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COMPARISONS BETWEEN AUTONOMOUS ACOUSTIC RECORDINGS AND AVIAN POINT COUNTS IN OPEN WOODLAND SAVANNA

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ABSTRACT.—In order to evaluate the possibility of using this method in the Brazilian Cerrado or other open vegetation areas, we compared the performance of point counts and autonomous recording units (ARU) for avian monitoring. From September to November 2012, we surveyed birds in 13 points established in six localities in central Brazil by using simultaneously ARU and point counts for species presence only comparisons. We identified a total of 84 species and found no significant differences between the number of species obtained by each method. Differing from what we initially expected, few records in point counts were obtained only by visual detection. The number of species registered by ARU corresponded to 90.4% of all observed species. About 92% of the recorded species sang at least once during point counts. Of all species recorded, 17% were not recorded by point counts and 10% were missed by ARU. Jaccard's index of similarity was 68%. Our results indicate that the ARU can be an effective method to sample bird assemblages in open vegetation areas, such as the Brazilian Cerrado, being as efficient as the point count proceeding is. The disadvantages of ARU have already been highlighted in the literature (huge data volume to process, high costs to acquire the equipment, malfunctioning and loss, among others), but we must add that missing visual contacts with species must be considered depending of the study's scope and the type of bird species in question. Nevertheless, the use of ARU can be a cost-effective method for long-term monitoring programs and also helps to quickly obtain the necessary data to characterize species assemblages associated with highly threatened ecosystems, such as the Brazilian Cerrado. *Received 11 July 2014. Accepted 24 April 2015.*

Key words: birds, Brazil, monitoring, savanna, SongMeter SM2+.

Point counts have been widely used to estimate bird richness and relative abundance and density of species (Bibby et al. 2000). This method consists of choosing a specified location and registering all species that can be detected and identified visually and/or acoustically in a sampling time unit varying from 3 to 20 min. When applying this survey technique, most bird records occur by acoustic detections (Blake 1992, Brandes 2008, Dawson and Efford 2009) especially if dense vegetation imposes some difficulty in observing individuals. Particularly, in tropical regions, high species richness makes it necessary for researchers to be very familiar with a large number of species (Blake 1992, Haselmayer and Quinn 2000), and their regional song variations. The number of individuals that may be singing simultaneously is also a challenge, because it is hard to separate sounds and to identify individuals in a short time (Celis-Murillo et al. 2009).

The use of autonomous recording units (hereafter ARU) is gaining increased importance as an aid in monitoring biodiversity acoustically. ARU methodology involves placing autonomous recorders programmed to record during hours of interest, such as dawn (Gil et al. 2014, Zwart et al. 2014). ARU is a useful technique in places where visibility of individuals is very limited and species richness is high (Acevedo and Villanueva-Rivera 2006). This method allows the researcher to sample many areas simultaneously, eliminating temporal differences between samples and reducing required time for fieldwork (Hobson et al. 2002, Buxton and Jones 2012). Reducing time spent in the field also reduces the observer's field costs. Some authors argue that costs associated with equipment acquisition are not advantageous (Hutto and Stutzman 2009), but they may be rewarded by the amount of data collected on several expeditions.

ARU does not require skilled observers in the field (Haselmayer and Quinn 2000, Hobson et al. 2002), and the absence of human influence reduces disturbance of activities and behavior of the birds being surveyed (Acevedo and Villanueva-Rivera 2006). A further advantage is that recordings obtained through ARU deployment create a permanent record of the studied site (Haselmayer and Quinn 2000, Acevedo and Villanueva-Rivera 2006, Celis-Murillo et al. 2009), providing information for several studies and future comparisons. The possibility of re-listening to the recordings

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TABLE 1. Summary of studies investigating differences between bird survey methods (i.e., human observers versus autonomous recording).

References	Equipment	Location and vegetation	Method performance
Haselmayer and Quinn (2000)	Portable cassette recorder and a highly directional microphone.	Peru (seasonal flooding areas, canopy height ranging from 35 to 40 m and closed canopy).	Equal
Hobson et al. (2002)	Digital recorder, one omni-directional microphone and two directional microphones.	Canada (Boreal mixed-wood Forest)	ARU better
Acevedo & Villanueva-Rivera (2006)	Manual recorder, one omni-directional microphone and a custom-made controller.	Puerto Rico (mangrove/brackish-forested wetland)	ARU better
Celis-Murillo et al. (2009)	Manual recorder fixed in a point and 4 omni-directional microphones.	USA- California (Cottonwood-Willow Riparian Forest- composed of tall trees, dense understory and almost full canopy cover- and Southern Willow Scrub- composed of dense stands of shrubs, found in and near stream channels.	ARU better
Hutto and Stutzman (2009)	SONGMETER SM1 (two omni-directional microphones)	USA- Montana (green mixed-conifer forest, burned mixed-conifer forest, and mixed riparian cottonwood bottomland)	Humans better
Venier et al. (2012)	SONGMETER SM1 (two omni-directional microphones)	Boreal forest	Equal
Celis-Murillo et al. (2012)	Manual recorder fixed in a point and 4 omni-directional microphones.	Yucatan Peninsula of Mexico (coastal dune scrub, mangrove, low-stature deciduous thorn forest, early and late successional medium-stature semi evergreen forest, and grazed pastures).	Equal
Zwart et al. (2014)	SONGMETER SM2+ SM1 (two omni-directional microphones)	UK – Northumberland (coniferous woodland, heather moorland, and a small amount of deciduous woodland)	ARU better

reduces errors in species identification and reduces the variation of identifications when multiple observers are involved (Hobson et al. 2002, Brandes 2008, Celis-Murillo et al. 2009). Conversely, the technique requires more time and effort to process data (Hutto and Stutzman 2009), species that seldom vocalize can be missed, and some species may remain unidentified due to the absence of visual cues when producing only short calls (Acevedo and Villanueva-Rivera 2006).

Studies aiming to investigate possible differences between bird survey methods (i.e., point counts versus autonomous recording) are increasing in number, but there is no consensus with results, which may be caused by differences in equipment used, by differences in vegetation structure, or by richness and composition of the bird community itself (Table 1). In Haselmayer and Quinn (2000), point counts detected an overall higher total number of species (172) than ARU (160), although they found no statistically significant differences. They argue that sound recordings are preferred when richness is high, and point counts are preferred when the objective is to detect rarely heard species. In Hobson et al. (2002), estimates of abundance and presence-absence were similar between methods, but the authors recommend sound recording as an improvement over field methods. In Acevedo and Villanueva-Rivera (2006), ARU registered more species than point counts, producing better quantity and quality data. In Celis-Murillo et al. (2009), methods presented similar species richness and detection probabilities, but there were differences in species composition. Hutto and Stutzman (2009) conclude that human observers are slightly better than ARU, since the mean number of species detected in each point was greater for humans than for recorders, although they admit that ARU captured species that observers were not able to detect due to observer limitations or oversight. In Venier et al. (2012), the recorder detected fewer species than the field survey, but they conclude that methods worked equally well. The last two studies used the older

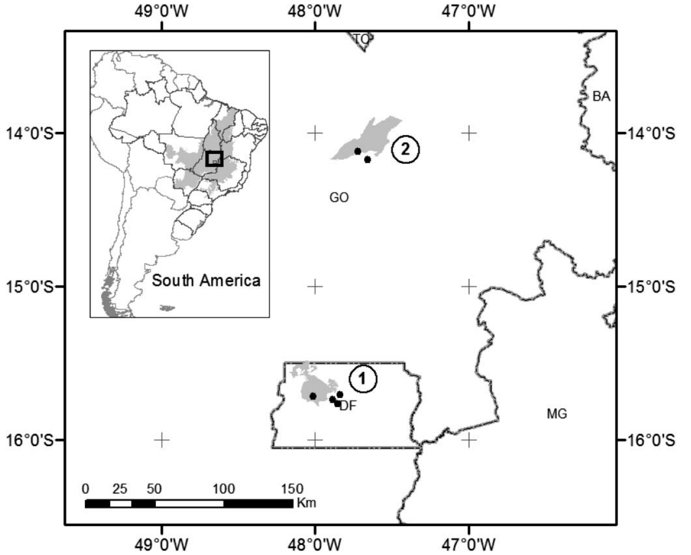

FIG. 1. Location of points sampled for this study. Number 1 corresponds to Federal District (DF) region and Brasilia National Park (gray area). Number 2 corresponds to areas in Goiás state (GO) and Chapada dos Veadeiros National Park (gray area). Points located outside these two large protected areas correspond to other sampled localities. The gray area on the South America map represents the limits of the Brazilian Cerrado.

version of recorder used here. Celis-Murillo et al. (2012) found similar species richness and composition for methods in different vegetation types, providing comparable results. More recently, Zwart et al. (2014) tested the method for nightjars and found that recorders detected the studied species better than human observers.

Here, aiming to evaluate the feasibility of using autonomous systems for avian monitoring in a tropical savanna, we compare the performance of ARU and point counts conducted by field observers in the Cerrado. The Cerrado is a tropical biome found mainly in Brazil and is considered one of 34 world biodiversity hotspots for conservation (Myers et al. 2000). It is a mosaic of natural vegetation types that varies from open grasslands to semi-deciduous or deciduous forests (Eiten 1972, Ribeiro and Walter 1998) where canopy cover can vary from zero in grasslands to 100% in forest formations. Cerrado *sensu stricto* is the most common physiognomy found in the biome and its canopy cover ranges from 40 to 60% (Ribeiro and Walter 1998). It includes scattered small, medium and high trees and comprises a rich avifauna of approximately 420 species, out of which 36 are endemic (Da Silva 1997, Marini and Garcia 2005).

Cerrado *sensu stricto* vegetation facilitates the visual identification of birds due to its spatial structure, characterized by relatively sparse trees mixed with small patches of grasslands. Because bird visual records in open vegetation are easier to make than in forests, we expect that point counts will record a higher number of species than ARU. Although expected differences for number of species recorded, we expect a high similarity in species composition of samples, since the lower number of species recorded by ARU must be caused by a lack of species in the ARU sample and not by different species being recorded.

METHODS

The study was conducted at Federal District (Brasília-DF) and Goiás state, Brazil, in Cerrado *sensu stricto* areas. A total of 13 points were sampled by ARUs and observers simultaneously, from September 2012 to November 2012. Sampling points were selected based on area characteristics, which were all located in Cerrado fragments with scattered medium high trees and shrubs. We chose the sampled points in two different regions in Central Brazil (Fig. 1), being 10 points in region 1 (Brasília, Federal District) and three points in region 2 (Alto Paraíso, Goiás state).

We used a SongMeter SM2+ (Wildlife Acoustics Inc., Maynard, MA, USA) , which is a waterproof ARU developed for long duration recordings of birds, anurans, mammals, insects and other wildlife acoustic signals. Although the ARU is a programmable device, we manually started the recordings in each point after the researcher (RDA) was ready to start the observation activity. We defined a sample rate of 44.1 kHz and 16 bits in stereo mode for all recordings. All data collected were archived as a compressed (.wac) format and stored at the Brasília University. These data are available by request for any interested researcher.

At each point, we made three 15 min ARU recordings (in the same day and observing a 10-min interval between samples), totaling 39 samples (three sample times, 13 points). Samples taken on the same point are not spatially independent, but consecutive recordings are useful to highlight how new species are added as more samples are taken. Simultaneously with each 15 min ARU recordings, one observer (RDA) conducted point counts, when, all seen and heard species were registered. The observer registered bird species as "seen", "heard" or "seen and heard". After conducting the recording and observation activities three times in a point, the observer moved to the other points established in each area (apart around 200 m from each other). Recordings were conducted during the first 2–3 hrs of day light, since this is the period during which most birds are vocally active (Blake 1992).

All point counts and ARU recordings were conducted and analyzed by the same observer (RDA) using Cool Edit Pro (Adobe Systems Inc., San Jose, CA, USA) and Philips SHL5500 headphones (Koninklijke Philips N.V., Amsterdam, the Netherlands). The observer has considerable previous experience in identifying species in the field by visual and acoustic cues. Identification for doubtful species was performed manually by comparing recordings with bird songs available on on-line bioacoustic libraries such as Xeno-Canto Foundation and Macaulay Library (Cornell University, Ithaca, NY, USA).

Paired *t*-test was performed using R 2.12.1 (R Core Team 2009) to compare the number of species detected by each method for each 15 min observation period. We were not able to include one 15 min unit in the final analysis because of recorder failure. Samples were compared in four different ways, comparing only the first, second or third sample of each point, and all 38 samples together. We took this approach to show that the second and third samples were not influenced by the previous one.

We calculated four sampling errors associated with the ARU and point count methods for each of the 38 samples. For the following formulas, variables are coded as (a) number of species detected by ARU, (o) number of species detected by observer (point counts), (t) total number of species detected by both methods, (h) number of species detected by observer (point counts), excluding detections made only by visual contact, (n) number of samples. Error values are presented as mean values of errors from all samplings.

Sampling errors associated with ARU were "recorder error 1", indicating the number of species detected by both methods but not detected by ARU:

$$\text{recorder error 1} = \frac{1}{n}\sum\left(1-\frac{a}{t}\right),$$

and "recorder error 2" indicating the number of species detected by the observer that were not detected by ARU:

$$\text{recorder error 2} = \frac{1}{n}\sum\left(1-\frac{a}{o}\right).$$

Sampling errors associated with the point count method were "observer error 1", indicating how many of species detected by both methods were not detected by observer:

$$\text{observer error 1} = \frac{1}{n}\sum\left(1-\frac{o}{t}\right),$$

and "observer error 2" indicating how many of the species detected by ARU were not detected by the observer:

$$\text{observer error 2} = \frac{1}{n}\sum\left(1-\frac{h}{a}\right).$$

For the last error, we excluded visual detections (i.e., detected by the observer), in order to compare species exclusively detected by sound in each method.

We identified differences in species composition detected by each method using *Jaccard's similarity index,* calculated on R 2.12.1 (R Core Team 2009). Based on species detection data, a Jaccard's index was calculated for each sample and values presented are mean values.

RESULTS

We identified 84 species in 968 records (Table 2). Out of 968 records, 81 species were detected in

TABLE 2. List of detected species (Species Lists of Birds for South America Countries and Territories). Columns represent points at which data was collected. Observation status are coded as (h) species only heard by observer; (s) species only seen by observer; (b) species both seen and heard by observer; and (a) species identified on ARU recordings (Names of species based on AOU list of 2014).

Family		Sample points												
Scientific name	Common name	1	2	3	4	5	6	7	8	9	10	11	12	13
Tinamidae														
Crypturellus parvirostris	Small-billed Tinamou	-	h,a	-	h,a	-	h,a	-	-	h,a	h,a	-	-	h,a
Rhynchotus rufescens	Red-winged Tinamou	-	h,a	h	-	h,a	-	-	-	-	-	h,a	h	h,a
Ardeidae														
Egretta thula	Snowy Egret	-	-	-	-	-	-	-	-	-	s	-	-	-
Threskiornithidae														
Mesembrinibis cayennensis	Green Ibis	-	-	-	-	b	s	-	-	-	-	-	-	-
Theristicus caudatus	Buff-necked Ibis	-	-	-	-	h,a	h,a	-	-	-	-	-	-	-
Cathatidae														
Coragyps atratus	Black Vulture	-	-	-	s	-	-	-	-	-	-	-	-	-
Accipitridae														
Geranoaetus albicaudatus	White-tailed Hawk	-	-	-	b,a	-	-	-	-	-	-	-	-	s
Rupornis magnirostris	Roadside Hawk	b,a	-	-	-	-	-	-	-	-	-	-	-	-
Falconidae														
Caracara plancus	Southern caracara	-	-	s,a	b,a	-	s	-	-	b,a	h,a	-	-	-
Falco femoralis	Aplomado Falcon	-	-	-	-	b,a	-	-	-	-	-	-	h,a	-
Rallidae														
Aramides cajaneus	Gray-necked Wood-rail	-	-	-	-	h,a	-	-	-	-	-	-	-	-
Cariamidae														
Cariama cristata	Red-legged Seriema	h	-	-	h,a	h	-	-	-	-	-	h,a	-	h,a
Charadriidae														
Vanellus chilensis	Southern Lapwing	-	-	-	h,a	-	-	-	-	-	-	-	-	-
Columbidae														
Columbina squammata	Scaled Dove	-	-	-	-	-	a	-	b,a	-	-	-	-	-
Patagioenas picazuro	Picazuro Pigeon	-	b,a	-	s	-	s,a	-	s	h,a	-	-	b,a	-
Psittacidae														
Amazona aestiva	Turquoise-fronted Parrot	-	h,a	h,a	-	b,a	-	-	-	h,a	-	-	b,a	-
Ara ararauna	Blue-and-yellow Macaw	-	-	-	-	-	-	-	-	-	-	-	-	h,a
Brotogeris chiriri	Yellow-chevroned Parakeet	b,a	-	-	b,a	h,a	h,a	h,a	b,a	b,a	b,a	-	-	-
Diopsittaca nobilis	Red-shouldered Macaw	-	-	-	-	-	-	-	-	-	-	-	h,a	-
Eupsittula aurea	Peach-fronted Parakeet	-	-	-	-	h,a	s,a	-	-	-	-	-	-	h,a

TABLE 2. Continued.

Family *Scientific name*	Common name	Sample points 1	2	3	4	5	6	7	8	9	10	11	12	13
Forpus xanthopterygius	Blue-winged Parrotlet	-	-	-	-	-	-	h,a	-	a	-	-	-	-
Orthopsittaca manilatus	Red-bellied Macaw	-	-	h	-	-	-	-	-	-	-	-	-	b,a
Cuculidae														
Crotophaga ani	Smooth-billed Ani	-	-	-	-	-	-	-	-	-	b	-	-	-
Guira guira	Guira Cuckoo	-	-	-	-	-	h,a	-	-	-	-	-	-	-
Tapera naevia	Striped Cuckoo	-	-	-	-	-	-	-	-	-	-	-	-	h,a
Trochilidae														
Amazilia fimbriata	Glittering-throated Emerald	-	-	h,a	-	h,a	s	-	-	-	-	-	-	-
Amazilia lactea	Sapphire-spangled Emerald	-	-	-	-	-	h,a	a	b,a	s,a	a	-	-	-
Colibri serrirostris	White-vented Violetear	-	-	-	-	h,a	-	-	-	-	-	-	-	-
Eupetomena macroura	Swallow-tailed Hummingbird	-	-	-	-	h,a	-	-	b,a	s	a	-	-	-
Bucconidae														
Nystalus chacuru	White-eared Puffbird	-	h,a	h,a	a	h,a	-	-	-	-	-	-	-	h,a
Nystalus maculatus	Spot-backed Puffbird	-	-	h	-	-	-	-	-	-	-	-	-	-
Ramphastidae														
Ramphastos toco	Toco Toucan	-	h,a	-	-	-	-	-	-	-	-	-	-	-
Picidae														
Campephilus melanoleucos	Crimson-crested Woodpecker	-	-	-	-	-	b,a	-	-	-	-	-	-	-
Colaptes campestris	Campo Flicker	-	h,a	-	b,a	a	h,a	-	-	h,a	-	-	-	h,a
Colaptes melanochloros	Green-barred Woodpecker	-	-	-	-	-	-	-	-	s	h,a	-	-	-
Melanerpes candidus	White Woodpecker	-	-	-	-	-	-	-	-	-	h,a	-	-	-
Thamnophilidae														
Thamnophilus torquatus	Rufous-winged Antshrike	-	h,a	-	b,a	-	-	-	-	-	b,a	-	-	-
Melanopareiidae														
Melanopareia torquata	Collared Crescentchest	-	h,a	-	-	h,a	-	-	-	-	-	h,a	-	-
Dendrocolaptidae														
Lepidocolaptes angustirostris	Narrow-billed Woodcreeper	-	h,a	h,a	-	-	-	-	-	-	-	h	h,a	h,a
Furnaridae														
Furnarius rufus	Rufous Hornero	-	-	-	h,a	h,a	h,a	h,a	h,a	h,b,a	h,a	-	-	-
Phacellodomus ruber	Greater Thornbird	-	-	-	-	-	-	-	a	-	-	-	-	-
Synallaxis albescens	Pale-breasted Spinetail	h,a	h,a	h	-	h,a	-	-	-	-	-	-	-	-
Tyrannidae														
Camptostoma obsoletum	Southern Beardless-tyrannulet	h,a	h	b,a	h,a	b,a	-	h,a	h,a	h,a	h,a	-	h,a	h,a
Elaenia flavogaster	Yellow-bellied Elaenia	-	-	-	h,a	-	-	h,a	h,a	h,a	h,a	-	-	-
Elaenia chiriquensis	Lesser Elaenia	h,a	b,a	b,a	h,a	h,a	b,a	-	b,a	b,a	b,a	-	b,a	b,a

TABLE 2. Continued.

Family *Scientific name*	Common name	Sample points 1	2	3	4	5	6	7	8	9	10	11	12	13
Elaenia cristata	Plain-crested Elaenia	b,a	h,a	h,a	h,a	b,a	b,a	-	-	-	h,a	h,a	h,a	h,a
Empidonomus aurantioatrocristatus	Crowned Slaty Flycatcher	-	-	-	-	-	-	b,a	-	-	-	-	-	-
Myiarchus swainsoni	Swainson's Flycatcher	h,a	h	-	-	-	-	-	-	h,a	-	-	-	a
Myiodynastes maculatus	Streaked Flycatcher	-	-	-	-	-	-	b,a	s,a	-	-	-	-	-
Suiriri suiriri	Suiriri Flycatcher	a	h	b,a	-	-	h,a	h,a	b,a	h,a	b,a	h,a	h,a	-
Todirostrum cinereum	Common Tody-flycatcher	-	-	-	-	-	-	-	a	-	-	-	-	-
Tyrannus melancholicus	Tropical Kingbird	-	-	-	b,a	s	h	b,a	h,a	-	h,a	-	-	-
Tyrannus savanna	Fork-tailed Flycatcher	-	-	-	b,a	h	b,a	h	-	-	-	-	-	-
Pitangus sulphuratus	Great Kiskadee	-	-	-	b,a	a	h,a	b,a	b,a	b,a	h,a	-	-	-
Xolmis cinereus	Gray Monjita	-	-	-	b,a	h,a	-	-	-	-	-	-	-	-
Vireonidae														
Cyclarhis gujanensis	Rufous-browed Peppershrike	-	h,a	-	h,a	h,a	s	h,a	h,a	h,a	h,a	-	-	-
Corvidae														
Cyanocorax cristatellus	Curl-crested Jay	h,a	h,a	h,a	a	-	-	-	-	-	-	-	h,a	h
Hirundinidae														
Progne tapera	Brown-chested Martin	a	-	-	-	-	-	-	-	-	-	-	-	-
Stelgidopteryx ruficollis	Southern Rough-winged Swallow	-	-	b,a	-	-	-	-	-	-	-	-	s	-
Tachycineta leucorrhoa	White-rumped Swallow	-	-	h,a	-	-	-	-	-	-	-	-	-	-
Troglodytidae														
Cantorchilus leucotis	Buff-breasted Wren	-	-	-	-	h,a	h,a	h,a	h,a	a	h,a	-	-	-
Troglodytes aedon	House Wren	h,a	h,a	b,a	h,a	h,a	h,a	b,a	h,a	h,a	h,a	-	-	h,a
Poliptilidae														
Polioptila dumicola	Masked Gnatcatcher	-	-	-	-	-	-	-	a	h,a	-	-	-	-
Turdidae														
Turdus amaurochalinus	Creamy-bellied Thrush	-	-	-	-	-	-	-	-	-	-	-	-	h,a
Turdus leucomelas	Pale-breasted Thrush	-	-	-	a	-	h	b,a	-	-	-	-	-	-
Turdus rufiventris	Rufous-bellied Thrush	-	-	-	h,a	-	h	h,a	h,a	-	h,a	-	-	h
Thraupidae														
Coereba flaveola	Bananaquit	-	-	-	-	-	-	h,a	b,a	h,a	h,a	-	-	-
Cypsnagra hirundinacea	White-rumped Tanager	-	b,a	h,a	-	-	-	-	-	-	h,a	-	-	-
Emberizoides herbicola	Wedge-tailed Grass-finch	-	h,a	-	-	-	-	-	-	-	-	-	-	-
Neothraupis fasciata	White-banded Tanager	-	-	-	-	b	-	-	-	-	-	-	-	-
Porphyrospiza caerulescens	Blue Finch	-	-	-	h,a	-	-	-	-	-	-	-	-	-
Saltator similis	Green-winged Saltator	-	-	-	-	h,a	a	-	-	b,a	h,a	-	-	-

TABLE 2. Continued.

Family *Scientific name*	Common name	Sample points 1	2	3	4	5	6	7	8	9	10	11	12	13
Sicalis citrina	Stripe-tailed Yellow-finch	-	-	h,a	a	h,a	h,a	-	-	-	-	-	-	-
Sporophila plumbea	Plumbeous Seedeater	-	h,a	-	-	a	-	-	-	-	-	-	-	-
Tangara cayana	Burnished-buff Tanager	-	a	-	-	-	-	-	-	s	-	-	-	-
Thraupis sayaca	Sayaca Tanager	-	-	-	-	-	-	-	b,a	a	-	-	-	-
Thlypopsis sordida	Orange-headed Tanager	-	-	-	-	-	-	-	-	-	-	h,a	-	-
Volatinia jacarina	Blue-black Grassquit	-	-	-	-	s,a	-	s	h,a	-	b,a	-	-	-
Emberezidae														
Ammodramus humeralis	Grassland Sparrow	-	h,a	-	-	h,a	-	-	-	-	-	-	-	-
Zonotrichia capensis	Rufous-collared Sparrow													
Icteridae														
Gnorimopsar chopi	Chopi Blackbird	-	-	-	h	-	-	-	-	-	-	-	-	-
Molothrus bonariensis	Shiny Cowbird	-	-	-	h	-	-	-	-	-	-	-	-	-
Fringilidae														
Euphonia chlorotica	Purple-throated Euphonia	-	-	-	-	-	-	h,a	-	-	-	-	-	-
Euphonia violacea	Violaceous Euphonia	-	h,a	-	-	-	-	-	-	-	-	-	-	-

point counts by the observer (483 records) and 76 by the ARU (485 records). We were not able to identify species in a total of 50 records, and those were classified as unknown. Forty-two percent of unknown detections were not identified because individuals produced only short calls which were difficult to be distinguished, 32% could not be identified because we could not identify enough morphological or acoustic characteristics at the species level and 26% because recordings were not of good quality (i.e., at long distances) for correct identification. Thirty-nine species – mainly from families Tinamidae, Rallidae, Cariamidae, Charadriidae, Psittacidae, Cuculidae, Melanopareiidae and Dendrocolaptidae – were detected only by their vocalizations (heard) and were not visually detected during point counts. Two species were detected only in recordings produced by ARU (*Phacellodomus ruber* and *Todirostrum cinereum)* and eight species were detected only by the observer using point counts (*Egretta thula, Mesembrinibis cayennensis, Coragyps atratus, Crotophaga ani, Nystalus maculatus, Neothraupis fasciata, Gnorimopsar chopi* and *Molothrus bonariensis)*. Of these species, two were only visually detected (*Egretta thula* and *Mesembrinibis cayannensis*). Tyrannidae was the family with the highest number of species detected (13), followed by Thraupidae (12) and Psittacidae (7).

We found no significant differences between the number of species detected by point counts and ARU techniques regardless of the sample order. Regardless of whether we considered the first sampling interval (paired *t*-test: $t = 0.91$; df $= 12$; $P = 0.37$), the second (paired *t*-test: $t = 0.74$; df $= 12$; $P = 0.47$) or the third (paired *t*-test: $t = 0.94$, df $= 11$; $P = 0.36$), or whether we pooled all samples together (paired *t*-test: $t = 0.44$; df $= 37$; $P = 0.66$), we found no differences in the number of species. For the point count data, the inclusion of samples in the same point represented a mean of 36% more species than if we had taken only one sample. The same is valid for recorder data, which had 38% more species.

For point count data, 76% of the detections were made only acoustically, 16% both acoustically and visually, and 8% only visually. We took ~30 min to listen to each 15 min-unit of ARU recordings, excluding the time taken to listen the second time (needed to clarify doubts). The recorder error 1 (missing species by ARU in relation to all recorded species) represented 17%, which corresponds to 13 species registered in all points. Surprisingly,

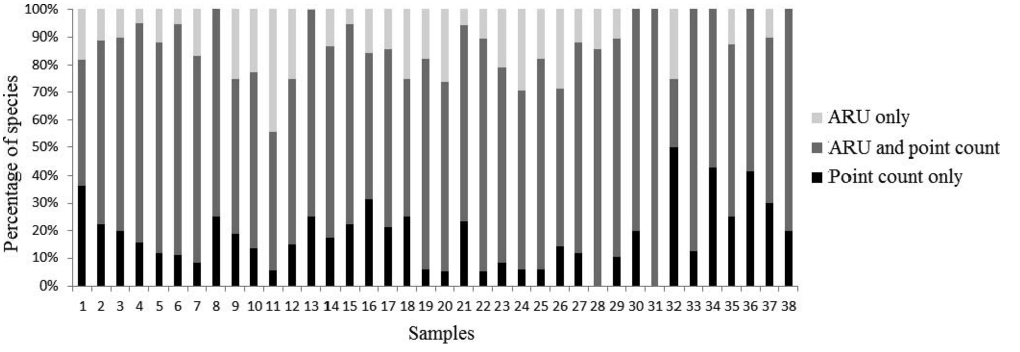

FIG. 2. Similarity of species composition in each method and sample. Each bar represents one sample, with detections made by both methods simultaneously in the center, and those made by each method independently on the ends.

the observer error 1 (missing species by observer in the field) represented 10% or eight species. Recorder error 2 was negative (-1%), indicating that more species were detected through ARU than in point counts and observer error 2 was 16%, indicating the proportion of species detected through ARU that were not detected acoustically in the point counts.

Jaccard's index value can vary between 0.0 (no similarity between samples) and 1.0 (100% similarity). Our two sampling methods showed 0.68 similarity for species composition detected in each pair-sample. Lowest Jaccard's index values were 0.25 for sample 32 and 0.45 for sample 1; highest values were 1.0 for sample 31 and 0.87 for sample 33 (Fig. 2).

DISCUSSION

Aiming to examine the feasibility of using ARU for monitoring birds in open vegetation areas such as the Brazilian Cerrado, we compared the performance of ARU relative to point counts at estimating species richness. The comparisons between human and ARU are well documented in the literature, but the findings differ greatly between studies, and the conclusions can be favorable to humans, to ARU or both (i.e., equal performances). Most of this lack of consensus may be caused by differences in equipment used, by differences in vegetation structure, or by richness and composition of the bird community itself. When considering vegetation structure, almost all studies were conducted in a forest environment, both in temperate (Hobson et al. 2002, Celis-Murillo et al. 2012) or tropical zones (Haselmayer and Quinn 2000, Acevedo and Villanueva-Rivera 2006), and our study is one of few conducted in open vegetation areas (e.g., Hutto and Stutzman 2009, Celis-Murillo et al. 2012).

In this study, data obtained on point counts and with ARU provided similar results for number of species registered (81 by point counts and 76 by ARU) and for species detected in each sample by the different methods (68% of similarity). ARU was able to register 90% of all species registered in point counts, and as we initially expected, part of the species did not vocalize and were not registered by ARU, representing 10% of all registered species. This result is similar to Celis-Murillo et al. (2009) where 7% of detections were exclusively obtained through visual contacts. Hutto and Stutzman (2009) associated most of the differences between humans and ARU not with the environment (they found no differences of recordings due to vegetation structure) but with the quality of the recordings and to species overlooked in the field by observers. Otherwise, Celis-Murillo et al. (2012) found vegetation structure as an important factor influencing detection of some species, but not important at the community level.

Species that are not usually detected by ARU include raptors, hummingbirds, species not breeding at the time when recordings are made and species that emit only short calls (Haselmayer and Quinn 2000, Hutto and Stutzman 2009), but these groups of species do not seem to be the reason for differences in similarity patterns for some authors (Celis-Murillo et al. 2009). In our case, we found no significant differences between the number of species detected by the different methods. Additionally, both methods yielded a similar percentage of errors "1" (17 and 10%) when we compared the number of detections with respect to the total number of detections. Our samples showed 68% similarity, which means that in 68%

of records, ARU and human observer detected the same register. In other studies (e.g., Hutto and Stutzman 2009) ARU had a much poorer performance than humans, when 40.7% of all species were detected only by humans. The similarity value found here is higher than values found in California (50–60%) by Celis-Murillo et al. (2009), and in Montana (54%) by Hutto and Stutzman (2009) and lower than values found in Canada (83–97%) by Hobson et al. (2002).

The use of ARU in ecological studies can present advantages and disadvantages compared with human-based methods. The possibility of listening to the recordings to confirm species identity later and storing data available for future studies can be strong reasons favoring ARU when methodologies are considered equivalent. Otherwise, the time needed to process field recordings and difficulties to obtain abundance or density data are two important issues to consider. In our study, for each 15 min of a sample unit, we took twice this time to analyze it. Depending on the desired analysis, data obtained can be viewed as biased, because not all species had the same chance to be registered, as occurred in our study and in others mentioned above.

Point counts, on the other hand, can generate additional useful information in ecology studies, such as abundance or data of species density and behavior, micro-habitat preferences. However, when point counts are used, an observer evaluates each sample point once, but the ARU method allows us to extend sampling at the same point at different times of the day increasing the chance of detecting more species that may be silent at the time of a single point count (Acevedo and Villanueva-Rivera 2006). This is perhaps the most important advantage of the use of ARUs in ecology studies, especially in large-scale and long-term studies.

Acoustic Biodiversity monitoring based on bioacoustics techniques may require the use of automated methods to process large amounts of data acquired by ARU, since it is very difficult to process all information in a short time period. One possible approach is to use recognition software to identify species present in the recording. The main problem associated with automated recognition software is that most of them do not work properly in noisy environments due to low signal-to-noise ratios (Kogan and Margoliash 1998, Chen and Maher 2006), and they fail to identify species when several individuals sing at the same time such as during the dawn chorus (Goyette et al. 2011, Wimmer et al. 2013). In addition, most of this software recognizes syllables rather than complete songs, making it harder to work with different species at the same time because of the number of different syllables that may be in a species' repertoire.

For the time being, the use of automated recognition software does not yet seem to be a realistic tool for studies involving long-term community monitoring when the research objective is to identify all the species present in the recordings (as is usually the scope of long-term monitoring). In order to improve the value of recognition software, researchers need to interact frequently, sharing recordings and song recognizers. ARU provides a good source of recordings, which appropriately edited and archived, can be used for training software and quantifying vocalization characteristics. But, for a while, it seems preferable that the use of an automated recognizer is restricted for other objectives, such as the recognition of one or few species of interest (Swiston and Mennill 2009, Goyette et al. 2011, Zwart et al. 2014), preferably in low noise environments.

Environmental ecology is characterized by long-term phenomena (Franklin et al. 1990), but the data sampling required for this kind of research is often limited, because data collection is usually based on small spatial and temporal scales (Aide et al. 2013). Long-term and standardized acoustic monitoring allows researchers to measure temporal dynamics in bird populations and communities, using a non-invasive technology to track effects of climate changes and habitat fragmentation (Blumstein et al. 2011). New promising approaches on the processing of large amounts of data in monitoring projects are aimed to focus not on species but on the community as a whole (Sueur et al. 2008, Pieretti et al. 2011, Towsey et al. 2014). Studies conducted in France revealed that the use of an acoustic index is valid and can reflect the diversity of a community of animals (birds, in that case; Depraetere et al. 2012).

Although ARU and point counts presented similar and complementary results, ARUs have been shown to be useful tools that can be used to detect birds in open Cerrado areas and that can augment studies in monitoring communities, especially if semi-automatic or automatic analysis are used. This combination can increase the knowledge and the accuracy of decisions in management and conservation of species. Nevertheless, we expect that techniques of species or community recognition will improve with time and thus be applicable to regions with high biodiversity, such as the tropics.

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