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Biometrics, sexing and moulting of Snow Finch *Montifringilla nivalis* in Central Italy

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As a small passerine typical of several Palaearctic mountain ranges, the Snow Finch *Montifringilla nivalis* is susceptible to climate change and studies into its ecology are badly needed. Data on biometric measurements and moult parameters are essential to underpin ecological studies and the aim of this study was to provide such data for a central Italian breeding population. Between 2003 and 2009, 404 individuals were ringed and measured. In the majority of morphometric measurements (wing length, eighth primary length [P8], bill depth, bill length, mass) adults were significantly larger than juveniles. Adult males had longer wings than females, but the sexes were similar for all other size parameters. Differences in wing length could be used to sex safely 88% of all adult individuals. Wing and P8 length measurements were influenced by feather abrasion, which was more pronounced in females and reduced wing measurements by 2 mm in summer compared to winter. The duration of primary moult was estimated to be 85 days in juveniles, 80 days in adult males and 67 days in adult females. In general, adults started moulting earlier than juveniles and males earlier than females. As usual among passerines, secondary moult started later than primary moult in both juveniles and adults and was accomplished in 50 and 65 days, respectively.

The Snow Finch *Montifringilla nivalis* is a small passerine typical of several Palaearctic mountain ranges, being distributed from Iberia to Himalaya with different subspecies (Cramp & Perrins 1994). Despite this large range, it shows a very patchy distribution and is confined to the alpine zone above the tree line (around 2,000 m asl in Europe). In particular, the European subspecies *nivalis* is fragmented with a few breeding nuclei on the highest southern European mountain ranges: Cantabrian mountains (Spain), Pyrenees, Alps, Apennines (Italy), Dinaric Alps and Pindo mountains in Greece (Cramp & Perrins 1994).

The Snow Finch shows interesting adaptations to its high-alpine habitat (Heiniger 1991) and during the breeding season relies on areas of melting snow for finding food for its nestlings (Strinella *et al* 2007). During the winter, by contrast, Snow Finches feed mainly on insect fallout and frozen seeds present in the snow (Antor 1995), although they also forage for food around mountain villages and even winter-sport resorts (Wehrle 1989, Heiniger 1991). Given the dependency on snow patches during the breeding period, the Snow Finch may be a species at major risk of local extinction in Europe, as global warming takes hold (Rose & Hurst 1992). The vulnerability of this species to temperature increases demands an urgent need for studies into its ecology and population dynamics. For such studies, data on biometrics and moult of birds of different populations are necessary, since they may allow us to distinguish populations during both breeding and migration periods (*eg* Meissner 2007) and to attribute age and sex to different individuals. Therefore, biometric and moult studies are important for ecological field studies and for conservation programmes.

To date, few studies have focused on this species, and data on biometrics and moult relate only to a few individuals of the alpine population (Svensson 1992, Cramp & Perrins 1994). The aims of this study were to provide new data on the biometrics and moult of Snow Finches of a central Italian population and to estimate the effect of feather abrasion on wing measurements in this species.

METHODS

Study site and data collection

From June 2003 to June 2009, 331 Snow Finches were caught with mist nets and mealworm-baited spring traps in the area of Campo Imperatore, in the National Park Gran Sasso Monti della Laga, central Italy (42°27′ N, 13°34' E). Furthermore 73 chicks were ringed in artificial nests placed in the same area (nine in 2004, 20 in 2005, 12 in 2006, 12 in 2007, 17 in 2008, and three in

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2009). Once caught, all birds were ringed. On the basis of current literature (Svensson 1992), it was only possible to distinguish between juveniles prior to their first complete moult and older birds (EURING age codes 3 and either 2 or 4, respectively). Birds during the reproductive periods were sexed on plumage characteristics following Svensson (1992) and Svensson *et al* (1999). Yearlings after their complete moult were indistinguishable from older birds and were included in this age class.

From the birds caught, the following biometric data were collected: wing length (maximum chord method, to 0.5 mm), the length of the eighth primary feather (±0.5 mm; primary numbering is proximal to distal) [P8], bill length (tip to skull), bill depth (at distal edge of nostril) and maximum tarsus length, all measured to 0.1 mm using callipers. Body mass was recorded with an electronic scale to 0.1 g. All measurements were taken by a single observer (ES). Furthermore, for all birds the moult status was recorded following Ginn & Melville (1983) and each flight feather was given a score from 0 (old) to 5 (fully grown and new). Because the relationship between feather mass grown and time may be more linear than between moult score and time (Underhill & Zucchini 1988, Dawson 2003) all primaries and secondaries of an adult female Snow Finch found dead during the ringing sessions were weighed.

Biometrics, sexing and feather wear

For analyses of morphometrics in relation to age and sex, only birds newly captured (no recaptures) were used (total 404, comprising eight juvenile males, eight juvenile females, 173 juveniles of undetermined sex, 80 older males, 44 older females, and 91 older birds of undetermined sex). Since the ringing station was situated at a very high altitude (2,170 m asl), and faces very severe weather, it was sometimes necessary to release the birds as soon as possible and take fewer measurements (wing, P8 and tarsus). Thus, the sample sizes for biometric variables differ. Because body mass can change to a large degree across the year, we compared juvenile birds only to adults caught in the same period, that is from May to November.

We tested whether sex may affect body mass, wing, P8 and tarsus length in juvenile birds using Mann–Whitney U tests, because of the very low sample size ($n = 16$, eight males and eight females). Bill depth and bill length were excluded from this analysis because the sample size was too low (three birds and one bird respectively). The effect of age, sex and year of ringing in older birds was tested with univariate linear models. Although wing and P8 length were not normally distributed, their distribution showed very low skewness and a kurtosis lower than 1.5. More importantly, all residuals of the models were normally distributed, and thus these results can be considered robust. Because almost no juveniles were sexed, sexes were lumped together when testing for age, while juveniles were excluded when testing for sex.

The possibility that morphometrics could be used to sex adult Snow Finches was investigated using a stepwise discriminant analysis with jack-knife classification. All biometric parameters together with some derived variables, such as wing length divided by tarsus, were entered into the analysis.

Wing and P8 length might be affected by feather abrasion. Therefore, in the statistical models with these two variables, we also included the time (in months) between the beginning of November, a date by which most birds will have finished their wing moult, and capture, as an estimate of feather age and wear. Finally, we calculated the effect of feather abrasion on wing length and P8 by dividing the sample into two groups. Because Snow Finches of all ages undertake an annual complete moult which is completed by the end of October (see below), we divided the sample into birds caught from November to April which should have rather fresh plumage, and birds caught from May to mid October with theoretically abraded plumage. Birds from mid October to November were included in either group, according to whether their longer primaries were already moulted or not. We then tested with a Mann–Whitney U test whether wing and P8 lengths differed between these two groups, according to sex. For these tests, U values are tabulated but standardised scores (Z value) are referred to in the text where $P < 0.05$ if $|Z| > 1.96$. All statistical analyses were performed with SPSS 13.0.

Moult

To analyse moult data we first calculated the percentage of the total flight-feather mass accounted for by each flight feather (Appendix; Underhill & Zucchini 1988, Dawson 2003). We then multiplied this index by the moult score of each feather for each individual, following Underhill & Zucchini (1988). Finally these values were used to estimate the starting date, its standard deviation (SD) and moult duration, according to the maximum likelihood method of Underhill & Zucchini (1988), using a script for the program R (R Development Core Team 2008) written by Walter Zucchini. Because we had moult data for birds before, during and after moult we used the model for type 2 data, which is the most precise for estimating moult parameters (Underhill & Zucchini 1988).

RESULTS

Biometrics

All biometric measurements of juveniles, adults, males and females are summarised in Table 1, while the results of statistical models are presented in Table 2. Biometric parameters differed significantly between juvenile and older birds with the exception of tarsus length. Conversely, only wing length and P8 length differed significantly between males and females, although tarsus length showed a tendency to be higher in males than in females (Table 1). We did not measure tail length, which other authors have found to be sexually dimorphic in this species (Cramp & Perrins 1994).

Wing and P8 length differed significantly between older males and females, with males having longer wings and P8 than females (Table 1). Furthermore, both parameters decreased with increase of the time between moult and catching date, an indication that wing length was reduced by feather abrasion. Interestingly, the interaction term sex*month-from-moult was significant, indicating that sexes were differently affected by feather wear (Table 2a). Indeed, male wing length decreased only slightly, by 0.5 mm from 122.9 ± 1.7 mm (mean ± SD) in fresh plumage to 122.4 ± 2.7 mm in worn plumage (n = 104, Z = −1.8, $P = 0.06$, non-significant), while female wing length decreased significantly by 2.1 mm from 118.7 ± 2.6 mm in fresh plumage to 116.6 ± 2.3 mm in worn plumage (n = 62, Z = −2.2, $P = 0.02$; Table 3). Compared to wing length, male P8 length showed bigger changes during the season, being 96.0 ± 2.6 mm in fresh plumage and 94.2 ± 2.6 mm in worn plumage (n = 104, Z = −2.53, $P = 0.01$; Table 3), while in females it decreased from 92.1 ± 2.8 mm in fresh plumage to 89.5 ± 2.5 mm in worn plumage (n = 62, Z = −2.5, $P = 0.011$; Table 3). The year of ringing did not affect either P8 or wing length. Also juveniles and older birds differed markedly in wing and P8 length, with older birds having much longer wings and P8 than juveniles (Table 1). The year of ringing did not affect either of the two variables, while the interaction year*age was significant for P8, indicating that P8 length varied between years in a different way between juveniles and older birds (Table 2b). Finally, wing and P8 length also differed between juvenile males and females (n = 16, wing length: Z = −2.7, $P = 0.007$; P8 length: Z = −2.0, $P = 0.04$).

Bill length, bill depth and body mass did not differ between sexes (Table 1) and were not affected by ringing year. In contrast, juveniles had shorter bills than older birds (Table 1), and bill length varied according to the year of ringing. Body mass also differed between juveniles and older birds, which were heavier (Table 1). There was also significant variation between years in juvenile body mass. In contrast to adult birds, body mass in juveniles varied in relation to sex (n = 16, Z = −2.3, $P = 0.02$), with males being heavier than females.

Tarsus length differed between older males and females only marginally, with males having slightly longer tarsi than females. Juveniles did not differ from older birds in tarsus length, but the difference was affected by the year of ringing. Tarsus length did not differ between juvenile males and females (n = 16, Z = −1.7, $P = 0.1$).

Discriminant analysis

In the stepwise discriminant analysis, only wing length entered the final model (λ Wilks = 0.478, canonical correlation $r = 0.722$, $P < 0.0001$) as no other variables made a significant contribution to sexing Snow Finches. With this single variable, 89% of birds with a wing length >120 mm were sexed correctly as males and 87% of birds with a wing length of ≤120 mm were correctly classified as females. Therefore, on average, on the basis of this criterion alone, wing length may be used to sex 88% of birds correctly. However, all birds with wings longer than 123 mm were males, while all those with wings shorter than 118 mm were females (Fig 1). In the wing length range 121–123 mm, more than 90% of individuals were males, whereas for the range 118–121 mm there were approximately equal numbers of males and females (Fig 1).

Moult

Of the 404 birds examined, 203 were in active moult, 166 juveniles, 19 adult males and 18 adult females (total adults = 37). The mean start date of primary feather moult in juvenile birds was 29 July (SD ±13.2 days) with a duration of 85 days (estimated completion of moult 21 October; Fig 2). For adults the mean starting date was 10 days earlier, with birds starting primary moult on 19 July (±11.8 days) on average, and a duration of 76 days (estimated completion of moult 3 October; t-test on starting date: n = 203; t = 4.3, $P = 0.0001$; Fig 2).

Adult males and females differed in their moult timing, since males started on average ten days earlier than females (16 July and 26 July respectively, ±11.0 days in both sexes), but required longer to complete the moult, taking 80 days instead of 67 in females (t-test on starting date: n = 37; t = −2.7, $P = 0.01$). Therefore, the estimated date of completion of moult for males was 4 October, while for females it was 1 October (Fig 2).

Secondary moult was represented less well in our sample, because it generally starts later in the season, when captures of Snow Finches were less frequent. We

Table 1. A summary of biometrics for Snow Finches (juveniles and older birds, males and females) ringed in this study in Campo Imperatore, in the Gran Sasso Laga National Park (Central Italy), showing mean ± standard deviation (SD), the number of birds (n), and the range for each category of measurement. For bill length and bill depth, data were available for only three and one sexed juveniles, respectively, and these data were therefore omitted.

	P8		Wing length		Bill length		Bill depth		Tarsus		Body mass	
	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n
Juveniles all	81.9 ± 3.1	189	110 ± 3.8	189	12.8 ± 0.6	47	7.9 ± 0.3	19	22.5 ± 0.6	186	34.1 ± 1.6	187
Range	72.0–94.0		97.5–120.5		11.1–14.0		7.4–8.5		21.0–24.0		27.4–39.3	
Juvenile males	86.3 ± 1.5	8	114.5 ± 1.0	8					22.8 ± 0.0	8	34.9 ± 0.3	8
Range	82.0–94.0		112.0–121.0						22.5–23.2		33.5–36.3	
Juvenile females	82.6 ± 1.1	8	110.2 ± 0.9	8					22.5 ± 0.1	8	33.8 ± 0.2	8
Range	80.0–89.0		107.0–113.0						21.9–23.0		33.3–34.9	
Adults all	92.8 ± 3.4	208	120.3 ± 3.6	215	13.9 ± 0.3	135	8.2 ± 0.19	117	22.6 ± 0.5	212	36.9 ± 1.8	116
Range	85.5–105.0		113.0–130.0		13.0–14.4		7.8–8.7		21.0–24.3		32.9–43.2	
Adult males	95.5 ± 2.6	78	123.3 ± 2.4	80	13.9 ± 0.3	47	8.3 ± 0.2	41	22.7 ± 0.5	80	37.1 ± 1.6	74
Range	90.0–105.0		118.0–130.0		13.0–14.4		8.0–8.7		21.4–23.7		32.2–41.2	
Adult females	90.2 ± 2.4	44	117.3 ± 2.4	44	13.9 ± 0.2	26	8.2 ± 0.2	22	22.5 ± 0.6	44	36.7 ± 2.2	40
Range	85.5–96.0		113.0–123.0		13.5–14.4		7.8–8.6		21.0–24.3		32.9–43.2	

Table 2. Results of the statistical tests using univariate linear models to compare biometric parameters with respect to sex, year and time from moult for older birds (a) and with respect to age and year of ringing for juvenile and older birds (b). df, degrees of freedom; F, F statistic.

(a) Effect of sex on biometric parameters

Biometric parameter	df	Model overall		sex		year		Month-from-moult		sex*year		sex*month-from-moult	
		F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Wing length	62	6.6	<0.0001	137.3	<0.0001	1.9	0.09	2.4	0.01	1.1	0.38	2.5	0.01
P8 length	61	6.8	<0.0001	122.1	<0.0001	1.2	0.33	3.6	<0.0001	1.2	0.33	2.1	0.04
Tarsus	13	3.3	0.07	3.3	0.07	1.6	0.16			0.7	0.6		
Bill length	22	1.1	0.35	1.4	0.2	1.1	0.3			0.4	0.8		
Bill depth	33	1	0.49	0.9	0.3	1.1	0.3			0.5	0.8		
Body mass	13	1.2	0.24	0.9	0.3	1.9	0.9	0.8	0.6	0.6	0.7	1.1	0.34

(b) Effect of age on biometric parameters

Biometric parameter	df	Model overall		age		year		age*year	
		F	*P*	F	*P*	F	*P*	F	*P*
Wing length	12	54.8	<0.0001	264.8	<0.0001	1.6	0.15	1.1	0.34
P8 length	12	87.9	<0.0001	421.9	<0.0001	1.8	0.09	3.8	0.02
Tarsus	12	3.5	<0.0001	0.4	0.5	3.9	0.001	0.9	0.4
Bill length	8	32.8	<0.0001	167.7	<0.0001	2.6	0.04	2.6	0.06
Bill depth	6	7.1	<0.0001	16.6	<0.0001	2.7	0.05	3.1	0.05
Body mass	12	16.1	<0.0001	63	<0.0001	4.1	0.001	1.5	0.18

Table 3. Results of statistical tests on feather abrasion. Results of the Mann–Whitney tests (U values and *P* values) carried out on the variation of wing length and P8 length according to season and sex. Shown are mean ± standard deviation, and number of individuals sampled (n).

	Season	P8	Mann–Whitney U	*P*	Wing	Mann–Whitney U	*P*
Males	May–Oct	94.2 ± 2.6 (n =74)	674.5	0.002	122.4 ± 2.7 (n = 78)	903	0.06
	Nov–Apr	96.0 ± 2.6 (n = 30)			122.9 ± 1.7 (n = 30)		
Females	May–Oct	89.5 ± 2.6 (n = 52)	128	0.01	116.6 ± 2.3 (n = 52)	144.5	0.03
	Nov–Apr	92.1 ± 2.8 (n = 10)			118.7 ± 2.6 (n = 10)		

thus caught 57 birds in active secondary moult (26 adults, of which 14 were males, nine females and three undetermined, and 31 juveniles). The relatively small sample of moulting females did not allow us to compare secondary moult parameters between the sexes. The mean starting date of secondary feather moult in juvenile birds was 7 September (±15.8 days) with a duration of 50 days (estimated completion of secondary moult 27 October). For adults the mean starting date was 17 days earlier (21 August; ±15.0 days), and lasted 65 days, being completed by an estimated 25 October (t-test on starting date: n = 57; t = 4.2, $P = 0.0001$).

DISCUSSION

Biometrics

The present study shows that, on average, juvenile Snow Finches are smaller than adult birds, having shorter wings, shorter and thinner bills, and weighing less than

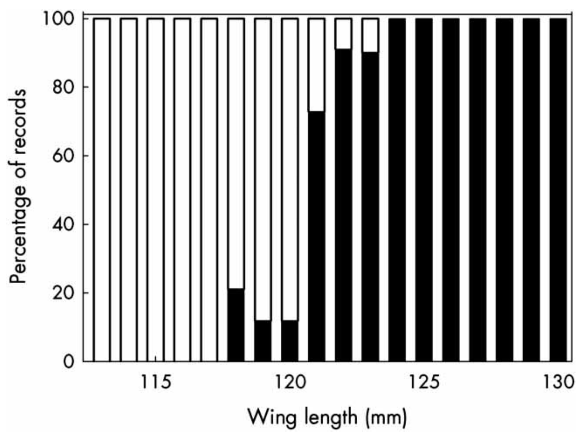

Figure 1. Proportion (in percent) of sexes for each wing length in our sample. Although some females (open bars) had wings longer than 121 mm, these represented only 4.5% of birds in this category.

older birds. In particular, while bill depth was only slightly larger in older birds, both wing length and P8 length were on average more than 10 mm longer, and bill length was 1 mm longer in older birds compared to juveniles. The fact that tarsus length did not differ among age classes is not surprising, since the tarsus should not grow noticeably after the first few weeks of life (Potti & Merino 1994).

Among juvenile birds, males had longer wings and P8, and were heavier than females. In juveniles, all males had wing length above 112 mm and all females below 113 mm. However, given the very small sample size, with only eight males and eight females compared, at the moment we cannot provide any useful measurement range to sex juvenile birds.

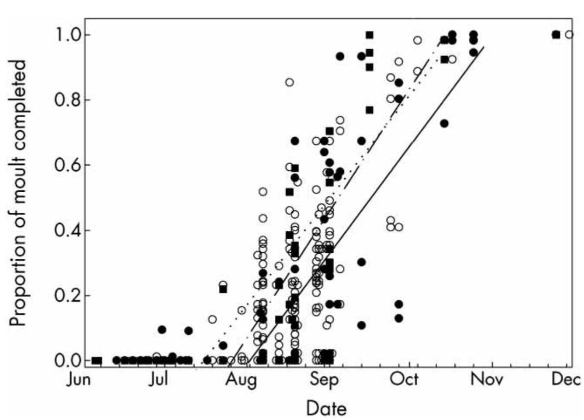

Figure 2. Moult scores of primaries of adult male (filled circles), adult female (filled squares) and juvenile (open circles) Snow Finches. The lines show the average starting and finishing date for primary moult for adult males (dotted line), adult females (dashed line) and juveniles (solid line), as calculated with the model described in the text.

Among adult birds, males showed longer wings (both wing length and P8) and marginally longer tarsi than females, while no other measures differed between sexes. The discriminant analysis was able to sex correctly 88% of the birds using only wing length. According to our measurements, birds with wings longer than 123 mm were males, while birds with wings shorter than 118 mm were females. Within the range 118–123 mm, the presence of a limited number of male or female birds with short or long wings, respectively, prevents the use of wing length as an completely accurate sexing criterion. However, in the wing-length range 121–123 mm, more than 90% of the individuals were males, so that one might consider sexing as males all birds with wings above 121 mm. In this way, a total of 81% of males could be correctly sexed, while only 4.8% of females would be wrongly sexed. Since there were approximately equal numbers of males and females in the range 118–121 mm, birds with wing lengths within range cannot be sexed on this criterion. Clearly, wing length provides an additional criterion to sex some birds outside the breeding season, when plumage characteristics might not allow the sex of all individuals to be determined.

The measurements of wing lengths in this study were similar to those reported from the Alps and other European mountain ranges in the literature (Svensson 1992, Cramp & Perrins 1994), although the range of wing lengths was wider than previously reported. Given the relative rarity of such extreme individuals, this is likely due to the larger sample size of our study, rather than reflecting differences in wing length range between different populations. Therefore, we are not able to distinguish the central Italian population of Snow Finches from populations in other European mountains using wing-length data.

Effect of feather wear on wing length measurements

In our study, P8 and wing length were affected by the time between moult (November) and catching date. This was presumably due to feather abrasion, which was more prevalent in the summer months, when flight feathers are older. The difference in feather length between freshly moulted and worn feathers reached 2 mm in adult females, a large difference compared to other values reported in the literature (Francis 1989, Alonso & Arizaga 2006). This degree of flight-feather abrasion can be explained by the habit of Snow Finches of using small rock crevices for roosting and nesting cavities (Cramp & Perrins 1994). Similarly, the finding that females showed greater wing abrasion than males can be explained by the fact that only females incubate the eggs and, therefore, spend more time in rock crevices than males (Cramp & Perrins 1994).

Moult

Our observations on Snow Finch moult agree with reports in the literature (Svensson 1992, Cramp & Perrins 1994), that birds of all ages have a complete moult in late summer and have no partial pre-nuptial moult. On average, older birds begin primary and secondary moult 10 and 17 days, respectively, earlier than first-year birds. Males started their primary moult 10 days earlier than females, but, given the longer moult duration, finished on average three days later. At this stage it is difficult to find an explanation for the different moult timing between sexes, which has been already described in other species, such as the Greenfinch *Carduelis chloris* (Newton & Rothery 2005).

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(MS received 22 September 2009; accepted 13 January 2010)

Appendix. Individual feather masses within each feather group expressed as a percentage of the total mass for that group.

Feather group	Feather number	Percentage mass within each group
Body		
tertial	3	25.8
tertial	2	33.3
tertial	1	40.8
secondary	6	14.7
secondary	5	16.8
secondary	4	17.0
secondary	3	17.1
secondary	2	17.2
secondary	1	17.2
primary	1	8.9
primary	2	9.3
primary	3	9.5
primary	4	10.1
primary	5	10.8
primary	6	11.9
primary	7	13.2
primary	8	13.1
primary	9	13.0
primary	10	0.1
Outermost		