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Repertoires and geographical variation in song of oriental magpie robin (*Copsychus saularis*) in northern Thailand

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The relation of geographical variation of magpie song to study area, can show obvious degree of similarities and differences in the structure of the song. Spectrogram studies revealed that all song types shared some common features. The frequency range of song was fixed between 1.99 and 5.57 kHz. A basic strophe (syllable) and a climax strophe are synthesized to form a complete song. It was found that songs were always introduced by repeating a basic strophe followed by a climax strophe and terminating with the basic strophe. A strophe contains one or more core elements. The last core element is referred to as the marking element, which is followed by a fine structure of specific elements. Discriminant function analysis revealed that the mean length of strophe (MLSt), the mean length at terminal part of strophe (MLTPSt), the number of element at the terminal part of strophe (NETPSt) and the number of element in strophe (NESt) were found to be the best determinants for differentiating song structure and classifying it into eight study sites. The geographical isolation and long distance of the study site, allowed birds to learn and produce song variations. This variation of song structure can show the unique characteristic of songs in each study area as well.

Keywords: *Copsychus saularis*, song dialect, song syntax, song variation, species recognition, spectrogram.

SONGS are produced by syrinx, which is a structure at the bottom of the trachea. Its development is controlled by the song repertoire in the brain[1,2]. The size and complexity of song repertoire as well as the unique features of the song, enable birds to recognize their own species or other species and to implement mate selection and territorial defense[3,4]. Species recognition provides mechanisms for production and reception of species-specific signals, acting as inter-specific barriers between members of different populations[5–7]. Acoustic parameters appear to be involved in species recognition and these differ from species to species in their relative importance. Studies show that the song structure of normal indigo bunting (*Passerina cynaea*) has a very evident syntax in which, elements are usually repeated and occur in pairs[8]. The rhythm or temporal patterning of the song appears to be

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an important factor in species recognition that is revealed in European robin (*Erithacus rubecula*) and Bonelli's warbler (*Phylloscopus bonelli*)[9]. Dunmak and Sitasuwan[10] reported song variations of the oriental magpie robin in northern Thailand. It was found that the male bird has a large song repertoire and a complicated song. Here, we present an acoustic analysis of oriental magpie robin songs from eight study sites in northern Thailand. Song types are characterized by element, strophe and syntax structure. Song playback experimental methodology was used to prove recognition of songs between various populations of this species.

Northern Thailand (17°N, 97°E; 20°N, 101°E) is characterized by multiple mountain ranges and drainage basins. The northern plains are isolated by parallel mountain ranges which extend from the western to the eastern border; Thanon Thong Chai Range, Khun Tan Range, Daen Lao Range, Phi Pan Nam Range, Luang Prabang Range, and Phetchabun Range. These ranges also harbour a series of rivers including the Ping, Wang, Yom and Nan[11]. Eight study sites in northern Thailand were selected in Chiang Mai, Chiang Rai, Lampang, Lamphun, Mae Hong Son, Nan, Phayao, and Phrae provinces (Figure 1).

The Oriental Magpie Robin (*Copsychus saularis* Linnaeus, 1758) is a small passerine bird in the family Muscicapidae[12]. This species is distributed through most of the Indian subcontinent, some areas of Southeast Asia, and the East Indies archipelago. The robin is a resident that is born, breeds and dies in cultivated areas often close to human habitations. The territories defended by the monogamous pairs of this species range from 1 to 2 km^2. Calls and songs are generally used to communicate amongst this species[13–15].

The territories of male birds in each populations were disclosed by the marked location of individual singing. The territorial maps have been prepared under three conditions. First, the territory of birds was marked to be the areas where singing is heard regularly. Secondly, each territory reveals a nest and their own families. Lastly, the song matching process where an individual bird sings and a neighbour sings back was found to be the best evidence to indicate ownership of the adjacent territory (Figure 2).

The songs of five male birds in each site were recorded and their behaviour observed during the breeding and non-breeding seasons from November 2013 to October 2014, for at least two days per month for each location. The acoustics of males was recorded along study trails from sunrise to sunset. The sound recording equipment included a condenser microphone (RODE, model), connected to a digital recorder (ZOOM handy recorder H4N). The sound was recorded in digital form and collected on an SD memory card. Finally, the sound data were analysed by SASLab Pro (v. 4.40; Avisoft Bioacoustic, Berlin) and SPSS programmes (v 16.0).

The acoustic variables used in analysis were: mean length of song (MLSo, s), average of the number of strophes (syllable) per song (ANSSo), maximum and minimum frequencies (MaxF and MinF, kHz), frequency range (FR, kHz), mean length of strophe (MLSt, s), number of elements per strophe (NESt), number of elements in the first second of strophe (NEFSt), mean length of the terminal part of each strophe (MLTPSt, s), number of

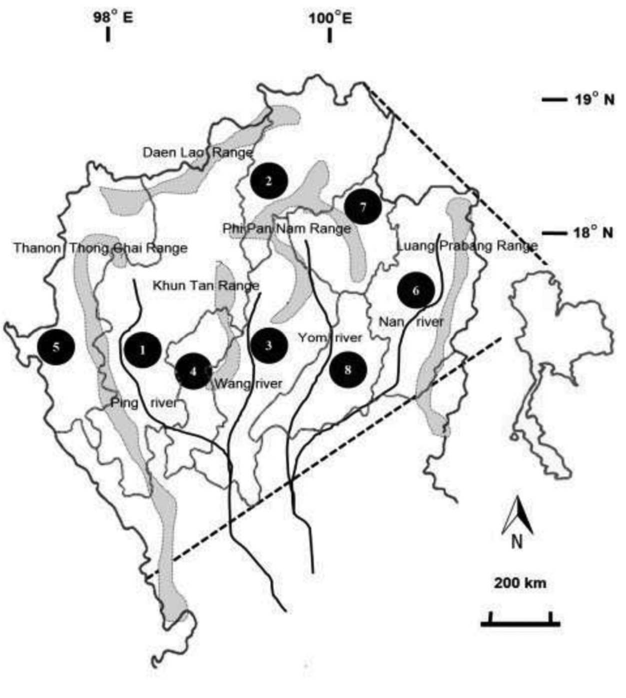

Figure 1. Locations of the eight study areas in north of Thailand. The study site provinces are (1) Chiang Mai, (2) Chiang Rai, (3) Lampang, (4) Lamphun, (5) Mae Hong Son, (6) Nan, (7) Phayao and (8) Phrae.

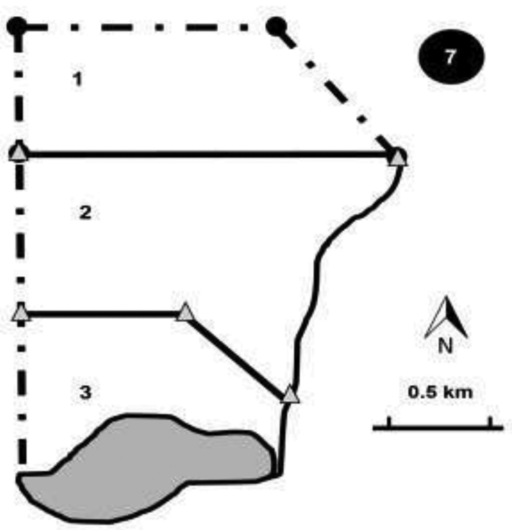

Figure 2. The location of each male's singing area is marked by a territorial song map. Territorial maps show the probable territory of this species, i.e. a black circle for the first territory and a shaded triangle for the second territory.

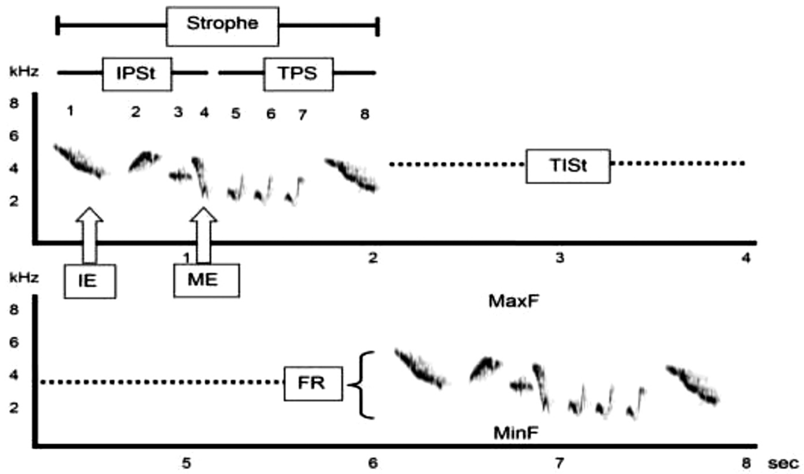

Figure 3. Spectrogram of a typical male oriental magpie robin song. IE, introductory element; ME, Marking element; TISt, Time interval of strophe; IPSt, Initial part of strophe; TPSt, Terminal part of strophe; FR, Frequency range; MaxF, Maximum frequency; MinF, Minimum frequency.

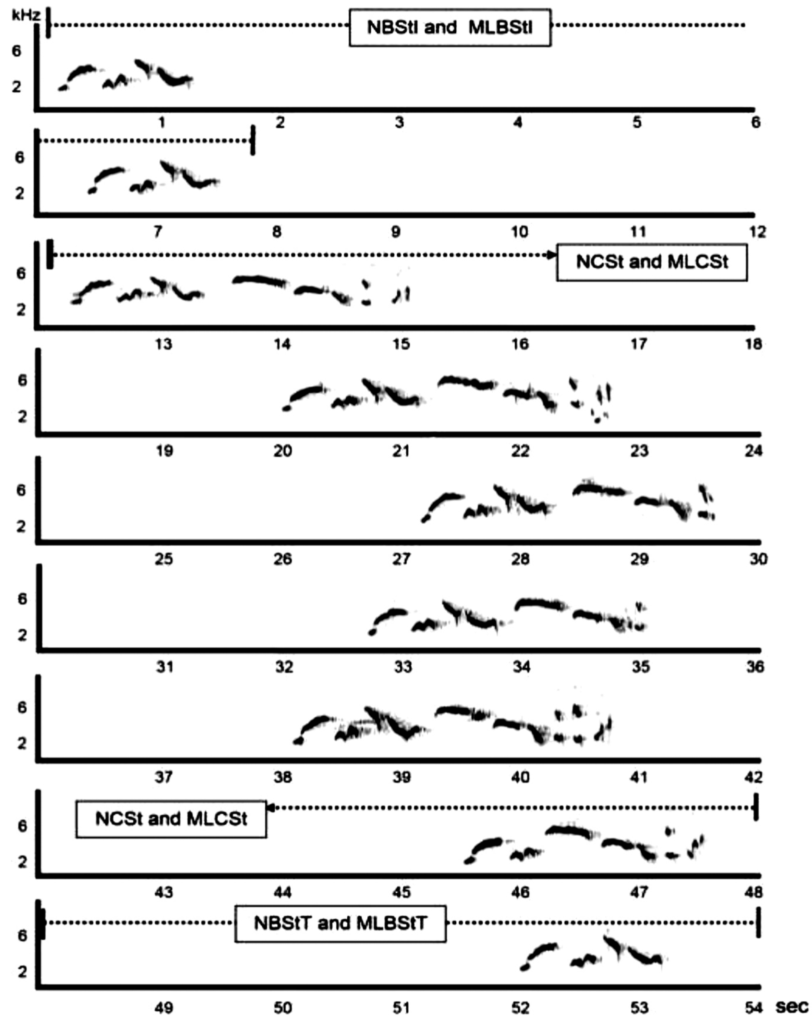

Figure 4. Song syntax of the full song of the oriental magpie robin of Chiang Mai province: this includes the number of basic strophes in the song introduction (NBStI), the mean length of basic strophes in the song introduction (MLBStI, s), the number of basic strophes in the termination of the song (NBStT), the mean length of basic strophes in the termination of the song (MLBStT, s), the number of climax strophes in the song (NCSt) and the mean length of climax strophes in the song (MLCSt, s).

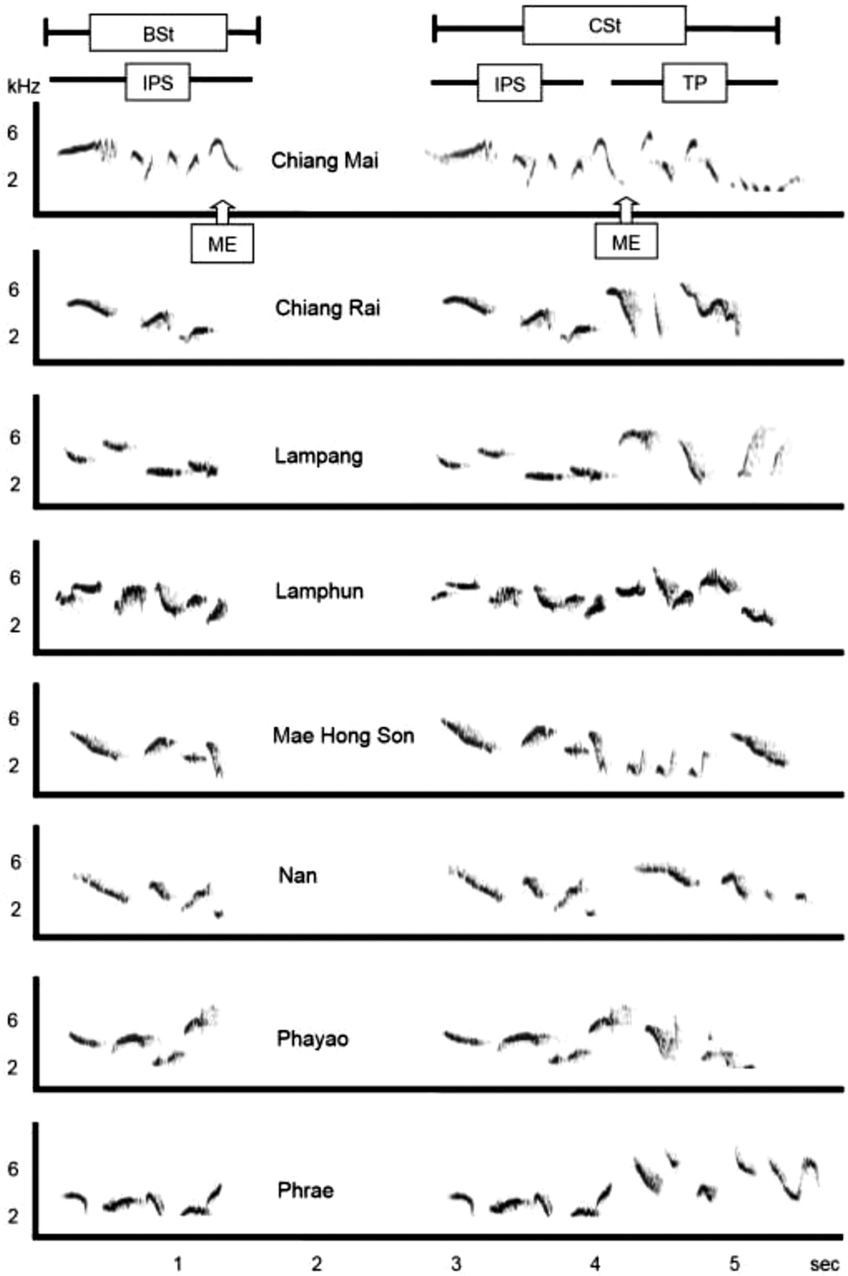

Figure 5. A comparison of spectrograms recorded at 8 study sites. BSt, Basic strophe; CSt, Climax strophe; IP, Initial part; TP, Terminal part; ME, Marking element.

elements in the terminal part of each strophe (NETPSt), time interval between strophes (TISt, s), position of marking element (PME), number of basic strophes in song introduction (NBStI), mean length of basic strophes in song introduction (MLBStI, s), number of basic strophes when terminating the song (NBStT), mean length of basic strophes when terminating the song (MLBStT, s), number of climax strophes in songs (NCSt) and a mean length of climax strophe in song (MLCSt, s)[16,17] (Figures 3–5). In addition, discriminant function was analysed by calculating Wilk's lambda and the eigenvalue and canonical correlation were quoted in assessing the relative validity of discriminant functions.

Forty male birds of eight study sites were heard during three playback trials at two minute intervals of eight song types of the basic strophe from each study site, using eight song types of climax strophe from each study site, and the acoustics of the Eurasian sparrow (*Passer montanus*) was the control group. We chose song types from complete songs that had the most mean song length for each population, as a representative of song types in each study areas for playback trials. The reaction of males to

Table 1. Variables measured of the fine structural features of the 8 study sites of the oriental magpie robin song in northern Thailand

Variables	Mean ± SD (n = 40)	Wilk's lambda	Eigen value	Canonical correlation	p-value	F
MLSo	70.53 ± 40.96	0.855	–	–	0.613	0.774
ANSSo	11.10 ± 5.96	0.795	–	–	0.341	1.181
MaxF	5.57 ± 0.39	0.878	–	–	0.725	0.633
MinF	1.99 ± 0.03	0.821	–	–	0.449	1.002
FR	1.99 ± 0.03–5.57 ± 0.39		–	–	–	–
MLSt	1.71 ± 0.36	0.177	4.638	0.907	0.0001	21.205
NESt	6.63 ± 1.83	0.357	1.799	0.802	0.0001	8.223
NEFSt	4.05 ± 0.74	0.822	–	–	0.456	0.990
MLTPSt	0.63 ± 0.46	0.198	4.054	0.896	0.0001	18.532
NETPSt	2.74 ± 1.35	0.340	1.941	0.812	0.0001	8.871
TISt	4.79 ± 1.28	0.687	–	–	0.075	2.083
PME	4.07 ± 0.72	0.847	–	–	0.574	0.825
NBStI	1.92 ± 1.09	0.684	–	–	0.071	2.111
MLBStI	7.72 ± 4.52	0.661	–	–	0.074	2.348
NBStT	1.72 ± 0.84	0.744	–	–	0.178	1.577
MLBStT	7.15 ± 4.17	0.756	–	–	0.212	1.473
NCSt	7.75 ± 4.74	0.817	–	–	0.433	1.025
MLCSt	55.28 ± 36.65	0.900	–	–	0.823	0.506

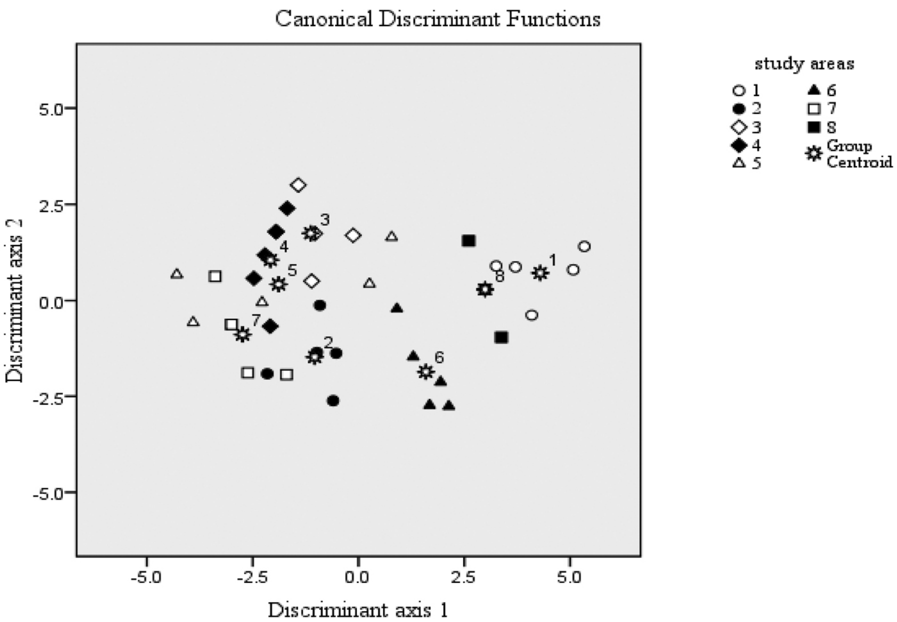

Figure 6. A scatter plot of the first two canonical discriminant functions of analysis acoustic features resulting from the discriminant analysis explained correctly 99.8% of variance.

sounds from the loudspeaker was compared with the criteria of Thielcke[18], 1 = the subject stands more than 15 m away from the loud speaker, 2 = the subject stands 10 to 15 m away, 3 = the subject stands 5 to 10 m away and performed countersinging, 4 = the subject stands less than 5 m away and performed countersinging, and 5 = the subject showed extremely aggressive behaviour, performed countersinging, and pecked the loudspeaker. The results of song response data of each trial were analysed by one-way ANOVA.

Spectrograms showed that all song types ranged in frequency between 1.99 (±0.03) and 5.57 (±0.39) kHz. The mean song length was 70.53 (±40.96)s that consisted of 11.10 (±5.96) strophes. The number of strophes per song was 11.10 (±5.96). We found that the minimum repetition of strophes in the song was 5.00 (±0.94) strophes that used a mean length 23.00 (±6.47)s and the maximum of strophe repetition was 30.00 (±0.94) strophes that used a mean length 188.00 (±6.47)s. The initial and terminal parts were used to synthesize a single strophe. The initial part of the strophe, the first second, contained 4.05 (±0.74) elements. The terminal part of the strophe had a mean length 0.63 (±0.46)s and contained 2.74 (±1.35) specific elements (Table 1). The initial part of a strophe always starts with the core element, the introductory element, that appears within the first element of each strophe. The last section of the core element, the marking element, is located at 4.07 (±0.72) into the structure and is followed by the fine structure group of specific elements. The terminal part of strophes is compared with the degree of acoustic similarity and the difference of song structure. It was found that the terminal part of climax strophe in each populations showed significant difference in the quality of specific elements (Figures 3 and 5). Songs are always introduced with a basic strophe with 1.92 (±1.09) repeated strophes and a mean length of 7.72 (±4.52)s, followed by the climax strophe with 7.75 (±4.74) strophes and a mean length of 55.28 (±36.65)s and then terminated with a basic strophe that is repeated 1.72 (±0.84) times with a mean length 7.15 (±4.17)s. The time interval of strophes was 4.79 (±1.28)s. The strophe generally consisted of 6.63 (±1.83) elements and a mean length of 1.71 (±0.36)s (Table 1, Figure 4). Discriminant function analysis distinguished among the eight study sites of oriental magpie robin was based on eighteen fine structural variables. Analysis showed that this model could correctly classify 65% of original grouped cases overall. The best discriminator that predicted the degree of different song structures was the mean length of strophe (MLSt) (Wilk's lambda = 0.177, df = 32, eigenvalue = 4.638, canonical correlation = 0.907, $p < 0.0001$). The second function was a mean length at terminal part of strophe (MLTPSt) (Wilk's lambda = 0.198, df = 32, eigenvalue = 4.054, canonical correlation = 0.896, $p < 0.0001$). The third function was the number of elements in the terminal part of strophe (NETPSt) (Wilk's lambda = 0.340, df = 32, eigenvalue = 1.941, canonical correlation = 0.812, $p < 0.0001$) and the fourth function was the number of elements in strophe (NESt) (Wilk's lambda = 0.357, df = 32, eigenvalue = 1.799, canonical correlation = 0.802, $p < 0.0001$) (Table 1). These analyses generated two canonical axes that explained 99.8% of the total variance in structural characteristics of the songs in eight study areas. The first canonical axis explained 80.6% of the variance and showed strong positive relationship with mean length of strophe (MLSt). The second canonical axis explained 19.2% of the variance and showed strong positive relationship with number of elements per strophe (NESt). The multivariate analysis showed that the forty song structures of all eight study areas can be subdivided into four discrete groups. The first group is the largest consisting of those from Lampang, Lamphun, Mae Hong Son and Phayao. The second group comes from Chiang Mai and Phrae. The third and fourth groups are Chiang Rai and Nan respectively (Figure 6). We found that the average reaction to responses of the climax strophe was generally higher than the basic strophe. There was a significant difference between the three groups of eight song types of climax strophe and the eight song types of the basic strophe, Moreover, the acoustics of the Eurasian sparrow was 1.50 (±0.28) at the 0.05 level (Table 2).

Table 2. Response of male birds to song playback trials

Song playback trials (n = 40, 5 male birds of 8 study sites)	Basic strophe Mean ± SD	Climax strophe Mean ± SD
Mae Hong Son	3.42 ± 0.24^a	4.00 ± 0.23^b
Chiang Mai	3.32 ± 0.14^a	4.02 ± 0.29^b
Chiang Rai	3.35 ± 0.25^a	4.05 ± 0.25^b
Phayao	3.27 ± 0.18^a	4.05 ± 0.36^b
Nan	3.20 ± 0.26^a	3.98 ± 0.29^b
Phrae	3.27 ± 0.26^a	4.05 ± 0.17^b
Lampang	3.20 ± 0.21^a	4.10 ± 0.30^b
Lamphun	3.25 ± 0.25^a	4.02 ± 0.29^b
Acoustics of the Eurasian sparrow		1.50 ± 0.28^c

Spectrogram studies revealed that all song types shared some common features. The frequency range was fixed from 1.99 to 5.57 kHz. Strophes of song can be classified into two types. A basic strophe is the initial part whilst the climax strophe contains initial and terminal parts. The song syntax is synthesized from strophes to form complete songs. The standard pattern of song syntax in oriental magpie robin is of prime importance for song recognition signals[19]. Members of species communicate and recognize their population members with core elements, the number of elements, song frequency and the rhythm or temporal pattern of the song that approximate to the song syntactical pattern in other passerine birds, e.g. indigo bunting, European robin, Bonelli's warbler, and the three species of *Acrocephalus* (Reed warbler, Marsh warbler and Sedge warbler). The stability of these patterns occurs after the song patterns have been learnt and shared among members of a particular group and the same basic song pattern has direct transmission relationship inheritance that stretches from adults to their progeny[20]. Acoustic features that strongly influenced discrimination included the mean length of strophe (MLSt), the mean length at terminal part of strophe (MLTPSt), the number of elements at the terminal part of strophe (NETPSt), and the number of elements in strophe (NESt). This evidence suggests that intraspecific vocalizations of the oriental magpie robin developed with particular song variations in each study site. The obstruction of mountain ranges and long distance separation in each study area allow birds to learn and produce song variations to establish their own unique song characteristics which involved territorial defense that was intruded by outer territories and promoted mate attraction[21–24]. However, song playback technique suggests that the levels of reaction of an owner of its territory depend on the degree of song similarity and differences of intraspecifics and intruders[25,26]. In general, territorial male birds respond strongly to familiar songs, followed by foreign songs and heterospecific songs[27–29]. These experiments provide evidence that such recognition occurs.

Songs can reflect the survival of population in each territory. Our study demonstrates that the oriental magpie robin has a complicated song repertoire and a song variation. The present results will help to understand the song structure and song syntax of this species. For future research, the song dialect of this bird species in another region of Thailand will be studied. Song data will be compared with the degree of acoustic similarity and difference of song syntax structure along with other possible factors that cause song dialect.

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