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Morphological differentiation of mainland Citril Finches, *Carduelis [citrinella] citrinella* and insular Corsican (Citril) Finches, *Carduelis [citrinella] corsicanus*

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The Citril Finch is one of the few endemic bird species restricted to European mountains (VOOUS 1960; NEWTON 2003). Two allopatric forms may be distinguished. Insular Corsican (Citril) Finches, *Carduelis [citrinella] corsicanus*, live exclusively on Corsica, Sardinia and some Tuscany islands (Capraia, Elba, Gorgona) (ARCAMONE 1993; BACCETTI & MÄRKI 1997; CRAMP & PERRINS 1994; THIBAUT 1983; THIBAUT & BONACCORSI 1999; MOLTONI 1975), whereas mainland Citril Finches, *Carduelis [citrinella] citrinella*, occur at higher elevations in the mountain ranges of central and south-western Europe (Alps, Black Forest, Vosges, Jura, Massif Central, Cevennes, Pyrenees, Cantabrians and Sierras of central Spain), generally above 800 m asl. (BACCETTI & MÄRKI 1997; CRAMP & PERRINS 1994; GLUTZ VON BLOTZHEIM & BAUER 1997; HÖLZINGER 1997).

There is an ongoing debate about the taxonomic status of Citril Finches and Corsican Finches. In spite of recently detected genetic differences (mitochondrial DNA differs by 2.7 %), the authors of these studies still regard the two forms as conspecific (PASQUET & THIBAUT 1997; THIBAUT & BONACCORSI 1999). In contrast, SANGSTER (2000) assigned species status to the Corsican Finch, referring to the same genetic results. Based on his recommendations in combination with data on variations in plumage colouration (CRAMP & PERRINS 1994; PASQUET 1994) and vocalization (CHAPPUIS 1976; CRAMP & PERRINS 1994; recently confirmed by FÖRSCHLER & KALKO 2007), the Association of the European Rarities Committees (AERC) now treats the two forms as full species with their own evolutionary histories (SANGSTER et al. 2002). Furthermore the two species have been recently reclassified within the genus *Carduelis* instead of being a member of *Serinus* (ARNAIZ-VILLENA et al. 1998, 1999). Both forms are therefore members of the superspecies *Carduelis [citrinella]* (BARTHEL & HELBIG 2005; Helbig 2005).

Only little data has been published on evidence for differentiation in morphological character traits between the two forms. According to the available notes on morphometry, both species do not show large geographical differences in body size (ALONSO & ARIZAGA 2006; BORRAS et al. 1998; BRANDL & BEZZEL 1989; CRAMP & PERRINS 1994; MÄRKI & BIBER 1975), with the exception that Corsican Finches seem to have generally slightly shorter wings than nominate Citril Finches (CRAMP & PERRINS 1994). Nominate birds in the Eastern Pyrenees appear to have longer wings than do nominate birds in the Alps, but evidence is weak and may be also due to variation between different measurers (BRANDL & BEZZEL 1989; BORRAS et al. 1998; MÄRKI & BIBER 1975). Adult male Citril Finches have an average population weight of 12.5 g in the Eastern Pyrenees (BORRAS et al. 1998), while adult male Corsican Finches are little bit lighter with 11.5 g in average (NICOLA BACCETTI, GILLES FAGGIO, SERGIO NISSARDI & PHILIPPE PERRET, pers. comm.).

We analysed 20 morphological character traits following the methods of LEISLER & WINKLER (1985, 1991, 2001), LEISLER et al. (1997) and KORNER-NIEVERGELT & LEISLER (2004). The following external features were measured. (1) wing length (the distance between carpal joint and tip of flattened wing); (2) tail length (from insertion of central pair of feathers to tip of longest rectrix); (3) fork of the tail (difference from longest to shortest inner rectrix); (4) wing width (the distance between carpal joint and the tip of the longest secondary); (5) primary projection (the distance between tip of 1st secondary and wing tip); (6) distal (the distance between tip of 10th primary and wing tip); (7) alula (the distance between carpal joint and tip of the longest alula); (8) notch P2i (length of notch on inner web of second primary); (9) notch P3o (length of notch on outer web of third primary); (10) Kipp Index (distance of 1st secondary to wing tip x 100/ wing length see KIPP

1959) (11) bill length (from tip to skull); (12) bill width (at the rear end of nostrils); (13) bill height (maximum depth); (14) rictal bristles (the length of the vibrissae at the bill base) (15) tarsus length (from notch of the intertarsal joint to the lower edge of the last complete scale); (16) tarsus diameter 1 (lateral maximal diameter of tarsus); (17) tarsus diameter 2 (sagittal maximal diameter of the tarsus); (18) hind toe (length of digit 1); (19) middle toe (length of digit 3); (20) hind claw (the cord from the tip to edge of the skin of nail); (21) middle claw (the chord of nail 3); (22) index of wing length/ tarsus length.

In total we measured 23 individuals of mainland Citril Finches from the Northern Alps and 13 individuals of insular Corsican Finches from Corsica and Sardinia. For our study we used only adult males to guarantee comparability. All measurements were conducted by KARL HEINZ SIEBENROCK. Museum specimens from the following museum collections were used exclusively: Zoologische Staatssammlung München (Munich), Zoologisches Museum der Humboldt Universität (Berlin) and Naturkundemuseum Rosenstein (Stuttgart).

We found significant morphological differentiation between mainland Citril Finches and insular Corsican Finches (see Table 1). Corsican Finches are generally smaller. Wings are considerably longer and more pointed (Kipp Index) in Citril Finches. Accordingly, significant variations may be also found between other wing measurements (secondary, primary projection, distal, alula, notch P2i, notch P3o). Corsican Finches have a shorter tail and their tail is less forked. Furthermore Citril Finches possess significantly broader, higher and longer bills than Corsican Finches. No significant difference was found for the length of the rictal bristles. Citril Finches have longer and stonger tarsi, a longer middle toe and longer claws. However the length of the hind toe (maybe due to measurement errors) and the ratio of wing length to tarsus length are not significantly different.

Climate is known to play an important role in geographic size variation (JAMES 1970; JOHNSTON & SELEANDER 1973). Corsican Finches appear to inhabit generally areas of warmer climate than do Citril Finches (THIBAUT & BONACCORSI 1999) and may therefore have developed

Table 1. Mean values of 20 morphological traits and 2 indices of Citril and Corsican Finches. Comparisons were conducted with t-tests (parametric distributed data sets) and Mann Whitney U tests (non-parametric distributed data sets).

	Citril Finch (n=23) in mm	Corsican Finch (n=13) in mm	Statistical comparison	Sign-Level
Flight apparatus				
Wing length	76.4±1.5 SD	72.5±2.2 SD	t-test; t=6.569; df=34; p≤0.001	***
Tail length	53.3±1.8 SD	50.4±2.2 SD	t-test; t=4.336; df=34; p≤0.001	***
Fork of the tail	-10.0±1.1 SD	-7.2±1.1 SD	MWU; T=94; p≤0.001	***
Wing width	53.5±1.6 SD	51.0±1.6 SD	MWU; T=126.0; p≤0.001	***
Primary projection	22.6±1.2 SD	20.1±1.5 SD	t-test; t=5.319; df=34; p≤0.001	***
Distal	54.1±1.4 SD	50.3±2.1 SD	MWU; T=118.5; p≤0.001	***
Alula	56.4±1.5 SD	52.8±2.3 SD	MWU; T=119; p≤0.001	***
Notch P3o	23.1±1.4 SD	21.0±1.2 SD	t-test; t=4.692; df=33; p≤0.001	***
Notch P2i	19.8±0.8 SD	17.7±1.1 SD	MWU; T=94; p≤0.001	***
Kipp index	29.6±1.3 SD	27.8±1.9 SD	t-test; t=3.439; df=34; p=0.002	**
Feeding apparatus				
Bill length	12.2±0.6 SD	11.6±0.5 SD	MWU; T=133.0; p≤0.001	***
Bill width	5.3±0.2 SD	4.8±0.3 SD	MWU; T=115.5; p≤0.001	***
Bill height	6.2±0.3 SD	5.6±0.3 SD	t-test; t=6.432; df=34; p≤0.001	***
Rictal bristles	2.6±0.7 SD	2.4±0.7 SD	t-test; t=4.950; df=34; p=0.420	ns
Hind limb				
Tarsus length	14.4±0.6 SD	13.5±0.5 SD	t-test; t=4.653; df=34; p≤0.001	***
Tarsus diameter 1	0.88±0.08 SD	0.82±0.06 SD	t-test; t=2.278; df=34; p=0.034	*
Tarsus diameter 2	1.34±0.13 SD	1.15±0.06 SD	t-test; t=4.950; df=34; p≤0.001	***
Hind toe	6.5±0.4 SD	6.4±0.3 SD	t-test; t=0.599; df=34; p=0.553	ns
Middle toe	10.9±0.6 SD	10.2±0.6 SD	t-test; t=3.240; df=34; p=0.003	**
Hind claw	6.1±0.5 SD	5.6±0.5 SD	t-test; t=2.926; df=34; p=0.008	**
Middle claw	5.4±0.4 SD	4.7±0.4 SD	t-test; t=5.534; df=34; p≤0.001	***
Wing length/ tarsus index	5.3±0.2 SD	5.4±0.2 SD	MWU; T=267; p=0.392	ns

smaller body size and body weight. However, this supposed climatic difference is essentially not the case for a majority of Corsican Finches, living on the highest mountain slopes of Corsica, where climatic conditions are quite comparable to the Alps or Pyrenees. Furthermore, measurements conducted by BORRAS et al. (1998) revealed no clear clinal variation in size from north to south in mainland Citril Finches as expected. They propose that other factors such as habitat or diet may be of larger importance.

We suggest therefore that the morphological differentiation observed in our study may have evolved as a consequence of different habitat conditions, since Citril and Corsican Finches differ in several features of habitat choice (FÖRSCHLER & KALKO 2006b). While Citril Finches prefer semi-open conifer forests, especially pine woodland in higher mountains, Corsican Finches generally inhabit more open habitats dominated by Tree Heath, *Erica arborea*. It is highly probable that Citril Finches are adapted to forage over longer distances (longer and more pointed wings, longer tail) and probably also to perch on stronger branches and twigs of pine trees (stronger feet), whereas Corsican Finches appear to show rather adaptations to the Macchia thickets with Tree Heath or other scrub vegetation of Mediterranean islands (FÖRSCHLER & KALKO 2006b). As a consequence Corsican Finches may have developed smaller and less pointed wings and shorter tails due to the reduction of long distance migration (THIBAUT & BONACCORSI 1999), favouring more the manoeuvrability within the Mediterranean scrub vegetation. In this context, the difference in bill size might be explained by variations in feeding ecology of the two species (FÖRSCHLER & KALKO 2006a) with Citril Finches probably more adapted to larger seeds (mainly those from pines) and Corsican Finches more adapted to smaller herb seeds (e.g. Shepherd's Purse). Further analyses may reveal how the morphological differentiation in the locally isolated populations of these two allopatric forms has evolved in relation to distinct ecological conditions and adaptation processes.

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