



<http://dx.doi.org/10.11646/zootaxa.3895.1.6>

<http://zoobank.org/urn:lsid:zoobank.org:pub:DF4F2353-158E-4788-AD0E-73DC6F87A4D9>

Analysis of plumage, morphology, and voice reveals species-level differences between two subspecies of Prevost's Ground-sparrow *Melospiza biarcuata* (Prévost and Des Murs) (Aves: Emberizidae)

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Abstract

Melospiza biarcuata (Prevost's Ground-sparrow) has traditionally been divided into two allopatric groups based on differences in vocalizations and plumage characteristics: *M. b. cabanisi* in Costa Rica and *M. b. biarcuata*/*M. b. hartwegi* in northern Central America. However, the relationship between these subspecies has not been studied using a modern taxonomic approach. In this study, our objective was to provide the first detailed taxonomic comparison between these three subspecies using an integrative multi-trait analysis. We analyzed morphometric features, qualitative plumage patterns, and quantitative plumage measurements using spectral reflectance from all three subspecies, and we analyzed vocalizations for subspecies *M. b. biarcuata* and *M. b. cabanisi*. Our results show that *M. b. cabanisi* can be readily distinguished from the two other subspecies on the basis of morphometrics (*M. b. cabanisi* are smaller), plumage patterns (*M. b. cabanisi* have different facial markings and plumage patches), color differences (*M. b. cabanisi* have plumage patches that differ in color and brightness), and vocalizations (*M. b. cabanisi* have songs and calls that are acoustically distinct from those of *M. b. biarcuata*). By contrast, the two northern subspecies *M. b. biarcuata* and *M. b. hartwegi* were very similar for most traits, supporting previous suggestions that the two northern subspecies should be considered a single subspecies. Our data reveal that the differentiation in phenotypic characteristics between *M. b. cabanisi* versus *M. b. biarcuata* and *M. b. hartwegi* is similar to that reported for other complexes of subspecies where species status has been recognized. We argue that *M. b. cabanisi* should be treated as a species separate from *M. biarcuata* and propose that it be called *Melospiza cabanisi*, White-faced Ground-sparrow. Our findings will contribute to the conservation efforts of the White-faced Ground-sparrow, which is endemic to Costa Rica's Central Valley and Turrialba Valley, by bringing focus to conservation policies that preserve ground-sparrow habitat (thickets, shade coffee plantations, and young secondary forest).

Key words: color differences, Emberizidae, ground-sparrows, *Melospiza biarcuata*, *Melospiza cabanisi*, morphology, plumage patterns, vocalizations

Introduction

The taxonomy of the family Emberizidae, which includes sparrows and buntings, has been the focus of several recent studies at different hierarchical levels. These studies have significantly altered our understanding of the family, such that species that were previously considered members of the Emberizidae have been moved into other families, and species from other families have been moved into Emberizidae (Klicka *et al.* 2000; 2007; García-Moreno *et al.* 2001; Barker *et al.* 2013, Klicka *et al.* 2014). Recent research has suggested that New World sparrows should be classified as a new family called Passerellidae (Barker *et al.* 2013). The evaluation and reorganization of species relationships within the family has involved (1) disentangling species relationships within such problematic genera as *Aimophila* and *Pipilo* (DaCosta *et al.* 2009), and (2) studying subspecies relationships in depth, such as in the genus *Arremon* (Cadena *et al.* 2007; Cadena & Cuervo 2010). Although these important studies provide us with a better understanding of the relationships between species of the Emberizidae, it is still necessary to carry out work on other species and genera to develop a more comprehensive understanding of species relationships within this family.

intermediate individuals (Cadena & Cuervo 2010), just as we observed for *M. b. cabanisi* versus the *M. b. biarcuata*/*M. b. hartwegi* group. *Arremon t. assimilis* and *A. t. atricapillus*, and *A. t. poliophrys* and *A. t. torquatus* showed 100% correct classification between the species groups based on discriminant analysis using acoustic features of songs, whereas our analysis showed 96% correct classification between subspecies *M. b. biarcuata* and *M. b. cabanisi*.

Conservation implications for White-faced Ground-sparrow. The White-faced Ground-sparrow is endemic to the Central Valley of Costa Rica (from Atenas and San Ramón in Alajuela province to Paraiso in Cartago province), the Turrialba Valley on the Caribbean side of the country, and the western part of Monteverde mountain range, Guanacaste province, from 500 to 1700 m (Stiles & Skutch 1989; Garrigues & Dean 2007; L. Sandoval pers. obs.). This ground-sparrow inhabits mainly thickets, shade coffee plantations, and young secondary forest (Stiles & Skutch 1989; Garrigues & Dean 2007; Sánchez *et al.* 2009), habitats that are not protected by any conservation laws in Costa Rica. The intense levels of urbanization in Costa Rica's Central Valley endanger these thicket habitats and coffee plantations, reducing the total coverage of this habitat and fragmenting what habitat remains (Joyce 2006; Biamonte *et al.* 2011). If urbanization of thicket and shade coffee habitat continues at its current pace, the White-faced Ground-sparrow faces an uncertain future, potentially making this species one of the more endangered birds in Costa Rica. This endemic taxon brings to light the importance of conserving early successional habitats.

Acknowledgements

We thank the Museo de Zoología Universidad de Costa Rica, Museo Nacional de Costa Rica, the Field Museum of Natural History, the University of Michigan Museum of Zoology, and the Musée National d'Histoire Naturelle for access to skins of the study species; and to the Macaulay Library of Natural Sounds, the Laboratorio de Bioacústica Universidad de Costa Rica, Jesse Fagan, and Knut Eisermann for recordings. We thank Reserva Los Tarrales, Guatemala, for logistic support. LS was supported by scholarships and grants from the Ministerio de Ciencia y Tecnología (MICIT) and the Consejo Nacional para Investigaciones Científicas y Tecnológicas (CONICIT) of Costa Rica, the Government of Ontario, the University of Windsor, and the Visiting Scholar program of the Field Museum of Natural History. PPB was supported by a CGS D scholarship from the Natural Sciences and Engineering Research Council of Canada (NSERC). Additional funding was provided by NSERC, the Canada Foundation for Innovation (CFI), and the Government of Ontario to SMD and DJM.

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APPENDIX A. List of skins used in this study, measured at Museo de Zoología Universidad de Costa Rica (UCR), Museo Nacional de Costa Rica (MNCR), the Field Museum of Natural History (FMNH), the University of Michigan Museum of Zoology (MZUM), and the Muséum National d'Histoire Naturelle (MNHN).

Melospiza biarcuata biarcuata:

Female: FMNH 109482, FMNH 22986, FMNH 109483, FMNH 109480, MNHN 1880-3400.

Male: MZUM 98401, MZUM 108106, MZUM 89016, MZUM 108105, FMNH 212687, FMNH 212685, FMNH 109481, FMNH 23374, FMNH 22988, FMNH 22990, FMNH 22985, FMNH 22987, FMNH 22983, FMNH 22984, FMNH 22989, FMNH 23373, FMNH 212682.

Melospiza biarcuata hartwegi:

Female: MZUM 94608, MZUM 103527, MZUM103529, MZUM107783, MZUM 107784, MNHN 1975-798, MNHN 1975-799, MNHN 1975-800.

Male: MZUM 94610, MZUM 94609, MZUM 94607, MZUM 103526, MZUM 103528, MZUM 103530, MZUM 103531, MZUM 107780, MZUM 107781, MZUM 107785, MZUM 103959, MNHN 1975-797.

Melospiza biarcuata cabanisi:

Female: UCR 3176, UCR 2577, MNCR 186, FMNH 6834, FMNH 72939, FMNH 72938.

Male: UCR 2436, UCR 2435, UCR 1218, MNCR6335, MNCR23050, MNCR5175, MNCR 23051, MNCR 4561, FMNH 374214, FMNH 6835, FMNH 72940, FMNH 72937, MNHN 1999-2299, MNHN 1999-2297.

APPENDIX B. List of recordings used in this study, obtained from Laboratorio de Bioacústica Universidad de Costa Rica (UCR), the Macaulay Library of Natural Sounds Cornell Laboratory of Ornithology (ML), the private collection of Jesse Fagan (JF), and the private collection of Knut Eisermann (KE). Asterisks indicate recordings made by L. Sandoval that are being archived in Laboratorio de Bioacústica Universidad de Costa Rica and are awaiting catalogue numbers.

Melospiza biarcuata biarcuata:

15259ML El Salvador, Santa Ana, Cerro Verde; 106025ML El Salvador, Sonsonate, Finca Altamira; KE57 Guatemala, Tukurú,