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Migration and staging patterns of the Red-throated (*Anthus cervinus*) and Tree Pipits (*Anthus trivialis*) at the migratory bottleneck of Eilat, Israel

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We studied the migration patterns of Red-throated (*Anthus cervinus*) and Tree Pipits (*A. trivialis*) ringed during 25 years at Eilat, Israel. The number of migrants was four times greater in spring than in autumn for the Tree Pipit but was similar for the Red-throated Pipit. Stop-over during the migration seasons was also different. Both young and old Red-throated Pipits used Eilat as a stop-over site at similar intensity during both seasons. However, most of the Tree Pipits in autumn were juveniles, but young and old individuals were almost equally abundant in spring. In both species, body-condition index was higher in autumn than in spring and was not related to the age of the birds. This finding illustrates differences in body condition before and after the crossing of the Saharo-Arabian desert belt.

1. Introduction

Bird migration is a period of exceptional energy demand, and most of the energy is derived from muscle and fat reserves accumulated before migration flight (Moore & Kerlinger 1987). The energetic demand is particularly acute for long-distance migrants that must often cross ecological barriers such as high mountains or extensive areas of water or desert. Therefore, migration is often characterized by alternating periods of flight and stopover, and the habitats bordering ecological barriers are crucial to migrants because they provide resources to build up energy reserves for a non-stop flight or to replenish energy reserves following a long flight (Moore & Kerlinger 1987). Birds that breed in Europe and winter in central or southern Africa must cross a great ecological and geographical barrier, the huge Saharan desert belt, twice a year.

Most studies on long-distance migrants that breed in Europe have been carried out near breeding areas or on wintering grounds in sub-Saharan Africa (e.g., Schaub & Jenni 2001). However, little attention has been paid to critically located staging areas at the edge of the combined barrier of the Sinai, Sahara and Sahel deserts. Furthermore, much more is known about bird populations crossing west and central Europe than about those that use the eastern Palaearctic flyway and nest in eastern Europe and Asia (Jonzen *et al.* 2006, Chernetsov *et al.* 2007). Such populations can be different in some respects, such as age ratio and sex-related biometric characteristics (Zduniak & Yosef 2008), and stop-over strategy and migration phenology (Tøttrup *et al.* 2008). This aspect is inadequately understood for species in which migration has not been studied for the species' entire geographic distribution.

To fulfill this knowledge gap, we analyzed the migration patterns of Red-throated (*Anthus cervinus*) and Tree Pipits (*A. trivialis*) caught and ringed during 25 years at the migratory bottleneck of Eilat, Israel, which lies on the relatively little-studied eastern circum-Mediterranean flyway. These two pipit species are small passerine migrants that breed in northern Europe and Asia and winter in sub-Saharan Africa and the Indian subcontinent and Southeast Asia (Alström & Mild 2003). The populations must therefore cross the Saharo-Arabian desert belt twice a year. These species differ in their breeding and partly in wintering ranges, and are geographically separated in their breeding grounds, but are similar in appearance and behavior. The Tree Pipit has a relatively large breeding range while that of the Red-throated Pipit is more restricted. Of interest is the fact that Eilat is one of the few places where both species can be studied simultaneously. Moreover, the migration of the Red-throated Pipit is poorly understood (Alström & Mild 2003).

The aim of this paper was to examine and compare the patterns of migration of the two pipit species in relation to passage season in the Eilat region, an important stopover site for many bird species due to its location near the northeastern edge of the Sahara-Sahel desert. We focused on the numbers, age ratio and body condition of the two species, and on the basic parameters of their staging ecology at Eilat.

2. Material and methods

2.1. Study site

The data were collected at the bird ringing station of the International Birding and Research Center in Eilat (IBRCE) located in Eilat (29°33'N, 34°57'E), at the southernmost tip of Israel and at the northern tip of the Gulf of Aqaba. In Eilat, mean annual rainfall is 25 mm, and the maximum temperature in the summer reaches +47°C. Across a narrow strip in Eilat there are open-water reservoirs, agricultural fields, cultivated gardens, and a salt marsh: an oasis squeezed between extensive areas of desert (Tryjanowski & Yosef 2002, Yosef *et al.* 2002a, b). Indeed, to the south there is approx. 2,000 km of desert, to the northeast there is 650 km of the Syrian Desert, to the east there is the Arabian Desert, and directly to the north there is 150 km of the Negev Desert before the more fertile lands of northern Israel (Safriel 1968).

For migrating birds, Eilat appears in front of (autumn) or behind (spring) the Sahel, Sahara, and Sinai deserts (Yosef & Tryjanowski 2002a, 2002b, 2002c, Yosef & Chernetsov 2004, 2005, Zduniak & Yosef 2008). Therefore, pipits caught in spring have just almost completed their desert crossing, while those caught in autumn are about to begin this demanding flight. Eilat is used for stopovers by over 280 avian species in spring and autumn seasons (Shirihai 1996, Yosef 1997, Yosef *et al.* 2002a, 2002b, Yosef & Tryjanowski 2002a, 2002b, 2002c, Yosef & Chernetsov 2004, 2005, Zduniak & Yosef 2008).

IBRCE is the only long-term ringing station in the Middle East (Yosef & Tryjanowski 2002a) and has conducted regular ringing since 1984. This has resulted in a dataset containing information on more than 180,000 individual birds from 272 species. In the years 1984–1999, birds were trapped using mist nets for ca. six hours per day, and since 2000, birds were trapped using eight Helgoland/Rybachy traps located in the boundaries of the Eilat Bird Sanctuary and were operating, on average, for six hours per day during the migration seasons. The trapping effort did not differ between spring and autumn seasons in individual years and did not change throughout each season. Migratory and sedentary birds were caught and ringed during 25 spring (March–June) and 24 autumn (September–November) seasons during the years 1984–2008. To date, a total of 2,315 Red-throated Pipit and 2,327 Tree Pipit have been ringed in Eilat. Regrettably, there are no ring-recovery data from other sites or regions for Red-throated and Tree Pipits ringed in Eilat. Hence, birds caught in Eilat may originate from the eastern range of their distribution: this area is characterized by very few ringing stations and low public awareness of bird populations and their migration (e.g., Yosef & Wineman 2010).

All birds trapped were ringed using standard aluminum rings along with standard measurements of biometric parameters. The birds were classified into juveniles on their first migration (EURING code 3) and adults (4) in the autumn, and second-year birds (5) or adults (6) in the spring (Alström & Mild 2003). Flattened maximum wing chord was measured to the nearest millimeter, and body mass was determined using Pesola or digital scales to the nearest 0.1 g. The relative body condition of the birds was compared using a body condition index (body mass divided by wing length; Safriel & Lavee 1988, Gorney *et al.* 1999, Walton & Walton 1999, Yosef *et al.* 2003, Markovets *et al.* 2008, Zduniak & Yosef 2008).

2.2. Study species

The Red-throated Pipit breeds in a narrow belt from the Arctic Fennoscandia across northern Siberia to the Bering Sea and south to Kamchatka and, in western Alaska (Alström & Mild 2003). Most of the breeding range is north of the Arctic Circle. The western populations overwinter mainly in Africa south of the Sahara, but also on the southern and eastern coasts of the Mediterranean region, in the Nile Valley, and along the Red Sea. Birds from the eastern parts of the breeding range winter mainly in southern China, Taiwan and south-eastern Asia. In Israel, the Red-throated Pipit is considered a common to abundant passage migrant and a fairly common winter visitor over most parts of the country (Shirihai 1996). In Eilat most of the migrating population is transient and very few over-winter in the region (Morgan & Shirihai 1997).

Tree Pipit breeds over most of Europe and eastwards in the Taiga belt of Russia and north-western Mongolia, and south to the Pamir and Himalayan mountain ranges. It also breeds in northern Turkey, Caucasia and northern Iran (Alström & Mild 2003). It is a long-distance migrant, wintering in the Afro-tropics and the Indian subcontinent. In Israel, it is a common to abundant passage migrant, and a rare winter visitor in central and southern parts of Israel (Shirihai 1996).

2.3. Data processing and analysis

Data from first captures were used to examine the similarity in numbers between spring and autumn seasons in individual years, and these similarity values were treated as "matched pairs". Furthermore, seasonal means calculated separately for each age class were used as dependent variables. Mean values for each age class in individual seasons were treated as "matched pairs". Only seasonal means from seasons with a minimum of ten ringed individuals were used, resulting in different sample sizes between the evaluated parameters. Because of these data limitations, a relatively small number of seasons were represented for both species. For Tree Pipit ten spring and seven autumn seasons were used, and for Red-throated Pipit 21 spring and five autumn seasons were used. Consequently, direct comparisons between the two species could not be done. The data were thus analyzed separately for each species, and comparisons were indirect.

Using seasonal means from seasons with a minimum of 10 individuals ringed, the similarity in age ratio of ringed birds between migration seasons was evaluated. Moreover, the influence of age on capture time in both migration seasons was examined using mean migration times of juvenile and adult birds in the same season with a minimum 10 individuals recorded. Here, samples were treated as "matched pairs" in paired-samples *t* tests. Furthermore, the possible combined effect of age and season on body condition of the ringed birds was tested. Here, indices of juvenile and adult birds in the same season were treated as "matched pairs" and analyzed using repeated-measures ANOVA.

Three additional aspects were studied: the portion of recaptures for each season in relation to the total number of birds caught, time difference between ringing and controlling to obtain a minimum estimate of stay (i.e., the time lapsed from the first to the last catch of each retrapped bird in particular season), and changes in body condition of recaptured birds (based on the index described above; first and last capture considered) for both passage seasons. The relative capture time for each individual for each season was obtained by subtracting the seasonal median capture date from each capture date. Standard statistical methods

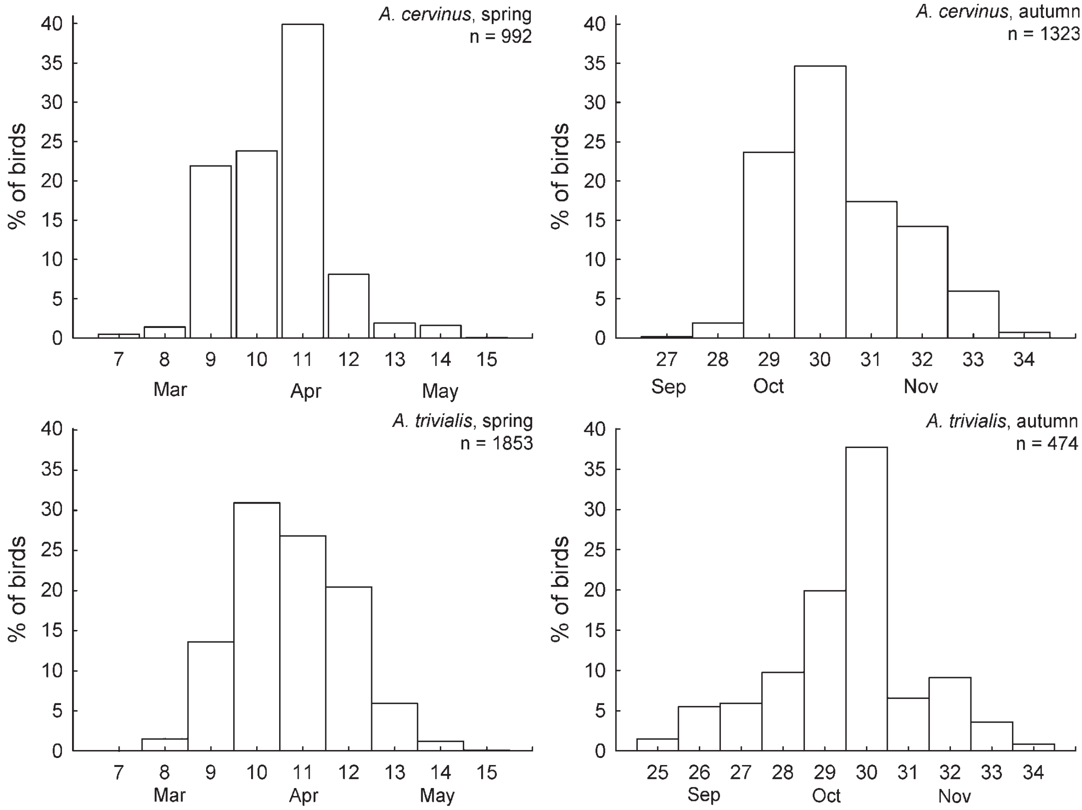

Fig. 1. Spring and autumn migration phenology of Red-throated and Tree Pipits at Eilat, 1984–2008. Data are presented in 10-day periods.

were used to describe and analyze the data (Sokal & Rohlf 1995). Throughout the text, mean values are presented with standard error. All calculations were performed using STATISTICA for Windows (StatSoft Inc. 2007).

3. Results

3.1. Number of birds caught in relation to season

A total of 2,315 Red-throated Pipits were ringed at Eilat. Of these, 992 were caught in spring ($\bar{x}$= 39.7 ± 17.2, range 0–359) and 1323 ($\bar{x}$= 55.1 ± 28.9, 0–664) in autumn (Fig. 1). The number of birds caught in spring and in autumn were similar (Wilcoxon matched-pairs test, $Z = 0.36$, $n = 24$, $P = 0.721$). However, Tree Pipit was more abundantly caught in spring than in autumn (Wilcoxon matched-pairs test, $Z = 3.92$, $n = 24$, $P < 0.001$). From a total of 2,327 Tree Pipits recorded during the study period, 1853 were caught in spring ($\bar{x}$=74.1 ± 21.37, 0–483) and 474 ($\bar{x}$=19.7 ± 9.63, 0–222) in autumn. The numbers of Red-throated and Tree Pipits recorded in spring and in autumn were significantly correlated ($r_s = 0.66$, $n = 25$, $P < 0.001$ and $r_s = 0.48$, $n = 24$, $P = 0.016$, respectively).

3.2. Age ratio in relation to season

Of the 2,315 ringed Red-throated Pipits, 1,327 (57.3%) were adults, 890 (38.4%) were juveniles, and 98 (4.2%) were of undetermined age. Similarly, of the 2,327 Tree Pipits, 1,013 (43.5%) were adults, 1254 (53.9%) were juveniles and 60 (2.6%) were not aged. In seasons with at least 10 ringed birds, the age ratio of the Red-throated Pipit was similar between spring and autumn (Mann-Whitney U test, $n = 1.95$, $P = 0.051$). In spring, adults comprised on average 67.0 ± 7.8% (n = 10) of all birds, and in autumn on average 40.7 ± 7.6% (n = 7) of all birds. However, for the Tree Pipit, adults made up a significantly higher share in spring than in autumn, respective numbers being 54.6 ± 5.9% (n = 21) and 20.0 ± 12.6% (n = 5) of all migrants (Mann-Whitney U test; Z = –2.50, P = 0.012).

3.3. Phenology of migration

Spring migrants from both species were trapped mainly between the second decade of March and the second decade of May (Fig. 1). In autumn, Tree Pipits were recorded from the first and Red-throated Pipits from the third decade of September. Both species were ringed until the end of November (Fig. 1). Ringing dates between adults and juveniles of the Red-throated Pipit were similar in spring (paired-samples t test; t = 0.11, df = 9, P = 0.911). However, in autumn adults were ringed on average 5.5 days earlier than juveniles (standardized time; adults $\bar{x}$= –1.88 ± 1.06, n = 10, juveniles $\bar{x}$= 3.81 ± 2.33, n = 7; t = 3.35, df = 6, P = 0.015). The migration time between adults and juveniles of the Tree Pipit were similar in spring (t = 0.48, df = 19, P = 0.639) and in autumn (t = 0.24, df = 4, P = 0.820).

3.4. Body-condition index in relation to age and season

For both species, the body-condition index was higher in autumn than in spring (repeated-measures ANOVA; Red-throated Pipit $F_{1.14}$ = 5.87, P = 0.029; Tree Pipit $F_{1.23}$ = 21.96, P < 0.001; Fig. 2). In this respect there were no significant differences between juveniles and adults (Red-throated Pipit $F_{1.14}$ = 2.34, P > 0.148; Tree Pipit $F_{1.23}$ = 0.53, P = 0.472; Fig. 2).

3.5. Retraps

Twenty-seven previously ringed Red-throated Pipits were caught in spring (2.7% of all caught birds) and 148 (11.1%) in autumn. Respective numbers for Tree Pipits were 124 (6.7%) and 43 (9.1%). Analysis for seasons with more than 10 ringed individuals did not show significant differences in the proportion of recaptures to the total number of birds recorded between seasons (Red-throated Pipit, spring: 5.8 ± 1.6%, 0–15.4, n = 10; autumn: 10.9 ± 4.2%, 0–34.2, n = 8; Z = –0.58, P = 0.563; Tree Pipit, spring: 6.1 ± 1.4%, 0–20.0, n = 21; autumn: 10.2 ± 1.3%, 7.7–13.6, n = 4; Z = –1.59, P = 0.111).

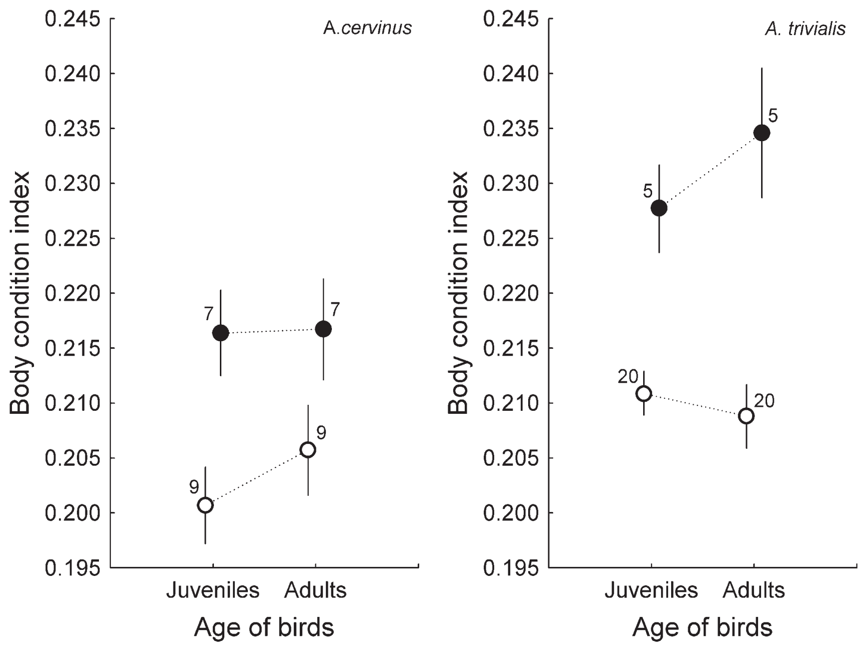

Fig. 2. Mean ± SE of body-condition index of juvenile and adult Red-throated and Tree Pipits ringed during spring (open symbols) and autumn (solid symbols) at Eilat, Israel. Numbers represent sample sizes.

Red-throated Pipits stopped over for shorter periods of time during spring than in autumn (Z = –2.68, P = 0.007). The minimum stopover duration lasted on average 3.7 ± 0.61 days (range 1–10, n = 27) in spring and 6.4 ± 0.47 days (1–27, n = 148) in autumn. There was no significant difference between seasons in the Tree Pipit (Z = –1.13, P = 0.250). The minimum stopover period lasted on average 4.2 ± 0.3 days (1–18, n = 124) in spring and 4.8 ± 0.6 days (1–17, n = 43) in autumn. In spring, recaptured Red-throated Pipits were in better body condition than birds at first capture (paired-samples t test; t = –2.54, df = 24, P = 0.018, first capture: $\bar{x}$ = 0.191 ± 0.004, recapture: $\bar{x}$ = 0.200 ± 0.004). In autumn, there were no significant differences in the body condition of Red-throated Pipits between the first capture and recapture (t = 0.11, df = 138, P = 0.908). Similarly, Tree Pipits recaptured in spring were in significantly better condition than birds at first capture (t = –6.24, df = 111, P < 0.001; first capture $\bar{x}$ = 0.208 ± 0.002; recapture $\bar{x}$ = 0.220 ± 0.002) and a similar pattern was observed in autumn (t = –2.80, df = 38, P = 0.008; first capture $\bar{x}$ = 0.227 ± 0.005, recapture $\bar{x}$ = 0.237 ± 0.004).

4. Discussion

The number of migrants was four times greater in spring than in autumn for the Tree Pipit, which is typical of many passerine migrants in Eilat (Markovets & Yosef 2005, Yosef & Chernetsov 2004, 2005, Yosef & Tryjanowski 2002a, b). Furthermore, most of the Tree Pipits that had a stop-over in Eilat during autumn were juveniles, whereas no significant difference was found in the age ratio for spring passage. We suggest that this disparity can be explained by the majority of the Tree Pipits migrating on a very broad front on their way south to Africa, especially the experienced adults, or that they perform a loop migration by flying straight across the Mediterranean Sea and then returning north to the breeding grounds by taking the more easterly route through Eilat and its adjacent areas (cf. Markovets & Yosef 2005, Pilastro *et al.* 2008). It is also possible that there is an age-related difference in the migration pattern, wherein adults in the spring migrate using a different route (across Eilat) than in the autumn (across Mediterranean Sea), which is reflected in the difference in trapping success between seasons and differences in age ratio between seasons.

The numbers of Red-throated Pipits were similar between autumn and spring. Moreover, both age classes of this species seemed to utilize Eilat as a stopover site in similar intensity, which was unexpected as in autumn juveniles could be assumed to outnumber adults for such short-lived species. We suggest that Eilat is known by adults as a staging site, while the inexperienced juveniles are more spread out. The different migration strategies of the focal species, described above, can result from the distance-to-be-covered between wintering and breeding grounds. Thus, Red-throated Pipits should be able to migrate from south of the Sahara to the arctic region, whereas Tree Pipits only have to migrate to central Eurasia. The longer migration distance covered by the Red-throated Pipit could result in similar stop-over at Eilat in both spring and autumn, whereas this pattern appears different for the Tree Pipit that has to rely on the Eilat site only after crossing the desert, i.e., in the spring. In addition, in spring Red-throated Pipits have a shorter breeding season in the arctic than the Tree Pipit (Alström & Mild 2003). This may be reflected in their relatively shorter period of stop-over during spring than during autumn, which was not noted for the Tree Pipit. However, the importance of Eilat for both species, especially in spring, is underlined by the fact that the recaptured individuals were in better condition than at the first capture.

In contrast to the above, Chernetsov *et al.* (2007) found that the energy strategy of migration was similar between adults and first-year birds. However, they did find that at migratory stopovers in Central Asia, mist-netted Spotted Flycatchers (*Ficedula parva*) were lighter than those shot by sporting guns, i.e., birds carrying large fuel loads were under-represented in the mist-netting sample. This difference suggests that birds with appropriate energetic loads overfly staging areas and only those requiring refueling have to stopover. Hence, the body condition of these individuals is improved as documented in the present study. Furthermore, Jenni-Eiermann *et al.* (2010) investigated which species or individuals use oases in the western Sahara during spring migration and how they use them, and demonstrated that a minority of species adapted to dry vegetation cross the Sahara with low energy stores and intermittent refuelling in vegetation patches. These birds avoid the costs of transporting large energy stores, in contrast to most other passerine migrants which fuel up before crossing the Sahara and adopt an intermittent strategy without refuelling. The birds which rely on refuelling at oases (e.g., Biebach *et al.* 1986) probably often have a slow refueling rate and may even run the risk of not finding appropriate patches of foraging habitat. Birds apparently use a wide variety of strategies to cross the Sahara. The particular strategy adopted depends on the species, and is modulated according to weather conditions aloft at the time, existing energy stores, the availability of stopover sites, and the suitability (food availability, competitors) of stopover sites.

The phenology and dynamics of migration of the focal species were similar in spring, but the first Tree Pipits were recorded ca. 20 days earlier than the first Red-throated Pipits in autumn. This appears to be a clear case of proximity to Eilat influencing migration phenology wherein the species from central Europe arrive before the more northern species. Furthermore, in autumn adult Red-throated Pipits were ringed on average 5.5 days earlier than juvenile birds, but no such difference was found for the Tree Pipit. This suggests that adults leave the breeding grounds earlier than juveniles, and wherein different individuals may follow different decision rules (Bowlin *et al.* 2005).

The progress in the autumn migration phenology is now well documented for the Red-throated Pipit. Individuals of this species leave their breeding grounds in mid-August to early September (Dementev & Gladkov 1954), pass southern Sweden between late August and early October (Karlsson 1992), migrate through central Europe mainly in September and October (Dierschke & Dierschke 1991), and reach the Sudan coast in Africa in mid-September and Kenya between late October and November (Keith *et al.* 1992). Red-throated Pipits pass through Israel in October and November (Shirihai 1996, present study), suggesting that this is a separate population, possibly from Eurasia. In spring, the species leaves Kenya during March–April (Fry *et al.* 1974), migrates through Israel in March–April (Shirihai 1996, present study), moves through central Europe in the first half of May (Dierschke & Dierschke 1991), and arrives to the breeding grounds in Siberia in late May to early June (Dementev & Gladkov 1954). Similarly, Tree Pipits start their autumn migration from Eurasia in August and September (Dementev & Gladkov 1954, Karlsson 1992), migrate through Israel mainly between mid-September and late October (Shirihai 1996, present study), and reach wintering grounds in Africa in late October (Keith *et al.* 1992). In spring, the species migrates north from Africa in March and April (Cramp 1988), passes through Israel between mid-March and mid-May (Shirihai 1996, present study), and arrives to the breeding grounds across Eurasia from early April onwards (Dementev & Gladkov 1954, Alstrom & Mild 2003).

Our results indicate that the body condition of both species was higher during autumn than in spring and was not related to the age of the birds. This illustrates differences in the condition before and after crossing the geographical barrier of the Saharo-Arabian desert belt. Before the crossing individuals are in good condition, requiring only a minimum stop-over at Eilat. However, upon their return from wintering grounds they are in poorer condition after the desert crossing, which requires them to stop over and refuel prior to continuing their migration north (Wojciechowski *et al.* 2005). Perhaps individuals also acquire reserves to facilitate the move to the next refuelling site on their way to the breeding grounds.

Our results also indicate that both species considerably increase body condition during stopover at Eilat in spring, after having just crossed the Sahel, Sahara and Sinai deserts. Data presented here also show that migrants gain significantly more mass during stop-overs at Eilat in spring than in autumn (e.g., Yosef & Chernetsov 2004, 2005, Markovets *et al.* 2008). Significant increases in mass by migrants reflect the suitability of a stopover site (Bibby & Green 1983, Moore & Kerlinger 1987). Additionally, habitat use by migrants during stopovers differs seasonally (Winker *et al.* 1992a, b, Weisbrod *et al.* 1993, Morris *et al.* 1994). Therefore, differences in body condition between seasons may indicate that the different habitats of the Eilat Bird Sanctuary provide a suitable stopover site for both species in spring, but in the autumn food scarcity and competition may increase.

Alternatively, this stop-over site is simply not required by the species because they either over-fly the region or undertake a loop-migration strategy.

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Lapin- ja metsäkirvisen muutto ja lepäily muuttolintujen pullonkaulassa, Israelin Eilatissa

Tutkimme lapin- (*Anthus cervinus*) ja metsäkirvisen (*Anthus trivialis*) muuttoa 25 vuoden rengastusaineistolla Eilatissa, Israelissa. Metsäkirvisen muuttajamäärät olivat keväällä neljä kertaa syksyjä korkeampia, mutta lapinkirvisellä kevät ja syksy olivat tässä mielessä samanlaisia. Myös muutonaikainen lepäily oli erilaista. Nuoret ja vanhat lapinkirviset käyttivät Eilatia levähdysalueena samalla tavoin keväisin ja syksyisin. Metsäkirvisten pääjoukko taas oli syksyisin pääosin nuoria, mutta keväisin nuoria ja vanhoja oli suunnilleen yhtä paljon. Molemmilla lajeilla ruumiinkuntoa kuvaava indeksi oli korkeampi syksyllä kuin keväällä, eikä ollut yhteydessä yksilöiden ikään. Tulokset heijastavat ruumiinkunnon eroja ennen ja jälkeen Saharo-Arabian aavikkovyöhykkeen ylittämistä.

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