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SOCIÉTÉ D'ÉTUDES ORNITHOLOGIQUES DE FRANCE - MNHN

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STRUCTURE DU CHANT, IMITATIONS EXTRASPÉCIFIQUES ET LEUR UTILISATION SYNTAXIQUE CHEZ LA **GORGEBLEUE À MIROIR BLANC** ***Luscinia svecica cyanecula*** (I re partie)

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ABSTRACT.– Song structure, extraspecific imitations and their syntaxic use in the Bluethroat *Luscinia svecica cyanecula* (first part). In Passerine songs, vocal imitation is very widespread, but it always raises many questions. In the song of the Bluethroat, few heterospecific imitations have been confirmed so far by sonagraphic analyses and the various modes of integration of imitations into the song are still poorly documented. Long vocal sequences of 10 territorial males were recorded in Belgium (Liège region). Many potential models (birds, amphibians) were also recorded in the same area. The sonagrams of all these recordings were used to compile detailed catalogues of vocal repertoires and to classify their syllables on the basis of visual examination of the sonagrams. This study clarifies the syntax of Bluethroat song, adds to the inventory of heterospecific imitations (birds, amphibians and crickets) and illustrates their quality. The number of syllables borrowed from the same species varies greatly from phrase to phrase. The second part of the phrases includes «complex motifs», consisting of ticks and various imitations, which needed to be described more precisely in the song of this species. If the Bluethroat can copy the syntax and syllable structure of heterospecific vocalizations, it can also combine imitations of different species and create new sounds, a bit like some human musicians. This vocal learning process can continue during migratory journeys and in the winter quarters. Finally, the possible functions of this imitative song are discussed, but remain open to further investigation.

Mots-clés : *Luscinia svecica cyanecula,* Imitations, Innovations, Apprentissage, Syntaxe du chant.

Keywords: *Luscinia svecica*, Mimicry, Innovations, Song learning, Song syntax.

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INTRODUCTION

Vocal imitation in birds raises many questions, most of which have yet be definitively answered (BAYLIS,1982; KELLEY *et al.* 2008). Understanding this behaviour requires in-depth investigations, even in a species as studied such as the European starling *Sturnus vulgaris* (GOLLER, 2020).

This behaviour is very common. In Europe, for example, 31.6% of passerines are thought to be "flexible" mimics (i.e. species that often imitate a variety of sounds), but this percentage rises to 60%. (GOLLER & SHIZUKA, 2018). This percentage is underestimated. To identify certain imitations, it is necessary to have extensive collections of good quality recordings and sonograms.

In the Bluethroat, the imitative repertoire is extensive, reminiscent of that of the Marsh Warbler *Acrocephalus palustris* (GÉROUDET & CUISIN, 1998), but is still poorly understood. In the few studies that have been devoted to it, the inventory of imitated species only concerned species from western and central Europe (KEULEN, 1983 ; SCHMIDT, 1988). However, in the course of its movements, the the Bluethroat has the opportunity to hear many other species. Moreover, few of these have been confirmed by sonagraphic analysis and none of the published sonograms presented any imitations of amphibians (WALLSCHLÄGER, 1978 ; KEULEN, 1983 ; TRETZEL *in* GLUTZ von BLOTZHEIM & BAUER, 1988). The study by WALLSCHLÄGER (1978) also focused on imitations of *Luscinia s. svecica*, another subspecies. As for the of these imitations into the sentences of the Bluethroat *Luscinia s. cyanecula*, it was still very poorly documented. Structure of its song remained to be clarified.

Before the development of micro-computing, roughly before 1990, the "*Kay Electric*" sonagraph used in bird song studies hardly allowed for the analysis of long sequences of song, as recordings had to be selected first by ear. Since then, digital sound recorders and high-capacity hard disks allow detailed studies of birds' vocal behaviour. the vocal behaviour of birds. Finally, in order to interpret the sonograms, potential models should be recorded in the same areas as the Bluethroats, as well as in their periphery of these areas.

In the song of the Bluethroat, vocal borrowing always raises a series of questions, which need to be placed in the life history of the species. For example:

- Does it concern entire songs or only-imitations (cries, isolated syllables)?
- Is it characterised by the simple repetition of syllables, motifs or even whole phrases without restructuring the sound material ? or, on the contrary, is it a source of new syntactic and/or rhythmic turns, in other words innovations ?
- Is it selective ?
- When and where does it take place ?
- What role does it play in the function(s) of song ?

The present study attempts to provide some answers to these many questions and to identify any common or distinctive features between the song of the Bluethroat and that of other other passerines, such as the Marsh Warbler, a virtuoso mimic (LEMAIRE, 1974 & 1975; DOWSETT-LEMAIRE, 1979), and the Chaffinch *Fringilla coelebs*, a lesser mimic (SLATER & INCE, 1982; METZMACHER, 2016). Carried out in the Liège region (Belgium), essentially based on sonographic analysis of numerous recordings of Bluethroat and their potential models.

METHODS AND MATERIAL

Recording sites

In the Liège region (Belgium), there are few sites for Bluethroat reproduction., Their origin are anthropogenic and they are located within a radius of around 20 km (TAB. I). The two nearests wetlands, Amay and Saint-Georges-sur-Meuse (Flône), are 4 km apart.

TABLEAU I.– Dates, sites, nombre de mâles et nombre de phrases (N) de Gorgebleue enregistrées par séquence et par mâle.
Dates, sites, number of males and number (N) of Bluethroat phrases recorded per sequence and per male.

Année N mâle	Amay (23 ha) 50°33' N/ 05°18' E		Saint Georges (Flône) (23 ha) 50°34' N/ 05°21' E		Hollogne-sur-Geer (33 ha) 50°40' N/ 05°12' E		Tienen (8 ha) 50°48' N/ 04°58' E	
	Date	N	Date	N	Date	N	Date	N
2006 (2)	15 avril 22 avril	78 21						
2007 (3)	11 avril 21 avril 29 avril	19 27 74						
2008 (3)	2 juin	59			4 juin	49	18 juin	24
2009 (2)	16 avril	113	20 mai	57				

PHOTO 1.– Gravière d'Amay dans la vallée de la Meuse, près d'un domaine boisé. *Amay gravel pit in the Meuse valley, near a wooded area.*

Two of these areas, Amay and Hollogne-sur-Geer, are recognised as *Site of Great Biological Interest* (SGIB, in in the Walloon region database which details their interest) and Tienen is the *Tiens Broeck* nature reserve. The low density of the species in this region (VERROKEN, 2003 ; *obs. pers*), the large number of visits to most of these wetlands, make it possible to record the songs of the males that are confined there. I have also recorded a number of species likely to be imitated by the Bluethroat and which also nest in these wetlands or on their edges, or which regularly fly over them.

In Amay, on the Meuse alluvial plain, the site of an abandoned industrial wetland is a former gravel pit. All that remains is a body of water bordered by a fringe of marsh vegetation. punctuated by a few small islands of trees (photo 1). The site is close to a wooded area.

At Saint Georges (Flône), Hollogne and Tienen, the wetlands correspond to settling ponds, i.e. those of a quarry at Flône and sugar factories at Hollogne and Tienen. As the Bluetroat is confined to the reedbeds of these ponds, its habitat only covers a part of the total surface area of these wetlands, as some water bodies have no phragmites or vegetation high enough to serve as a singing post.

Recording methods and study material

Song recordings were made using a *Sennheiser ME 64* cardioid microphone fixed at the focus of a parabolic reflector (diameter: 74 cm), connected to a *Tascam* DA-P1 digital recorder, using a sampling frequency of 48 kHz and 16-bit resolution. These recordings were stored as audio files in wav format. To record some songs in flight, a *Telinga* reflector was used. *Telinga* reflector (diameter: 57 cm), lighter and easier to handle, was used, but with the same microphone.

From 2006 to 2009, sufficiently long recordings of 10 Bluetroat (included in Tab. I), other birds and amphibians, were made during the breeding season (April to July), when weather conditions were sufficiently favourable (little or no wind, dry weather). The location of each singer was noted on an aerial photograph of the area surveyed. In addition to these data, i also analysed the recordings published by various authors, in particular those made available to me by François CHARRON, Pascal DHUICQ, the *Sonatura* association, the *British Library* and those in my sound library, a copy of which is archived in the collections of the *British Library*.

Concerning African birds, i have analysed recordings of birds from the savannahs of CHAPPUIS (2000 and 2008). For the Batrachians, i based my analysis on the records of DEROUSSEN *et al.* (1996). For the Orthopterans, i used the records of ANDRIEU & DUMORTIER (1984), CHARRON *et al.* (2004), ROESTI (*in* SARDET *et al.*, 2015) and of the *Sonatura* association. The website of the *Inventaire National du Patrimoine naturel* INPN) was also consulted to precise the range of certain species. during the different study seasons.

Each individual was recorded for as long a period as possible. the number of sentences analysed per individual and in the Table I. Next, all Bluetroat recordings, as well as those of their potential models, were analysed on a PC with the *WaveSurfer* software (Version 1.8.5, Hanning window, Fourier transform FFT = 512, frequency band 0-10 kHz, but up to 20 kHz for songs in flight).

The song of the Bluetroat is very high-pitched, so it stands out from the noise pollution associated with human activities (car traffic, boats, etc.), which generally does not exceed 1.500 Hertz. When the intensity of the background noise was significant, and after an initial sonographic analysis, the *Sound Forge* 4.0 software filter made it possible to purify these low frequencies, apart from the frequency amplitude of the song.

The sonograms of all these recordings were subjected to a meticulous visual inspection to identify and classify the syllables (see definition below), as well as their different versions, on the basis of morphological structure, duration, frequency amplitude and, finally, to draw up a syllable catalogue for each individual, which is stored electronically. This morphological approach used in other studies to classify avian vocalizations. (for example: NICHOLSON *et al.*, 2007; DAROLOVA *et al.*, 2012; VARGAS-CASTRO *et al.*, 2015), also made it possible to assess the fidelity of the imitations in relation to the models, as well as the ways of combination and insertion of these imitations in the song.

Correlation coefficient and coefficient of determination

The correlation between sentence length and between sentences was calculated using the "*Excel*" spreadsheet, as well as the coefficient of determination. This coefficient corresponds to the square of the correlation coefficient.

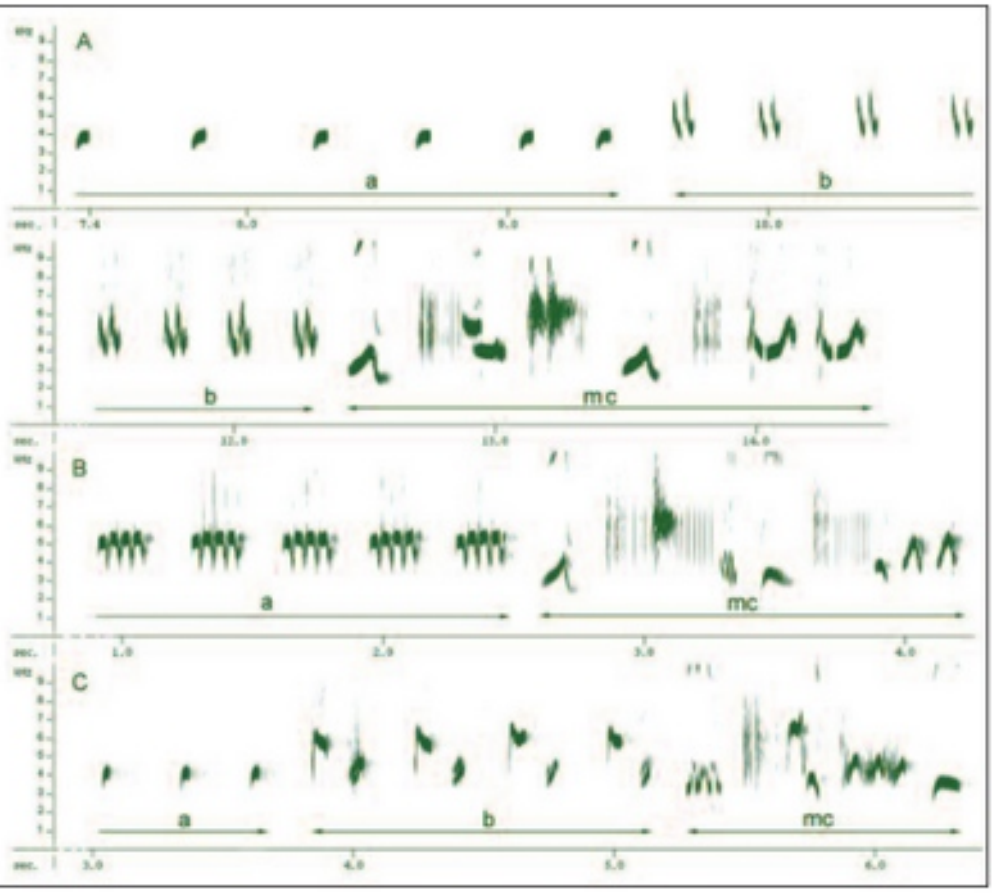

FIG.1.– Structure du chant de la Gorgebleue *Luscinia s. cyanecula*. (**A, B, C**) Trois extraits de phrases (mâle enregistré à Amay, avril 2007). **a** et **b**: motifs de la première partie de la phrase; **mc**: motif complexe (seconde partie de la phrase).

*Structure of Bluethroat song. (**A, B, C**) Three extracts of phrases (male recorded in Amay, April 2007). **a** and **b**: motifs of the first part of the phrase; **mc**: complex motif (second part of the phrase).*

This quantity, which lies between 0 and 1, is therefore the proportion of variance in y that is explained by the regression of y on x (DAGNELIE, 2013). In other words, it is an indicator that can be used to judge the quality of a simple linear regression.

The song of the Bluethroat: description and terminology

The long phrases of the Bluethroat consist of two parts: an introductory part composed of one or more motifs, and a final more complex final motif (**mc**), a sort of pot-pourri (FIG. 1). Its notes and syllables are mainly between 2 500 and 5 500 Hz. Some imitated notes can, however, reach 9 000 Hz (FIG. 18B).

The first part of the phrase begins with the repetition of a short note (for example: Fig. 1A, motif a), or a syllable, the flow of which, slow and hesitant, then accelerates. FIG. 1C shows that, in a motif (i.e. b) of this first part, a syllable can also be made up of two different notes.

Definitions - The terminology used to describe sound vocalisations can vary from one author to another (LEROY, 1993). In this article, i have used the terms of BERGMANN *et al.* (2008).

- ***Note or element*** - the smallest fragment. Part of a syllable.

- ***Syllable*** - a sequence of several different elements which, when heard, are perceived as a single entity.

- ***Motif*** - coherent part of a sentence made up of a succession of elements or syllables of the same structure.

- ***Complex or composite motif*** - a sequence of several different elements or syllables.

- ***Phrase*** - coherent sequence of elements, syllables or motifs, separated from the next by a pause.

- ***Song*** - vocal emission consisting of a succession of phrases, separated by silences.

RESULTS

Characteristics and structure of the song

The length of phrases, as well as the pauses between phrases, can vary significantly from one phrase to another and from one individual to another (TAB. II), as shown, for example, by the five individuals in this table. The maximum duration of a complete phrase is sometimes more than 20 seconds. The correlation between the length sentences and pauses between sentences is really very weak, as confirmed by the coefficient of determination.

In addition to the averages, this table also presents the medians, because in this case "*the result obtained does not depend on extreme values, which are sometimes very abnormal or dubious*" (DAGNELIE, 2013). But this is not the case here, as the medians are very close to the averages.

Introductory part - In the first part of the sentence, the notes or syllables can be repeated in two ways (FIG. 1). By way of example, a detailed analysis of a sequence of 50 sentences of the same male, alternating repetitions of two notes are much rarer (8.5%) than repetitions of a single note (91,5 %).

In this sequence, the introductory part of the song most often comprised two motifs (FIG. 2A). in total, the diversity of motifs amounted to 18 types, but in this sample, only five were found more than seven times (FIG. 2B). Two of these patterns were always found at the beginning of a sentence and one was almost always found there. In addition, before the complex pattern, a pattern repeating a syllable made up of two simple elements was almost always sounded.

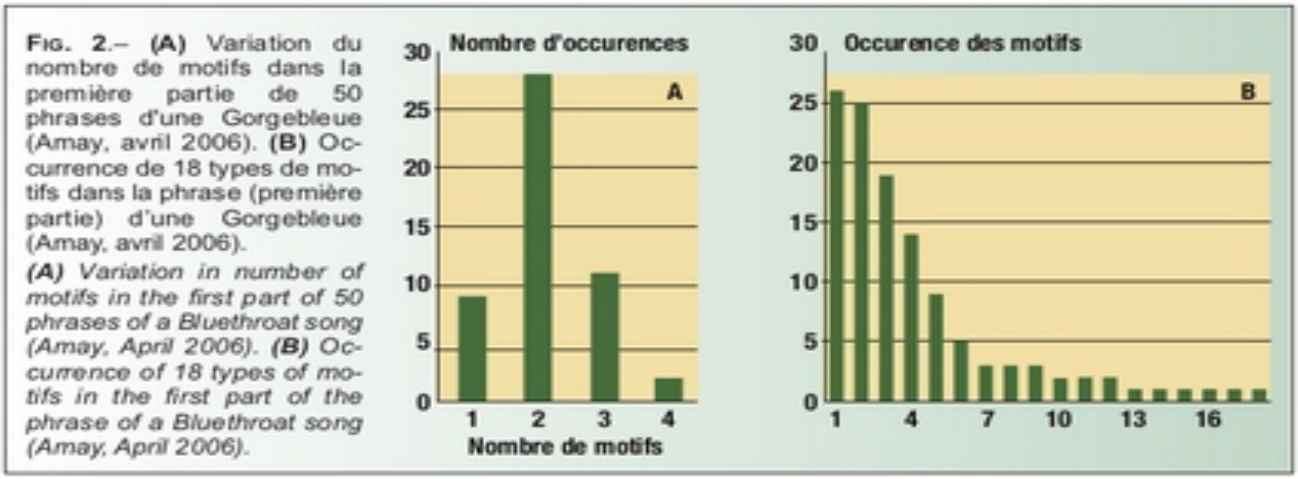

FIG. 2.– **(A)** Variation du nombre de motifs dans la première partie de 50 phrases d'une Gorgebleue (Amay, avril 2006). **(B)** Occurrence de 18 types de motifs dans la phrase (première partie) d'une Gorgebleue (Amay, avril 2006).
(A) *Variation in number of motifs in the first part of 50 phrases of a Bluethroat song (Amay, April 2006).* ***(B)*** *Occurrence of 18 types of motifs in the first part of the phrase of a Bluethroat song (Amay, April 2006).*

TABLEAU II.– Durées en secondes des phrases et des pauses.
Duration in seconds of phrases and pauses.

Année Site	2007 Amay A		2008 Amay A		2008 Hollogne		2009 Amay A		2009 Flône	
Durées phrase (A) / pause (B) Min - Max	A	B	A	B	A	B	A	B	A	B
	5,6-17,7	4,1-11	6,3-20,4	0,1-10,5	5,6-12,2	2,8-13,8	4,8-15,2	1,2-10,4	5-25,7	1-16,1
Nombre	41		56		42		111		53	
Moyenne / Ecart-type / Médiane	10,83 2,68 10,20	5,97 1,73 5,40	11,76 3,28 12,20	6,27 1,87 6,20	7,90 1,61 7,55	6,71 2,84 5,85	9,17 1,92 8,90	3,90 1,34 3,70	12,90 3,98 12,70	5,51 2,36 4,90
Coefficient de détermination	0,03		0,01		0,03		0,01		0,05	

Les séquences de chants étant sujettes à des interruptions, le nombre de phrases dans ce tableau peut être plus faible que dans d'autres tableaux où les pauses ne sont pas prises en compte. *As song sequences are subject to interruptions, the number of phrases in this table may be lower than in other tables where pauses are not taken into account.*

Fig.3.– Exemples de « motif composite » (**mc1** et **mc2**) dans le chant d'une Gorgebleue (Amay, avril 2009). Dans ***mc1***, imitation d'un cri d'Hirondelle de rivage, précédée de clics.
*Examples of a « composite motif » (**mc1** and **mc2**) in a Bluethroat song (Amay, April 2009). In mc1, imitation of a call of Sand Martin preceded by « ticks ».*

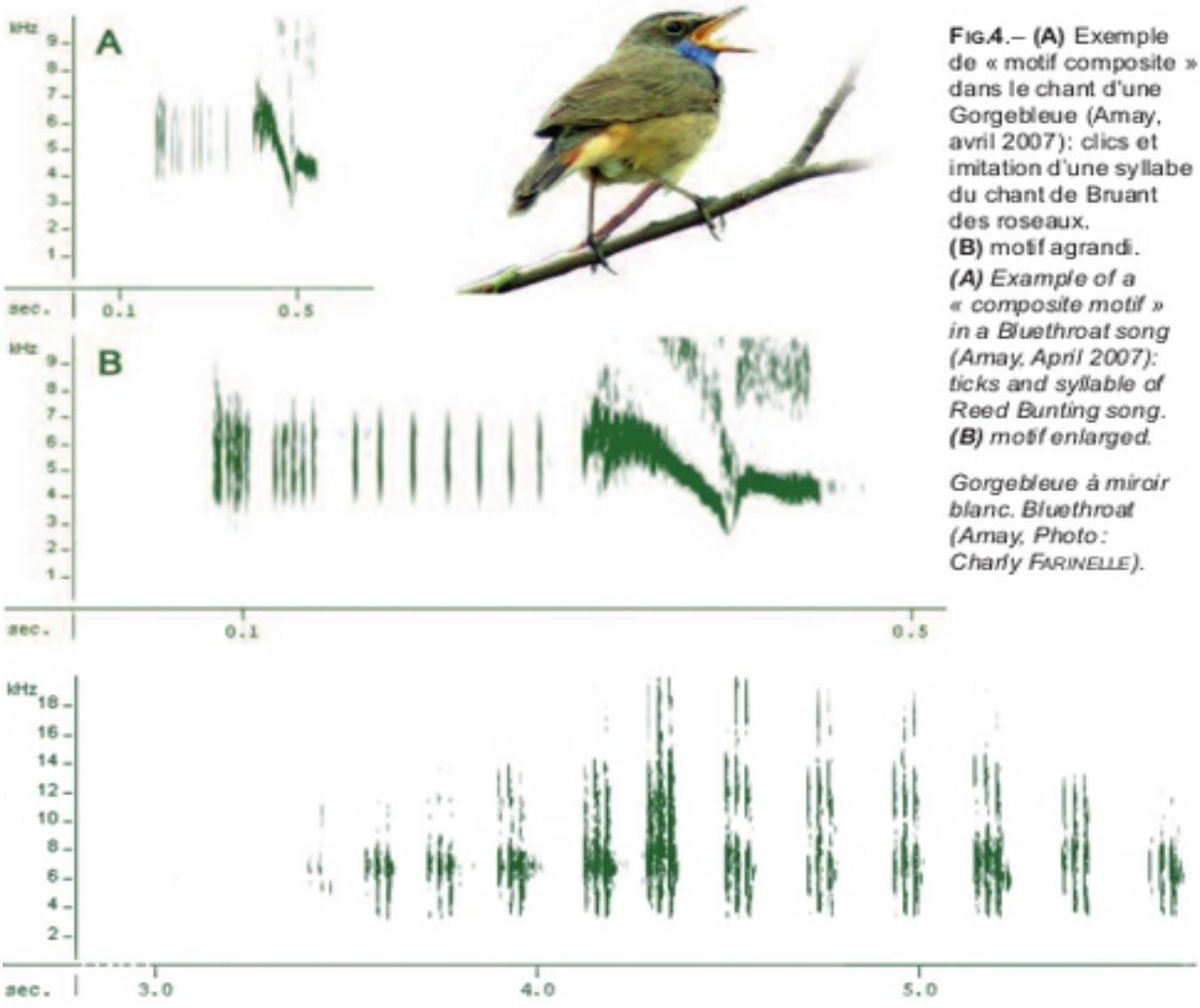

Fig.4.– **(A)** Exemple de « motif composite » dans le chant d'une Gorgebleue (Amay, avril 2007): clics et imitation d'une syllabe du chant de Bruant des roseaux.
(B) motif agrandi.
***(A)** Example of a « composite motif » in a Bluethroat song (Amay, April 2007): ticks and syllable of Reed Bunting song.
(B) motif enlarged.*

Gorgebleue à miroir blanc. Bluethroat (Amay, Photo: Charly Farinelle).

Fig.5[1].– Série de clics dans un chant en vol d'une Gorgebleue (Amay, avril 2006).
Serie of « ticks » in a song-flight of a Bluethroat (Amay, April 2006).

(1) **Ndlr**. Cette figure montre un effet Doppler: intensité et fréquence augmentent (l'oiseau se rapproche) puis diminuent (l'oiseau s'éloigne).

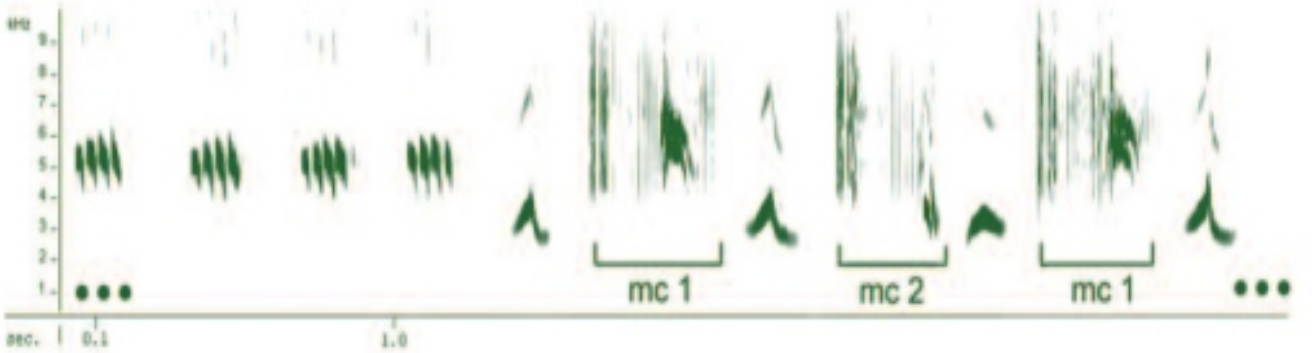

FIG.6.– Exemple de stéréotypie partielle: « motif composite » **mc1** répété dans le chant d'une Gorgebleue (Amay, avril 2006.
*Example of partial stereotypy: « composite motif » **mc1** repeated in a Bluethroat song (Amay, April 2006).*

TABLEAU III.– Stéréotypie partielle du chant dans 8 phrases de Gorgebleue enregistrées à Amay (dans le même territoire) en 2007 et une phrase enregistrée en 2008. *Partial song stereotypy in 8 Bluethroat phrases recorded in Amay (within the same territory) in 2007 and in one phrase recorded in 2008.*

	Avril 2007	
N° phrase	I	II
49	A	B C D E F **G G H**
51	A	B C D E F **G G I**
54	A	B C E E F **G G H**
55	A	B C D E F **G G H**
57	A	B C D E F **G G H**
66	A	B C D E F **G G I J K L**
69	A	B C D E F **G G**
71	A	B C D E F G G
	Juin 2008	
53	A	B M E F N E F **G G**

Dans la première partie (I) des phrases, **A** est une imitation de Grillon champêtre. Dans la seconde partie (II), **G, H, I, J** sont des imitations de syllabes d'un chant de Bruant des roseaux. Les autres syllabes sont peut-être des imitations d'oiseaux, mais les espèces n'ont pas été identifiées.
*In the first part (I) of the phrases, **A** is an imitation of a Field Cricket. In the second part (II), **G, H, I, J** are imitations of syllables of Reed Bunting song. The other syllables are perhaps imitations of birds, but the species have not been identified.*

Second part: "composite" motifs

The second part of the Bluethroat song includes specific patterns made up of one or several syllables preceded or sometimes framed by a series of clicks (ticks), CONSTANTINE, 2006; FIG. 3, 4 and 5). FIG. 3 gives an example of an imitation of a Sand Martin call integrated into one of these figures, and FIG. 4 shows an imitation of one syllable of a Reed Bunting song. In all these distribution of clicks can take different forms.

Song stereotypy

Composite motifs are sometimes repeated in the same phrase, resulting in partial stereotypy of the Bluethroat's song (FIG. 6). Table III gives other examples of this stereotypy. In 2007, 8 sentences of the same sequence (from the 49 th) shared 8 syllables of the same type and in the same order. In 2008, in the same territory, the singer still had 5 of these syllables, but in a single phrase. This partial stereotypy was also noted in other phrases.

Repertory size

Figure 7 gives an example of the evolution in the diversity of the number of notes and syllables as a function of the number of phrases recorded. This curve begins to reach a plateau at around thirty phrases. This diversity totalled 77 notes and and syllables for the 59 phrases in the sequence.

Variations in syllable structure

Certain syllables, whether imitated or not, are repeated a large number of times in a single the same sentence, particularly in the introductory part. They are also often found in several phrases in the same song sequence. Close examination of the structure of these syllables (number, form, frequency and duration of their elements) makes it possible to identify on their sonograms the characteristics a singer and those which, for the same type of syllable, vary from

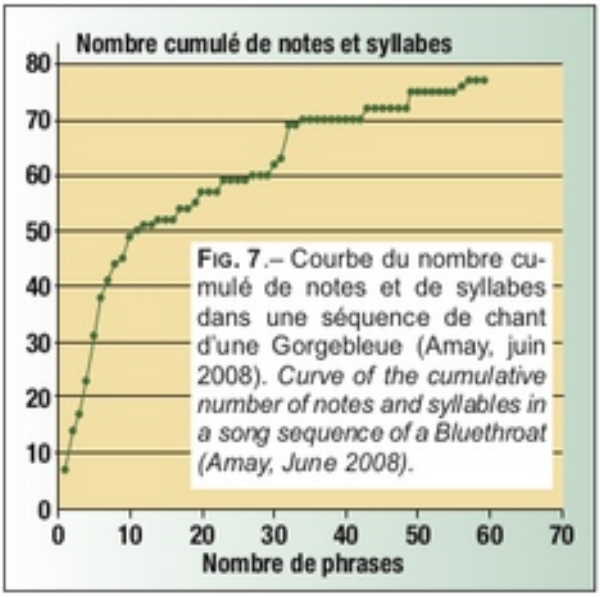

FIG. 7.– Courbe du nombre cumulé de notes et de syllabes dans une séquence de chant d'une Gorgebleue (Amay, juin 2008). *Curve of the cumulative number of notes and syllables in a song sequence of a Bluethroat (Amay, June 2008).*

one individual to another, as shown by the examples in FIG. 8 et 9 of similar structure. The syllables in Figure 9 appear to be imitations of Barn Swallow calls.

TABLEAU IV.– Imitations d'oiseaux européens dans le chant de la Gorgebleue *Luscinia svecica cyanecula*.

European bird imitations in the song of the Bluethroat Luscinia svecica cyanecula.

A correspond à un cri ; **B, C, D**… à une syllabe du chant. ***A** for a call; **B, C, D**… for a song syllable.*

		2006			2007		2008			2009	
		15 avril	22 avril	11 avril	21 avril	29 avril	2 juin	4 juin	18 juin	16 avril	20 mai
		Amay A	Amay B	Amay B	Amay C	Amay A	Amay A	Hollogne	Tienen	Amay A	Flône
Nombre de phrases		78	21	19	27	74	59	49	24	113	57
Espèce	Type										
Falco tinnunculus	A		xxxx								
Actitis hypoleucos	A								xxxx		
Tringa ochropus	A1	xx									
	A2					xx					
	A3							x			
Apus apus	A1										
	A2										
	A3									xxxx	
	A4										xxxx
Alcedo atthis	A1	xxxx						x			
	A2					xxx	x				
	B									x	
Cyanistes caeruleus	A1									xx	
	A2										xxx
Poecile palustris	A	xx									
Alauda arvensis	B								x		
Riparia riparia	A1									xxxx	
	A2										x
Ptyoprogne rupestris	A1				xxxx						
	A2						xx				
Hirundo rustica	A1	xxx									
	A2		x								
	A3				xxxx						
	A4						xxx				
	A5							xxxx			
	A6								xxxx		
	A7									xxx	
	A8										xxxx
Phylloscopus trochilus	B						x				
Phylloscopus collybita	A	xxxxx	xxxxx		xxxx						
Sylvia communis	A								xxx		
Turdus merula	A1										
	A2									xx	
	A3										xxxxx
	A4									xx	
	B1	x									
	B2						xxx				
	C						xxx				
	D1						xx				
	D2							xx			
	D3								x		
	E							x			

TABLEAU IV *(suite)*

		2006			2007		2008			2009	
		15 avril	22 avril	11 avril	21 avril	29 avril	2 juin	4 juin	18 juin	16 avril	20 mai
		Amay A	Amay B	Amay B	Amay C	Amay A	Amay A	Hollogne	Tienen	Amay A	Flône
Nombre de phrases		78	21	19	27	74	59	49	24	113	57
Espèce	Type										
Turdus philomelos	B1			xxxxx				x			
	B2										xx
	C1										
	C2									x	
Phoenicurus ochruros	A1					xx	xxx				
	A2							xxx			
	A3								xxx	xxx	
Passer domesticus	A	xx									
Anthus trivialis	B1									XXX	
	B2										XXX
Anthus pratensis	A1	x					xxx				
	B1			xxx				xxx			
	B2									xxxx	
	B3										xxx
Motacilla flava	A1			xxx				xx			
Motacilla alba	A	x								x	
	B1	xx									
	B2			xxxx							
	B3					x	xx				
	B4									x	
Fringilla coelebs	A		xxxx					xxx			
	B							x			
Carduelis chloris	B							xxx			
Emberiza citrinella	A			xxx							
Emberiza schoeniclus	A				xx						
	B *					xxxx	xxxx				
	B **	xxxx									

Type imité A: cri, B: syllabe de chant.
x : 1 à < 5 %; xx: 5 à < 10 %; xxx: 10 à < 20 %; xxxx: 20 % à < 40 %; xxxxx: > 40 %
B *: groupe de syllabes, B **: syllabe atypique

Diversity of imitations

The imitations of some 27 bird species (26 in the song of perched birds, TAB. IV; 1 of the Striped Kingfisher *Halcyon chelicuti* in a song in flight on 15 April 2006 at Amay), one species of amphibian and at least 5 species of cricket were identified (TAB. V) in the 10 repertoires listed in TAB. I. the sonograms (FIG. 8, 10, 11, 13 to 19, 21 and 23 for birds; 24 for a frog, 25-30 for crickets) give an overview of the many calls, songs or song syllables that could serve as models.

Green Sandpiper *Tringa ochropus*
The syllables in Fig. 10B and C correspond to an imitation of syllables of the Green Sandpiper *Tringa ochropus* (FIG. 10A).

Common Sandpiper *Actitis hypoleucos*
The imitation of the call of this Sandpiper (FIG. 11A) can be emitted in series (FIG. 11B) or in pairs (FIG. 11C). This imitation has only been found in a single Bluethroat (TAB. IV).

Common Swift *Apus apus*
Common Swift calls are emitted in series (FIG. 12A and B). The duration, frequency amplitude and form of the imitation of these calls can also vary significantly from one Bluethroat to another, reproducing the different types of Common Swift calls (FIG. 13A and B). In 2007, as early as 12 April, Common Swift calls were already noted in the song of this Bluethroat, but at that time the had not yet returned from migration.

European Kingfisher *Alcedo atthis*
The Bluethroat can imitate some of the Kingfisher's calls, emitting them in a comparable tempo, but at a slightly lower frequency (FIG. 14).

Sand Martin *Riparia riparia*
In the first part of the song (introduction), the Bluethroat can imitate the call of the Sand Martin (FIG. 15B) in a long series, but they can also include it in a composite motif (FIG. 3).

Crag Martin *Ptyonoprogne rupestris*
In the "introductory" part of its song, the Bluethroat may repeat an imitation of the call of the Crag Martin in a slightly higher frequency band (about 1,000 Hz). FIG. 16B and 16C give two versions.

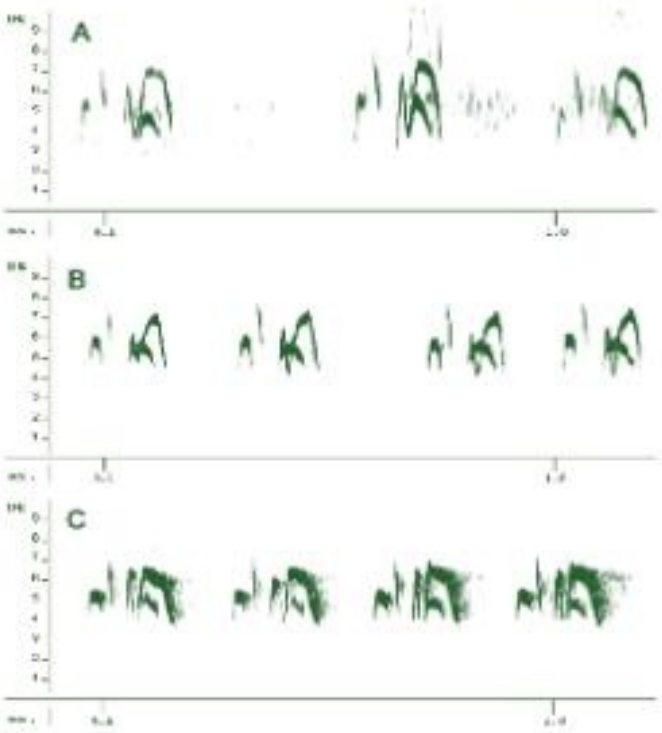

Fig. 8.– **(A)** Cris d'Hirondelle rustique (Amay, avril 2008) ; **(B, C)** imitation par la Gorgebleue ; **(B)** Hollogne, juin 2008. **(C)** Tienen, juin 2008). ***(A)*** *Calls from a Barn Swallow (Amay, April 2008);* ***(B, C)*** *imitations by a Bluethroat;* ***(B)*** *Hollogne, June 2008;* ***(C)*** *Tienen, June 2008).*

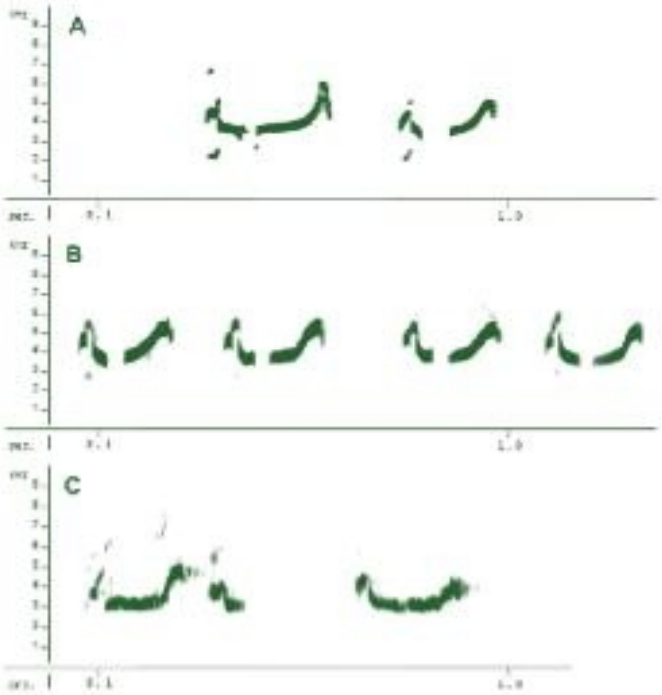

Fig. 10.– **(A)** Cri du Chevalier cul-blanc (Bergmann & Helb, 1982) ; **(B)** Imitation par la Gorgebleue en Belgique (Amay, avril 2006) ; **(C)** et au Sénégal (Morel & Morel *in* Chappuis, 2000). ***(A)*** *Call of Green Sandpiper;* ***(B)*** *Imitation by Bluethroat in Belgium (Amay, April 2006);* ***(C)*** *and in Sénégal (Morel & Morel in Chappuis, 2000).*

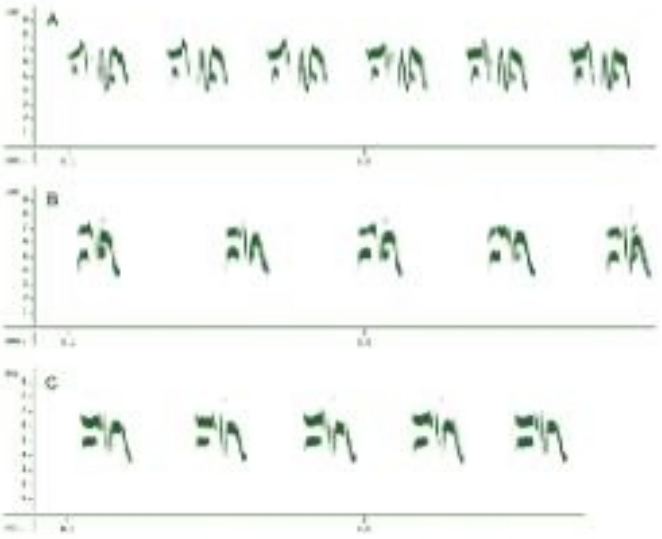

Fig. 9.– **(A, B, C)** Comparaison d'un même type de syllabe chez trois Gorgebleues : **(A)** Amay, 2007 ; **(B)** Amay, 2009 ; **(C)** Flône, 2009). ***(A, B, C)*** *Comparison of same type of syllable in three Bluethroat:* ***(A)*** *Amay, 2007;* ***(B)*** *Amay, 2009;* ***(C)*** *Flône, 2009.*

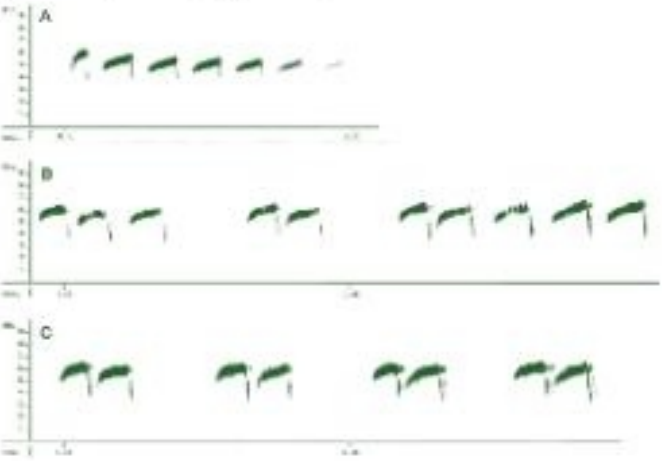

Fig. 11.– **(A)** Cris de Chevalier guignette (Chappuis, 2000). **(B, C)** imitation par la Gorgebleue (Tienen, juin 2008). ***(A)*** *Calls of Common Sandpiper (Chappuis, 2000).* ***(B, C)*** *imitation by a Bluethroat (Tienen, June 2008).*

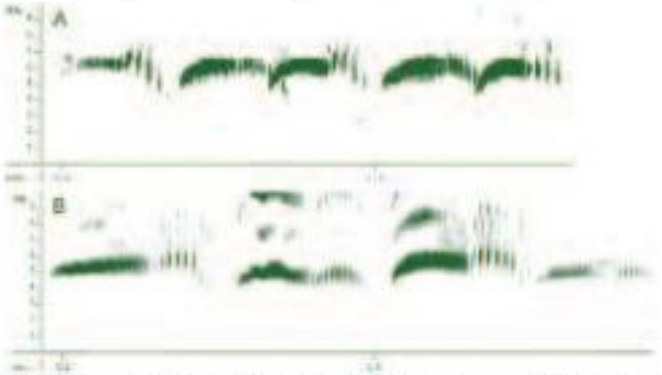

Fig. 12.– **(A)** Cris de Martinet noir (Charron *in* Bossus & Charron, 2010 ; **(B)** Cris enregistrés à Malmedy (mai 2000). ***(A)*** *Calls of Common Swift (Charron in Bossus & Charron, 2010;* ***(B)*** *Calls recorded in Malmedy (May 2000).*

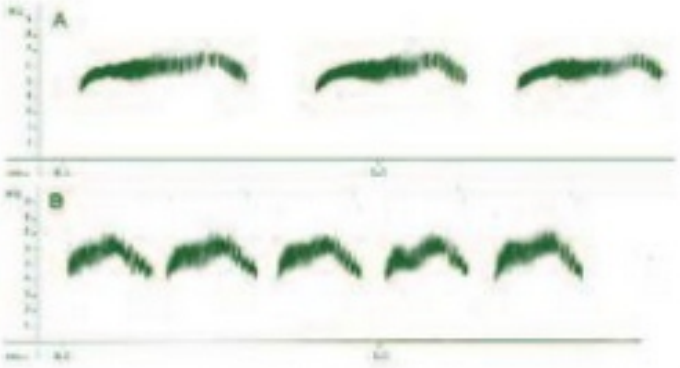

Fig. 13.– **(A, B)** Imitations par la Gorgebleue de cris de Martinet noir **(A)** Hollogne, juin 2008 ; **(B)** Amay, avril 2007). ***(A, B)*** *Imitations by a Bluethroat of calls of Common Swift* ***(A)*** *Hollogne, June 2008;* ***(B)*** *Amay, April 2007).*

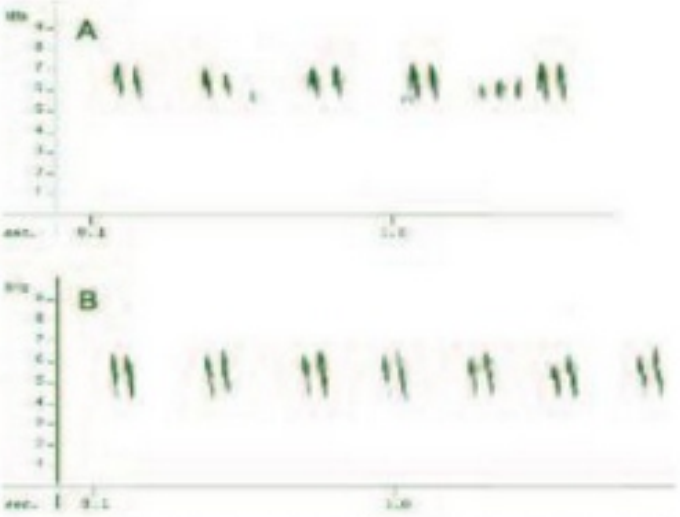

Fig. 14.– **(A)** Cris de Martin-pêcheur (Chappuis, 2000). **(B)** Imitation par la Gorgebleue (Amay, mai 2008). ***(A)*** *Calls of European Kingfisher (Chappuis, 2000).* ***(B)*** *Imitation by a Bluethroat (Amay, May 2008).*

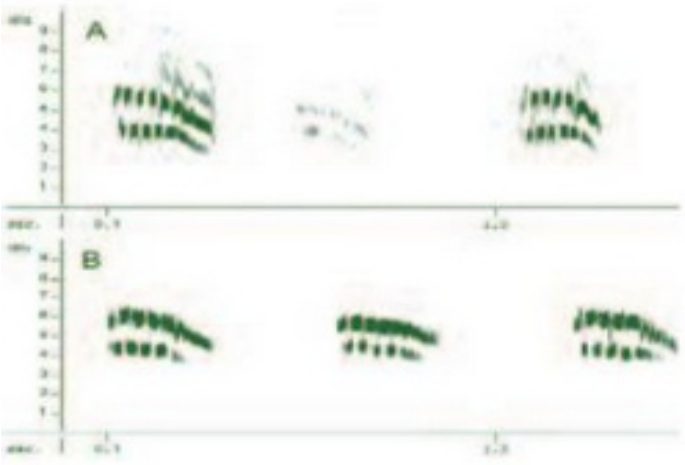

Fig. 15.– **(A)** Cris d'Hirondelle de rivage (Chappuis, 2000). **(B)** Imitation par la Gorgebleue (Amay, mai 2008). ***(A)*** *Calls of Sand Martin (Chappuis, 2000).* ***(B)*** *Imitation by a Bluethroat (Amay, May 2008).*

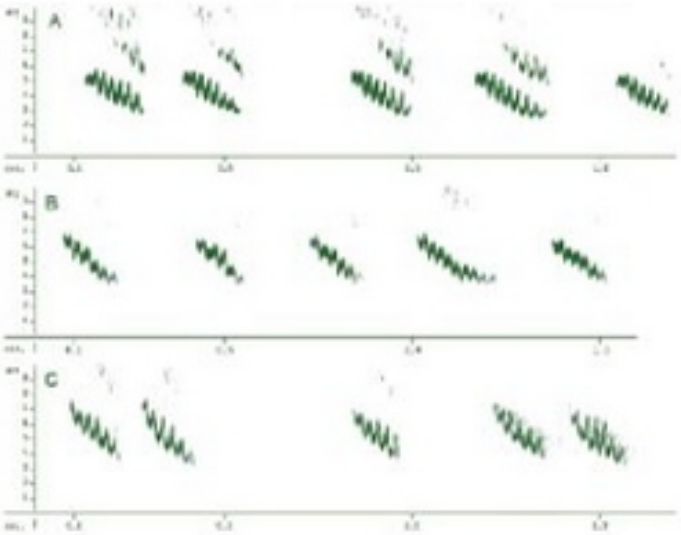

Fig. 16.– **(A)** Cris d'Hirondelle de rochers (enregistrement de Charron *in* Bossus & Charron, 2010). **(B, C)** imitation par la Gorgebleue; **(B)** Amay, avril 2007 ; **(C)** Amay, mai 2008).

(A) *Crag Martin calls (Charron's recording in Bossus & Charron, 2010).* ***(B, C)*** *Imitation by Bluethroat* ***(A)*** *Amay, April 2007;* ***(B)*** *Amay, May 2008).*

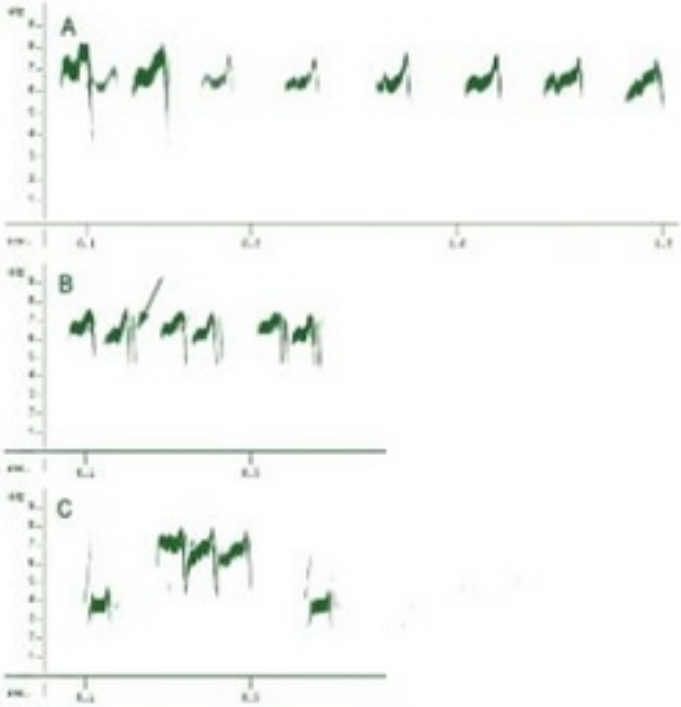

Fig. 17.– **(A)** Cris de Pipit farlouse (Amay, avril 2007). **(B) (C)** Imitations par la Gorgebleue ; **(B)** Hollogne, juin 2008 ; **(C)** Amay, mai 2008). La flèche indique une différence de structure entre ces imitations.

(A) *Calls of Meadow Pipit (Amay, April 2007).* ***(B, C)*** *Imitations by a Bluethroat;* ***(B)*** *Hollogne, June 2008;* ***(C)*** *Amay, May 2008). The arrow indicates a structural difference between these imitations.*

Meadow Pipit *Anthus pratensis*
The call borrowed from the Meadow Pipit (Fig. 17A) is of two types: the imitation of the Hollogne Bluethroat (Fig. 17B) contained a brief element that was absent from the imitation of the singer recorded the same year in Amay. The latter, on the other hand, was always accompanied by a note of lower frequency (Fig. 17C).

Blue tit *Cyanistes caeruleus*
A Bluethroat imitated a very high-pitched call of the Blue (Fig. 18A) while modifying its tempo (Fig. 18B). It can also imitate (Fig.19B) a longer, more complex call (Fig.19A).

Reed Bunting *Emberiza schoeniclus*
The recording of Reed Buntings, which were the same wetlands as the Bluethroat, made it possible to compile a detailed catalogue of their songs and detected the imitation of at least 13 different types of Bunting syllables in the song of the Bluethroat (Fig. 20 and 21). Figure 21A shows an entire song of a Reed Bunting song integrated into a phrase with the characteristic note (note 1) that that initiates and and distinguishes the song of each Bunting (GAILLY, 1982).

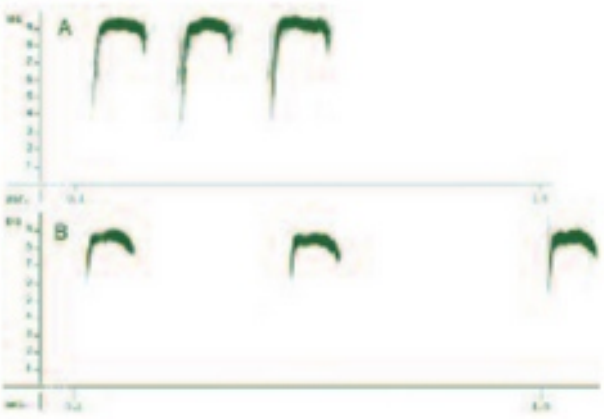

FIG. 18.– **(A)** Cris de Mésange bleue (CHARRON *in* BOSSUS & CHARRON, 2010). **(B)** Imitation par la Gorgebleue (Amay, avril 2007). ***(A)*** *Calls of Blue Tit (*CHARRON in *BOSSUS & CHARRON, 2010).* ***(B)*** *Imitation by a Bluethroat (Amay, April 2007).*

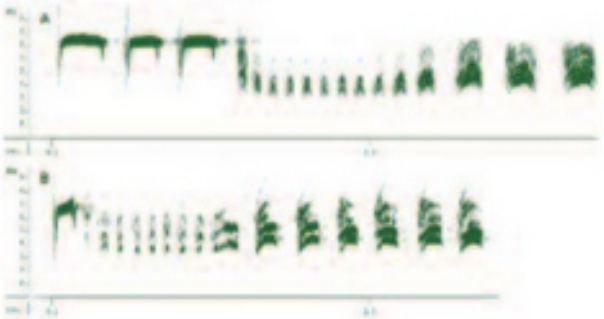

FIG. 19.– **(A)** Cri de Mésange bleue (Nomont, mai 1999). **(B)** imitation par la Gorgebleue (Amay, avril 2009). ***(A)*** *Blue tit call (Nomont, May 1999).* ***(B)*** *Imitation by Bluethroat (Amay, April 2009).*

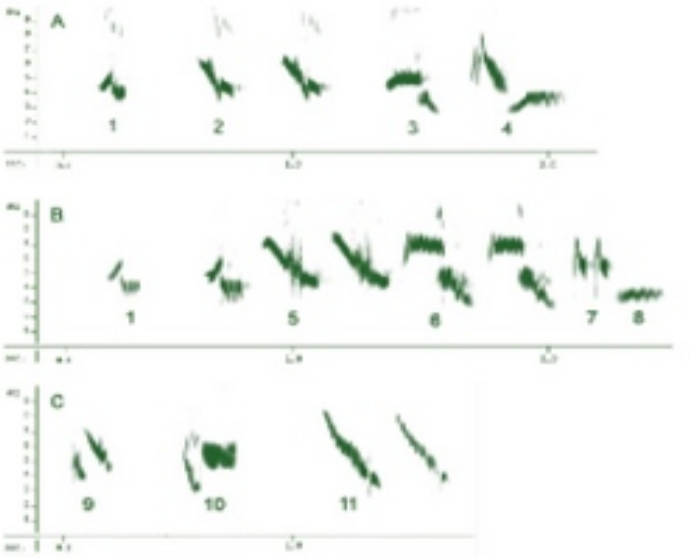

FIG. 20.– **(A, B, C)** Trois phrases de Bruant des roseaux : Amay **(A)** Juin 2007 ; **(B)** Juillet 2007; **(C)** juin 2008) et onze types de syllabes. ***(A, B, C)*** *Three songs of Reed Bunting: (Amay* ***(A)*** *June 2007;* ***(B)*** *July 2007;* ***(C)*** *June 2008) with eleven types of syllables.*

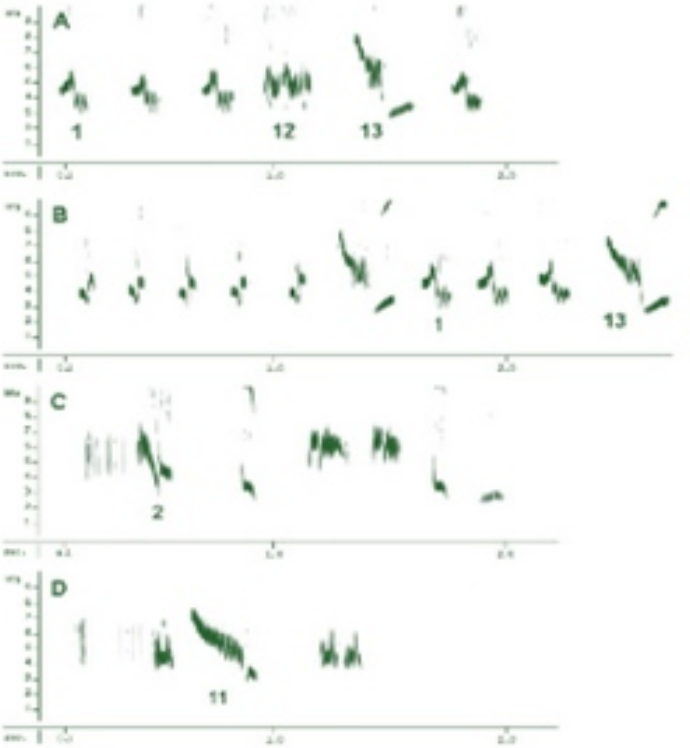

FIG. 21.– **(A)** Imitation d'un chant entier de Bruant des roseaux dans une phrase de Gorgebleue (Amay, avril 2007); **(B, C, D)** Imitations de différentes syllabes (1, 2, 11 et 13) de Bruant des roseaux (Amay, avril 2007 et mai 2008). ***(A)*** *Imitation of an entire Reed Bunting song in a Bluethroat phrase (Amay, April 2007);* ***(B, C, D)*** *Imitations of different syllables (1, 2 , 11 and 13) of Reed Bunting songs (Amay, April 2007 and May 2008).*

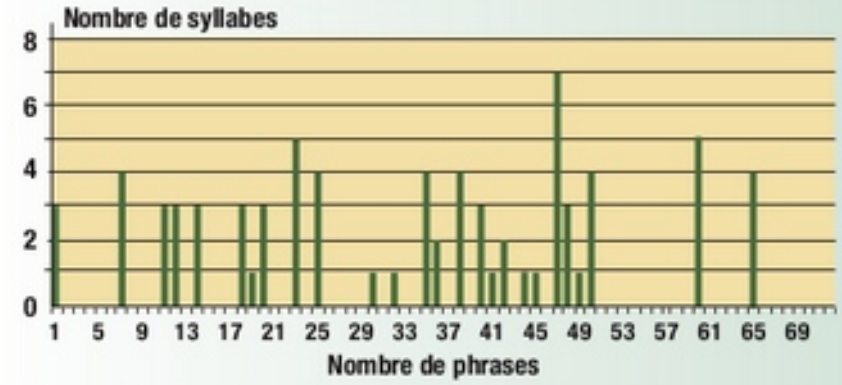

Fig. 22.– Nombre de syllabes de Bruant des roseaux par phrase dans une séquence de 72 phrases d'une Gorgebleue (Amay, 19 mai 2008). *Number of syllables of Reed Bunting songs per phrase in a sequence of 72 phrases of a Bluethroat (Amay, 19 May 2008).*

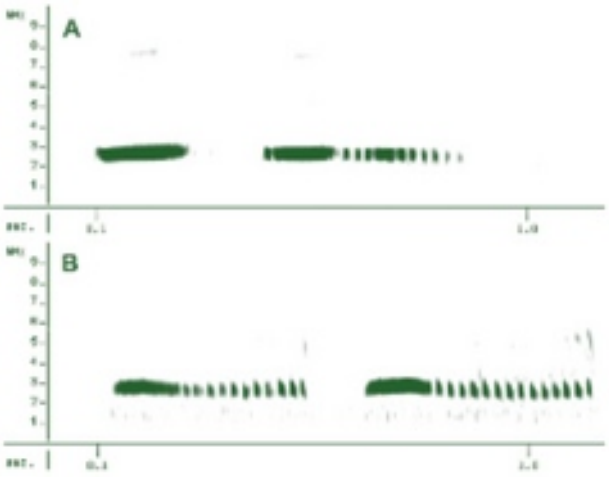

Fig. 23.– **(A)** Chant du Martin-chasseur strié (Chappuis, 2008). **(B)** Imitation par la Gorgebleue (Amay, avril 2006).
***(A)** Song of Striped Kingfisher (Chappuis, 2008). **(B)** Imitation by a Bluethroat (Amay, April 2006).*

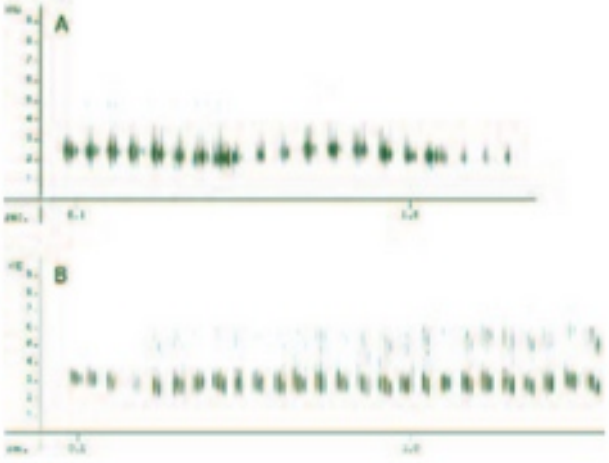

Fig. 24.– **(A)** Sonagramme d'un chant de Grenouille de Lesson (enregistrement de Deroussen *et al.*, 1996). **(B)** imitation par la Gorgebleue (Amay, avril 2007).
***(A)** Sonagram of a song of Pool Frog (Deroussen* et al., *1996). **(B)** Imitation by a Bluethroat (Amay, April 2007).*

Figures 21 B, C and D show various examples of the integration of syllables of this bunting (or even fragments of its song), either in the introductory part (Fig. 21B), or in a composite motif (Fig. 21C and D). Iimitations of Reed Bunting syllables can vary from one phrase to another. In a sequence of 72 sentences from the same male, 35% contained one or more Bunting syllables, in one case a maximum of *7* (Fig. 22).

Striped kingfisher *Halcyon chelicuti*
(an African bird)

The call of the Striped kingfisher, which is often repeated, normally consists of a detached note followed by a trill of rapid notes, but sometimes it consists of "*2 or 3 trills in succession without the first note being isolated*". (Serle & Morel, 1979). A motif emitted by a Bluethroat (Fig. 23B), singing in flight (Amay, 15 april 2006), is in a comparable frequency band and the first note is pure (not rolled), as is the case in the song of a Bluethroat in West African territorial song (Fry *et al*., 1988).

Imitation of batrachians

My sonograms also suggest the imitation of the Pool Frog *Pelophylax lessonae*, as the Bluethroat can emit a long series of calls, the structure and tempo of which are very similar to those of the Pool Frog. Structure and tempo are very similar to those of this frog (Fig. 24A), but at a slightly higher frequency (around higher frequency 3 khz instead of 2.5 khz, Fig. 24B). This imitation recorded in Amay in early april 2007 at one of the three Bluethroat, was also in early april 2008 at the same location, but this time during a song in flight.

End of the first part