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SEXUALLY DIMORPHIC BODY PLUMAGE IN JUVENILE CROSSBILLS

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ABSTRACT.—Sexual dimorphism in color and pattern of contour feathers is rare in juvenile songbirds. We describe how captive-bred juvenile males of Scottish Crossbill (*Loxia scotica*) and nominate Red Crossbill (*L. curvirostra curvirostra*) can be differentiated from females prior to prebasic molt by an unstreaked patch on the males' upper breast. There may be a functional relationship between sexual dimorphism and the formation of pair bonds or breeding while the birds are still in juvenile plumage. Sexually dimorphic Red Crossbills and Bearded Tits (*Panurus biarmicus*) are known to form pair bonds, and even breed successfully, while still in juvenile plumage. *Received 6 August 2004, accepted 10 July 2005.*

Among songbirds, sexual dimorphism in juvenile flight feathers (which are often retained until after the first breeding season) is not unusual, but sexual dimorphism in juvenile contour feathers is rare (Pyle et al. 1987, Svensson 1992). Sexual dimorphism in juvenile crossbills (*Loxia* spp.) has not been reported in the scientific literature (e.g., Svensson 1992, Cramp and Perrins 1994, Adkisson 1996), but, in an unreviewed bulletin for breeders of captive birds (United Kingdom), Castell (1983) reports that juvenile crossbills are sexually dimorphic. Females are described as completely streaked on the underparts, from the base of the lower mandible to the belly. Males differ in that they have a yellowish, unstreaked band or patch at the upper breast, just below the throat (Fig. 1) and an unstreaked chin (but see Fig. 1). In addition, the streaks on the breasts of males are less bold, narrower, and rounder-edged (not square-edged), and the ground color of the breast is a richer color (more yellowish, not whitish). Here, we address the reliability of using the unstreaked breast patch to sex juvenile crossbills. We only assessed and report on results pertaining to the breast patch; no quantitative information was available to us for evaluating the reliability of other reported sexually dimorphic traits, although we concur that juvenile males are generally more yellowish in color than juvenile females.

From 1993 to 2003, we tested the validity of using the unstreaked patch to sex 228 juvenile crossbills bred in captivity. All birds were kept in chicken wire and metal-frame aviaries. Adults and chicks were fed with commercial birdseed, supplemented with grit, eggshell or fish bone, and high protein egg feed, and were provisioned regularly with conifer cones. Birds were banded as nestlings with uniquely numbered bands. Pedigrees were known, and most birds were related due to regular inbreeding. The putative and actual sex of each bird was determined by each of three breeders.

Our study entailed sexing juveniles from two different crossbill taxa. The identification of some crossbill taxa can be challenging, and birds in the wild should be identified primarily on the basis of vocalizations, measurements, and geographic location (Groth 1993, Summers et al. 2002, Edelaar et al. 2003). Despite the fact that calls of captive birds are unlike those of wild birds, the (nominate) Red Crossbill (*Loxia curvirostra curvirostra*) is readily distinguished in captivity from other crossbill taxa by bill and body size, as long as the partly overlapping—but typically larger—Scottish Crossbill (*L. scotica*) can be excluded. Our Red Crossbill stock originated from continental Europe (Germany, Austria, and Russia) and had not been crossed with other crossbill

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FIG 1. A juvenile female (left) and male (right) Scottish Crossbill (*Loxia scotica*). Note the continuous streaking across the underparts of the female and the unstreaked patch on the upper breast of the male (upper arrows), the denser streaking on the underparts (lower arrows) of the female (dark stripes wider than pale stripes) than those of the male (pale stripes wider than dark stripes), and the more yellowish ground color of the male than that of the female. Contrary to initial reports, however, both sexes seem to have a streaked chin.

taxa. The Scottish Crossbills used in this study were all progeny of wild birds caught in the Scottish highlands and subsequently isolated from other crossbill taxa during breeding. Our Scottish Crossbill stock has an average bill size thought to correspond closely with that of wild Scottish Crossbills (REP and R. W. Summers unpubl. data), confirming that it did not derive from sympatrically breeding smaller-billed Red and larger-billed Parrot crossbills (*L. pytyopsittacus*).

The putative sex of individuals in juvenile plumage was determined only by the presence (males) or absence (females) of an unstreaked patch on the upper breast, before any juvenile contour feathers had been molted. Actual sex was determined by plumage after prebasic molt. It is known that adult coloration of captive crossbills is dependent on whether many carotenoids are provided during molt (Hill and Benkman 1995). If carotenoids are not provided, the normally red males develop a yellowish, female-like plumage. On the other hand, unlike many other species, female crossbills in captivity may develop a red plumage when provided with food that is artificially enriched with carotenoids (e.g., Hill and Benkman 1995). Hence, overall color (yellowish or reddish) is of little use when attempting to sex adult birds in captivity. Carotenoid-enriched food was given only to some juveniles (putative males) during the study, but this did not preclude us from correctly sexing all of them after they had undergone prebasic molt. Whether in yellow or red plumage, males have brighter, unmarked feathers on the crown and have a colored (yellow or reddish) chin; females (at least in the taxa we investigated here) have small dark spots on the crown and have a grayish chin

TABLE 1. Reliability of body plumage for sexing captive-bred juvenile crossbills. Putative sex of juveniles was based on the presence (males) or absence (females) of an unstreaked patch on the upper breast and compared to actual sex following prebasic molt. *P* is from a Fisher exact test.

		Males		Females		
Taxon	*n*	Putative	Actual	Putative	Actual	*P*
Scottish Crossbill	205	101	99	104	104	<0.001
Red Crossbill	23	8	8	15	15	<0.001

(Phillips 1977, Castell 1983; REP pers. obs.). In offspring kept for subsequent breeding, sex determined on the basis of these adult plumage characteristics was always confirmed by reproductive behavior.

We used Fisher exact tests to determine the correspondence between the putative sex determined by juvenile plumage and the actual sex determined after prebasic molt. A significant *P*-value ($P < 0.05$) indicates that the putative and actual sex correspond better than predicted by chance. We assumed that there were no effects of relatedness, parental care, or rearing environment; we also assumed no differences between observers.

Scottish and Red crossbills were sexed in juvenile plumage with a high degree of reliability (Table 1). Only 2/205 juvenile female Scottish Crossbills were sexed incorrectly ($P < 0.001$), and all 23 Red Crossbills were sexed correctly ($P < 0.001$) in juvenile plumage. We also obtained small sample sizes for Parrot, Himalayan (*L. c. himalayensis*), and Two-barred crossbills (*L. leucoptera bifasciata*). Preliminary information suggests that sexual dimorphism in juvenile plumage of these taxa is not as evident as in Scottish and Red crossbills, as several individuals of both sexes were identified incorrectly as males or females: 6/20 (30%), 2/6 (33%), and 3/7 (43%), respectively. In order to determine the usefulness of plumage dimorphism to sex juvenile crossbills of different taxa, more data on sexual dimorphism in juvenile body plumage should be collected, especially in wild crossbills and for the many Eurasian and North American subspecies of Red Crossbill.

There appears to be a correlation between life history and the occurrence of sexual dimorphism in juvenile body plumage. Juvenile Bearded Tits (*Panurus biarmicus*), which have sexually dimorphic contour feathers, normally form pair bonds and, like juvenile Red Crossbills, may even reproduce successfully while still in juvenile plumage (Glutz von Blotzheim and Bauer 1993, Adkisson 1996; K. van Eerde pers. comm., PE pers. obs.). Because reproductive behavior is at least as rare as sexual dimorphism among birds in juvenile plumage, the coincidence of these two traits suggests a possible functional relationship. However, a few other passerine species that exhibit sexual dimorphism in juvenile body plumage (e.g., *Serinus citrinella* [Borras et al. 1993], *S. serinus* [Senar et al. 1998], *Parus major* [Domènech et al. 2000], *P. caeruleus* [Johnsen et al. 2003]) are not known to form pair bonds or breed while in juvenile plumage. Thus, we hypothesize that species that form pair bonds or reproduce while still in juvenile plumage will show sexual dimorphism in juvenile body plumage; the reverse is not necessarily true. For instance, the Red Crossbill subspecies *L. c. tianschanica* is often reported to breed in juvenile plumage (Edelaar et al. 2003); therefore, we predict that juvenile males of this taxon can be distinguished easily from juvenile females on the basis of traits we describe in this paper.

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