towards Asian breeding grounds, much more pronounced at reversed graphs, could show crossing of Mesopotamia and area around the Caspian Sea, leading towards eastern areas. Clear presence of NW and NE directions was also reported in spring in Israel by Ożarowska *et al.* (2004) and Dinevich and Leshem (2010). The high repeatability of directional preferences pattern could be an evidence of a strong influence of the same geographical factors in the areas through which different species migrate.

The southern headings of tested birds could indicate the directions from where birds have just arrived (Zehtindijev *et al.* 2003). If so, in Azraq we have two directions of origin: the first – from the Arabian Peninsula and then towards Europe (assuming axial behaviour, see Trocińska and Busse 1999), and the broad second – through the Arava Valley (then towards Asia), leading from wintering grounds in Africa or, like for the Chiffchaff or Bluethroat, even in the Middle East (Fig. 7).

Clearly pronounced NE headings in spring were found in Egypt and Eilat in Israel (Ibrahim 2011). If birds migrate on a broad front through Africa and then through the Middle East, a part of them could encounter Jordan afterwards. It is interesting why NE headings at Eilat have lower angle (are closer to the N axis) than these in Azraq (with larger angle, closer to the E axis). In Eilat, this could be caused by funnelling by the narrow Arava Valley, bordered by high mountains. With the northward progress of migration, these mountains end before the Dead Sea region, so then migrants could fly north-eastwards more easily. Ożarowska *et al.* (2004) also reported NE headings for the Blackcap and Lesser Whitethroat in Eilat, but these directions dominated only in the Chiffchaff.

A precise description of the route of birds migrating from somewhere in Africa and then passing through the Arabian Peninsula, is less easy. Studies of migrants in this vast area are still lacking and mainly refer to large soaring birds, like raptors (Shirihai 1996). Nevertheless, there are some spring recoveries of passerines from there, which support the existence of the spring flyway towards Europe through the Arabian Peninsula. Individuals of the Barn Swallow, Lesser Whitethroat, Marsh Warbler, Red-backed Shrike, Thrush Nightingale and Willow Warbler ringed in the Czech Republic, Italy, Slovakia or Sweden were recovered in Jemen, Saudi Arabia or Iraq (Hendenström and Pettersson 1987, Cramp 1998, Cepák *et al*. 2008, Fransson and Hall-Karlsson 2008, Spina and Volponi 2008). For these species, it is also mentioned that their spring migration follows a more eastern route through the Middle East than in autumn.

Pearson and Lack (1992) divided north-eastern Africa (Sudan, Ethiopia and Somalia) into four sectors from west to east. They found that Palearctic species migrate in autumn or in spring on a broad or narrow (more eastern or western) fronts. Moreover, a number of species perform loop movements, crossing the Arabian Peninsula further east in spring than in autumn. The species, such as the Whitethroat and particularly the Red-backed Shrike and Lesser Grey Shrike, are more abundant during spring migration at the most eastern part of north-eastern Africa than in autumn, crossing in spring the Red Sea at its most southern coasts and even the Aden Bay. The loop migration of the Red-Backed Shrike is confirmed by the results of spring catching in Egypt – during nine spring catching seasons (2001-2008), at five stations there was caught only one individual, whereas, during autumn seasons, there were caught above 300 individuals in total (Ibrahim 2011). The Red-backed Shrike in spring is almost absent in Egypt, but quite numerous in nearby Israel (Shirihai 1996). As was reported by Goodmann and Meininger (1989), some birds fly around much of Egypt along the Sinai Peninsula and then migrate towards the Arava Valley. The headings on the NE-SW axis in Azraq could be thus shown by birds crossing the most northern part of the Red Sea and then reaching Jordan, but distinct NW-SE headings – by a larger group of birds showing loop migration along the Arabian Peninsula.

Some species (*e.g*. Sedge Warbler, Reed Warbler, Great Reed Warbler, Blackcap and Garden Warbler) are absent in Somalia and east Tanzania in autumn, but present in spring (Pearson and Lack 1992). Another species, such as the Barn Swallow, Yellow Wagtail and Blue-cheeked Bee-eater, migrate in spring through north-eastern Africa on the same broad front as in autumn. All this supports our findings that birds exhibiting NW direction could migrate from Africa by crossing the Red Sea somewhere at its more southern part and then flying along the Arabian Peninsula towards Europe. Orientation results from Egypt given by Ibrahim (2011) support crossing the Red Sea by migrants – there was a considerable share of NE headings among birds tested in spring at all Egyptian stations, inland and coastal at the Red Sea. Moreover, there exists also a distinct route along the coast of the Red Sea in Hurghada and Wadi Gemal. As was suggested by Shirihai (1996), some birds following the leading line of the Red Sea turn by the Sinai Peninsula and then migrate towards the Arava Valley in order to go round the Mediterranean Sea, reaching Israel and Jordan.

Another interesting thing is why the proportions of northern and southern headings on the NW-SE and NE-SW axes are so different. As was mentioned above, in Azraq there is a very low share of the reversed directions, especially SE. The nature of reversed migration is still not well recognized – it is supposed that it could be caused by weather conditions, age, fatness, endogenous factors or geographical barriers (*e.g.* Åkesson *et al.* 1995, Komenda-Zehnder *et al.* 2002, Zehtindjiev *et al.* 2003). In our paper we focused on the last reason.

Towards SE from Azraq there are large sandy deserts of the Arabian Peninsula – contrary to SW directions, where there is close to the many types of vegetation in the Arava Valley. This could explain why there is a much lower share of SE headings than that of SW direction. Bruderer (1994) claims that reverse migration in southern Israel is even more pronounced in autumn than in spring, suggesting that birds in autumn are prone to return to (previously experienced) better habitats, while in spring most of them have experienced the desert before. If so, the birds that migrate in Azraq towards Europe through the Arabian Peninsula (along the SE-NW axis) are determined to fly exactly in the right direction – moving backward to the large geographical barrier of the Arabian Desert would be very dangerous for them. Birds migrating from the Arava Valley (along the SW-NE axis), on the other hand, had crossed the Sahara Desert earlier and did not have such unfriendly habitat immediately behind them like the birds coming from the Arabian Peninsula. This could also explain why the proportions of NE and opposite SW headings are quite alike.

The directional preferences of birds in Azraq are similar to a general radar graph from Eilat (Ibrahim 2011). There was also a very low proportion of southern directions there. The only difference was the predominance of NE headings in Eilat, but the difference between NE and NW was much smaller than in Azraq there. Similar pictures from spring migration in Eilat are reported also by Ożarowska *et al.* (2004). They revealed a very small share of southern headings for the Lesser Whitethroat, Blackcap and Chiffchaff. In Egypt, however, it was otherwise. The general radar graphs of raw data at Egyptian spring stations were characterized by considerable shares of southern headings (Ibrahim 2011).

It is clearly visible that migrants in Azraq fly mostly towards European breeding grounds. The breeding areas of the majority of species presented here spread also in Asia, but it is possible that the most eastern Asiatic populations migrate there by even more eastern flyways (Cepák *et al.* 2008, Fransson and Hall-Karlsson 2008), maybe even along the eastern coast of the Arabian Peninsula and then the Persian Gulf.

The recoveries of birds ringed in Azraq or reported here with foreign rings are scarce, but they confirm the passage of birds from wide breeding areas through this region (Al-Omari *et al.* 2005, Al-Omari *et al.* 2007). According to these authors, up to now in Azraq there have been reported birds from: Denmark (one Lesser Whitethroat), Slovakia (one Chiffchaff), Romania (one Reed Warbler) and Israel (three Reed Warblers, one of them on 30 March 2008). There were also recoveries of birds ringed in Azraq and then caught in: Israel (one Chiffchaff), Bulgaria (one Reed Warbler) and even Great Britain (one Lesser Whitethroat). As was emphasized by Formella and Busse (2002) and Ożarowska *et al.* (2004), the ringing recoveries from eastern areas, which could better confirm the existing of eastern routes towards Asia, are still lack-

ing due to very low, if any, ringing activity there – contrary to Europe. Nevertheless, a distinct share of NE headings at many SEEN stations located within a huge area of north-eastern Africa and Middle East demonstrated that the passage towards east-European and Asian breeding grounds really exist.

CONCLUSIONS

Seasonal dynamics and directional preferences of the most numerous species in Azraq give an interesting picture of passerine migration through this area. Timing of migration, shape of seasonal dynamics and directional preferences of many species presented here are often quite similar to results from nearby Israel or Egypt, from which a part of migrants could pass Jordan. Birds belonging to more northern or more southern Palearctic species, different subspecies, which occurred in Azraq, as well as the variation of preferred directions are an evidence that the migration routes of European and Asiatic populations cross each other in the Middle East. Our study provides information about the migration of small birds through this still poorly investigated area and indicates a necessity of more detailed studies. The richness of over 120 bird species ringed and observed in Azraq supports the strong need for the permanent protection of such places in the desert areas of the Middle East as important habitats for Palearctic migrants. The mosaic of wet and drier habitats, surrounded by a large desert, make the Azraq Wetland Reserve attractive for many species, including numerous habitat-specialists like *Acrocephalus* warblers. Those studies would give us an opportunity to extend our knowledge about bird migration system and migratory strategies of species on the still poorly known south-eastern flyway.

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