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Call variation in mixed-species and single-species flocks of the common Chlorospingus in Monteverde, Costa Rica

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ABSTRACT

The Common Chlorospingus (*Chlorospingus flavopectus opthalmicus)* is a common highland bird found from Mexico to Bolivia that travels and forages in mono-especific and mixed-species flocks. When foraging in mixed-species flocks, the Common Chlorospingus plays an integral role as a nuclear species and forages primarily for arthropods instead of fruit. The purpose of this study was to determine whether or not there is a difference between chlorospingus chip calls in mixed species versus single species flocks, and if there is then to explore why they exhibit this difference. I recorded the calls of *C. ophtalmicus* both in single species and in mixed species flocks and analyzed them using Raven Pro 5.1 sound analysis software. I found that the calls of the common chlorospingus in mixed-species flocks had lower high frequency, a smaller frequency range, and longer call duration than in single species flocks. These findings lean toward support of the Acoustic Adaptation Hypothesis, which states that animals can adjust their calls to best suit their environment. Chlorospingus in mixed flocks might lower their calls in order to increase sonic transmission, in response to denser vegetation when arthropod foraging, more background noise from other bird species, or increased flock size. The influence of these three factors on chlorospingus calls should be further studied to better understand the effect that different foraging strategies can have on *C. ophtalmicus* calls.

Variacion de llamados de Chlorospingus f. opthalmicus en bandadas mixtas y bandadas intra-específicas

RESUMEN

Chlorospingus ophtalmicus es una ave común que habita en las montañas desde México hasta Bolivia. Esta especie usualmente forrajea en bandadas intra-específicas e inter-específicas, estas últimas conocidas como bandadas mixtas. Mientras forrajea en bandadas mixtas, *C. ophtalmicus* juega el papel de especie núcleo de la bandada y presenta cambios en su comportamiento habitual, por ejemplo forrajear en busca de artrópodos en vez de frutos. El propósito de este estudio fue determinar si existe una diferencia entre los llamados de esta especie cuando se encuentra en una bandada intra-específica y una bandada mixta, y en caso de existir una diferencia explorar las posibles causas de la misma. Grabé llamados de *C. ophtalmicus* mientras forrajeaban en bandadas intra-específicas y mixtas, y analucé los cantos utilizando el programa de análisis de audio Raven Pro 5.1. Encontré que los llamados de esta especie en bandadas mixtas presentaron menor frecuencia alta, menor rango de frecuencia y mayor duración de llamado que en bandadas intra-específicas. Estos resultados podrían sugerir que los llamados cambian en las bandadas mixtas para optimizar la transmisión del sonido en estratos con mayor densidad vegetal mientras forrajean por artrópodos. Otras posibilidades son que *C. ophtalmicus* cambie sus llamados en respuesta a los llamado de las otras especies dentro de la bandada o al tamaño de la bandada. La influencia de estas variables sobre los llamados de *C. ophtalmicus* deberían ser estudiados a futuro y así llegar a comprender mejor los efectos de diferentes tipos de forrajeo sobre los llamados.

Also known as the Common Bush Tanager, the Common Chlorospingus (*Chlorospingus flavopectus opthalmicus)* is a common highland bird found from Mexico to Bolivia (Weir *et al.* 2008). They are found in both single-species flocks (exclusively Common Chlorospingus), where they mainly forage for fruit, and mixed-species flocks, where they forage for insects (Valburg 1992). Mixed-species flocking, commonly observed in temperate and tropical habitats, is a feeding behavior in which multiple bird species forage in a single group. It is extremely beneficial to birds' foraging success, increasing duration of feeding bouts as well as protection from predators (Rubenstein *et al.* 1977, Mönkkönen *et al.* 1996, Thiollay 1999). Studies have also been shown that flock members can enhance their foraging success by learning from or mimicking other flock members' foraging behavior (Moynihan 1962, Krebs 1973). When in mixed-species flocks, chlorospingus fulfill an important role as a nuclear species, holding the flock together, coordinating foraging activity, and providing anti-predator vigilance (Sridhar *et al.* 2009).

There are many purposes of bird calls, but in foraging situations, they are most likely used for species recognition, coordinating and holding together the flock, and relaying information about food (Marler 2004). I observed the Common Chlorospingus making short chip calls in both single-species and mixed-species flocks. Based on their differences in behavior between the two types of flocks, I speculated that their calls might reflect these differences. The ability for birds and other animals to vary their calls has been supported by studies based on the Acoustic Adaptation Hypothesis (Morton 1975), which states that animals can adjust their calls to best suit their environment. Environmental reasons that have been studied are primarily vegetation thickness and background noise (Mockford 2009). My study is to find out if and how their call varies between mixed-species (MS) and single-species (SS) flocks.

MATERIALS AND METHODS

Field Procedure

I recorded flocks in Monteverde at three locations: La Estación Biológica, Curi-cancha Reserve, and the road up to the Monteverde Cloud Forest Reserve. All locations are above 1400 meters in elevation in tropical cloud forest. I recorded using a Sennheiser directional microphone and an Olympus LS-12 Linear PCM Recorder, recording their calls as long as I could before the flock became inaccessible. I located and identified the Chlorospingus and, in mixed-species flocks, other bird species.

Computer Analysis Procedure

On Raven Pro 1.5 (Bioacoustics Research Program), I located the Chlorospingus elements on the spectrogram. An element refers to a single call and a spectrogram is the visual representation of the recording that I used to measure and collect the calls. For each element there is a fundamental frequency and its harmonic frequencies, which are higher frequency components of the fundamental frequency. For each call I measured the harmonic that contained the maximum frequency of the entire element in order to best reflect the actual pitch that would be heard in nature (Figure 1). Maximum frequency refers to the most intense relative frequency. For each element's harmonic that contained the maximum frequency, I measured highest frequency, lowest frequency, maximum frequency, delta frequency, and delta time (call duration, Figure 2). I used R Statistical Software to test for differences between calls in mixed and single-species flocks. I used NMDS (Non-metric Multi-dimensional Scaling) to find the relative similarities between each flock in relation to the five element measurements.

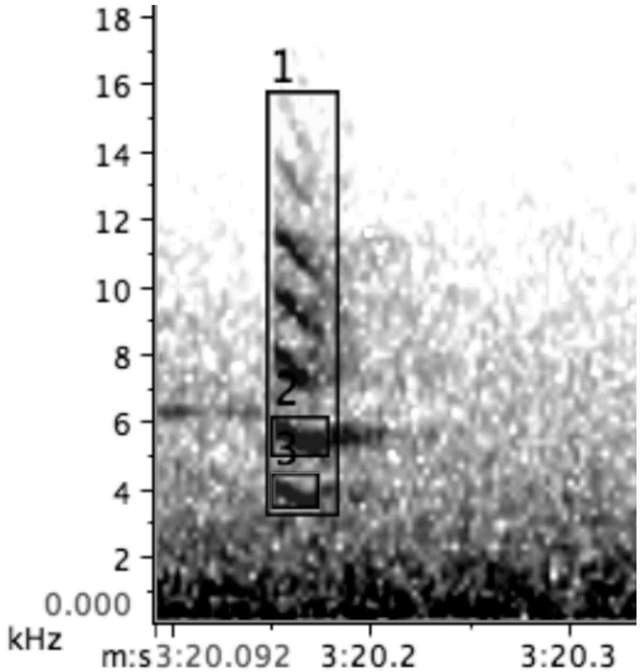

Figure 1. Example of Chlorospingus call element in Raven Pro. X-axis is time in seconds and Y-axis is frequency in KHz. Box 1 surrounds Entire element: includes fundamental and harmonic frequencies. Box 2 surrounds harmonic that contains max frequency of entire element. This harmonic was the focus of the study. Box 3 surrounds fundamental frequency. In many elements, the max frequency would be in the fundamental frequency.

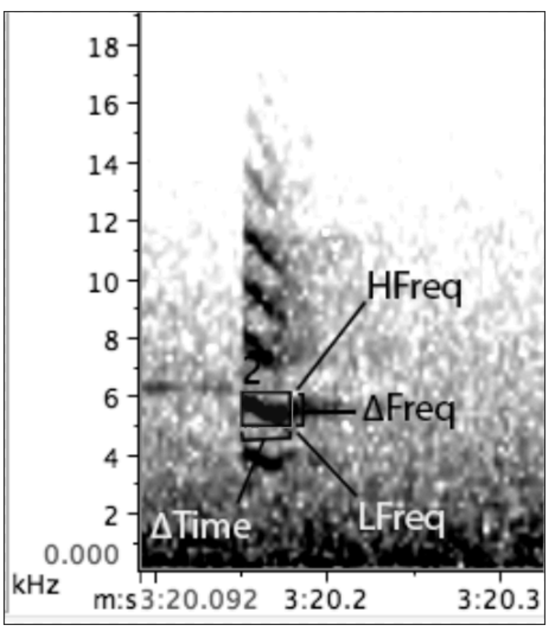

Figure 2. Example of chlorospingus call element in Raven Pro. Shows which measurements were taken and how they are represented on the spectrogram. (Max freq. isn't labeled, but would be a point value somewhere inside the box.)

RESULTS

I recorded a total of 737 call elements between 8 flocks, distributed among four mixed-species and four single species flocks (Table 1). Foraging behavior matches the results found in Valburg's study in 1992: single-species flocks foraged for fruit while mixed-species flocks foraged for insects. All flocks were found in the forest, except two single-species flocks that were foraging in fruit trees at the forest edge and in open grassy areas.

Table 1. General information for each flock of chlorospingus observed and recorded in Monteverde. Note: Estación=La Estación Biológica; Chloro=Chlorospingus. MVRR=Monteverde Reserve Road. Averages are given for numerical categories.

Kind	Date	Time	Rec. Time	# Elements	Location	Foraging	#Chloro
MS1	22/11/16	13:12	11:48	28	Estación	Insects	3
MS2	25/11/16	09:20	04:01	147	Estación	Insects	5
MS3	30/11/16	10:25	04:01	52	Curi-cancha	Uncertain	3
MS4	1/12/16	10:30	08:05	90	MVRR	Insects	4
SS1	22/11/16	12:44	11:16	81	Estación	Uncertain	3
SS2	25/11/16	11:46	08:05	129	Estación	Fruit	4
SS3	30/11/16	11:00	05:59	70	Curi-cancha	Uncertain	6
SS4	1/12/16	09:15	13:26	144	MVRR	Fruit	7
			Avg=9:33	Avg=92.6			Avg=4.37

In the mixed species flocks, I recorded the number and species of birds. The flocks ranged from two to eight different species, all of which were present and active in the flock (Table B). Migratory warblers were the most common bird to find with the chlorospingus. I did not include birds that were in the vicinity but not part of the mixed flock, including Coppery-Headed Emeralds, Brown Jays, Mountain Thrushes, and any other birds that were present but not actively involved in the flock (foraging for insects). In total, I observed 16 other species (Appendix 1).

When comparing mixed-species versus single-species flocks, there is a significant difference between their calls ($F_{29,167}$,=1, 734, p<0.001). These differences occurred in the high frequency, delta frequency, and time. Compared to single-species flocks, calls in mixed-species flocks had a lower high frequency, a smaller frequency range, and longer elements (Table 3). There was also a difference in calls between each flock. ($F_{10, 793}$=7, 728, p<0.001; Table 4).

Table 3. Average values of call elements for single species vs. mixed species flocks. Significantly different variables between mixed and single-species calls were Hfreq, ΔFreq, and ΔTime.

Type	Lfreq (KHz)	Hfreq (KHz)*	ΔFrequency(KHz)*	Max Frequency (KHz)	ΔTime (s)*
Single	5515.2±1804.3	7044.3±2232.6	1529.2±682.4	6385.7±2000.8	0.049±0.018
Mixed	5439.2±1513.7	6730.4±1697.5	1291.2±447.3	6184.2±1599.6	0.063±0.033

An NMDS analysis comparing the calls of the eight individual flocks showed that three of the four mixed flocks are clustered close to each other on the graph, which shows that they are more similar: M4, M2, and M1 which are most related by delfreq (delta frequency). The single species flocks are more spread in the spectrum, with a slight cluster around lfreq (low frequency), maxfreq (maximum frequency), and hfreq (high frequency) (Fig. 3).

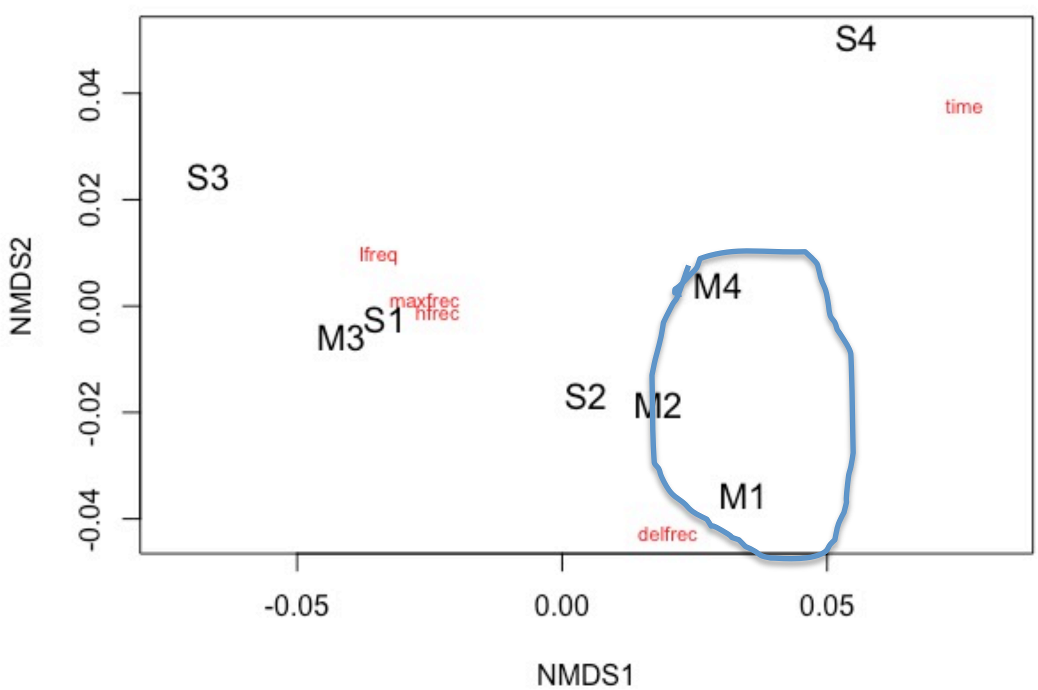

Figure 3. NMDS graph shows similarities between flocks and which factors (red words) most influence relatedness. Mixed-species flocks 1, 2, and 4 are clustered, showing similarity to each other. Delta frequency seems to most influence their similarity.

Table 4. Average values of call elements for individual flocks.

Type	Lfreq (KHz)	Hfreq (KHz)	ΔFrequency(KHz)	Max Frequency (KHz)	ΔTime (s)	Location
MS1	4909.8±1210.9	6639.3±1501.6	1729.5±498.5	5973.9±1289.0	0.051±0.018	Estación
MS2	5566.9±1758.5	7236.3±1938.3	1669.3±556.9	6522.7±1870.3	0.054±0.026	Estación
MS3	5705.3±1340.2	7071.0±1518.1	1365.7±347.9	6539.5±1420.2	0.040±0.040	Curi-cancha
MS4	4951.9±1900.0	6332.6±2525.5	1380.7±845.6	5805.3±2237.6	0.055±0.018	MVRR
SS1	6422.0±1587.4	7911.0±1859.8	1489.0±620.1	7110.5±1717.6	0.048±0.027	Estación
SS2	5103.6±1637.5	6540.4±1881.2	1436.8±416.8	5974.5±1718.3	0.047±0.011	Estación
SS3	5737.1±1810.5	6801.7±2083.5	1064.7±566.1	6327.1±1956.0	0.036±0.017	Curi-cancha
SS4	5478.4±1413.2	6783.3±1523.7	1304.9±352.6	6204.0±1478.8	0.081±0.017	MVRR

DISCUSSION

Analysis of the data found that calls in mixed-species flocks tend to have a significantly lower frequency. A lower frequency call in mixed-species flocks may likely occur in order to increase call transmission. This hypothesis reflects the Acoustic Adaptation Hypothesis (AAH), stating that animals can adapt their call to best suit the habitat they are in (Morton 1975). Lower frequencies tend to be favored because they are physically able to travel further and be less degraded by physical obstacles than higher frequencies. Higher frequencies have shorter wavelengths, which are more easily absorbed by molecules in the air and in solid objects, such as plant matter. I present three different factors that may cause Chlorospingus to lower their calls in mixed-species flocks: habitat, background noise, and flock size.

Two of the single-species flocks were found in relatively open habitat, eating guavas and figs at the forest edge. Contrarily, all mixed-species flocks were found inside the forest, which had denser vegetation. It is also possible that in mixed-species flocks, Chlorospingus forage in denser foliage where arthropods are more abundant, and in single-species flocks they either find fruit at the forest edge or in the upper contours of fruit trees, where there is more fruit and less physical obstacles that could degrade their calls. It was found that birds do tend to have higher frequency calls in more open areas and lower frequency calls in more closed areas (Boncoraglio 2006). In order to test these trends, habitat type, including vegetation density, should be considered in future research. Besides predicting lower frequency calls in denser vegetation, he AAH also predicts narrower frequency range and longer inter-element intervals. These two factors should also be studied in order to determine whether habitat type influences Chlorospingus call variation.

Background noise (the noise of the other bird species) could also be a possible reason for the Chlorospingus' lower calls in mixed-species flocks. If the other species' calls are originally higher or similar to the Chlorospingus' calls, the Chlorospingus would benefit from lower their call in order to prevent sonic interference. Lower calls could be more easily distinguishable from other calls and more audible for Chlorospingus and the other species. Studies have shown that birds can adapt their call in response to sonic disturbances by both increasing volume and changing pitch (Nemeth 2010, Mockford 2009). When collecting data on the spectrogram, I noticed that other bird species' calls were often a higher frequency or similar frequency as the Chlorospingus calls. This data should be collected and analyzed in order to test for effect of background noise on Chlorospingus calls in mixed-species flocks.

Chlorospingus may lower their calls as flocks get larger and their calls need to travel further in order to be heard by other flock members. Mixed-species flocks seemed to be larger and more spread out than single-species flocks, which seemed much denser. The density of single-species flocks could be due to their food target of fruit, which is found in denser patches than arthropods. Single-species flocks also seemed to have more coordinated and efficient flocking behavior. It is possible that when they are by themselves they are better able to coordinate flocking, which allows them to be closer to each other and in turn allows them to hear less transmittable, higher frequency. I have not found any studies on flocking coordination between single-species and mixed-species flocks. Studies should be done to determine the energy cost of high versus low frequencies. A lower energy cost for high frequency calls would support this hypothesis. Flock size should be considered in future research to determine reasons for differences in Chlorospingus calls in mixed-species and single-species. Also, overall flock size could be compared to number of Chlorospingus to see if they try to increase transmission for only their own species or the entire flock.

The ability of the Common Chlorospingus to vary their calls, not just between single-species and mixed-species flocks but between populations and individuals, shows that there are some mechanisms at play, whether it is related to sound transmission, population variation, individual variation, or something else. In order to control for possible natural variation between populations, future research, if possible, should record the same flock both in a mixed-species and single-species flock. More flocks should also be recorded to increase sample size, which may end up revealing a more noticeable trend. While lower frequency in mixed-species flocks was the focus of this discussion, ideas about the significant differences in delta frequency and call duration (delta time) should be further developed and studied.

Further research and development of the reasons behind Chlorospingus call variation will help us to understand Chlorospingus behavior, as well as the dynamics of mixed-species flocks and the purpose of birdcalls during foraging. Studying mixed-species flocks from an acoustic perspective may provide insight into the importance of nuclear species for the success of a mixed-species flock and their impact on flock member fitness. As temperatures rise at higher elevations due to climate change, highland habitats such as tropical cloud forest are shrinking, with lowland climates and organisms coming in to take their place (Foster 2001, Pounds 1999, Böhning-Gaese 2004). The shrinkage of highland habitat could negatively impact Chlorospingus populations as well other bird species that may rely on the Chlorospingus as a nuclear species, and the more we study the more we may understand how to combat the effects of climate change and preserve biodiversity.

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APPENDICES

Appendix 1. Other species present in each of the mixed flocks.

Flock	MS 1	MS2	MS 3	MS 4
Warbling Vireo	1			
Golden-winged Warbler	1	3		
Black-throated Green Warbler		2		
Black-and-white Warbler		1		2
Mountain Elaenia		1		2
Brown-capped Vireo		1		
Olivaceous Woodcreeper		1		
Prong-billed Barbet			3	
Three-striped Warbler			2	1
Tyrannid sp.			1	
Woodcreeper sp.			1	
Hermit Warbler				2
Slate-throated Redstart				2
Paltry Tyrannulet				1
Silver-throated Tanger				>2
Blue Dacnis				3
Total	2	6	4	8