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A Song Transition among the Geographic Populations of Bush Warbler (*Cettia diphone*)

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휘파람새 (*Cettia diphone*) 개체군간 song 변이의 방향

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ABSTRACT

This study was to examine the occurrence of geographic song variation and its pattern of transitional direction among bush warbler populations distributed in Korea and Japan. Bush warbler songs (n=284) of 25 males from Cheongwon and Jeju, Korea, and from Chiba, Japan were analyzed. Chiba individuals had more song types and had the higher dominant frequency and longer duration of the introductory whistle portion than Cheongwon and Jeju individuals. In measure of eight song parameters, the parameters constantly showed a decreasing or increasing tendency. The constant tendency showed direction related with the geographic location from Chiba to Cheongwon. The difference in song parameters between Cheongwon and Chiba populations was the greatest in comparison to that of other sets of geographic populations. The degree of discrimination among the three populations was 92.00%. These results indicate that there is a geographic song variation between bush warblers of Japan and Korea, and that the song transition has been directed from Chiba (Japan) through Jeju to Cheongwon (Korea).

Key words: *Cettia diphone*, Geographic variation, Repertoire size, Song mode, Song type

INTRODUCTION

Many bird vocalizations include 'tradition', a new and important source of variation (Mundinger 1982). The geographic variation of songs has been known as a widespread isolating mechanism in song birds (Thielcke 1969, Mayr 1963, Nottebohm 1969, Bradley 1977). It has been renewed in a provocative way recently as the concept of "behavioral drive," and as an explanation for certain patterns of biological diversity (Wyles *et al.* 1983).

Bush warbler ranges from Japan through Korea to southern China. The geographical variation of bush warbler songs has been a subject of recent studies (Yoon 1995, Park and Yang 1988) in Korea. Studies were based on analyses of song characteristics and identified locally separable song variations among the species populations. Also, characteristics of phenotype (Abe 1984, Hamao 1992), song type (Hamao 1993), and the related population density (Haneda and Okabe 1970) were studied in Japan for Japanese bush warbler (*Cettia diphone cantans*).

The Korean bush warbler populations can be separated into two geographic groups, the inland and the south-coastal groups by the birds' song variation. Two groups are separable approximately along the 35° 35′ N latitude. The inland group is distributed to the north, and the south-coastal group, in which the local populations of Geoje, Yeosu, Wando are included, is to the south of the latitude (Yoon 1995). It was assumed that the transition of the geographic song variation in Korean bush warbler populations might have been directed from the south-coastal to the inland group (Yoon *et al.* 1995). It was suggested that in order to clarify the origin and the transitional direction of the geographic song variation, further studies on the variation of song characteristics of the Korean and Japanese bush warbler populations may be necessary (Yoon 1995).

In that respect, this study was designed to clarify whether another geographic song variation exists between Korean and Japanese populations, and to determine, if it does, how the transition is being directed. For these purposes, we compared the characteristics of bush warbler songs that were field recorded from Cheongwon (i.e., inland population), Jeju (i.e., south-coastal population), and Chiba (i.e., Japanese population).

MATERIALS AND METHODS

During the breeding season, April through July in 1994 and 1995, songs of 19 male bush warblers from Cheongwon and Jeju were tape-recorded. The number of recorded songs and individuals is as follows; 73 songs of 7 individuals from Cheongwon, 118 songs of 12 individuals from Jeju.

Most songs were recorded at 8~10 a.m., or 5~7 p.m. within 10 m distance from the singing individuals, but some recordings were made at other times of a day. The tape was recorded at the speed of 19 cm/sec by an Uher 4000 Report IC tape recorder and an AKG c1000s microphone mounted on a 54-cm parabolic reflector. Recorded songs were analyzed by a sonagraph (Kay Elemetric Co., Model 5500). It was set for a wide band spectrum, 0~8000Hz frequency range, Hi input shape, and 10dB channel sensitivity.

Song recordings of Chiba population were supplied by Dr. Teruyo Oba (Natural History Museum and Institute, Chiba, Japan), in which 93 songs of six males were recorded during March through May 1990 and 1992. The Recording was made using Sony TCD-D10 and F-115A microphone mounted on a parabolic reflector. The Chiba songs were analyzed in

Fig. 1. A typical song of bush warbler consists of introductory whistle portion and complex ending syllable portion.

the same way, as described above.

Eight song parameters were selected for the analysis of numerical song characteristics (Fig. 1). Mean test, correlation analysis, one-way-ANOVA, and discriminant function analysis were used for statistical analyses.

RESULTS

Repertoire size

Each male bush warbler has repertoire, stereotyped song types, which are repeated in bouts (Fig. 2). Each individual has one to three song types (1.67 ± 1.03 $n=7$) in Cheongwon population, one to four (2.16 ± 0.84 $n=12$) in Jeju and two to five (2.86 ± 0.69 $n=6$) in Chiba populations. The difference in repertoire size between Cheongwon and Chiba population was significant ($df=1,12$, $F=6.1494$, $P<0.05$), while differences between any other pairs of populations were not significant.

In relationships between the number of notes in a whistle portion (NNWP) and the number of syllable in an ending complex syllable portion, only songs of Chiba population have shown a negative correlation ($r=-0.6614$, $P<0.001$).

Song characteristics

Results of the eight song parameter analyses showed that the NNWP, the maximum frequency of complex syllable portion (MACSP), and the duration of complex syllable

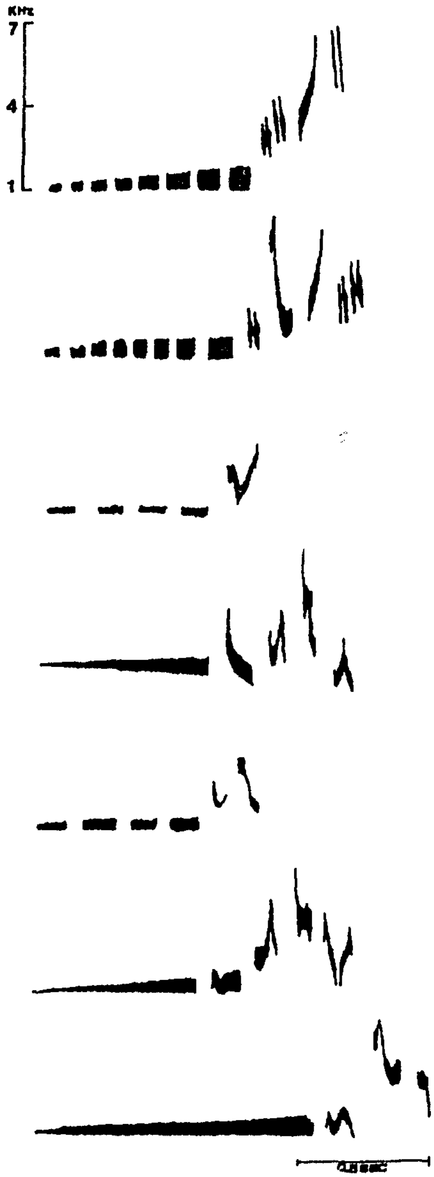

Fig. 2. Examples of song types from each of Cheongwon (top two), Jeju (next two in the middle), and Chiba (bottom three) individual.

portion (DCSP) decreased, while the other parameters increased as the bird's geographic range moved northward from Chiba, Japan to Cheongwon, Korea. (Table 1).

In comparison of song parameters among the three geographic populations, Cheongwon and Jeju songs were significantly different in the NNWP ($F=31.9591$, $P<0.001$), dominant frequency of the whistle portion (DOWP) ($F=22.0506$, $P<0.001$), duration of the whistle portion (DWP) ($F=5.5712$, $P<0.05$), maximum frequency of the complex syllable portion (MACSP) ($F=40.0340$, $P<0.001$), minimum frequency of the complex syllable portion (MICSP) ($F=20.6593$, $P<0.001$), and song duration (SD) ($F=6.7714$, $P<0.05$). In comparison between Cheongwon and Chiba populations, all song parameters but the interval between whistle and complex syllable portions (IWC) were significant ($P<0.001$). In comparison between Jeju and Chiba songs, however, only the difference in DWP ($F=8.81$, $P<0.01$) and duration of the complex syllable portion (DCSP) ($F=11.0977$, $P<0.01$) were significant.

Results of correlation analyses showed that differences existed in the eight song parameters of each population. In Chiba population, as the NNWP increased, the values of DOWP ($r=-0.7758$, $P<0.001$) and MACP ($r=-0.6042$, $P<0.001$) decreased, and the DCSP ($r=-0.7758$, $P<0.001$) shortened. In Jeju population, as the NNWP increased, lower DOWP ($r=-0.7512$, $P<0.001$) and shorter IWC ($r=-0.4443$, $P<0.001$) values were observed. However, in Cheongwon population, as the DWP value increased, higher values of NNWP ($r=0.6807$, $P<0.001$), DOWP ($r=0.5553$, $P<0.001$), and DCSP ($r=0.4455$, $P<0.01$), as well as higher MACSP, MICSP

Table 1. The characteristics of eight song parameters of bush warblers from Cheongwon, Jeju, and Chiba populations

Parameters	Whistle Portion			Interval between the whistle and complex syllable portion(sec)	Complex Syllable Portion			Song duration (sec)
Populations	Number of notes	Dominant frequency(Hz)	Duration (sec)		Maximum frequency(Hz)	Minimum frequency(Hz)	Duration (sec)	
Cheongwon	5.58±2.62*	945.56±184.96	0.65±0.21	0.05±0.01	5486.67±716.91	910.00±108.34	0.39±0.06	1.07±0.25
Jeju	2.98±1.69	1244.79±349.55	0.76±0.22	0.05±0.01	4512.31±705.65	1075.92±199.37	0.38±0.13	1.23±0.29
Chiba	2.58±1.43	1383.45±464.55	0.89±0.22	0.07±0.10	4360.85±973.76	1076.60±125.89	0.29±0.11	1.24±0.23

* : Standard deviation

Table 2. The discriminant function analysis on the eight song parameters of bush warbler from Cheongwon, Jeju, and Chiba populations

	Discriminant function*	
	1	2
Eigenvalue	3.6947	0.3885
% of variance	90.49	9.51
Number of note in the whistle portion	0.98544	0.26099
Duration of the whistle portion	−0.81382	4.46590
Interval between the whistle portion and complex syllable portion	−0.23920	0.49127
Duration of the complex syllable portion	0.88263	−5.52876
Song duration	−0.20149	2.75138

* : Two functions are significant at $P<0.0001$.

Table 3. The classification results by eight song parameters of bush warbler from Cheongwon, Jeju, and Chiba populations

Actual Group	No. of Cases	Predicted Group Membership		
		Cheongwon	Jeju	Chiba
Cheongwon	7	6 85.7%	1 14.3%	0 0.0%
Jeju	12	0 0.0%	12 100.0%	0 0.0%
Chiba	6	0 0.0%	1 16.7%	5 83.3%

Note; Percent of grouped cases correctly classified: 92.00%

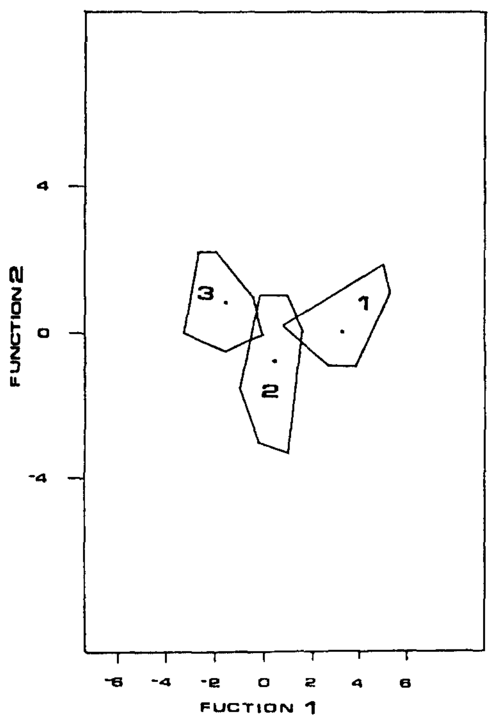

Fig. 3. Polygon of the two discriminant functions among Cheongwon, Jeju, and Chiba populations. A symbol □ indicates a centroid of each population. No. 1, Cheongwon; No. 2, Jeju; and No. 3, Chiba populations.

($r=0.5718$, $P<0.001$) and shorter CSP ($r=-0.4000$, $P<0.01$) values were observed.

In order to clarify the degree of discrimination among the populations, a discriminant analysis was used. The five significant Standardized Canonical Discriminant Function Coefficients related to function 1 and function 2 among the three populations are shown in Table 2. The most discriminant variable was NNWP, and DWP was the second, and grouped cases correctly classified was 92.00 % (Table 3, Fig. 3).

DISCUSSION

Among individuals, there is a great variation in song structure, and many studies document macro- and microgeographic variation of song (Slater *et al.* 1984, White 1985). Song variation caused by geographic isolation can crystallize into dialect (Trainer 1983). Through this process, dialects can procure the diversion of species (Raikow 1986). The three populations examined showed large differences in song parameters. Each study group showed a high discrimination responses to self groups. In particular, the percent of misjudgment discriminating Cheongwon as Chiba population was 0%. However, the discrimination between Cheongwon and Jeju, and between Jeju and Chiba were similar. The eight song parameters showed a constant tendency along the geographic direction from Chiba to Jeju. This result represents that there is a geographic song variation between Korea and Japan, and that the transition of geographic song variation has a constant directional tendency, from south to north among the study populations.

The clearest examples of dialects have been found in species with either one or a small number of song types in their repertoires (Marler and Tamura 1964, McGregor 1980). In general, the repertoires play a role in intersexual selection (Catchpole 1980, Krebs 1977), intrasexual selection (Yasukawa *et al.* 1980), and antihabituation (Hartshorne 1973). Bush warbler in Korea has approximately two song types ($M=1.94$; range 1～4) (Yoon 1995), while Chiba individuals have distinctly more song types ($M=2.86\pm0.69$; range 2～5) than those of Cheongwon and Jeju. In particular, one individual in Chiba had five song types which might be an indication that individuals of Chiba suffer from the higher inter- and intraspecitic competitions. Our study populations showed a tendency of increasing repertoire size along the geographic location, from Cheongwon to Chiba. This result may have been caused in accordance with an increase in population density (Yoon 1995, Abe 1984). It is known that the increase of repertoire size is closely related with increased population density (Lemon *et al.* 1987). Conversely, the difference in population density may have been an important force for bush warbler to adapt themselves to geographically different song characteristics. This could be a major factor in determining which geographic song variation groups are formed among the separate populations of bush warbler. It is also suggested (Yoon 1995) that characteristic features of song and of song modes may have played a critical role in adaptation of geographically separable song variations in bush warblers.

Song mode of bush warbler can be defined by the characteristics of its compositional structure, particularly by introductory notes of the whistle portion (Yoon 1995). The α mode is a song with two or fewer notes and the β mode is a song with three or more notes in the whistle portion (Yoon *et al.* 1995). In our analysis, some individuals of Jeju showed no α mode, as seen in Yoon (1995), while all individuals of Chiba commonly had two song modes. To understand the function of two song modes precisely, it would be important to study further the geographic patterns and the use of song modes, particularly of bush warblers distributed in Korea and Japan.

In contrast to previous studies, our study revealed that there is a transitional tendency in the geographic song variation among the Korean and Japanese bush warblers. It is still premature to verify the species' origin or the phylogenic transition patterns in many aspects, because the information presently available is yet fragmentary. However, this study clarified that there is an evidence of song transition that is directional from one population toward another among bush warblers. On the basis of our study, we may conclude that the transition in an aspect of song variation is directed from south to north.

적 요

휘파람새에 있어서 한국과 일본사이의 지리적 변이의 존재와 변천 방향을 알아보고자 내륙 그룹지역의 청원, 남부해안 그룹지역의 제주와 일본의 지바로부터 25개체의 284 song을 녹음 분석하였다. 지바의 개체들은 청원이나 제주의 개체들에 비하여 더 많은 song type을 가지고 있었으며, whistle portion의 길이는 긴 반면, complex syllable portion의 길이는 더 짧았다. Song의 8개의 변수들의 분석결과, 지바에서 제주, 청원으로 이동함에 따라 song의 각각의 변수들이 감소 또는 증가하는 일정한 경향을 나타내었다. 세 개체군에 있어서 자신의 집단을 올바로 판단할 확률은 92.00% 이었다. 이상과 같은 결과로 한국과 일본 사이에는 휘파람새 song의 지리적 변이가 존재하며, 휘파람새가 일본 지바에서 제주를 거쳐 한반도로 확산 분포된 것으로 사료될 수 있다.

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