An investigation into the provenance of northern bullfinches *Pyrrhula p. pyrrhula* found in winter in Scotland and Denmark

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The 2004 invasion of northern bullfinches into parts of western Europe was the largest on record. It also involved some birds that gave the normal piping call of the species, and others that gave a different ‘trumpet’ call, previously unknown to most observers in the invasion areas. This suggests that many birds in the 2004 invasion were drawn from areas outside the usual breeding range of immigrants to western Europe, and a summer sound-recording of a similar trumpet call had previously been obtained from a bullfinch in the Komi Republic of northern Russia. Measurements of δD values in feather samples suggested that bullfinches in the 2004 invasion could have come from a wide area of northern Europe eastward into Russia. No difference in the range of δD values was apparent between the 2004 birds obtained in Scotland compared with Denmark, nor between birds obtained in the 2004 invasion and others from the 1910 invasion to Scotland. Northern birds obtained in autumn-winter in Denmark and Scotland showed a wider spread in δD values than resident bullfinches from either Denmark or Scotland. In almost all the samples, females had generally lower δD levels than males. The reason for this sex difference is unknown, but could not be attributed to differences in moult timing, location or diet between the sexes.

In this paper, we report our attempts to investigate the region of origin of the northern bullfinches *Pyrrhula p. pyrrhula* which irrupted into large parts of western Europe in autumn 2004. In most years, small numbers of northern bullfinches occur in Scotland and Denmark, but the numbers vary greatly from year to year (Newton 1972, Cramp and Perrins 1994, Riddington and Ward 1998, Pennington and Meek 2006). Large invasions to Scotland averaged less than one per decade during the last century. The irruption of 2004 was not only the largest in living memory, but was marked by the presence of some individuals which gave the usual piping call, and others which uttered a more wheezy ‘trumpet’ call, unfamiliar to most observers in these wintering areas. Particular birds were consistent in giving one or other type of call (Fox 2006). These findings suggested that many of the immigrants in 2004 came from areas outside the usual range of immigrants to Britain and Denmark, but no ring recoveries were obtained to reveal their place of origin. However, the peculiar call was similar to a sound-recording of a Bullfinch obtained near Syktyvkar (61°41′N, 50°48′E) in the Komi Republic of northern Russia (west of the Urals, c. 1,400 km east of Helsinki). This recording was available at the time on the web. Since then, other relevant recordings have been placed on the web, notably at: www.britishbirds.co.uk/sounds.

In an attempt to gain further insight into the provenance of bullfinches in the 2004 irruption, we
collected feather material from a number of specimens of northern and local resident birds in Scotland and Denmark, and analysed these feathers for deuterium (hereafter δD), a stable isotope of hydrogen. This isotope in rainfall varies in geographical distribution across land masses, according to mechanisms associated with temperature, altitude, distance from ocean and general weather pattern (Hobson 2003, Hobson et al. 2004; Bowen et al. 2005). It is taken into plants, from which it becomes incorporated into the tissues of herbivorous animals, and thence moves up the food chain. The abundance of deuterium in bird feathers reflects the levels in food eaten at the time and place where these feathers were grown, and these values are, in turn, usually associated with growing-season average values from the precipitation that supports plants. Analyses of feather material can therefore provide a clue to the region of origin (feather growth) of individual birds, or at least indicate whether different samples of birds arise from the same or different regions (Hobson 2005a, b; for previous studies on European birds see Pain et al. 2004 and Bearhop et al. 2005).

The largest race of the bullfinch, the so-called ‘northern bullfinch’ Pyrrhula p. pyrrhula breeds across the boreal zone of the Western Palearctic. It is replaced further south mainly by smaller bullfinches, divided into a number of races in different regions, including P. p. coccinea which breeds in Denmark and P. p. pileata which breeds in Britain. Individuals of the ‘northern’ race can be readily distinguished from individuals of these other two races by their larger size, including wing-length values. Birds of the race P. p. coccinea are slightly larger, on average, than those from the race P. p. pileata, but except for the most extreme individuals, they cannot be distinguished morphologically (Cramp and Perrins 1994). The northern race is irruptive, leaving the breeding range in numbers that vary greatly from year to year, wintering partly in lower latitude areas occupied by the smaller races, which in western Europe are either resident or migratory over short distances. Northern bullfinches have been found by ringing to move distances well over 1,000 km, and have been found in widely separated localities in different winters (Newton 2006).

Materials and methods

All the bullfinches obtained for this study from Denmark were caught by ADF during the autumn-winter of 2004-2005 at a feeder in a garden near the village of Nimtofte (56°26’N, 10°38’E) in East Jutland. Every individual was metal-ringed and colour-ringed, sexed and aged (first year or older), measured and weighed, and its call was noted upon release (normal or trumpet). These birds included 20 northern birds, of which 13 gave the trumpet call on release and four the normal call, and nine smaller birds (assumed to be P. p. coccinea).

Those bullfinches obtained from Scotland were either found dead during the irruption of 2004 (six northern birds), or had been obtained in earlier years and were housed as skins in the Royal Scottish Museum in Edinburgh (16 northern birds obtained in autumn-winter and 15 smaller birds, assumed to be P. p. pileata, obtained in summer). The summer birds from Scotland came from within an area bounded by latitudes 56°42’ and 57°38’N and longitudes 2°37’ and 4°55’W. Details were taken from each specimen of collection (or finding) date, locality, age (first-year or older), sex and wing-length. Although bullfinches giving ‘trumpet’ calls were present in Scotland during the winter of 2004, from carcasses alone we could not distinguish them from other northern bullfinches. Yet other northern birds sampled in the museum had been collected in the breeding season in the Amur region of eastern Asia (one male, 48°25’N, 134°59’E), the Pechora region of northern Russia (two males, one female, 65°09’N, 57°13’E) and Sweden (one female, 57°30’N, 18°20’E).

In these various samples, northern birds could be readily separated by their larger body size and wing-length from the smaller native Scottish and Danish birds, with no overlap in total body-length or wing-length (maximum chord). However, the smaller pileata and coccinea races were separated only on location. From each of these birds, about 0.05 g of material from several feathers was clipped from the flank, and used for analysis of δD value. Prior to isotopic analysis, feather material was cleaned with a 2:1 chloroform:methanol solvent mixture to remove surface contaminants and oils. Cleaned feather vanes were then analysed for δD using the methodology described in Hobson et al. (2004). Stable isotope ratios were expressed in δ-notation as parts per thousand deviation from international standards. The resulting data were grouped into ten series as in Fig. 1, and analysed by General Linear Models (GLM), with δD as the response variable, and series and sex as the explanatory variables. Series differences were examined after allowing for sex, and sex differences after allowing for series.

A full list of the 71 birds sampled is given in Table 1. Most of the northern birds available to us came from two main invasions, in 1910 (six males, four females) and 2004 (11 males, 15 females) respectively, with others from four other years (one male from 1912, one male and two females from 1913, one female from 1921, one male from 1932). All the 22 northern birds from Scotland were obtained in autumn-winter, mostly on the Northern and Western Isles where no bullfinches are known to breed, with a few in autumn 2004 from oil rigs in the North Sea. These locations pointed to all these birds being migrants, an inference supported by their
body-sizes and wing-lengths. Any immigrant northern birds obtained in the late winter (after 31 December) were attributed to an influx in the preceding autumn.

Feathers from four birds were subjected to chemical analysis on two occasions to gain an indication of the repeatability of measured δD values. Repeat values were about 5% lower, on average, than their first-time values (−115 vs −105‰, −102 vs −98‰, −105 vs −103‰, −115 vs −108‰), a trivial difference compared with the wide spread of values found between individuals (Fig. 1).

Results

Collectively, feather samples from these various bullfinches showed wide variation in δD values, which ranged from −75 to −128‰ (Fig. 1). No one series spanned this entire range, although birds from the 1910 irruption to Scotland spanned almost the whole range (−75 to −122‰).

Table 1. Numbers of bullfinches from different regions obtained for analysis

<table>
<thead>
<tr>
<th>Region</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn-winter birds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark, P. p. coccinea</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Denmark, P. p. pyrrhula, normal calls</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Denmark, P. p. pyrrhula, trumpet calls</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Scotland, P. p. pyrrhula, calls unknown*</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Summer birds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotland, P. p. pileata</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Sweden, P. p. pyrrhula</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pechora, P. p. pyrrhula</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Amur, P. p. pyrrhula</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Overall totals</td>
<td>36</td>
<td>35</td>
</tr>
</tbody>
</table>

*Included three males and three females from the 2004 irruption, six males and four females from the 1910 irruption, one male from a 1912 immigration, one male and two females from a 1913 immigration, one female from a 1921 immigration, and one male from a 1932 immigration.

The different series thus showed wide overlap in δD values, but statistically significant variation among series (after adjustment for sex differences, F_{12,57} = 6.99, P < 0.001). The same held after excluding from the GLM analysis all five samples represented by only single individuals (Amur, Sweden, and ‘northern’ birds from Scotland in 1912, 1921 and 1932; after adjusting for sex differences, F_{8,61} = 9.08, P < 0.001). Based on estimated mean values, the different series were ranked as in Fig. 1. The highest δD values were found in resident birds from Scotland-Denmark and the lowest among birds from Amur-Pechora. All northern birds obtained in the non-breeding season from Denmark and Scotland had δD levels broadly intermediate between the most easterly and westerly breeding birds sampled. This suggests that these migrants came from intermediate breeding areas: in Fennoscandia and northern Russia.

Northern birds obtained in Scotland could not be distinguished by their δD values from northern birds obtained in Denmark. Nor could northern birds obtained in 2004 be distinguished by their δD values from northern birds obtained in Scotland in earlier years. Moreover, among northern birds obtained in Denmark in 2004, the δD values of individuals with trumpet calls could not be distinguished from those of individuals with normal calls (Fig. 1).

The migratory northern bullfinches obtained in Scotland and Denmark collectively showed a significantly greater variance in δD values than the native Scottish birds (after allowing for sex differences, F_{40,13} = 3.33, P < 0.05). Similarly, they also seemed to show greater variance in δD values than the native Danish birds, but with only a small sample of Danish birds, this difference was not statistically significant (F_{40,7} = 1.99, P = 0.17). In addition, the ten birds obtained from the 1910 irruption showed greater variance in δD values than the 26 from the 2004 irruption (1910, SD = 16.9‰; 2004, SD = 6.6‰, allowing for sex and country of recovery, F_{8,24} = 6.45, P < 0.002). The effect of country of recovery alone (Scotland or Denmark) on δD values was not significant.

The most unexpected finding was that, in most series, females had lower δD levels, on average, than males, and in an analysis of variance on the overall sample (excluding singles), allowing for series effects, the association with sex emerged as statistically significant (mean sex difference = 5.4‰, SE 2.5‰, F_{4,61} = 4.80, P < 0.032).

Discussion

Most of the geographical variation in δD values across Eurasia is associated with rainfall, and occurs as a southwest-northeast gradient across Europe into Asia, settling to almost level values eastward across much of
the boreal zone (Hobson 2003, Hobson et al. 2004, Bowen et al. 2005). This makes it almost impossible to separate isotopically all but the westernmost Bullfinch samples from one another. In determining the provenance of the 2004 immigrants, we are therefore little further forward than might have been deduced from the sound recording obtained in the Komi region of Russia (as discussed by Pennington and Meek 2006). There is nothing in the data to suggest that the birds in different invasions came from essentially different regions. A striking finding, however, is the wide range of variation in δD levels among northern birds from a single invasion (−76 to −122‰ in the 1910 irruption and −97 to −123‰ in the 2004 invasion), which may suggest a wide region of origin. Overall, these immigrant birds exhibited a significantly wider spread of variation in δD values than was shown by the native Scottish birds (−89 to −109‰) and a non-significantly greater spread than the small sample of Danish birds (−78 to −101‰). This may suggest how invasions arise, as birds faced with food shortage, move through region after region, continually joined by others to form a large invasion force. The combined use of several isotopes might allow more precise determination of the provenance of the migratory northern birds, but other isotopes (such as δ13C and δ15N) show most variation on a south-north (rather than west-east) gradient and, to our knowledge, have not been mapped in the same way as δD (but see Still et al. 2003).

An unexpected finding was the greater δD values in males than females, which was evident in almost all the samples examined, and highly significant overall. Because bullfinches moult in their breeding areas before migrating, this finding could not be attributed to a sex difference in moultng areas. Nor could it be attributed to differences in the timing of moult, for the two sexes moult at the same time of year. Among bullfinches studied over several years near Oxford, Newton and Rothery (2000) noted no difference in the moult start dates of males and females, but a spread of start times among individuals in the same locality exceeding 40 d. In theory, the sex difference could also have arisen if the two sexes migrated different distances, so that males and females reaching western Europe were from partly different breeding areas. This seemed an unlikely explanation for the sex difference in δD values, however, because it was also evident in the two resident populations sampled. Moreover, the sexes are practically identical in size, structure and bill shape, and feed in mixed-sex flocks from the same plant-species, so are unlikely to have significantly different diets (Birchall et al. 2005). We can only assume, therefore, that there may be some physiological difference between the sexes, which results in females laying down different isotope ratios in their feathers than males. The flank feathers that were sampled are grown around the middle of an individual’s moult cycle. Other researchers have found evidence for evaporative cooling related to ambient conditions or possibly energy expenditure, resulting in more enriched tissue δD values in birds (McKechnie et al. 2004, see also Smith and Dufty 2005). Almost certainly, males expend more energy than females during the breeding season, as they are responsible for all the food collection for most of the breeding season, the females remaining at the nest to incubate the eggs and brood the chicks (Newton 1972).

There is additional evidence to suggest that the region of origin of the bullfinch irruption of 2004 extended further east than many previous ones. Exceptional numbers of birds were seen not only at some Swedish migration stations, and the Danish station at Christiansø (Fox 2006), but also further east at various sites in Finland (Pennington and Meek 2006) and on the southern Baltic coast of Poland (P. Busse in litt.). Larger numbers than usual were also seen at the research station at Lake Ladoga, just east of the Finnish-Russian border (J. Bojarinova pers. comm.). It seems that some of these Russian birds could have reached as far west as Scotland and Denmark, as also concluded by Pennington and Meek (2006).

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