

The distribution of Lemon-rumped Warbler *Phylloscopus chloronotus* and Sichuan Leaf Warbler *Phylloscopus forresti* in north-eastern India: An analysis based on their vocalisations

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Abstract

The vocalisations of the Lemon-rumped *Phylloscopus chloronotus* and the Sichuan *P. forresti* Leaf Warblers differ both, in song, and in principal call note. However, the occurrence of the Sichuan Leaf Warbler in north-eastern India has been contentious until recently, when more call recordings were made available on public sound repositories. We analysed all available principal call recordings of both these leaf warblers, across their distribution ranges and established that Sichuan Leaf Warbler indeed occurs in north-eastern India. However, we found that recordings from Arunachal Pradesh did not entirely fit one species: those from western Arunachal being acoustically closer to the Lemon-rumped, and those from eastern Arunachal, to the Sichuan. We hypothesize that this could be a result of hybridisation or introgression and should be explored further by genetic research.

Introduction

The *Phylloscopus* genus of leaf warblers is a morphologically poorly differentiated group, which has seen significant taxonomic changes in recent decades (Rheindt 2006; Martens 2010). This is largely due to the evolution of taxonomy from a museum-based science in which morphology and plumage were considered exclusive criteria for determining a taxon to a more integrative approach that includes additional assessment tools such as bioacoustics and genetic analysis. The elevation of many taxa to species level has also created a new challenge in field identification, as many of these hardly differ in plumage. Additionally, most migrating birds breed in the Holarctic region and travel long distances to wintering areas, occasionally turning up as vagrants outside their regular range, adding complexity to their field identification. Therefore the increasing sophistication of identification techniques used nowadays is quite impressive: genetic analysis correcting identification in the hand by bird-ringers in the case of Common Chiffchaff *P. collybita* taxa (de Knijff 2012); comparison of sound parameters to re-identify a Pale-legged Leaf Warbler as the first wintering record of a Sakhalin Leaf Warbler in Singapore (Yap et al. 2014); or using Principal Component Analysis (hereinafter, PCA) of vocalisations to prove the first occurrence of a Chinese Leaf Warbler *P. yunnanensis* in South Korea (Moores & Borzée 2020).

In the present paper we aim to zoom in on a closely related species-pair in order to determine their occurrence in India. An in-depth taxonomic analysis of the Pallas's Leaf Warbler *P. proregulus* complex (Martens et al. 2004) led to the recognition of four distinct species of which, the Lemon-rumped Warbler *P. chloronotus* occurs across the length of the Himalaya from Pakistan to north-eastern India, and the Sichuan Leaf Warbler *P. forresti* occurs in central western China, with the Gansu

Leaf Warbler *P. kansuensis* occurring just north-westwards of it, and Pallas's Leaf Warbler in north-eastern Asia, wintering further eastwards. These two species are morphologically indistinguishable (Martens et al. 2004) and can only be identified by their voice or genetic traits. Martens et al. (2004) used data from Kashmir (India) and Nepal for the Lemon-rumped Warbler, and from Sichuan (China) for the Sichuan Leaf Warbler, but lacked information about birds in between, in the eastern Himalaya. The authors acknowledged that the exact boundaries of the breeding (and wintering) region of both species were unknown. Though there are c.20 museum specimens from north-eastern India (portal.vertnet.org) for genetic analysis, their status has remained largely unchanged from 2004 to date (Grimmett et al. 2011; Rasmussen & Anderton 2012; del Hoyo et al. 2020). The Sichuan Leaf Warbler was not included in the 'India Checklist' (Praveen et al. 2016) until recently (Dhyey et al. 2021; Praveen et al. 2021) despite documented claims of its presence in north-eastern India (Vercruyse 2017; but see Jayapal & Praveen 2017). Lemon-rumped Warblers are regularly observed in Bhutan, and in Arunachal Pradesh, and the other north-eastern Indian hill states, but without a detailed analysis of its vocalisation, identification in the field is based on the assumption that the species occurs all along the Indian Himalaya, while the Sichuan Leaf Warbler does not (Fig. 1).

Methods

The vocalisations of the Lemon-rumped- and Sichuan Leaf Warblers differ both, in song, and in principal call note say Martens et al. (2004), who described these differences in a qualitative way and based these on a quantitative PCA, but they did not provide any key that would allow identification of both species unequivocally.

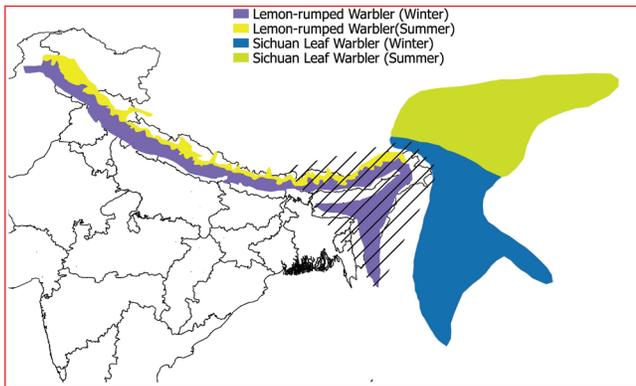


Fig. 1. Occurrence of Lemon-rumped- and Sichuan Leaf Warblers during their breeding and non-breeding periods, based on current knowledge (Alström et al. 2020; del Hoyo et al. 2020); the hatched area being the region of uncertainty. Map is hand-drawn using the maps of both species in *Birds of the World*. [National and international boundaries are only indicative, and may not reflect current political or geographical realities.]

Given that many bird observations in the Himalaya are made in winter and early spring, when birds are not necessarily vocal and, in many cases, do not sing—as they are most likely not on their breeding grounds—we chose to focus here on identifying the call notes.

We gathered all recordings of calls available online of both, Lemon-rumped- and Sichuan Leaf Warblers from the Xeno-Canto (<https://www.xeno-canto.org/>) and the Macaulay Library (<https://www.macaulaylibrary.org/>) sound archives. We also requested additional recordings from the British Library of Natural Sounds (hereinafter, BLNS; <http://cadensa.bl.uk/>), including the recordings of Jochen Martens from Nepal and Sichuan, which were used in his original research study. We also received several additional sound recordings from Per Alström.

We first analysed recordings from two regions: the Himalaya westwards of Bhutan (which are assigned to the range of the Lemon-rumped Leaf Warbler, in accordance with the findings of Martens et al. 2004), and China (assigned the range of the Sichuan Leaf Warbler). We measured the following parameters: total duration of the call note, duration and minimum frequency of the final ascending part, intermediate frequency whenever a discontinuity is present, and the overall minimum and maximum frequency of the call note (Fig. 2, Table 1).

Measurements were made manually, on sonograms, using Cooledit Pro software (with settings Blackmann-Harris window and 512 Bands resolution to obtain the sharpest image). Depending on the duration of the sound recording, and the number of

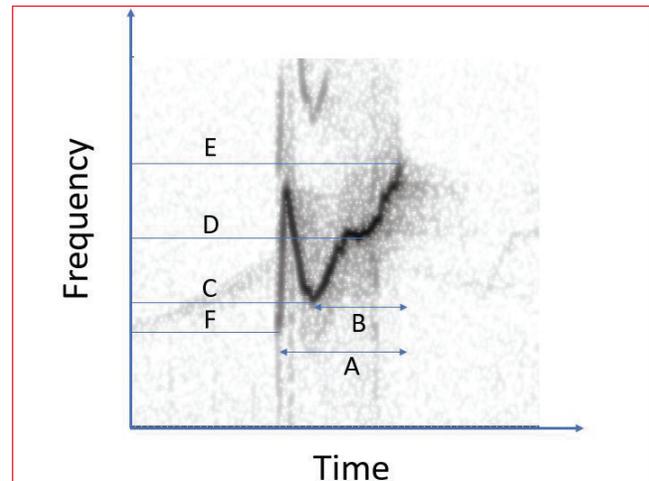


Fig. 2. Parameters of the call notes that were measured.

Table 1. List of acoustic parameters and their descriptions

Parameter	
A	Total Duration (in s)
B	Duration of the final ascent (in s)
C	Minimum Frequency of the final ascent (in Hz)
D	Frequency of the discontinuity/bend, if present (in Hz)
E	Maximum Frequency
F	Minimum Frequency

call notes present, we measured either one, two, or three call notes in order to include individual variation without giving too much weight to individual vocalisations that had extremely long recordings. In total, we measured 29 call notes of the Lemon-rumped- and 24 call notes of the Sichuan Leaf Warbler. We identified differences between these two vocal groups. Based on these findings, we then measured the same parameters for all available sound recordings from the intermediate region, ranging from Bhutan to extreme eastern India. Despite the relative high number of observations of Lemon-rumped type of leaf warblers in this region (eBird 2021) we could only gather the following sound recordings (Table 2):

We did a PCA on all these parameters (For D, we imputed the value for recordings that did not have a bend) to identify the clusters.

Table 2. List of sound recordings of Lemon-rumped/Sichuan Leaf Warblers from north-eastern India.

No	Recordist	Date	Location	Reference
1	Edward Verduyseye	December 2002	Shillong, Meghalaya	XC619183
2	Per Alström	June 2009	Jang, Western Arunachal Pradesh	Private
3	Per Alström	June 2009	Mandala road, Western Arunachal Pradesh	BLNS163715
4	Edward Verduyseye (2017)	February 2015	Saiha, Mizoram	XC346297
5	Peter Boesman	March 2018	Shillong, Meghalaya	XC426770
6	Edward Verduyseye	April 2019	Anini, Eastern Arunachal Pradesh	XC619165
7	Dhyey Shah (Shah et al. 2021)	December 2020	Tilam Top, Eastern Arunachal Pradesh	ML295353311
8	Arka Sarkar	January 2021	Tilam Top, Eastern Arunachal Pradesh	XC616399

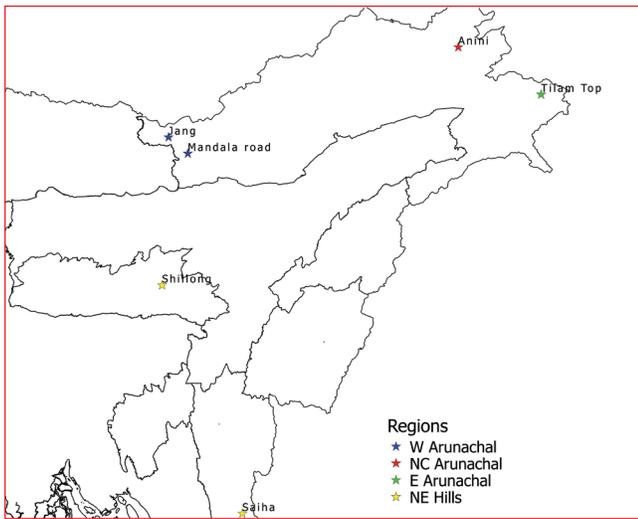


Fig. 3. Localities of sound recordings from north-eastern India

Results

Call notes of both species are quite stereotypic and are considered innate (Martens et al. 2004). Nevertheless, we found substantial variations in the note shapes on the sonograms. Figs. 4A, 4B illustrate the range of shapes for both species. Quantitatively, we found that the main differences in the call notes between the two regions are the total duration of the call note (range 0.056–0.100s for Lemon-rumped- vs 0.155–0.222s for Sichuan Leaf Warbler), and the duration of the ‘final rise’ (range 0.033–0.077s for Lemon-rumped- vs 0.104–0.173s for Sichuan Leaf Warbler). We used the same data in a PCA analysis. 57% (PC1) of the difference could be explained by the first principal component and 20% (PC2) by the second. Highest loading for PC1 is duration of the final ascent (0.52), and total duration (0.49) confirming our qualitative assessments. Highest loading for PC2 is maximum frequency (0.25).

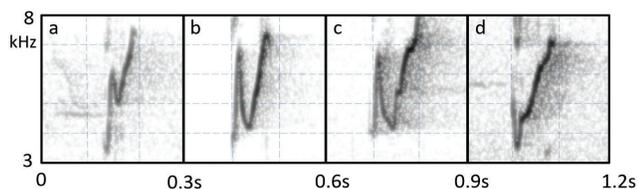


Fig. 4A. Sonograms of main call of Lemon-rumped Warbler. a: Pakistan (P. Alström), b: Uttarakhand, India (XC547671, A. Spencer), c: Uttarakhand, India (XC472909, P. Boesman), d: Nepal (WR142859, J. Martens).

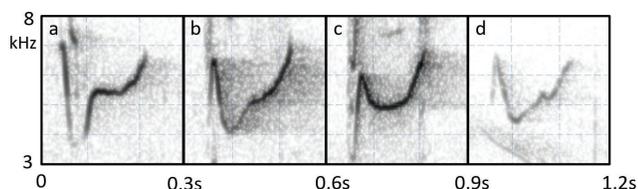


Fig. 4B. Sonograms of main call of Sichuan Leaf Warbler. a: Qinghai, China (XC491413, P. Boesman), b: Sichuan, China (WR142854, J. Martens), c: Sichuan, China (P. Alström), d: Sichuan, China (WR142857, J. Martens).

There are also differences in the average frequencies, but ranges show a partial overlap. The total absence of a bend in the ‘final rise’ is indicative of a Lemon-rumped Leaf Warbler, while the presence of a slight bend may be either species, while the

presence of a very strong bend is indicative of a Sichuan Leaf Warbler (Fig. 5).

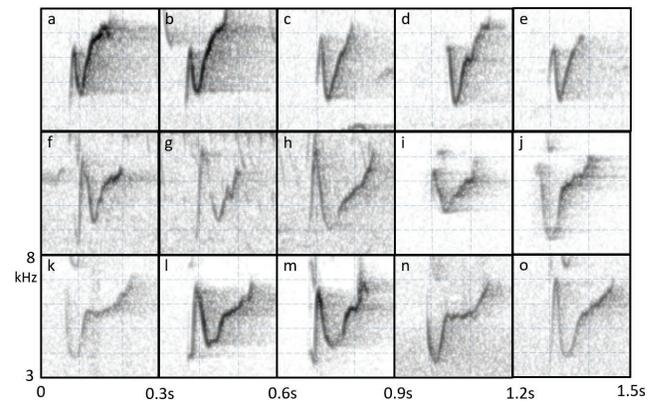


Fig. 5. Sonograms of calls from the ‘intermediate region’. a–b: Jang; c–e: Mandala Road; f–h: Anini; i–k: Tilam Top; l–n: Meghalaya; and o: Mizoram.

In the ‘intermediate region’, we found three cases:

- Recordings that fit 100% the parameter ranges for Sichuan Leaf Warbler (recordings from Meghalaya and one from Mizoram).
- Recordings that fit the best Sichuan Leaf Warbler, but that have at least one parameter not matching it. Most calls are slightly *shorter* than typical Sichuan Leaf Warbler (recordings from extreme eastern Arunachal Pradesh).
- Recordings that fit the best Lemon-rumped Leaf Warbler, but that have at least one parameter not matching Lemon-rumped Leaf Warbler. Most calls are slightly *longer* than typical Lemon-rumped Leaf Warbler (extreme western Arunachal Pradesh).

PCA results illustrated (Fig. 6), and a boxplot (Fig. 7) clearly show the three cases for the ‘intermediate region’ described above.

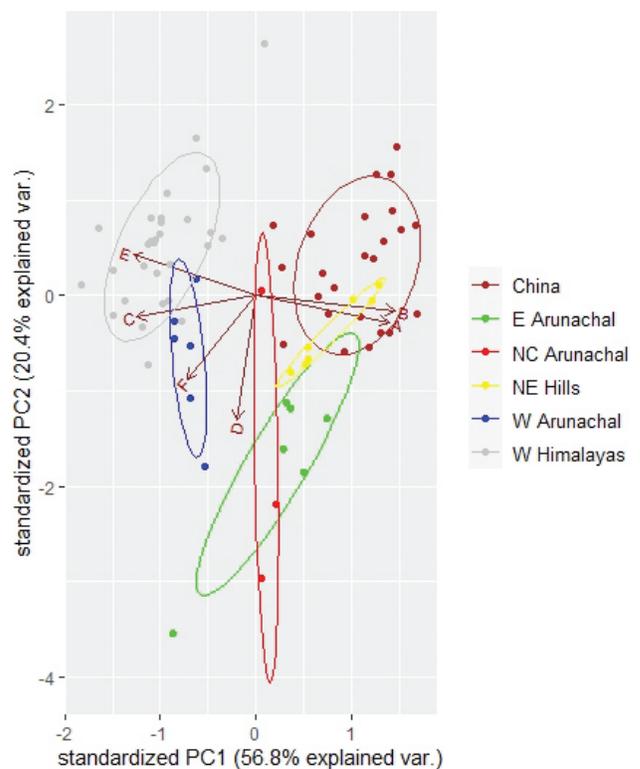


Fig. 6. Principal Component Analysis of the call parameters

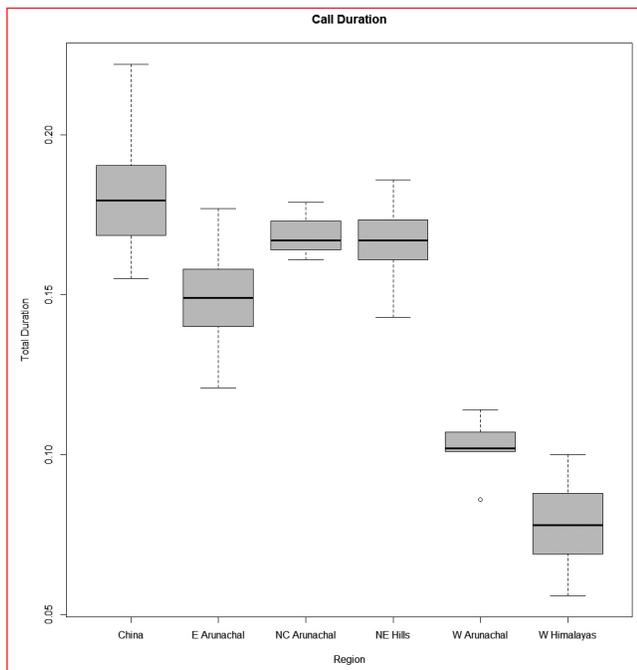


Fig. 7. Variations in the total duration of calls of Lemon-rumped- and Sichuan Leaf Warblers, across their ranges.

Discussion

In the case of two species that cannot be identified morphologically, but do have distinct songs and call notes, we expect a scenario in which any series of call notes can be assigned to either species. We did indeed find clear differences between the calls of Lemon-rumped- and Sichuan Leaf Warblers, and we did find call notes from birds observed in Meghalaya and Mizoram that fit entirely those of a Sichuan Leaf Warbler. This is, undoubtedly, the strongest evidence to date for the occurrence of the Sichuan Leaf Warbler in India. Only by taking samples from wintering birds for genetic analysis can one further strengthen the evidence. We therefore concur with the inclusion of Sichuan Leaf Warbler in the India Checklist, at least as a winter visitor.

However, we also found deviations from this 'ideal scenario'. Sound recordings from Arunachal Pradesh did not fit either species in their entirety. Vocalisations in western Arunachal were closer to a Lemon-rumped- while those in eastern Arunachal were closer to a Sichuan Leaf Warbler, albeit with some intermediate properties. We only measured a limited number of recordings from both these reference regions. It is possible that a more extensive sample set from the reference regions may encompass the variations we report in the Arunachal samples, and they may cluster cleanly within either of the species. While this may be true, it would still be remarkable that in Arunachal all Lemon-rumped type of calls tend to be of longer duration, while all Sichuan Leaf Warbler type of calls in tend to be of shorter duration.

Another explanation could be that there is a gradual cline in the call note from very short calls in the west to very long calls in the east, which would then explain the intermediate durations in Arunachal. However, when comparing recordings from Pakistan to Nepal, there is no clear gradual change, with parameter ranges being nearly equal in both sub-regions. We can, thus, also discard this hypothesis.

One may also argue that in the breeding and non-breeding periods, calls may differ slightly, as most recordings from the reference regions are from the onset of the breeding season in late spring. However, besides the possibility of uncrystallized calls in early autumn from juveniles, we should not expect this in analogy with other *Phylloscopus* species. Also, the recordings from extreme western Arunachal Pradesh are from June, and thus, deviation here cannot be explained by this hypothesis, which, as a consequence, is proven wrong.

From the western Himalaya to western Nepal is the range of the *simlaensis* Lemon-rumped Leaf Warbler. If it is indeed a diagnosable taxon, it could have a slightly different call note from the nominate that occurs eastwards from central Nepal. If all calls recorded in Arunachal Pradesh (east and west) belong to nominate Lemon-rumped (Type Locality: Nepal; restricted to Central Valley of Kathmandu by Ripley 1950: 401), these would then cover the entire range between *simlaensis* in the west and Sichuan Leaf Warbler in the east. The call of this connecting taxon would then be closest to *simlaensis* in the west while closest to Sichuan Leaf Warbler in the east. This does not seem to be a plausible explanation either, as all calls from eastern Nepal are clustering well within the calls from western Himalaya and the intermediate calls are only from Arunachal Pradesh.

A final possible explanation is that some hybridization or introgression has occurred. As a consequence, some vocal properties could have changed in this present or past contact zone and call duration may have shifted towards an average common value. This seems a plausible explanation, but hard to prove without genetic analysis. If this is the case, the region from eastern to western Arunachal Pradesh is, however, a broad zone of about 400 km, and the question arises how then would birds call in the middle of these two extremes, as we lack recordings from this region. A transition zone would be similar to e.g., the species pair Hoary-throated/Streak-throated Barwing *Actinodura nipalensis/waldeni*, for which, due to hybridisation, there is no consensus on the exact boundaries between both species, said to be either western (Collar & Robson 2020) or eastern Arunachal Pradesh if a race is moved to the other species (Rasmussen & Anderton 2012). Birds in Arunachal Pradesh may belong to a resident population only with short-range elevational migration with a wide zone of introgression. This may have implications on the existing accepted species limits for this pair, as previous studies did not consider this possibility. Wide-range hybridisation is typically a contra-argument for treating two groups as distinct species, but a stable hybrid zone where two parapatric groups meet is increasingly accepted for closely related species-pairs (Tobias et al. 2010).

Finally, it is also worth observing that we did not find two call types in any region, which could have pointed to the occurrence of both species together.

Concluding remarks

What started as a seemingly basic acoustical analysis to determine the identity of 'Lemon-rumped type' Leaf Warblers in north-eastern India has revealed that we still lack substantial knowledge about this species-pair. In his seminal overview of all *Phylloscopus* species Martens (2010) concluded with the sentence: 'Several populations presently accepted at species level need further substantiation'. This is definitely valid for Lemon-rumped Warbler

and Sichuan Leaf Warbler. Ten years later, we still know very little about the occurrence of both species in north-eastern India, although we can now conclude that there is little doubt that the Sichuan Leaf Warbler occurs at least in Meghalaya, and Mizoram in winter. Inversely, there is apparently no vocal evidence for the occurrence of Lemon-rumped Leaf Warbler in the north-eastern hill states of India and far eastern Arunachal Pradesh.

We highly recommend careful documentation of any Lemon-rumped type of leaf warbler in north-eastern India and adjacent regions in Yunnan, and Tibet in China, and Myanmar, during any period of the year, especially by making sound recordings of vocalisations. Such a larger set of samples should eventually allow one to compare also songs, to determine how birds sing and call during the breeding season when migrant Sichuan Leaf Warbler has left for its breeding grounds in China. As pointed out by Martens (2017), researchers could also perform genetic analysis of birds in this region either by using tissue samples from existing specimens, or during bird-banding activities, to establish the situation in Arunachal Pradesh.

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In Memoriam

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