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Biometrics and wing moult of migrating Red-rumped Swallows *Hirundo daurica* in Greece

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Published data describing the biometrics, moult and fat loads of migrant Red-rumped Swallows *Hirundo daurica* are scarce. Here we present data on wing and tarsus length, tail measurements, abdominal fat scores and weight for a sample of 457 birds captured at a reed-bed roost during autumn migration through the island of Lesvos in the Aegean Sea. Biometrics were similar to those reported from smaller samples of museum skins but with a greater range of values for several measures. Tail length and tail-fork length in adult birds were not markedly bimodally distributed, suggesting either that females were rare in the sample captured or that use of the sexing criteria proposed by Svensson (1992) should not be applied to the population migrating through this area. The majority of birds carried fat loads, and these were significantly larger in adult than in first-year birds, suggesting that adults might have been in better condition prior to long-distance migration. Moult of the inner primaries was found in 16.4%, and of tertials in 8.2% of adult birds. Its frequency varied significantly between years, but did not vary with size, mass or fat score.

Western Palearctic populations of the Red-rumped Swallow *Hirundo daurica rufula* breed across the Mediterranean from Iberia to Greece, the Balkans, Turkey, Cyprus and the Middle East. Of the estimated total population of 100,000–430,000 pairs, most are found in Portugal, Spain, Albania, Macedonia, Greece, Bulgaria and Turkey, each with at least 10,000 pairs (BirdLife International 2004). Migration is trans-Saharan, but the wintering grounds of European birds remain unconfirmed, probably because *rufula* is inseparable in the field from resident populations in the northern Afrotropics (Moreau 1972). Published biometric data are scarce; Cramp (1988) and Svensson (1992) present data from small samples of museum skins (Table 1), and Svensson suggests that the sex of a proportion of adult birds can be assigned on the basis of tail measurements (tail length <92 mm = female, >100 mm = male, n = 27; tail fork <50 mm = female, >55 mm = male, n = 22).

Both adult and first-year birds are thought to have a single, complete, 'winter' moult, taking place between October and February (Svensson 1992). However, there are occasional records of birds beginning primary-feather moult before migration (Cramp 1988) and, more recently, Frías (1999) noted that three of nine adult Red-rumped Swallows captured between 8 July and 23 September in central Spain were in primary moult with moult scores of 1 (5 August), 1 (10 September) and 7 (17 September). He suggested that this might indicate a suspended moult strategy, frequent in other European hirundines (Svensson 1992), in which birds begin moult before crossing the Sahara, interrupt the moult during migration, and recommence moult on reaching the wintering grounds. Of 11 juveniles captured over the same period, none were in moult.

In this study we describe the biometrics of Red-rumped Swallows from a larger sample of birds than hitherto available, and measure the frequency and extent, and biometric correlates of remex moult prior to autumn trans-Saharan migration. We also describe variation in fat loads and test whether this varies systematically with the age and size of the birds.

METHODS

Red-rumped Swallows were mist-netted as they entered a communal reed-bed roost at Charamida Marsh, Lesvos (39° 01'N 26° 33'E), on the following dates: 15–21 September 1994, 7–19 September 1995, 29 August–10

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September 1996, 6–16 September 1998, and 30 August–9 September 2002. A sound lure playing calls of a variety of hirundine species was played close to the nets for an hour before dusk to encourage the birds to enter the roost close to where the nets were set. Birds were ringed and measured immediately on capture, and then roosted overnight in cloth bags before being released at first light the following morning at the same location. Wing length (maximum chord), tarsus length (the 'bent toes' method), tail length and the length of the tail fork were all measured according to Svensson (1992). These methods match those used to measure museum skins in Table 1, except for tarsus length, where the method used on museum skins may give slightly shorter measures. All measurements were made to an accuracy of 1 mm using a steel ruler, except for tarsus length which was measured to 0.1 mm using dial calipers. Each bird was also weighed to an accuracy of 0.1 g using a Pesola balance, aged (as either adult or first-year) according to the plumage criteria given by Svensson (1992), and assigned a fat score of between 0 and 5 (Gosler 1996). The primary, secondary and tertial wing feathers of all birds were checked for signs of active or suspended moult, and moult scores were recorded according to Ginn & Melville (1983). Statistical analyses were carried out using MINITAB 14. One-way ANOVA was used to test correlates of variation in mass, and non-parametric equivalents (Mann–Whitney, Kruskal–Wallis and chi-square tests) were used to test correlates of variation in fat and moult scores.

RESULTS

Size measures

Data were available for 457 birds, all of which were identified as either first-year or adult. Table 2 reports the biometrics of this sample, classified by age. Adults were significantly longer winged (by 1.9%), heavier (by 9.0%), and had longer tails (by 26.1%) and tail forks (by 51.4%) than first-year birds. The large difference between these last two percentages reflects the fact that the greater length of the tail in adults is mostly accounted for by the outer tail feathers. The two age groups were not significantly different in tarsus length. The range of measurements recorded in this sample of birds was greater than those previously recorded for southern Europe (Table 1), mainly due to the presence of larger birds. For example, 44 of 256 (17.2%) first-year birds had a tail length greater than 84 mm (the longest recorded in Table 1), though only one bird exceeded 92 mm. Amongst adult birds, 16 of 120 (13.3%) exceeded the maximum of 109 mm recorded in Table 1, with the longest at 119 mm. Similar results were obtained for tail fork. For first-year birds, 24 of 249 (9.6%) had tail forks longer than the maximum of 42 mm recorded in Table 1, though only one bird exceeded 48 mm. Fifteen of 115 adult birds (13.0%) had tail forks longer than the maximum of 64 mm recorded in Table 1, though only one bird exceeded 69 mm. Overall, one adult bird (tail 119 mm, tail fork 80 mm) and one first-year bird (tail 107 mm, fork 66 mm) were outliers. Amongst adult birds, the distributions of tail and tail-fork length were not clearly bimodal (Fig 1).

Fat scores

Of 453 birds for which fat score was recorded, the distribution was 0: 38, 1: 41, 2: 100, 3: 149, 4: 101, 5: 24. Fat score explained 36.1% of variation in mass (one-way ANOVA, $F_{5,443} = 51.51$, $P < 0.001$; Fig 2), with birds of fat score 5 being 25.5% heavier than those with a fat score of 0. If size measures (wing length, tarsus length, tail length and tail fork) were added to the model as covariates, then the most parsimonious

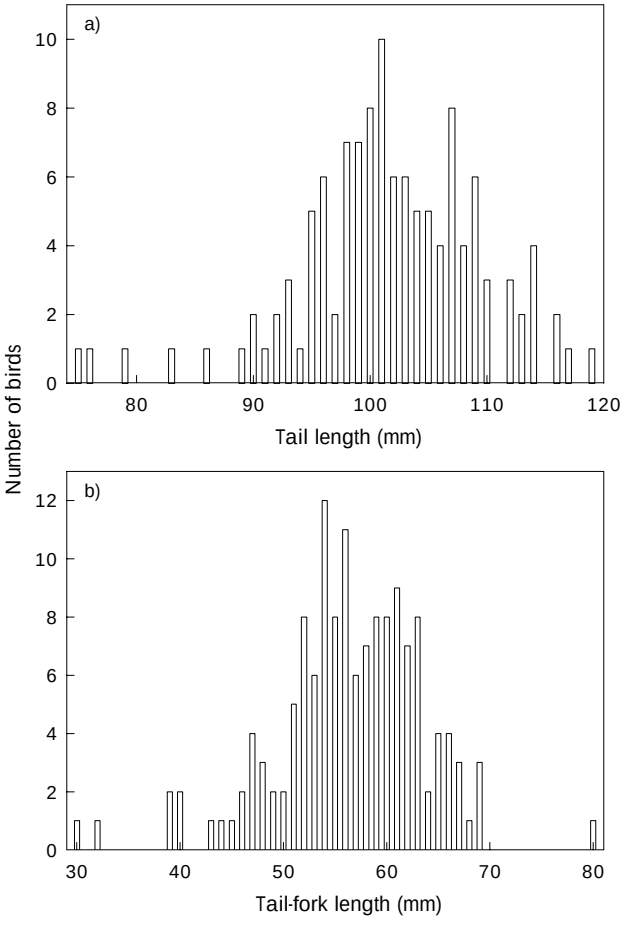

Figure 1. Tail length (a) and tail-fork length (b) distributions of adult *rufula* Red-rumped Swallows.

Table 1. Wing, tail and tarsus measurements (mm) of *rufula* Red-rumped Swallow museum skins summarised from Cramp (1988) and Svensson (1992). Data are for adult birds, except for the rows indicated.

Measure	Mean (SD)	Range	Sample size	Origin
Wing length				
		111—124	25	Spain
		111—129	49	SE Europe, Asia Minor, Levant
males	124.5 (2.10)	120—128	31	S Europe, Asia Minor, Cyprus, Levant
females	121.4 (2.48)	118—127	22	S Europe, Asia Minor, Cyprus, Levant
males	117.8 (3.17)	113—124	13	S Iran, Afghanistan, Arabia, W Pakistan
females	118.9 (3.52)	112—123	9	S Iran, Afghanistan, Arabia, W Pakistan
males	118.5 (2.3)	114—123	28	S Spain
females	116.7 (3.3)	111—125	25	S Spain
males	116.8	112—124	24	Former USSR
females	114.5	112—122	19	Former USSR
juveniles	120.5	116—125	13	S Europe, Asia Minor, Cyprus, Levant
Tail length				
		77—101	25	Spain
		80—107	49	SE Europe, Asia Minor, Levant
males	101.9 (3.97)	94—107	29	S Europe, Asia Minor, Cyprus, Levant
females	95.6 (4.18)	89—99	18	S Europe, Asia Minor, Cyprus, Levant
males	99.5 (4.5)	90—109	28	S Spain
females	92.5 (7.8)	68—102	25	S Spain
juveniles	77.8	71—84	13	S Europe, Asia Minor, Cyprus, Levant
Tail fork				
males	59.3 (3.32)	53—64	30	S Europe, Asia Minor, Cyprus, Levant
females	52.0 (2.94)	46—56	18	S Europe, Asia Minor, Cyprus, Levant
males	43.8 (2.3)	41—48	21	S Spain
females	42.3 (3.0)	39—46	20	S Spain
juveniles	37.3	30—42	13	S Europe, Asia Minor, Cyprus, Levant
Tarsus length				
males	14.1 (0.38)	13.5—14.7	13	S Europe, Asia Minor, Cyprus, Levant
females	13.8 (0.40)	13.2—14.3	10	S Europe, Asia Minor, Cyprus, Levant

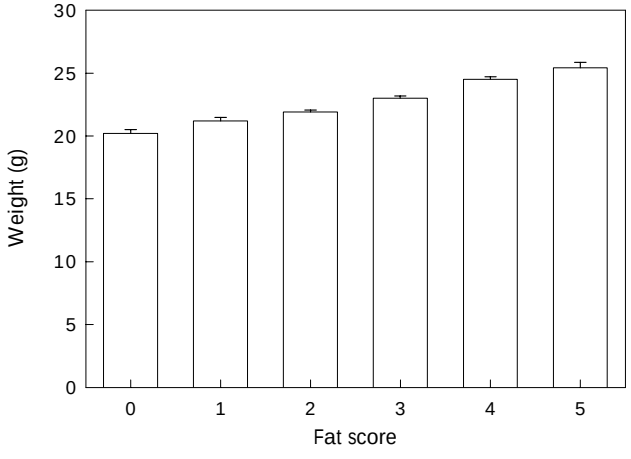

Figure 2. Mean weights (+SE) of Red-rumped Swallows in different fat score classes.

model included wing length (b = 0.17, $F_{1,351}$ = 25.21, P < 0.001) and tail fork (b = 0.048, $F_{1,351}$ = 23.43, P < 0.001) and explained a further 13.8% of variation in mass. Fat scores were significantly higher in adult than in first-year birds (Mann–Whitney W = 71506; P = 0.0013), but fat score did not vary significantly with any of the size measures. Fat scores also differed significantly between years (Kruskal–Wallis H = 59.6, df = 3, n = 452, P < 0.001; Fig 3) with the median fat score of 2 in 1998 being significantly lower than the medians of 3 or 4 in other years.

Moult

Of the 122 adult birds, 20 (16.4%) had active or suspended primary moult, and 10 of these also showed suspended moult of the tertials (Fig 4). None showed evidence of secondary moult. No first-year birds showed

Table 2. Biometrics of *rufula* Red-rumped Swallows captured on Lesvos, 1994–2002. All linear measurements are in mm. ***, $P < 0.001$.

Measure	Sample size	Age	Mean	SE	Min	Max	Difference between age classes
Wing length	334	First-year	120.7	0.16	111	128	t = 7.66***
	122	Adult	122.9	0.25	116	129	
Tarsus length	262	First-year	14.0	0.06	12.0	16.7	
	104	Adult	14.1	0.06	12.9	15.7	
Tail length	256	First-year	80.7	0.28	68	107	t = 27.39***
	120	Adult	101.7	0.72	75	119	
Tail fork	249	First-year	37.2	0.29	24	66	t = 24.88***
	115	Adult	56.3	0.71	30	80	
Weight (g)	332	First-year	22.3	0.12	15.7	28.5	t = 8.15***
	121	Adult	24.3	0.22	15.1	29.6	
Fat score	332	First-year	2.6	0.07	0	5	
	148	Adult	3.0	0.11	0	5	

evidence of remex moult. Primary moult appeared to be active in three individuals, as judged by the presence of waxy sheaths around the base of partly-grown feathers, but was suspended in the other 17 birds. All birds showing evidence of tertial moult had completely replaced and fully re-grown either one or two of the tertials, and had not replaced the remaining feathers. In four birds, primary moult scores differed between right and left wing, and this was also the case for tertial moult in one bird. Amongst birds with active or suspended primary moult, the median primary moult score, summing across both wings (maximum 100 if all primaries are new) was 7.5 (sign test lower 95% confidence limit = 6; upper 95% confidence limit = 10; n = 20), whilst amongst birds with tertial moult the mean tertial moult score (maximum 30 if all tertials are new) was 10 (95% confidence limits 10 and 20; n = 10). The extent of moult in the primary and tertial tracts was not significantly correlated (Spearman's r = 0.354, $P = 0.126$, n = 20). The frequency of wing moult in the samples of adult birds differed significantly between years ($\chi^2 = 13.53$, df = 3, $P < 0.01$), varying between none of 21 birds in 1998, and 11 of 31 birds in 1996. There were no significant differences in any size measures (one-way ANOVA) or fat scores (Mann–Whitney tests) between moulting and non-moulting birds. The distribution of growth stages of individual primary feathers on the 20 moulting adult birds is shown in Table 3. Feathers were found at all growth stages, but moult had not progressed beyond primary 4 (counting descendently from the carpal joint to the outer primary as in Ginn & Melville 1983) in any bird. In the majority of cases, moult had not progressed beyond primaries 1 and 2. The distribution of moulting primaries between the five growth stages (1: 15; 2: 19, 3: 6, 4: 17, 5: 13) did not differ from random expectation ($\chi^2 = 7.14$, df = 4, $P = 0.13$). Amongst the 10 birds showing moult of the tertials, this was usually one or both of the central tertials (20 cases), but with seven

Table 3. Distribution of primary feather growth stages from 20 adult *rufula* Red-rumped Swallows in active or suspended primary moult. Unmoulted primaries (*ie* growth stage = 0) are not included.

	Primary feather (1 = innermost)			
Growth stage	1	2	3	4
1	4	11	0	0
2	11	6	2	0
3	3	1	2	0
4	12	2	0	2
5	7	4	2	0

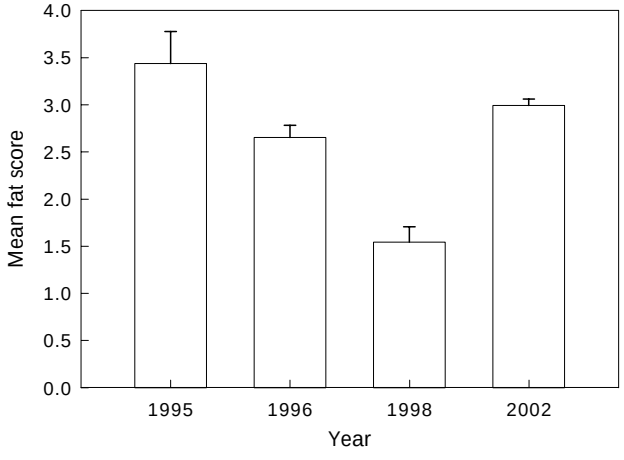

Figure 3. Mean fat scores (+SE) of Red-rumped Swallows in different years.

cases of moult of the inner tertials and one case of moult of an outer tertial.

DISCUSSION

The biometrics of a large sample of mist-netted Red-rumped Swallows accord with those reported for southeast Europe from smaller samples of museum skins but, as would be expected simply from the larger sample size, increase the range of values recorded for several of the measures, especially for tarsus, tail and tail-fork length. Longer tail measurements in the birds in this study may partly (but not wholly) be accounted for by the fact that the samples of museum specimens against which we are making comparisons may suffer shrinkage of 1–3% in length measures derived from the plumage (Svensson 1992). The distributions of tail length and tail-fork length in adult birds were not markedly bimodal, suggesting either that females were rare in the sample of birds captured at Charamida Marsh (only 10 of 145 (6.9%) adults had a tail length of <92 mm, and only 20 of 143 (14.0%) adults had a tail-fork length of <50 mm), or that use of the sexing criteria proposed by Svensson (1992) should not be applied to the population migrating through this area. Since we had no independent means of sexing birds, we cannot distinguish between these two possibilities.

Fat scores explained a high proportion of variation in weight, and over 60% of birds had fat scores of 3 or higher, suggesting preparation for a substantial autumn migration. Adults had significantly higher fat scores than first-year birds. Although swallows are able to feed as they migrate, this nonetheless suggests that adults may have been in better condition to face unpredictable feeding conditions during migration. Supporting the observations presented in Cramp (1988) and Frías (1999), we found evidence of suspended primary moult in 16.4% and tertial moult in 8.2% of autumn-captured adult birds, though the incidence of this varied greatly between years, with no moulting birds recorded in one year, but 35% of birds showing suspended moult in another. Moult usually extended only to the inner two primaries, but occasionally to primaries three and four. Tertial moult was typically, but not exclusively, of the central tertial feather. To our knowledge, this is the first substantive evidence of the frequency and extent of suspended moult in Red-rumped Swallows from a large sample of birds.

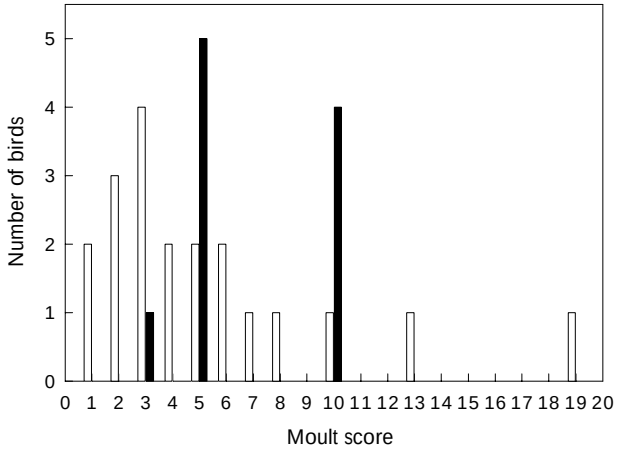

Figure 4. Distribution of primary (open bars) and tertial (filled bars) moult scores of adult *rufula* Red-rumped Swallows. Birds that had not begun moult are not included.

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