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Body weights and fat deposition of Palaearctic passerine migrants in the central Sahara

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Summary. 1. Data on body weight, fat score and length of stopover of Palaearctic passerine migrants trapped at two sites in the central Algerian Sahara in autumn 1983 are presented.
2. Birds found grounded in oases were in good condition. They were not critically short of fat reserves.
3. Some of the migrant species found there have probably terminated their migration whereas other species do only stopover for fattening and do in fact continue their migration if they have restored sufficient fat for a further flight.
4. The daily activity pattern of caged migrants depended on their fat reserves.
5. The available food supplies were high enough for fattening.

It is assumed that many migrant passerines increase their fat reserves during stopover periods at suitable sites in order to replenish energy reserves for further migration. Some studies deal with the amounts and rates of fat deposition in the temperate or mediterranean zones along the bird's migratory routes (Bibby and Green 1981, 1983, Cherry 1982, Finlayson 1981, Langslow 1976, Mueller and Berger 1966, Moreau and Dolp 1970, Rappole and Warner 1976). However, for migrants wintering south of the Sahara only little data is available on their body weights and fattening at stopover sites while crossing the Sahara, particularly during autumn migration (Bairlein et al. 1983). Furthermore there are the questions of whether palaearctic passerine migrants cross the Sahara by long nonstop-flights or whether they migrate more progressively with stopover periods at suitable sites for replenishing energy reserves, and whether birds found grounded at oases have terminated their migration too early or whether they do in fact continue their migration.

More information on the body weights, the amounts and rates of fat deposition, the length of stopover time, and the availability of food will be needed before answering the above questions. Therefore I will present field measurements of fat deposition of migrant passerines caught during a study of palaearctic bird migration in the central Algerian Sahara in autumn 1983.

Methods

The study was done at two sites in the central Algerian Sahara, at Hassi Marroket and at Arak (Fig. 1).

Hassi Marroket (30.2°N 2.8°E): a small vegetation "island" of about 17 ha (42 acres) at an artesian spring, 40 km south of El Golea, with a dense marsh and tamarisk vegetation and some small and shallow water pools. Here we trapped and recorded palaearctic migrants from August 27 – September 22, September 27–28 and October 2–16, 1983.

Arak (25.3°N 3.7°E): a vegetation strip along a temporary flooded river bed on the northwesterly border of the Ahaggar mountains consisting mainly of acacia trees and with some open water pools used as cattle watering sites. At Arak we trapped and recorded birds from September 10–29, 1983.

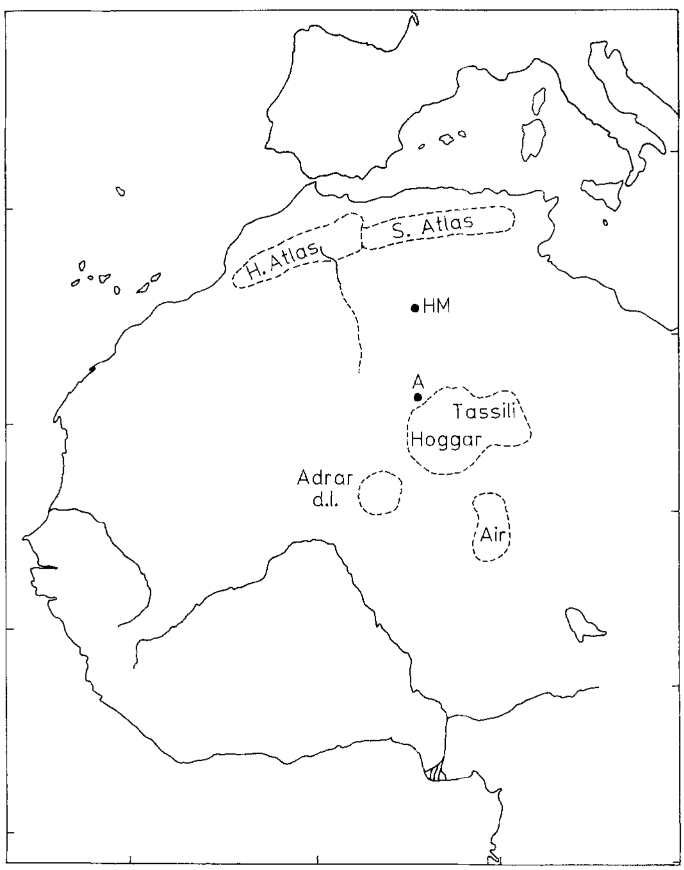

Fig. 1. The two stopover sites at which passerine migrants were trapped in autumn 1983. *HM* = Hassi Marroket, *A* = Arak

Birds were trapped with mist-nets which were checked at least once an hour. They were transported to our camp where species, age, sex, moult stage, wing length and weight (nearest 0.1 g) were determined. The amounts of visible fat were scored according to Fry et al. (1970) from 0 = no visible fat to 3 = a lot of visible fat. Usually the ringed birds were released within 30 minutes.

To compare migrant bird weights one must take into consideration that they vary throughout the day usually with a minimum value at early morning and a maximum value late in the afternoon (e.g. Baldwin and Kendeigh 1938).

Due to the fact that most of birds were trapped between 6.00 and 10.00, and due to the irregularities of individual weight changes found in birds retrapped the same day (Cherry 1982, Langslow 1976) I renounced such a correction. The analysis of fat deposition is based on values from retrapped individuals during our study period excluding those recaptured on the same day. The minimum stopover time is calculated by subtracting the date of the first capture from the date of the last recapture.

If not otherwise noted all data on weight gain reported here are from Hassi Marroket since the trapping period was long enough for such analyses.

Results

For species with a sufficient number of trapped birds the body weights at the two sites are given in Table 1. Furthermore, the question arose if there was a seasonal trend in body weights. Since there were also close correlations between body weight, wing length and season, partial correlation coefficients between body weight and date of trapping controlled by wing length were computed and summarized in Table 2. For example, the seasonal trends in body weight of two species are shown in Fig. 2.

As mentioned above repeated trappings of individuals are needed for the study of fat deposition. However the number of retraps other than on the day of ringing were to low for an analysis of fat deposition of a single species. Therefore, I analysed the entire pool of all migrant passerines trapped and retrapped at Hassi Marroket.

The frequency distribution of fat classes for all birds is shown in Fig. 3. Since there was the question of whether the pattern of fat class distribution of birds which were later retrapped differed from that of all trapped birds, the frequency distribution of fat classes of these two subsamples are shown separately. For the entire sample the two subsamples differ significantly (χ^2-test; $P < 0.0001$).

However, these entire samples involving all migrant passerine species trapped at Hassi Marroket could be divided into two different groups of species (Fig. 3, I and II). First, a group of species in which the frequency distribution of fat class of recaptured birds did not significantly differ from that of all first captures of these species. Second, a group of species in which the frequency distribution of fat class of retrapped birds differed significantly from that of all first captures with a high predominance of fat class 0 (χ^2-test; $P < 0.0001$).

From the species with a sufficient number of caught birds, the Yellow Wagtail (*Motacilla flava*), Olivaceous Warbler (*Hippolais pallida*), Sardinian Warbler (*Sylvia melanocephala*), Subalpine Warbler (*Sylvia conspicillata*), Chiffchaff (*Phylloscopus collybita*) and Spotted Flycatcher (*Muscicapa striata*) belong to group I, whereas the Swallow (*Hirundo rustica*), Reed Warbler (*Acrocephalus scirpaceus*), Garden Warbler (*Sylvia borin*), Willow Warbler (*Phylloscopus trochilus*), Pied Flycatcher (*Ficedula hypoleuca*) and Redstart (*Phoenicurus phoenicurus*) belong to group II.

Furthermore, these two groups differed also in their patterns of fat deposition. In group I the distribution of fat classes for first and last captures showed a slow decrease

Table 1. Body weights of Palaearctic passerine migrants trapped at Hassi Marroket or Arak in autumn 1983[a]

Species	Hassi Marroket	Arak
Swallow Hirundo rustica	17.2± 2.3(57) 12.1–23.1	15.0± 1.6(21) 12.0–17.6
Yellow Wagtail Motacilla flava	17.1± 2.7(56) 11.7–21.1	16.5± 1.9(42) 12.9–20.3
Woodchat Lanius senator	34.5± 5.1(4) 29.3–41.5	29.3± 3.8(10) 23.1–35.2
Reed Warbler Acrocephalus scirpaceus	11.6± 1.6(77) 7.4–15.9	
Olivaceous Warbler Hippolais pallida	11.8± 1.5(38) 8.2–15.3	11.0± 1.8(24) 8.3–14.7
Garden Warbler Sylvia borin	22.9± 3.8(49) 13.2–28.8	19.5± 1.5(13) 17.5–23.0
Sardinian Warbler Sylvia melanocephala	13.1± 1.0(16) 12.0–15.5	
Subalpine Warbler Sylvia cantillans	10.6± 1.5(13) 8.9±14.4	9.2± 1.0(52) 7.1–12.5
Chiffchaff Phylloscopus collybita	8.3± 1.0(20) 6.7–10.9	
Willow Warbler Phylloscopus trochilus	9.1± 1.3(67) 6.5–11.4	7.3± 1.3(13) 5.3–9.5
Spotted Flycatcher Muscicapa striata	16.0± 1.4(51) 11.8–18.3	
Pied Flycatcher Ficedula hypoleuca	11.2± 1.1(10) 9.7–13.2	
Redstart Phoenicurus phoenicurus	17.3± 3.3(28) 10.3–20.9	13.6± 3.2(6) 10.0–18.4

[a] Mean weights (g), standard deviation, number of birds (in parentheses) and range

Table 2. Seasonal trends in body weights of some migrants trapped at Hassi Marroket

Species	Sample size	Partial correlation coefficient	*P*
Swallow	57	0.076	0.290
Yellow Wagtail	56	0.110	0.213
Reed Warbler	77	0.080	0.247
Olivaceous Warbler	38	0.259	0.064
Garden Warbler	49	0.501	0.005[a]
Sardinian Warbler	16	0.342	0.116
Subalpine Warbler	13	0.405	0.108
Chiffchaff	20	−0.088	0.364
Willow Warbler	67	0.241	0.027[a]
Spotted Flycatcher	51	−0.005	0.485
Pied Flycatcher	10	0.902	0.001[a]
Redstart	28	0.501	0.005[a]

[a] Statistically significant seasonal correlations

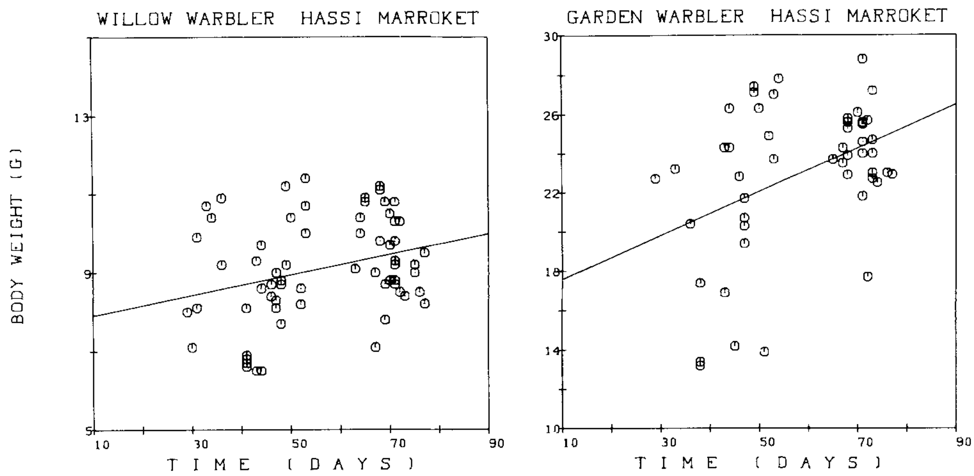

Fig. 2. Seasonal trends in body weight of Willow Warblers and Garden Warblers trapped at Hassi Marroket. The time-scale starts with the 10th of August

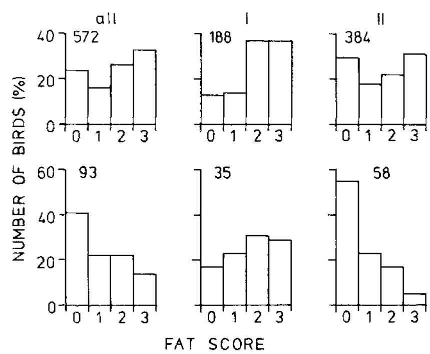

Fig. 3. Initial frequency distribution of fat classes of birds caught. Above: fat classes of birds trapped only once; below: fat classes of birds later retrapped. Left column: the entire pool of species; middle and right column: the two groups of species (for further explanation see text). Numbers of birds in each group are given

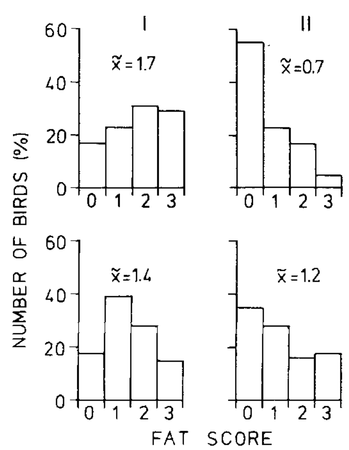

Fig. 4. Frequency distribution of fat classes at the first capture (above) and last capture (below) of birds trapped at least twice. Left: group I, right: group II. For further explanation see text and Fig. 3

to less fat at the last trapping (Fig. 4) although not significant (χ^2-test; $P>0.05$; $n=35$), whereas in group II the recaught birds increased their visible fat depots significantly (χ^2-test; $P<0.0001$; $n=58$). In group I the median value of the fat class decreased from initially 1.7 to 1.4 and in group II it increased from initially 0.7 to 1.2 respectively.

Table 3. Body weight changes of migrant passerines repeatedly trapped at Hassi Marroket. Since data from all recaught birds was used, changes in body weights are given as relative changes of the initial body weight per day

Weight change	Number of birds (%)	
	Group I ($n=35$)	Group II ($n=53$)
Weight loss ($>1\%\cdot d^{-1}$)	51.5	35.8
Near zero	37.1	26.4
Weight gain ($>1\%\cdot d^{-1}$)	11.4	37.8

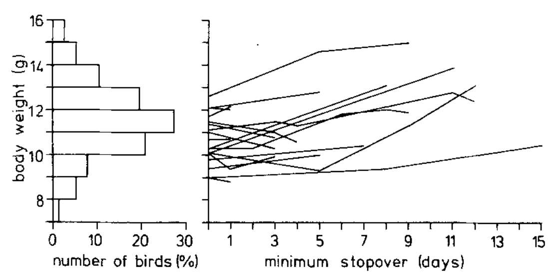

Fig. 5. Frequency distribution of the weights of Reed Warblers (left) and individual weight changes (right)

Since data of all species was pooled changes in body weights of recaptured birds were calculated as relative changes in per cent of the initial body weight per day (Table 3). The percentage of birds gaining weight was significantly higher in group II than in group I (χ^2-test; $P<0.001$).

On average, retrapped birds of group I decreased their body weight during stopover by a rate of -2.2% per day, birds of group II increased their body weight by 0.5% per day. Furthermore, there was a relationship between initial fat score and the percentage of birds that gained weight in group II. More birds with fat class 0 gained weight than individuals with higher fat reserves, although this was not significant (χ^2-test; $P>0.05$).

As an example of absolute individual weight variations the weight changes of individual recaught Reed Warblers are shown in Fig. 5.

Table 4. Percentage of retrapped birds, mean minimum length of stopover (days) and percentage of birds with weight gain for each of the initial fat classes

Initial fat score	Percentage retrapped	Mean minimum stopover (days)	Percentage of birds with weight gain
0	27.4(31)[a]	4.7	44.8
1	14.9(10)	3.1	27.3
2	11.9(9)	4.1	25.0
3	2.5(3)	[b]	[b]

[a] In parentheses number of individuals retrapped
[b] Due to the small sample size values not calculated

Table 5. Expected[a] and observed weight loss between Hassi Marroket and Arak

Species	Weight loss (g)	
	Expected	Observed
Swallow	1.3[b]	2.2
Yellow Wagtail	3.0	0.6
Olivaceous Warbler	2.3	0.8
Garden Warbler	3.6	3.4
Subalpine Warbler	2.2	1.4
Willow Warbler	2.0	1.8
Redstart	3.0	3.7

[a] Calculated according to the model of Robbins (1983) and an assumed speed of migration of 50 $km \cdot h^{-1}$
[b] Calculated according to Hails (1979)

The median minimum length of stopover time of individuals was 3.8 days in group I and 2.5 days in group II. But as seen in Table 4 the minimum length of stopover depended on the initial fat class. For group II, birds with an initial fat score 0 showed a longer minimum stopover than birds trapped for the first time with a higher amount of visible fat. Moreover, birds with no visible fat at first capture were recaught more than birds trapped with higher initial fat scores (χ^2-test; $P<0.001$). These correlations were not found in birds of group I. But in total, more birds were recaught in group I than in group II (19% and 15% respectively), although not significantly so (χ^2-test; $P>0.05$).

Discussion

Despite their variations and complexity of body weights of migrants the weights of birds trapped at the two oases in autumn 1983 presented in this study indicated that most birds found in oases were in good condition. The great majority of birds grounded at oases were not critically short of fat reserves. For species with sufficient number of trapped individuals at each stopover site the body weights at the two sites can be compared in order to get some information on the energetics of bird migration across the Sahara in autumn. But this should be done critically since variations between the two sites could be due to different origins of the specimens. Also nothing is known as to whether birds continuing their flights from Hassi Marroket migrate by a long hop of about 500 km to Arak or whether they stopover at intermediate points. In some species the differences in body weights agree with theoretical assumptions of weight loss for a flight of about 500 km, whereas in others the weight changes do not confirm the expected weight loss (Table 5).

From the seasonal increase in body weight in some species one may suggest that individuals which migrate later in the season have higher fat reserves, perhaps due to the fact that they must migrate faster than individuals migrating earlier. However, this variation may be caused also by differences between populations.

It is well known that birds regained fat reserves at stopover places in the temperate zone (e.g. Bibby and Green 1983, Cherry 1982, Langslow 1976). Although Moreau (1961, 1972) suggested that migrant birds grounded at oases in the Sahara would not be able to restore energy reserves, the data presented here shows that birds grounded at oases regained weight. According to Connell et al. (1960) these weight variations in migrant birds are almost entirely caused by changes in the amount of fat reserves. This is also shown in the present study since weight changes are always associated with changes in the amount of visible fat (fat score or fat class).

Furthermore, the variations between different groups of migrants indicate different strategies of migration and fattening up respectively. The first group with no increase in body weight and fat reserves of recaught birds could consist of species which have terminated their migration and perhaps winter at such localities. Therefore, the percentage of recaught birds and their minimum length of stopover were higher.

In addition, there were no significant difference in the initial fat class between birds which were trapped only once and those which were retrapped, and they decreased their fat reserves from first to last trapping. A seasonal increase in body weight was not found in this group. According to these results group I-species could be classified as medium-distance migrants (Berthold 1975). Birds of group II increased their weight and fat reserves during their stopover (Fig. 4), the percentage of retrapped birds was lower than in group I and depended on the initial fat class. Individuals arriving with no visible fat were more often recaptured and they stopped over longer than birds with higher amounts of fat. Furthermore, most of them did in fact regain weight. Therefore, it may be supposed that a bird will stopover longer if its fat depot is low.

Comparisons with published data on the fattening up of migrant passerines show that there could be a variation in the length of stopover and the fat deposition between different stopover sites (Cherry 1982), perhaps due to different local conditions. However, as shown by Caldwell et al. (1963) the amount of fat reserves could vary with the individual stage of migration too. Therefore, length of stopover and rates of fat deposition probably vary with the position of the stopover site relative to the length of expected further migration.

The results of this study can be summarized and evaluated as follows.

Birds grounded at Saharan oases or other possible stopover sites with high fat (energy) reserves are resting probably inactive in the shade during the daylight period and continue their migratory flight the following night. Due to their reduced activity such fat birds are trapped less and it is difficult to observe them.

Table 6. Activity of caged Garden Warblers at Hassi Marroket.

Body weight (g)	Active during	
	Daylight	Night
14.2	+	–
16.9	+	–
20.3	+	–
22.8	+	+
24.3	–	+
26.3	–	+

However, birds grounded with very low amounts of fat are active during the daylight hours catching food. Therefore, such birds were trapped and easily observed. If the amount of fat stored during the daylight period is sufficient for a further flight the bird will continue migration the following night. But if the bird has restored insufficient fat for further flight it stays at the stopover site until its fat reserves are high enough for a further flight (for such examples see Fig. 5). Moreover, it seems possible that fattening up at such localities occurs on a smaller scale than known from stopover sites in the northern part of the birds migration route in relationship to the closer expected end of migration. Also if migration across the Sahara is probably more progressive rather than in long hops only little weight gain is necessary at such stopover sites for shorter flights on successive nights.

Furthermore, new laboratory data on body weights of Garden Warblers (Bairlein, unpublished) suggest that body weights for existence and possible refeeding could be much lower than previously thought. Therefore, birds trapped at oases with very low body weights are not necessarily exhausted, dehydrated birds without any possibility of refeeding.

Although the presented results suggest that migrant passerines found at oases in autumn are able to continue their southward migration it is difficult to know whether they do in fact fly further. Therefore, we have already tested birds in Emlen-funnels (Emlen and Emlen 1966) in autumn 1981 and have shown that ten of 13 birds tested showed nocturnal restlessness (Bairlein et al. 1983). All these ten birds had a fat score of at least 1. In autumn 1983 I did additional experiments with caged Garden Warblers. The activities of the birds were recorded electromechanically in cages with two perches. The results from six birds tested are summarized in Table 6. Although the data are scanty they support well the above assumption that only birds with sufficient fat reserves show nocturnal restlessness, indicating migration, and that they are inactive during the daylight hours, whereas birds with no fat reserves on arrival are active only during the daylight feeding period.

All these data suggest that long-distance migrants found at oases do in fact continue their southward migration if at least a minimum amount of fat is available.

Besides these physiological considerations of the interpretation of bird weights from Saharan oases "selection of a time and place for fattening depends on the existence of an abundant food supply" (Bibby and Green 1983). In order to evaluate the importance of potential stopover sites in the Sahara for birds on this migration route more detailed measurement of the available food supply will be needed. At Hassi Marroket we estimated the potential food supply by repeated light-trapping and trapping with lime-sheets mounted in the vegetation at a height of about 1.5 m. In short the amount of caught insects showed a very high potential food supply, which might be high enough for the above mentioned fattening of some of the species.

The present study contributes some aspects to a better understanding of the problems of Transsahara-migration. But further studies on the occurrence of migrants in desert habitats, their diets and habitat selection (e.g. Bairlein 1983), their body weights, their rates of fat deposition and their activity patterns will be needed.

The data support the idea that the ecological conditions of oases are good enough for fattening of migrants and that, therefore, at least some species probably migrate in stages. But it still remains open how many birds are involved in the different strategies of crossing the Sahara either by long non-stop flights or by shorter hops. Therefore, radar studies of bird migration over the sahara will be needed (e.g. Alerstam 1972, Bruderer 1977, 1982).

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