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Photo: Rafael Cruz-Tirado

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Observation of female song in *Chlorophonia sclateri* (Puerto Rican Euphonia)

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Cover Page: A male Puerto Rican Euphonia (*Chlorophonia sclateri*) in front of its nest. Picture taken in Mameyes, Utuado, Puerto Rico on 18 May 2006 by Dr. Rafael Cruz-Tirado.

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Abstract

In avian communication, songs play vital roles, but documentation of female song remains scarce. We present the first recorded instance of female song vocalization in *Chlorophonia sclateri*, the Puerto Rican Euphonia. Our study explores potential differences between male and female vocalizations, highlighting the apparent complexity of female songs. During the rainy season in September 2022 in Puerto Rico's Guánica State Forest, we recorded songs of one male and one female, the latter of which had not been previously reported in *C. sclateri*. We plotted the values for the acoustic variables from the male and female, revealing that the singing female exhibited more song elements and a higher element rate and sound density. These findings suggest potential differences in the complexity and structure of female *C. sclateri* vocalizations compared to males, highlighting the need for further investigation into the intricacies of communication within this species.

Keywords

behavior, bioacoustics, Caribbean, *Chlorophonia sclateri*, communication, female birdsong, Puerto Rico, Puerto Rican Euphonia

Resumen

Observación del canto de la hembra en *Chlorophonia sclateri* (Jilguero de Puerto Rico) • En la comunicación de las aves, los cantos desempeñan un papel vital, pero la documentación sobre el canto de las hembras sigue siendo escasa. Presentamos el primer registro de vocalización del canto de una hembra de *Chlorophonia sclateri* (Jilguero de Puerto Rico). Nuestro estudio explora las posibles diferencias entre las vocalizaciones de machos y hembras, destacando la aparente complejidad de los cantos de las hembras. Durante la temporada de lluvias de septiembre de 2022 en el Bosque Estatal de Guánica, Puerto Rico, grabamos los cantos de un macho y una hembra, siendo este último un caso no reportado previamente en *C. sclateri*. Representamos gráficamente los valores de las variables acústicas de ambos sexos, revelando que la hembra exhibió más elementos en su canto, así como una mayor tasa de elementos y densidad de sonido. Estos resultados sugieren posibles diferencias en la complejidad y estructura de las vocalizaciones de las hembras de *C. sclateri* en comparación con las de los machos; lo que resalta la necesidad de realizar más investigaciones sobre las complejidades de la comunicación dentro de esta especie.

Palabras clave

bioacústica, Caribe, *Chlorophonia sclateri*, comportamiento, comunicación, canto de las hembras, jilguero, Puerto Rico

Résumé

Enregistrement du chant d'une femelle de *Chlorophonia sclateri* (Organiste de Porto Rico) • Chez les oiseaux, les chants jouent un rôle essentiel dans la communication, mais les chants des femelles restent rarement documentés. Nous présentons le premier cas d'enregistrement du chant d'une femelle de *Chlorophonia sclateri* (Organiste de Porto Rico). Notre étude explore les différences potentielles entre les vocalisations du mâle et celles de la femelle, en soulignant la complexité apparente du chant de la femelle. Pendant la saison des pluies en septembre 2022 dans la forêt d'État de Guánica à Porto Rico, nous avons enregistré les chants d'un mâle et d'une femelle, le chant de la femelle n'ayant jamais été signalé auparavant chez *C. sclateri*. Nous avons tracé les valeurs des variables acoustiques du mâle et de

la femelle, révélant que la femelle présentait des éléments de chant plus nombreux ainsi qu'un taux d'éléments et une densité sonore plus élevés. Ces résultats suggèrent des différences potentielles entre la femelle et le mâle de *C. sclateri* en matière de complexité et de structure des vocalisations, soulignant la nécessité d'une étude plus approfondie des subtilités de la communication au sein de cette espèce.

Mots clés
bioacoustique, Caraïbes, chant d'oiseau femelle, *Chlorophonia sclateri*, communication, comportement, Organiste de Porto Rico, Porto Rico

In the complex world of avian communication, songs are pivotal, serving many functions vital to survival and reproductive success. Avian songs not only facilitate mate attraction and territorial defense, but also underpin complex social interactions and convey critical information about the environment. Song was originally attributed only to the male birds (Odom and Benedict 2018), however, there is evidence that this behavior is also widespread in females (Odom *et al.* 2014, Odom and Benedict 2018, Riebel *et al.* 2019). Female song is overall poorly documented (Odom and Benedict 2018, Riebel *et al.* 2019), and generally dismissed as rare. This reflects a geographical bias towards more temperate regions (Odom *et al.* 2014), whereas singing by both sexes is more common in the tropics (Odom and Benedict 2018).

On Puerto Rico, female song has been reported for at least three endemic species including *Icterus portoricensis* (Puerto Rican Oriole; Campbell *et al.* 2016), *Setophaga adelaidae* (Adelaide's Warbler; Andersen 2006), and *Agelaius xanthomus* (Yellow-shouldered Blackbird; Odom *et al.* 2014). Additionally, females of other species on the island are known to sing, including *Quiscalus niger* (Greater Antillean Grackle) and *Setophaga petechia* (Yellow Warbler), as well as the non-native *Icterus icterus* (Venezuelan Troupial; Odom *et al.* 2017) and *Molothrus bonariensis* (Shiny Cowbird; Webb *et al.* 2016). Here we document the song of *Chlorophonia sclateri* (Puerto Rican Euphonia), a recently recognized endemic species, formerly part of the *C. musica* complex (Chesser *et al.* 2023).

In this species, both males and females vocalize (Ríos-Franceschi 2021), however, documentation of female song has not been previously published in a peer-reviewed journal. Other *Chlorophonia* species, such as *C. elegantissima* (Elegant Euphonia) and *C. cyanocephala*, (Golden-rumped Euphonia) have records of female song (Garrigues 2021 and Corrêa 2021, respectively). Although there are multiple recordings of *C. sclateri* available in the Macaulay Library and on xeno-canto.org, they attribute songs to males or lack sex-specific data. Our recording of a female singing (Costas Sabatier 2022) is the first documented for this species. The occurrence was documented during an observational survey for research focused on the song structure of *C. sclateri*. We sexed individuals based on coloration; both sexes have a distinctive blue cap, but females are mostly olive green while males are black and dark blue across the wings, upper sides, and head (Greeney 2023). We are confident that the bird we observed and recorded was a female for two reasons. First, although there are no details on molt pattern for this species, Wetmore (1916) stated that most adults were done molting by mid-August and the observation occurred in mid-September; any adult sexual dimorphism would have been evident by then. Second, the observed bird did not look to be molting into male plumage, as seen in other presumed first year males (Greeney 2023), so it was not a young male. We compared the recorded songs with recordings from a male individual obtained three days prior.

Methods

Field observations

Recordings were collected during the rainy season in September 2022 in the Guánica State Forest in Puerto Rico. At the site, a pair of *Chlorophonia sclateri* was sighted foraging. Their vocalizations were recorded with a Zoom H-6 handy recorder and an ultra-directional shotgun microphone. After approximately 2 min of recording, the pair flew to a tree on the opposite side of the trail. Soon afterwards the male left the area, after which the female climbed towards the top of the tree to an exposed patch, where she started vocalizing.

Analyses

The male and the female recordings were analyzed using Raven Pro from the Cornell Lab of Bioacoustics, Cornell University (Figs. 1 and 2). From each recording, we extracted the number of notes (elements), total time (s), and 90% duration (s) from each song. For the elements we also extracted start time (s) and end time (s) to calculate element duration and 90% element duration (s). Subsequently, we were able to calculate the element rate (number of elements / 90% duration of song) (Wilkins *et al.* 2020) as well as the sound density ([Σ 90% element duration / 90% duration of song] × 100) (Dudouit *et al.* 2022). Although both total time and 90% duration were extracted, we used 90% duration to account for any human error in the measurements of the song spectrogram and waveform. Mean 90% song duration, number of elements, and element rate were compared to a subset of songs from a *Chlorophonia sclateri* male recorded in the same location (Fig. 2) using bar graphs with standard error of the mean calculated using the R packages ggplot2 (Wickham 2016) and plotrix (Lemon 2006).

Results

A total of 48 songs were analyzed for acoustic variables, from which we calculated means. The female produced 19 songs in 82.5 s, with a mean 90% duration of 2.0 s per song, and a maximum of 73 elements, an average of 44.7 elements, and a minimum of 16 elements per song (Appendix A). Our results showed that this female produced songs with more elements, a higher element rate, and a higher sound density than the male recorded at the same site three days prior (Appendix B). When we plotted the values for acoustic variables for the male and the female, we noted that the average value for the female was higher in three out of four characteristics. The female and the male produced 45 and 35 song elements, respectively (Fig. 3A),

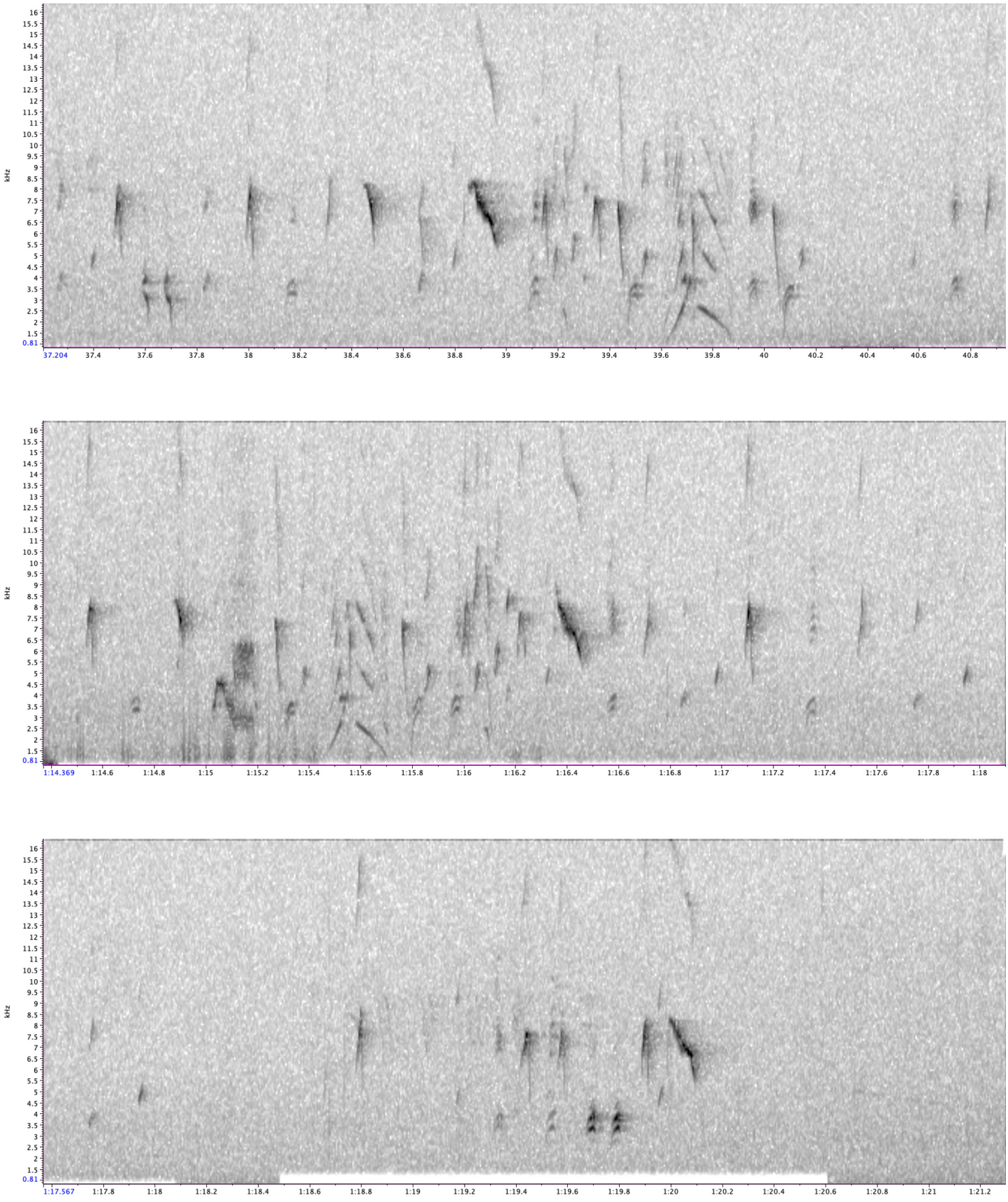

Fig. 1. Spectrograms of female *Chlorophonia sclateri* song recorded on 14 September 2022 in the Guánica State Forest. The y axis represents the frequency in Kilohertz (kHz) and the x axis represents the duration of the recording (mm:ss). From top to bottom: Song 3, Song 11, Song 13.

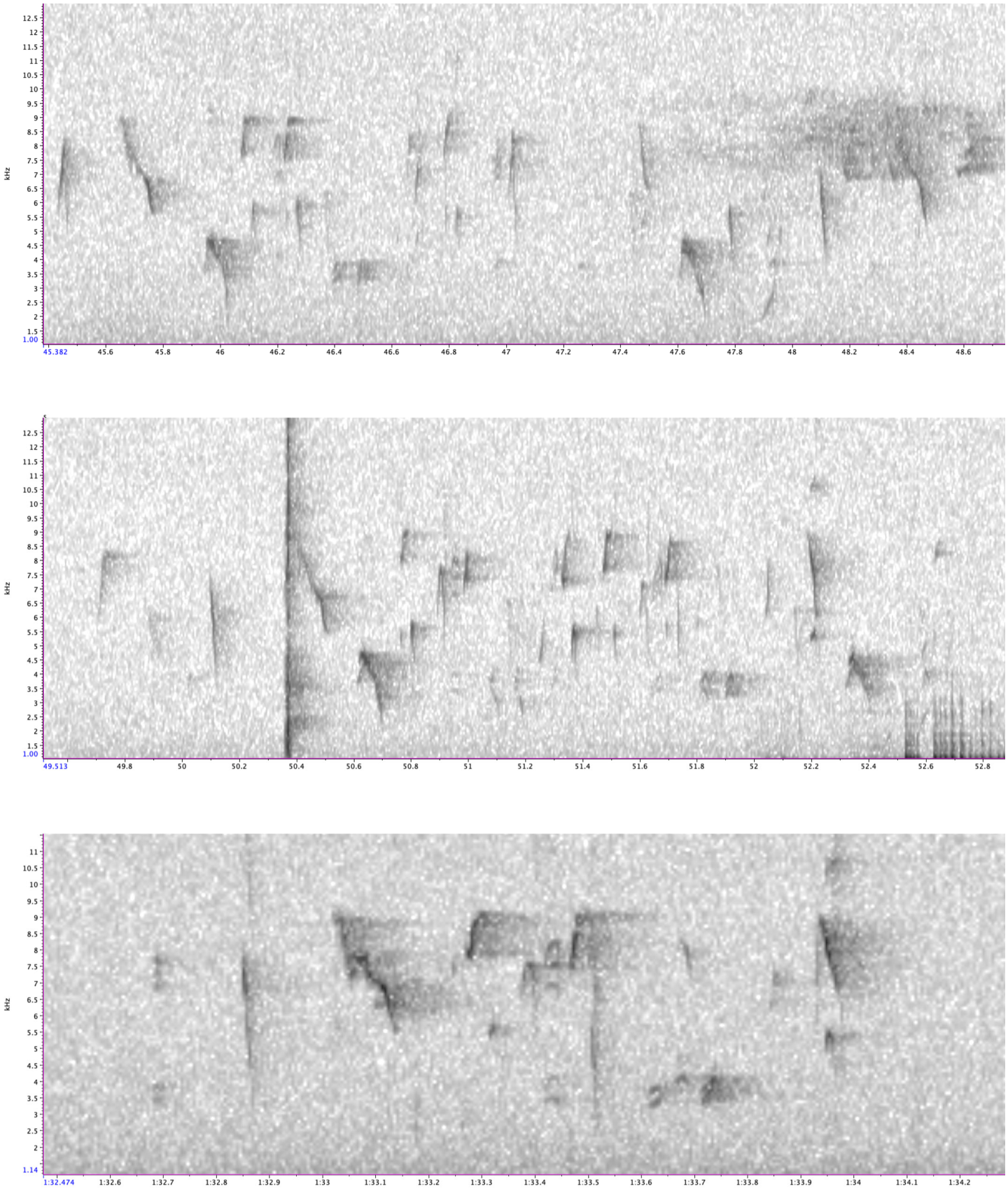

Fig. 2. Spectrograms of male *Chlorophonia sclateri* song recorded on 11 September 2022 in the Guánica State Forest. The y axis represents the frequency in Kilohertz (kHz) and the x axis represents the duration of the recording (mm:ss). From top to bottom: Song 3, Song 4, Song 22.

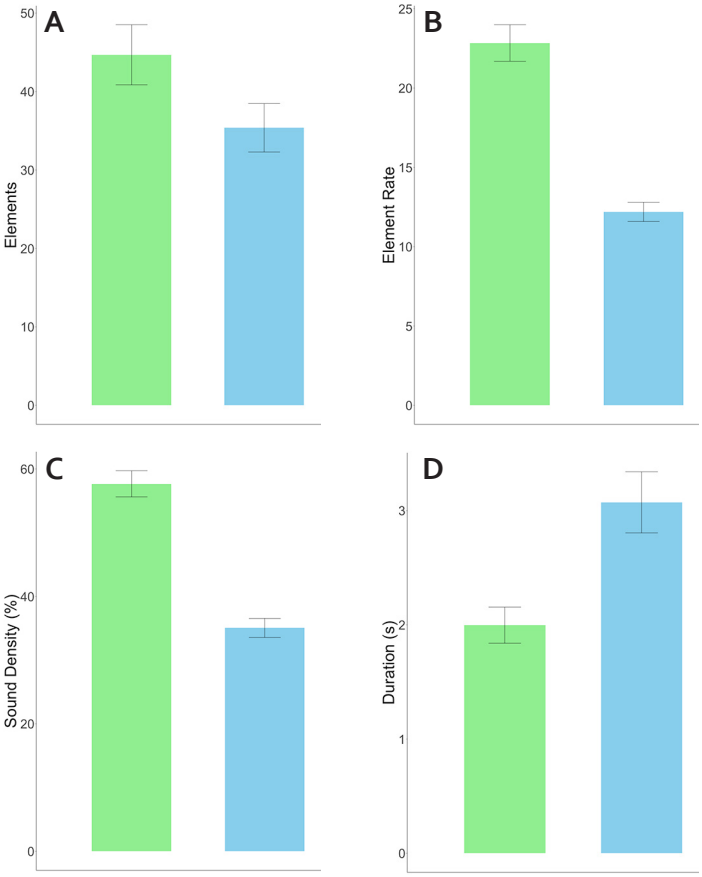

Fig. 3. Song characteristics of one female (green, *n* = 19) and one male (blue, *n* = 29) *Chlorophonia sclateri*. (A) Mean number of song elements; (B) mean song element rate; (C) mean song sound density; (D) mean 90% song duration. Standard error (± SE) is shown.

the element rate was higher in the female with approximately 23 elements per s (Fig. 3B), and the male showed 20% lower sound density than the female (Fig. 3C). The only characteristic in which the female had a lower value was in 90% duration (Fig. 3D), with a mean 90% duration of 2 s per song compared to 3 s per male song (Appendices A, B).

Discussion

The study of avian communication, particularly songs, is crucial for understanding the intricate dynamics of species interactions, mate selection, and overall survival strategies in birds (Byers and Kroodsma 2016, Schraft *et al* 2017, Odom and Benedict 2018).

Historically, bird song has been predominantly attributed to male birds, with their vocalizations often linked to mate attraction and resource defense (Odom *et al.* 2014, Byers and Kroodsma 2016, Odom and Benedict 2018). However, recent research has challenged this notion, revealing that female birds also engage in song production, albeit with varying degrees of prevalence across different geographic regions (Odom *et al.* 2014, 2016).

Female song is underrepresented in online collections, and when present, recordings might be missing sex data. Furthermore, the acoustic parameters are not analyzed, in contrast to our recordings. Our observation provides evidence for the presence of song in female *Chlorophonia sclateri*. Although our preliminary analyses suggested differences in song (element rate, sound density, duration, and notes) between sexes, the recordings analyzed did not represent the full variation due to low sample size (one male and one female). Continued research, with increased sample size and sex-specific banding will allow us to obtain a representative view of the variation in songs between male and female *Chlorophonia sclateri*. Nonetheless, our documentation of this song by a female sets a precedent that could help mitigate biases in future recording.

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Author Contributions

MCS observed and recorded the individuals. MCS annotated and analyzed the recordings. ARF supervised the annotation and analysis process. Field materials used were from the ARF Lab. MCS prepared the intial manuscript draft. ARF reviewed and edited the manuscript. Both authors edited and approved the submitted version.

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Appendix A. Measured traits of annotated songs of one female *Chlorophonia sclateri*, recorded on 14 September 2022 in the Guánica State Forest, Puerto Rico (Macaulay Library catalog number ML609987555). Means with Standard Deviation (± SE) is shown. See Methods for details.

Female Song	Element Number	Element Rate	Sound Density	90% Duration
1	73	27.10	58.36	2.69
2	51	29.68	67.86	1.72
3	43	21.23	56.41	2.03
4	39	21.33	44.84	1.83
5	63	28.71	19.86	2.19
6	52	19.95	27.09	2.61
7	53	19.22	27.94	2.76
8	71	25.01	30.19	2.84
9	48	19.55	26.25	2.46
10	52	21.69	29.15	2.40
11	66	21.95	35.70	3.01
12	43	18.99	28.15	2.26
13	16	21.53	43.30	0.74
14	35	23.28	45.60	1.50
15	29	16.38	36.51	1.77
16	26	18.58	34.85	1.40
17	43	22.79	28.61	1.89
18	25	19.23	44.77	1.30
19	21	37.68	24.46	0.56
Mean	44.68 ± 3.83	22.84 ±1.15	57.66 ± 2.05	2.00 ± 0.16

Appendix B. Measured traits of annotated songs of one male *Chlorophonia sclateri*, recorded on 11 September 2022 in the Guánica State Forest, Puerto Rico (Macaulay Library catalog number ML632119171). Means with Standard Deviation (± SE) is shown. See Methods for details.

Male Song	Element Number	Element Rate	Sound Density	90% Duration
1	25	9.47	31.19	2.64
2	57	9.84	31.15	5.79
3	31	9.64	33.92	3.22
4	37	18.69	44.84	1.98
5	21	7.73	19.86	2.72
6	54	10.59	27.09	5.09
7	48	10.10	27.94	4.75
8	57	12.79	30.19	4.46
9	21	7.61	26.25	2.41
10	35	12.13	29.15	2.89
11	29	11.59	35.70	2.50
12	19	11.52	28.15	1.65
13	51	11.75	43.30	4.34
14	15	11.91	45.60	1.26
15	50	15.06	36.51	3.32
16	42	12.81	34.85	3.28
17	75	13.70	28.61	5.47
18	64	12.22	44.77	5.24
19	26	6.30	24.46	4.13
20	15	10.29	30.66	1.46
21	34	13.72	38.38	2.48
22	20	15.66	39.97	1.28
23	9	16.67	50.51	0.54
24	11	20.82	47.21	0.53
25	41	13.79	42.20	2.97
26	40	13.73	42.20	2.91
27	36	11.48	33.50	3.13
28	29	6.85	26.19	4.23
29	34	14.01	47.10	2.43
Mean	35.38 ± 3.08	12.19 ± 0.61	35.05 ± 1.49	3.07 ± 0.27