J Ornithol (2006) 147:553–564
DOI 10.1007/s10336-006-0079-z

ORIGINAL ARTICLE

Breeding ecology and nest site selection in allopatric mainland Citril Finches *Carduelis[citrinella] citrinella* and insular Corsican Finches *Carduelis[citrinella] corsicanus*

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Received: 11 October 2005 / Revised: 3 January 2006 / Accepted: 3 January 2006 / Published online: 12 July 2006

Abstract The breeding ecology and nest site selection of mainland Citril Finches and insular Corsican Finches have been studied throughout their limited range. For many years both endemic forms were considered to be two sub-species; however, based on evidence from more recent molecular studies they have been split into two species. This study provides data on the variations in breeding ecology and nest site selection in the different sub-populations of these little studied species. A secondary aim was to search out evidence of ecological differentiation between mainland Citril Finches and insular Corsican Finches. We found that the studied sub-populations of both species largely overlapped in breeding ecology. Our data confirms the close similarity of Citril Finches and Corsican Finches, both which are, similar to mountain birds, well adapted to the local habitat conditions of their different mountain systems. Several differences were identified within the studied sub-populations of the two (sub-) species with respect to nest site selection, probably caused by environmental conditions and local predators. One of the main differences between the two species is that Citril Finches breed mainly in half-open conifer forests (especially pine forests), while Corsican Finches breed in the more open scrubby mountains of the Mediterranean islands dominated mainly by the Tree Heath as an adaptation to the different landscapes on the islands. In contrast to Citril Finches, this preference of the Corsican Finches for Tree Heath as nesting plants – even if suitable pines are available – is typical of the species. These behavioural changes result in a niche expansion into open habitats at lower altitudes. We suggest that the observed niche expansion and behavioural variations are not suitable criteria for taxonomic status, a proposal in contrast to that of Sangster [Ibis 142:487–490 (2000)]. We further suggest that the few ecological differences found in this study between the two (sub-)species are the result of the so-called insular syndrome, which includes changes in life history traits such as morphology, demography and behaviour.

Keywords Allopatry · Breeding ecology · Citril Finch · Corsican Finch · Insular syndrome · Nest site selection · Niche expansion

Communicated by F. Bairlein

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Introduction

The Citril Finch *Carduelis [citrinella]* is one of the few bird species restricted to European mountains (Voous 1960). Currently, two allopatric forms are distinguished. The Corsican Citril Finch *Carduelis [citrinella] corsicanus* lives exclusively on Corsica, Sardinia and several Tuscany islands (Capraia, Elba, Gorgona) (Whitehead 1885; Jourdain 1911; Armitage 1937; Thibault 1983; Moltoni 1975; Arcamone 1993; Cramp and

Perrins 1994; Baccetti and Märki 1997; Thibault and Bonaccorsi 1999). The nominate form, the Citril Finch *Carduelis [citrinella] citrinella*, occurs at higher elevations in the mountain ranges of central and south-western Europe (Alps, Black Forest, Vosges, Jura, Massif Central, Cevennes, Pyrenees, Cantabrians and the Sierras of Central Spain), generally above 900 m a.s.l. (Voous 1960; Bezzel 1993; Cramp and Perrins 1994; Bauer and Berthold 1996; Baccetti and Märki 1997; Glutz von Blotzheim and Bauer 1997; Hölzinger 1997). Populations of nominate Citril Finches in the northern part of their range, such as the mountain ranges of the Black Forest, have to adapt to wetter and colder conditions (Förschler 2001b) than birds in the southern mountain ranges, such as the Catalonian Pre-Pyrenees where the weather is very hot and dry (Gutiérrez 1991; Borras et al. 2003). Similarly, Corsican Finches in the high central mountains of Corsica are exposed to colder conditions than are birds in the dry and hot mountains of Sardinia.

There is an ongoing debate about the taxonomic status of nominate Citril Finches and Corsican Finches in Europe. Despite recently detected genetic differences (mitochondrial DNA differs by 2.7%), some authors still regard the two forms as conspecifics (Pasquet and Thibault 1997; Thibault and Bonaccorsi 1999), whereas others assign species status to the Corsican Finch *Serinus corsicanus*, referring to the same genetic results (Sangster 2000). Based on the recommendations of Sangster (2000) in combination with differences in morphology (Cramp and Perrins 1994; Pasquet 1994) and vocalization (Chappuis 1976; Cramp and Perrins 1994), the Association of the European Rarities Committees now treats the two forms as full species (Sangster et al. 2002).

The breeding ecology of the two forms has received little attention, mostly due to their limited distribution and the methodological constraints involved in studying them in their mountainous habitats (Förschler 2000). Generally, both forms prefer the transitional zone between woodland and open landscape as a breeding habitat. However, Citril Finches appear to be more strongly associated with wooded areas in higher elevations, whereas Corsican Finches may exhibit a habitat-niche expansion into lower Mediterranean habitats (Thibault 1983; Blondel et al. 1988; Cramp and Perrins 1994; Thibault and Bonaccorsi 1999). Niche breadth expansion of insular populations in comparison to mainland populations has also been observed in other birds of the Mediterranean islands settled by Corsican Finches (Martin 1982, 1992; Blondel 1985; Blondel et al. 1988, 1991).

In the study reported here, we analysed breeding phenology as well as nest site selection of Citril Finches and Corsican Finches at selected sites considered to be representative of their total range. Specifically, we focussed on differences between sub-populations of Corsican Finches on Corsica, Sardinia and Capraia and those of Citril Finches in the Pre-Pyrenees and the Black Forest.

Materials and methods

Study areas

We selected study sites throughout the total range of the species. Breeding sites of Citril Finches were investigated in the northern part of its distribution at Mount Schliffkopf in the German Northern Black Forest (April–July 1999, April–June 2000) and in the southern part of its distribution at Port del Comte in the Catalonian Pre-Pyrenees (April–July 2002) (Table 1). Populations of Corsican Finches were studied on Corsica (April–June 2001, May–June 2003), mainly in the high valley of Niolo (Haute-Corse) and the mountain range of the Massif de l'Ospedale (Corse-du-Sud), at Monte Limbara (Gallura) and Monte Discudu (Gennargentu) in Sardinia (April–June 2003) and on the island of Capraia (March–May 2003). For further information on the study areas see Table 1.

Searching for nests

We conducted systematic searches for nests in the study areas during the nest-building period (Förschler 2000, 2002a). With this aim, we selected 100- to 180-ha sample plots in suitable areas [Schliffkopf (180 ha), Port del Comte-Vansa (150 ha), Port del Comte-Prat de Botons (150 ha), Capraia (100 ha), Niolo-Calasima (100 ha), Niolo-Albertacce (100 ha), Massif de l'Ospedale (125 ha), Massif de l'Ospedale-Cartalvonu (100 ha), Monte Limbara (100 ha), Monte Discudu (100 ha)] in which we mapped all nesting pairs and territories. The largest number of all nests was found by following females engaged in nest building. Another suitable period to search for nests is during egg incubation when females are fed by males at their nest. This is a particularly good time to search for nests as during the first days of egg incubation, females call softly from their nest, presumably to attract their mate. Finally, we found a few nests just before the fledgling period, when young birds standardly utter soft calls from the nest. In total, 164 nests were detected at all

Table 1 Geographic position, elevation, zone, climate [average yearly rainfall (mm) and average yearly temperature (°C)], geology and habitat type of the selected study sites. Sources: Delaugerre and Cheylan 1992; Borras and Junyent 1993; Lambertini 2000, 2002; Bruno et al. 2001)

Study sites	Geographic position	Elevation (m a.s.l.)	Zone	Climate	Geology	Habitat type
Mount Schliffkopf (Black Forest)	8°12′–13′/48°33′–32′	900–1050	Montane	2000–2200 mm, 5°C	Red sandstone granite	Wet mountain meadows and heath land with *Pinus mugo rotundata*/*pumilio* and *Picea abies* forests
Port del Comte (Pre-Pyrenees)	1°30′–1°32′/ 42°12′–42°10′	1700–2200	Montane-subalpine	–	Limestone granite	Mountain meadows and ski runs with *Pinus mugo uncinata* forests
Niolo (Northern Corsica)	8°56′–9°00′/ 42°18′–42°21′	900–1100	Supra-Mediterranean (colline)	Approximately 1500 mm, 8–10°C	Granite gneiss rhyolith	Pastures and heath land with *Erica arborea* and *Pinus nigra laricio* forests
Massif de l'Ospedale (Southern Corsica)	9°10′–9°13′/ 41°39′–41°43′	950–1,100	Supra-Mediterranean (colline)	1000–1500 mm	Granite gneiss	Rocky heath land with *Erica arborea*, *Pinus pinaster* and *Pinus nigra laricio* forests
Monte Limbara (Northern Sardinia)	9°08′–11′/ 40°51–53′	1000–1350	Supra-Mediterranean (colline)	–	Granite	Rocky heath land with *Erica arborea*, *Pinus nigra* and *Pinus pinaster*
Monte Discudu (Central Sardinia)	9°16′–17′/40°02′	1450–1600	Supra-Mediterranean (colline)	–	Granite	Mountain meadows dominated by *Juniperus communis nana*
Capraia	9°49′–51′/ 43°01′–03′	20–400	Meso-thermo-Mediterranean	250 mm, 17°C	Basalt	Scrubby macchia with *Erica arborea*, *Arbutus unedo* and *Asphodelus* steppe

study sites: 118 nests of the Citril Finch and 46 of the Corsican Finch.

Nest parameters

After a nest was found, we noted the following characteristics of the tree or shrub in which the nest was placed: plant species, height of plant and nest and distance of nest to main trunk of tree and to the end of branches. To characterize the surroundings of the nesting sites, we recorded the minimum distances of the nests to an open landscape or forest patches as well as the distance to permanent bodies of water and nearest patches of important food plants with available seeds, in particular pines (*Pinus mugo*, *Pinus sylvestris*, *Pinus nigra*), herbs and grasses (*Taraxacum*, *Rosmarinus*, *Rumex*, *Anthoxanthum*, *Poa*) (Förschler 2001a; Borras et al. 2003; Förschler and Kalko 2006).

We also determined clutch size for each nest, which was checked every 3 days during the whole breeding attempt (nest-building period: 5–10 days; hatching period: 14±2 days; nestling period: 18±3 days; see Förschler 2002a). Finally, we calculated hatching, breeding and nesting success. Hatching success was defined as the number of young in relation to the total number of eggs per nest; breeding success refers to the number of fledglings in relation to the total number of eggs; nesting success represents the number of nests with at least one fledgling in relation to the total number of nests (Bairlein 1996).

Results

Breeding phenology and altitude

Nest building of the studied Citril Finch sub-populations took place between the 21st and 35th pentad from mid-April to mid-June (median: 25th pentad). We found a significant difference with respect to the time of nest building between the population of the Northern Black Forest and the Pre-Pyrenees, with the birds in the Pre-Pyrenees starting to build nests significantly earlier than those in the Black Forest (Table 3). However, Black Forest Citril Finches were nesting at much lower elevations than those in the Pre-Pyrenees (Table 3). Nest building time in the Black Forest was not correlated with elevation (linear regression, R=0.0409; p=0.792; n=44), whereas it increased significantly with elevation in the Pre-Pyrenees (linear regression, R=0.365; p=0.001; n=74).

The timing of nest building in Corsican Finches was similar to that of the Citril Finch. Therefore, we found no significant difference in nesting time between Citril Finches and Corsican Finches (Table 2). However, the studied Corsican Finches were nesting at a lower elevation. In Corsica and Sardinia, most birds were building nests between the 21st and 35th pentad (mid-April to mid-June; median: 25th pentad). Corsican Finches at lower altitudes began to build nests significantly earlier than those at higher elevations (linear regression, R=0.722; $p<0.001$; n=46). In the low breeding areas in Capraia, birds started nesting at the end of March (median: 19th pentad). This was significantly earlier than the start of the nesting period at higher altitudes on Sardinia (median: 26.5th pentad) and Corsica (median: 24.5th pentad) (Table 4).

Nesting plants and nest position

We found 12 plant species that Citril and Corsican Finches used for nesting. Citril Finches nested exclusively in conifers (Fig. 1), whereas Corsican Finches were mostly breeding in Tree Heath *Erica arborea* or other small bushes (Fig. 2). Nest height between the

Table 2 Comparison of nesting site parameters[a] of Citril Finches *Carduelis [citrinella] citrinella* (Black Forest, Pre-Pyrenees) and Corsican Finches *Carduelis [citrinella] corsicanus* (Corsica, Sardinia, Capraia)

Nesting site parameters	Citril Finch	Corsican Finch	MWU test	Significance
Elevation of nest (m a.s.l.)	1580.3±456.6; n=118	898±375; n=46	T=2147; $p<0.001$	***
Nest building (pentad)	26.3±3.8; n=118	24.7±4.6; n=46	T=3,359.5; p=0.111	ns
Nest height (m)	7.5±7.3; n=111	1.4±1.8; n=40	T=1024; $p<0.001$	***
Tree height (m)	9.6±1.1; n=111	1.9±2.6; n=46	T=1288; $p<0.001$	***
Trunk distance (m)	0.72±0.94; n=108	0.01±0.07; n=40	T=1623; $p<0.001$	***
End of branch (m)	0.30±0.16; n=108	0.24±0.14; n=40	T=2535.5; p=0.055	ns
Next track structures (m)	34.6±38.8; n=118	31.4±44.9; n=46	T=3710; p=0.757	ns
Next open space (m)	11.4±21.3; n=118	0.7±4.4; n=46	T=2646.5; $p<0.001$	***
Next forest (m)	41.9±74.4; n=118	837.2±1197.2; n=46	T=5145; $p<0.001$	***
Next pines (m)	14.0±36.7; n=118	652.2±1160.1; n=46	T=5683; $p<0.001$	***
Next feeding sites (m)	48.6±45.5; n=118	31.6±26.7; n=46	T=3255.5; p=0.048	*
Next fresh water (m)	281.4±315.5; n=118	76.3±80.4; n=46	T=2460.5; $p<0.001$	***
Clutch size (eggs)	4.1±0.8; n=61	3.6±0.8; n=19	T=582; p=0.034	*
Hatching success (%)	61.9±41.9; n=61	55.3±49.7; n=19	T=751; p=0.839	ns
Breeding success (%)	47.7±46.0; n=61	40.9±46.6; n=19	T=723.5; p=0.607	ns
Nesting success (%)	46.9±50.2; n=81	33.3±48; n=27	T=132; p=0.293	ns

*$p\leq0.05$; ***$p\leq0.001$; ns, not significant

[a]All of the nesting site parameters are given as the mean ± the standard deviation

Table 3 Comparison of nesting site parameters[a] in Citril Finches *Carduelis [citrinella] citrinella* in the Black Forest and the Catalonian Pre-Pyrenees

Nesting site parameters	Black Forest	Pre-Pyrenees	MWU test	Sign
Elevation of nest (m a.s.l.)	1018.8±27.2; n=44	1914.1±175.2; n=74	T=1034; $p<0.001$	***
Nest building (pentad)	27.8±3.9; n=44	25.4±3.5; n=74	T=3271; $p<0.001$	***
Nest height (m)	12.3±10.4; n=38	5.2±3.0; n=73	T=2538.5; p=0.011	**
Tree height (m)	13.8±10.8; n=37	7.6±2.6; n=74	T=2255; p=0.254	ns
Trunk distance (m)	0.11±0.2; n=37	1.04±0.2; n=71	T=1254.5; $p<0.001$	***
End of branch (m)	0.40±0.17; n=37	0.24±0.13; n=71	T=2721; $p<0.001$	***
Next track structures (m)	37.2±40.9; n=44	33.2±37.8; n=74	T=2767.5; p=0.407	ns
Next open space (m)	12.7±17.4; n=44	10.5±23.3; n=74	T=2980.5; p=0.044	*
Next forest (m)	23.4±44.2; n=44	52.8±85.9; n=74	T=2196.5; p=0.019	*
Next pines (m)	36.9±53.0; n=44	0.4±2.5; n=74	T=3370; $p<0.001$	***
Next feeding sites (m)	61.1±56.8; n=44	41.1±35.5; n=74	T=2861.5; p=0.176	ns
Next fresh water (m)	61.1±61.2; n=44	412.3±332.7; n=74	T=1207; $p<0.001$	***
Clutch size (eggs)	3.7±1.1; n=11	4.1±0.7; n=50	T=283; p=0.280	ns
Hatching success (%)	67.7±38.6; n=11	60.6±42.9; n=50	T=751; p=0.839	ns
Breeding success (%)	48.3±43.0; n=11	47.6±47.1; n=50	T=723.5; p=0.607	ns
Nesting success (%)	35.5±48.6; n=31	54±50.3; n=50	T=1127; p=0.164	ns

*$p\leq0.05$; ***$p\leq0.001$; ns, not significant

[a]All of the nesting site parameters are given as the mean ± the standard deviation

Table 4 Comparison of nesting site parameters[a] of Corsican Finches *Carduelis [citrinella] corsicanus* on Corsica, Sardinia and Capraia

Nesting site parameters	Corsica	Sardinia	Capraia	Kruskal-Wallis	Significance	Dunn's method
Elevation of nest (m a.s.l.)	1005.4±68.1; n=24	1223.3±188.7; n=12	253.0±117.1; n=10	H=28.286; df=2; $p<0.001$	***	Co vs. Ca; Q=3.835; $p<0.05$ Co vs. Sa; Q=2.292; ns Sa vs. Ca; Q=5.263; $p<0.05$
Nest building (pentad)	25.3±3.8; n=24	27.9±3.9; n=12	19.5±2.3; n=10	H=17.611; df=2; $p<0.001$	***	Co vs. Ca; Q=3.179; $P<0.05$ Co vs. Sa; Q=1.558; ns Sa vs. Ca; Q=4.082; $p<0.05$
Nest height (m)	1.7±2.3; n=21	0.7±0.5; n=12	1.8±0.4; n=7	H=13.506; df=2; p=0.001	***	Co vs. Ca; Q=2.137; ns Co vs. Sa; Q=2.198; ns Sa vs. Ca; Q=3.634; $p<0.05$
Tree height (m)	2.4±3.5; n=24	1.0±0.5; n=12	1.9±20.4; n=10	H=14.527; df=2; $p<0.001$	***	Co vs. Ca; Q=1.974; ns Co vs. Sa; Q=2.458; $p<0.05$ Sa vs. Ca; Q=3.716; $p<0.05$
Trunk distance (m)	0.02±0.09; n=21	0±0; n=12	0±0; n=7	H=0.905; df=2; p=0.636	ns	–
End of branch (m)	0.29±0.17; n=21	0.23±0.09; n=12	0.14±0.05; n=7	H=7.466; df=2; p=0.024	*	Co vs. Ca; Q=0.900; ns Co vs. Sa; Q=2.613; $p<0.05$ Sa vs. Ca; Q=1.713; ns
Next track structures (m)	15.7±11.4; n=24	45.6±50.0; n=12	52.0±72.8; n=10	H=4.298; df=2; p=0.117	ns	–
Next open space (m)	1.2±6.1; n=24	0±0; n=12	0±0; n=10	H=0.917; df=2; p=0.632	ns	–
Next forest (m)	62.9±136.0; n=24	666.7±762.7; n=12	2,900±210.8; n=10	H=26.160; df=2; $p<0.001$	***	Co vs. Ca; Q=5.229; $p<0.05$ Co vs. Sa; Q=2.160; ns Sa vs. Ca; Q=2.813; $p<0.05$
Next pines (m)	8.5±5.9; n=24	558.3±948.2; n=12	2,311±1,206; n=10	H=27.1; df=2; $p<0.001$	***	Co vs. Ca; Q=3.196; $p<0.05$ Co vs. Sa; Q=4.858; $p<0.05$ Sa vs. Ca; Q=1.631; ns
Next feeding sites (m)	16.0±8.6; n=24	32.5±17.6; n=12	68±29.7; n=10	H=23.356; df=2; $p<0.001$	***	Co vs. Ca; Q=2.458; $p<0.05$ Co vs. Sa; Q=4.665; $p<0.05$ Sa vs. Ca; Q=2.071; ns
Next fresh water (m)	38.3±37.6; n=24	122.5±109.2; n=12	112.0±77.4; n=10	H=12.454; df=2; p=0.002	**	Co vs. Ca; Q=2.792; $p<0.05$ Co vs. Sa; Q=2.885; $p<0.05$ Sa vs. Ca; Q=0.231; ns
Clutch size (eggs)	3.9±0.6; n=9	3.3±0.7; n=8	4±1.4; n=2	H=3.299; df=2; p=0.199	ns	–
Hatching success (%)	44.4±52.7; n=9	56.3±49.6; n=8	100±0; n=2	H=2.043; df=2; p=0.360	ns	–
Breeding success (%)	40.7±49.4; n=9	31.3±45.8; n=8	80.0±28.3; n=2	H=1.729; df=2; p=0.421	ns	–
Nesting success (%)	30.8±48; n=13	30±48.3; n=10	50.0±57.5; n=4	H=0.567; df=2; p=0.753	ns	–

*$p\leq0.05$; **$p\leq0.01$ ***$p\leq0.001$; ns, not significant

[a]All of the nesting parameters are given as the mean ± the standard deviation

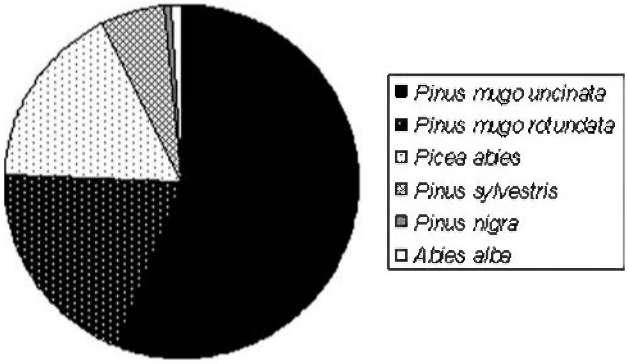


Fig. 1 Nesting trees used by Citril Finch *Carduelis [citrinella] citrinella* in the Black Forest (*n*=44) and the Pre-Pyrenees (*n*=74)

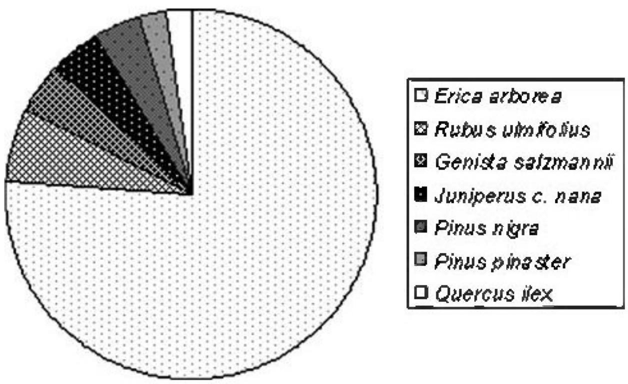


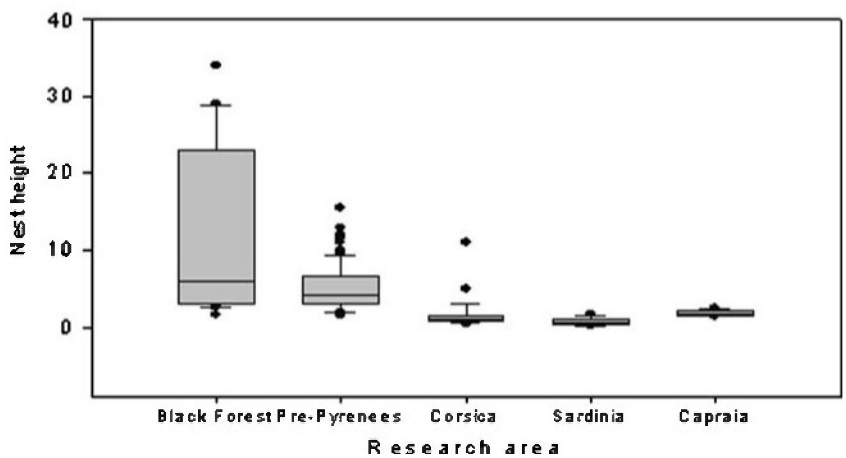
Fig. 2 Nesting shrubs and trees used by Corsican Finch *Carduelis [citrinella] corsicanus* on Corsica (*n*=24), Sardinia (*n*=12) and Capraia (*n*=10)

two species varied strongly (Fig. 3). In the Black Forest, there was a large variation in nest height that was a result of differences in the two main nesting trees: the spruce *Picea abies* and the Mountain Pine *Pinus mugo rotundata*/*pumilio* (Table 2). Birds in the Pre-Pyrenees that nested mainly in Mountain Pine *Pinus mugo uncinata* were nesting lower than birds in the Black Forest, but the differences were not significant (Table 3). Corsican Finches showed less variation in the height of nest and preferred significantly lower nesting sites than Citril Finches (Table 2). Although Corsican Finches nested mainly in Tree Heath, even when other suitable trees, such as pines, were present (Table 4), there were differences in nest height between the studied populations of Corsican Finches. Birds on Capraia nested significantly higher than birds on Sardinia (Table 4). The height of the nesting plants correlated positively with nest height, with significant differences between Citril and Corsican Finches (Table 2). No significant difference was found in the height of nesting plants in the Pre-Pyrenees and the Black Forest (Table 3), but there were significant differences between the heights of nesting plants in the three Corsican Finch populations. Birds on Sardinia nested in significantly lower bushes than those on Capraia and Corsica (Table 4).

A comparison of the average distance of the nest from the main trunk of a nesting tree revealed that birds from the Black Forest and the Pyrenees placed their nests differently. Nominate birds from the Black Forest nested significantly closer to the trunk than those from the Pyrenees (Table 3). In the Black Forest, most nests were situated in the crown, whereas finches in the Pre-Pyrenees nested in denser parts of the outer branches as well. On Corsica, Sardinia and Capraia, it was not possible to measure the distances from the nests to a discernable trunk, as most nests were placed in the shrub Tree Heath, which does not possess a discernable, central trunk (Table 4).

Citril and Corsican Finches showed a nearly significant difference with respect to the distance from the nest to the end of branches (Table 2), and Citril Finches showed a significant difference with respect to

Fig. 3 Nest heights of the nominate Citril Finch *Carduelis [citrinella] citrinella* in the Black Forest (*n*=38) and in the Pre-Pyrenees (*n*=73) and of Corsican Finch *Carduelis [citrinella] corsicanus* from Corsica (*n*=21), Sardinia (*n*=12) and Capraia (*n*=7). In the Black Forest the larger variation in nest height is due to the different nesting trees – Mountain Pine (*lower nests*) and Spruce (*higher nests*)



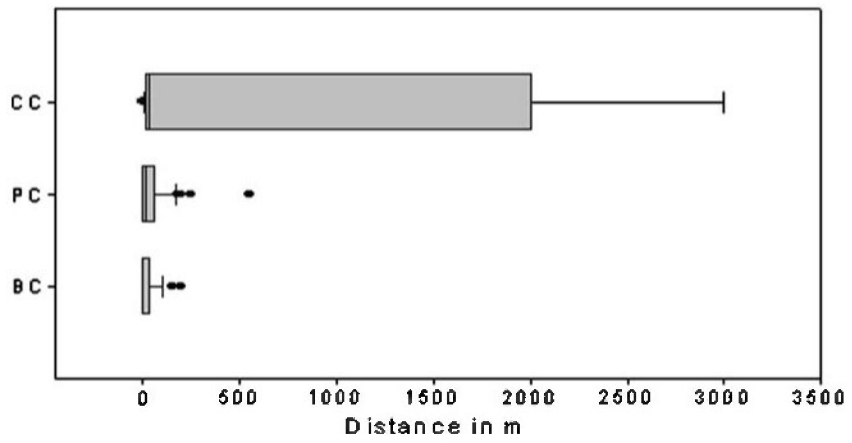


Fig. 4 Distances of Citril Finch *Carduelis [citrinella] citrinella* nests to the nearest forest patches in the Black Forest (*BC*, *n*=44) and the Pre-Pyrenees (*PC*, *n*=74) and of Corsican Finch *Carduelis [citrinella] corsicanus* nests on Corsica, Sardinia and Capraia (*CC*, *n*=46)

distances from the nest to the outer branches, with the distances being shorter for Citril Finches in the Pre-Pyrenees than in the Black Forest (Table 3). The nests of Corsican Finches on Sardinia were situated significantly closer to the end of branches than nests on Corsica (Table 4).

Parameters of nest surroundings

Corsican Finches nested significantly closer to open landscape than Citril Finches. Accordingly, the distance to next forest patches was significantly higher for Corsican Finches than for Citril Finches (Table 2; Fig. 4). Furthermore, we found a significant difference between sub-populations in the Black Forest and the Pre-Pyrenees, with birds in the Pre-Pyrenees nesting closer to the open landscape and further away from the closed forest (Table 3). No significant difference was found between Corsican Finch sub-populations with respect to distance to open landscape. However, birds on Capraia nested significantly further away from next forest patches than birds on Sardinia and Corsica (Table 4). Citril Finches nested significantly closer to pines, which provide one of their main food, than Corsican Finches (Table 2). Additionally, birds in the Pre-Pyrenees nested closer to pines than birds in the Black Forest (Table 3). Significant differences were also found between the sub-populations of Citril Finches, with birds on Corsica and Sardinia nesting closer to pines than those on Capraia (Table 4), which occasionally were found to nest at some distance from any pine.

In all of the study areas, the birds foraged during breeding season on seeds of grasses and herbs, in particular those of *Taraxacum officinale* (Asteraceae), *Rumex acetosa* (Polygonaceae), *Capsella rubella* (Brassicaceae), *Anthoxanthum odoratum* (Poaceae), *Poa annua* (Poaceae) and *Briza maxima* (Poaceae) (Förschler and Kalko 2006). Corsican Finches nested significantly closer to their feeding places than Citril Finches (Table 2). No significant difference was found between the sub-populations of the Black Forest and the Pre-Pyrenees (Table 3). However, Corsican Finches nested significantly closer to food resources than birds on Capraia and Sardinia (Table 4).

The Citril Finches studied nested significantly further away from the next water source than Corsican Finches (Table 2). Birds in the Black Forest nested closer to water than birds in the Pre-Pyrenees (Table 3). Nests in Corsica were situated closer to water sources than those on Capraia and Sardinia (Table 4).

Clutch size and reproductive success

In total, we obtained data on clutch size, hatching and breeding success for 80 nests of nominate Citril Finches and Corsican Finches. An overall count of 318 eggs led to an average clutch size of 4.0 (±0.8) eggs per nest. From 318 eggs, 188 young hatched (59%) and 149 fledged (46%). There was a significant difference in clutch size between Citril Finches and Corsican Finches (Table 2). Citril Finches laid on average more eggs than Corsican Finches. Clutch size in the Black Forest was not significantly different from that in the Pre-Pyrenees (Table 3). In addition, no significant difference was found the three Corsican Finch sub-populations (Table 4). In total, hatching, breeding and nesting success were higher in nominate Citril Finches than in Corsican Finches. However, the differences were not significant, neither between the distinct sub-populations nor among the two species (Tables 2–4). A pairwise χ^2-test revealed that there was a significant difference in nesting success between the birds of the Pre-Pyrenees and Corsica.

Discussion

Breeding phenology and altitude

We did not find significant differences between the mainland Citril Finches and insular Corsican Finches with respect to the start of nest building. This result is in contrast to those obtained in studies comparing insular and mainland populations of other species, among which the Blue Tits *Parus caeruleus* (Blondel et al. 1991). Both insular and mainland finches mainly nested between the 21st (11–15 April) and 35th (20–24 June) pentad. However, the Corsican Finches of our study clearly positioned their nests at lower elevations (Table 2), which translates into the relative date of breeding being later than for those on the mainland; this result fits with other components of insular patterns (Blondel et al. 1991, 1999; Blondel 2000). Only finches on Capraia appear to start with earlier broods in March due to their breeding habitat at lower elevations. As most Citril and Corsican Finches live in mountainous areas, the start of nest building depends strongly on the climate (Glutz von Blotzheim and Bauer 1997; Hölzinger 1997) and on food availability (Förschler and Kalko 2006). A small portion of both forms starts building nests as early opportunistic breeders at lower elevations under good food conditions, including those in the Black Pine *P. nigra* forest on Catalunya (Borras and Senar 1991) and in low coastal Macchia on Corsica and Capraia (Jourdain 1911; Thibault and Bonaccorsi 1999; personal observation). Similarly, a few early broods have been recorded in the Alps (Jouard 1930; Glutz von Blotzheim 1962; Glutz von Blotzheim and Bauer 1997).

Corsican Finches are reported to be one of the few forest species of the Mediterranean islands that exhibit an exceptionally large habitat-niche expansion (Blondel et al. 1988). Within the context of habitat descriptions, Corsican Finches are characterized, contrary to nominate Citril Finches, as nesting in all types of low vegetation, from coastal areas up to locations 2250 m a.s.l. (Thibault 1983; Cramp and Perrins 1994; Pasquet 1994; Thibault and Bonaccorsi 1999). Although we found a general trend supporting this observation, most of the Corsican Finches on Corsica and Sardinia also nest in mountainous habitats dominated by pines and Tree Heath between 800 and 1500 m a.s.l., which is more typical of Citril Finch habitats (personal observation). Only a small portion of Corsican Finches select lower areas for breeding, probably due to spill-over (Blondel et al. 1988) from high-density populations in the mountains.

Nesting plants and nest position

The selection of plants for nesting differed considerably between Corsican Finches and nominate Citril Finches. The preference of Citril Finches in the Black Forest and the Pre-Pyrenees for conifers (Pinaceae: *P. mugo*, *P. abies*) has also been observed in the Alps (Glutz von Blotzheim 1962; Maestri et al. 1989; Kaniss and Pfeiffer 1994; Glutz von Blotzheim and Bauer 1997). In contrast, we found that Corsican Finches prefer to nest in shrubby habitats, usually Tree Heath, broom or bramble, rather than in pine species that are also in the area. This confirms the little data available on nesting site selection of Corsican Finches (Armitage 1937; Marzocchi 1990; Cramp and Perrins 1994; Thibault and Bonaccorsi 1999). Consequently, the nests of Corsican Finches were also situated much lower in the vegetation than those of Citril Finches. However, some differences were found between the two studied subpopulations of Citril Finches, as birds in the northern Black Forest tended to utilize the crown of higher trees and locate their nest close to the trunk, whereas Pre-Pyrenean finches often preferred the ends of the lower lateral branches.

These adaptations in nesting behaviour may be caused by local predators. Avian predators, such as corvids, are supposed to predate elevated nests more easily, whereas mammalian predators prefer lower nests (Best and Stauffer 1980; Sockmann 1997; Liebezeit and George 2002; Schäfer and Barkow unpublished). Consequently, finches nest higher in areas inhabited by mammalian predators, like the Red Squirrel *Sciurus vulgaris* and Dormouse *Gliridae*, while in areas with more avian predators, birds are supposed to choose lower nesting sites. These effects could lead to the differences in nest height and position among the various study populations. Accordingly, the placement of nests in the crowns of trees of the northern Black Forest is perhaps associated with the high pressure exerted by mammalian predators, as the Red Squirrel is particularly abundant in that area (personal observation), whereas selection of lower heights for nests on lateral branches in the Pre-Pyrenees might be associated with the higher local abundance of avian predators, such as the Eurasian Jay *Garrulus glandarius* (Förschler 2002b). Additionally, even ants may play a role in predation and could force Citril Finches to nest on outer branches because nests near the trunk and on large lateral branches are more vulnerable to ant runs (Förschler et al. 2001).

As mammalian predators prefer lower nests and avian predators prefer higher nests, the low nests on

Corsica and Sardinia could also be due to the scarcity of mammalian predators on these islands (no Red Squirrels), whereas the Eurasian Jay is abundant in the woodlands of Corsica and Sardinia (personal observation). The higher placement of nests on Capraia may be explained by the lack of jays and the abundant presence of snakes. The Dark Green Snake *Coluber viridiflavus* is particularly abundant on Capraia (Lambertini 2002; personal observation) and is known to be an important predator of eggs and nestlings of passerine birds (Delaugerre and Cheylan 1992), especially on Montechristo (Bruno 1975), the neighbouring island closest to Capraia.

Climate factors also play a role in nest site selection and breeding success (Ricklefs 1969; Frey 1989a, b; Bairlein 1996; Rauter et al. 2002; Förschler et al. 2005). Thus, the prevalence of strong winds in the Black Forest may force Citril Finches to nest in denser and more stable parts of trees that are closer to the trunk. In contrast, Corsican Finches may have chosen Tree Heath thickets over pine trees because the interior of the thickets offer relatively calmer areas that are protected against the wind while at the same time providing safety from predators.

Nest surrounding

At all of the study sites, the nests of Corsican Finches were found in more open areas, away from closed forest structures, in comparison to those of Citril Finches. This corresponds with the more open landscapes of Corsica, Sardinia and Capraia, which in some cases also lack any forest (e.g. Capraia). Although Corsican Finches use pines for nesting – as do Citril Finches – it was evident that the dependence of the former on the presence of pine trees is not as high as that of the latter (Förschler 2002a; Borras et al. 2003). Corsican Finches can also be found nesting far away from any pine forest (e.g. Capraia). Pine seeds do not play as important role in the diet of the Corsican Finch nutrition as they do in that of the Citril Finches (Förschler and Kalko 2006). In contrast, the flight distance to other important food items (herbs and grasses) was lower for Corsican Finches than for Citril Finches. The fact that Corsican Finches generally nest closer to water sources than Citril Finches may be linked to hotter conditions in the breeding areas. However, the difference may also be related to the – in general –lower frequency of water bodies in the studied sites of the mainland Citril Finches. In particular, birds in the Pre-Pyrenees have to fly large distances to reach fresh water sources due to the general scarcity of water bodies.

Clutch size and reproductive success

Overall, the average clutch sizes of four eggs per nest (range: 2–5 eggs) found in this study confirm the little data available for Corsican (Armitage 1937; Thibault and Bonaccorsi 1999) and Citril Finches (Glutz von Blotzheim 1962; Maestri et al. 1989; Kaniss and Pfeiffer 1994; Glutz von Blotzheim and Bauer 1997; Förschler 2002a) as well as for other finches (genera: *Carduelis*, *Serinus*, *Loxia*) that also show similar clutch sizes (Glutz von Blotzheim and Bauer 1997). During a long-term study of the Serin *Serinus serinus*, an average clutch size of four eggs per nest (range: 2–5 eggs) was recorded by Gnielka (1978), and Khoury (1998, 2001) found similar clutch sizes for the Syrian Serin, with an average of 4.1 eggs per nest (range: 4–5 eggs).

We found significant differences in clutch size among the study populations. In total, mainland birds laid significantly more eggs (4.1±0.7) than those from island populations (3.6±0.8). Smaller clutch sizes have been observed for various bird populations on Corsica in comparison to mainland populations (Martin 1992) and is generally explained by differences in habitat selection and food availability (Martin 1982, 1992; Blondel et al. 1991).

Very little information has been published on thebreeding and nesting success of Citril and Corsican Finches (Maestri et al. 1989; Förschler 2002a). In our study, hatching and breeding success did not differ significantly between these two finches. Breeding success of all nests was about 46% (41% for Corsican Finches; 48% for Citril Finches), which is similar to the 45% recorded by Maestri et al. (1989) in the Italian Alps. Nesting success followed breeding success: there was no significant difference in nesting success, but it was clearly higher in the mainland Citril (47%) than in the insular Corsican Finches (33%). However, these results were obtained for each area from one breeding season only, so they must be treated cautiously since reproductive success may vary between years due to severe weather in the mountains (Bezzel and Brandl 1988; personal observation). Strong weather conditions during the breeding season may have considerable effects on reproductive success (Förschler et al. 2005). A good example of this is the spring of 2001 in Corsica, when hatching success seemed to be lower than normal, probably as a result of an unusually low availability of food (Förschler and Kalko 2006) and severe weather during the hatching period.

Conclusions

Citril Finches and Corsican Finches are currently treated as two species with independent evolutionary histories (Sangster 2000; Sangster et al. 2002). However, both forms show similar breeding ecology and behaviour. The main ecological difference that we observed was that Corsican Finches have expanded their range from exclusively half-open forests (Citril Finch) to more open landscapes located as some distance from forest patches. We suggest that the key component in this scenario is most likely the extraordinarily high abundance of Tree Heath in the mountainous regions of all the Mediterranean islands occupied by Corsican Finches. Corsican Finches use Tree Heath as a kind of 'pine substitute', which enables them to nest safely even when the next forest patch is relatively far away. Consequently, Corsican Finches also exploit – in contrast to Citril Finches – patches located some distance away from forested areas, provided these offer abundant and nutritious food resources. This behavioural difference is reflected as well by the variation in the composition of the diet during breeding season (Förschler and Kalko 2006). While Citril Finches in the Black Forest and the Pre-Pyrenees feed predominantly on pine seeds, birds on Corsica and Capraia consume mainly herb seeds (Shepherd's purse *C. rubella*; Rosemary *Rosmarinus officinalis*). However, as the Corsican Finches in Sardinia have also been observed to feed predominantly on pine seeds, this trait can not be considered to be a general behavioural pattern that separates the two forms.

We consider the observed niche expansion by Corsican Finches (Blondel et al. 1988) to be a result of variations in habitat conditions rather than result of fundamental behavioural differentiation between the two (sub-)species. In our opinion, niche expansion should not be used as an argument for taxonomic status (see Sangster 2000), since insular sub-populations of other bird species, such as the Coal Tit *Parus ater* and the Eurasian Tree-Creeper *Certhia familiaris*, differ as well comparably from their mainland counterparts in morphology, habitat selection and vocalization (Chappuis 1976; Martin 1992; Pasquet and Thibault 1997). In fact, most insular forms differ in many traits from their mainland conspecifics and are not considered to be full species (Blondel et al. 1999; Blondel 2000). Based on the results of our study, the ecological differences between the mainland and insular sub-populations are not much larger than those between the two mainland ones. The splitting of completely allopatric (sub-)species, as in the case of the Citril and Corsican Finches, is therefore subjective and rather arbitrary.

Our data on the ecological differentiation of insular Corsican Finches fits models of the so-called insular syndrome, which predicts changes in morphology, demography and behaviour due to reduced dispersal (Blondel 2000). The shift from dispersal to sedentariness and habitat fidelity on islands are potential factors for population differentiation at much smaller spatial scales than on mainland regions, which enhances within-species diversity (Blondel et al. 1999; Blondel 2000). In the light of this model the obvious differentiation of Corsican Finches with respect to their mainland counterparts in morphology (distinct plumage coloration, smaller size), demography (lower hatching and breeding success, smaller clutches, higher portion of non-breeding birds) and behaviour (increased niche breadth, niche expansion into open and lower habitats, preference for Tree Heath) may be easily explained.

Zusammenfassung

Brutökologie und Nistplatzwahl in allopatrischen Festlandspopulationen des Zitronenzeisiges Carduelis [citrinella] citrinella und Inselpopulationen des Korsenzeisiges Carduelis [citrinella] corsicanus

Wir untersuchten die Brutökologie und Nistplatzwahl von Festlandspopulationen des Zitronenzeisiges und Inselpopulationen des Korsenzeisiges. Beide für Europa endemischen Formen wurden lange Zeit als Unterarten betrachtet. Aufgrund von genetischen Untersuchungen werden sie neuerdings jedoch als eigenständige Arten behandelt. Wir beschäftigten uns sowohl mit Variationen in der Brutökologie und der Nistplatzwahl in verschiedenen Lokalpopulationen beider Arten, als auch mit der ökologischen Differenzierung zwischen Zitronenzeisigen und Korsenzeisigen. In der Brutbiologie fanden wir große Übereinstimmungen, die die Ähnlichkeit der Lebensweise beider Arten unterstreicht. Beide sind als Bergvögel gut an die lokalen Bedingungen ihrer Gebirge angepasst. Einige wenige Unterschiede finden sich in der Nistplatzwahl der untersuchten Populationen, was auf die jeweiligen lokalen Umweltbedingungen zurückgeführt werden kann. Im Gegensatz zum in Koniferen brütenden Zitronenzeisig bevorzugt der

Korsenzeisig die Baumheide als Neststandort, auch wenn genügend Kiefern in der Umgebung verfügbar sind. Dies führt dazu, dass Korsenzeisige auch in offenerem Gelände mit niedrigem Gebüsch und Macchia vorkommen, während Zitronenzeisige auf halboffene Nadelwälder (vor allem Kiefernwälder) beschränkt sind. Diese Verhaltensänderung ermöglicht es dem Korsenzeisig in einer Art Nischenerweiterung auch tiefere Lagen mit entsprechender Gebüschvegetation zu besiedeln. Dabei ist diese Nischenerweiterung unserer Meinung nach nicht als Argument für die taxonomische Einordnung des Korsenzeisiges geeignet (vgl. Sangster 2000). Die gefundenen ökologischen Unterschiede der beiden (Unter-)Arten können vielmehr als das Ergebnis des sogenannten 'Insel-Syndroms' betrachtet werden, dass schnelle Änderungen in Morphologie, Demographie und Verhalten in Lokalpopulationen aufgrund reduzierter Dispersion vorhersagt.

Acknowledgements The field work was kindly supported by Antonio Borras, Toni Cabrera, Josep Cabrera and Juan Carlos Senar (Museu Ciències Naturals, Barcelona, Spain), Philippe Perret (Centre d' Ecology Fonctionelle et Evolutive, Montpellier, France), Nicola Baccetti and Fernando Spina (Istituto nazionale per la Fauna Selvatica, Bologna, Italy), Sergio Nissardi (Cagliari, Italy), Ulrich Dorka (Tübingen, Germany) and Jürgen Kläger (Baiersbronn, Germany). Peter Berthold (MPI Vogelwarte Radolfzell, Germany), Ulrich Dorka (Tübingen, Germany) and Thomas Schäfer (MPI Vogelwarte Radolfzell, Germany) provided helpful comments on the manuscript. Alexander Tahori (Tel Aviv, Israel) kindly improved the English. We thank Franz Bairlein and Jacques Blondel for helpful comments on the manuscript. The study was conducted with financial support from the Max Planck Research Centre for Ornithology, Vogelwarte Radolfzell and the Landesgraduiertenförderung Baden-Württemberg, University of Ulm, to M. Förschler.

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