The case for alveolar fricative rhotics with evidence from Nusu

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Cross-linguistically, fricatives are the rarest types of rhotics, found in a few African and European languages (Ladefoged & Maddieson 1996) and as allophones in some Romance languages (Jesus & Shadle 2005; Recasens 2002; Bradley 2006; Colantoni 2006). Acoustic data from Nusu, phonotactic reasoning, and a cognate comparison demonstrate the presence of alveolar fricative rhotics in Tibeto-Burman. The Nusu rhotic appears in syllable-initial position as the first or second consonant and can be realized as alveolar approximants [ɹ] or [ɹʲ], non-sibilant voiced and voiceless fricatives [ɹ̝, ɹ̝̊], as well as voiced sibilant [ʐ]. In other studies on Nusu, these fricative rhotics have sometimes been reported as retroflex voiced sibilants (Sun & Lu 1986; Fu 1991), but intra-speaker and cross-variety comparison point to classification as rhotics. Evidence from other Tibeto-Burman languages suggests that alveolar fricative rhotics are not limited to Nusu. Together these data challenge the tradition of generally interpreting alveolar fricatives as sibilants.

Keywords: Nusu, rhotics, fricatives, sibilants

1. Introduction

Nusu is a Tibeto-Burman language spoken in Southwestern Yunnan Province, China and Northeastern Kachin State, Myanmar. Most likely, Nusu is part of the Loloish subgroup, also referred to as Yi or Ngwi (Bradley 2012). Similar to Yi languages, Nusu has a phonation distinction between stiff and slack voice. Previous analyses of Nusu conflict in their portrayals of phoneme /ɹ/. Sun and Lu (1986) document the rhotic as both an initial and medial /Cɹ/ consonant. Fu (1991) only lists /ɹ/ as a part of consonant clusters /Cɹ/. Both sources postulate initial sibilants /ʐ/ and /ʑ/. We utilize wordlists from five varieties to establish that depending on environment and dialect, the Nusu rhotic can be realized in many ways. These may

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include an apicoalveolar approximant [ɹ], a palatalized alveolar approximant [ɹʲ], a voiced alveolar non-sibilant fricative [ɹ̝], and a voiceless non-sibilant fricative [ɹ̝̊]. The sound transcribed previously as initial [ʐ] may in fact be an allophone of /ɹ/. The alveolo-palatal sibilant /ʑ/ is a separate phoneme.

Non-sibilant fricative rhotics in the dental-alveolar region may be articulated as alveolar or postalveolar, which is often referred to as retroflex. We do not have instrumental data to specify the exact point of articulation for the Nusu rhotic. Nusu rhotics can be alveolar, post-alveolar, retroflex and palatalized alveolar. As the most flexible part of the articulator, the front of the tongue is capable of tremendously fine-tuned movements that do not exclude further modifications of the tongue body. Therefore, it is not always easy to judge based on the auditory impression whether the articulation in the alveolar region is apical or flat, retracted or retroflex (see Hamann 2002 for their co-occurrence and shared feature [+back]), bunched or palatalized or velarized. For our discussion, we consider *retroflex* a tongue-tip constriction orientation (Gafos 2013) under the alveolar place of articulation. The label 'retroflex' is handled by the IPA as a place of articulation or passive articulator; from the articulatory point of view it is rather a modification of the active articulator. This can be illustrated through Ladefoged & Maddieson's description of retroflex articulation (1996). They point out that for the Toda retroflex sibilant, the tongue tip is raised towards the palate and is further back than the Tamil retroflex sibilant, but not as far back as the Dravidian stops with their extreme tongue tip retroflexion. So there is a wide range for retroflex articulations but they are all in the broad alveolar region. In this paper, we therefore use *alveolar* as a broad phonetic label.

Fricatives are the rarest types of rhotics, reported for a few African and European languages and as allophones in some Romance languages. Although a number of languages do not have an **r**-phoneme, the majority of languages have at least one (Maddieson 1984). Most rhotics are trills or flaps, whereas approximants and fricatives are rare. The most commonly known rhotic fricatives are dorsal/postpalatal, found in languages like French, German dialects, and Hebrew. Rhotic alveolar fricatives have been reported in a scattering of languages: the Bantu KiVunjo dialect of KiChaka, Volta-Niger Edo, Czech, and urban South African English (Ladefoged & Maddieson 1996: 232, 241). In a few other languages alveolar fricative rhotics are realized only in limited environments, i.e. consonant clusters involving obstruents. These include mostly European Romance languages (Jesus & Shadle 2005; Recasens 2002) and Latin American varieties of Spanish (Whitley 2003). In Spanish varieties from Chile, Argentina, and Ecuador, an alveolar non-sibilant fricative can occur before a vowel in initial and medial position (Colantoni & Steele 2005). In Travis Bradley's study on several varieties of Latin American Spanish (2006), voiced alveolar fricatives are nearly as frequent as approximant versions of /r/. Nusu demonstrates the presence of alveolar fricative rhotics in Tibeto-Burman languages. Evidence from other Tibeto-Burman languages such as Limi Tibetan, Mongsen Ao, Dayang Pumi, Dumi, Jejara, Rawang (Nangsing Tangsar), and Achang suggest that the phenomenon may be more widespread.

We present the case for alveolar fricative rhotics in Nusu by first presenting phonological evidence that the sounds in question should be treated as rhotics based on phonotactics and shared phonetic features. Then we provide acoustic data showing the range of phonetic realizations of Nusu /ɹ/, including voiced and voiceless alveolar fricatives. Finally, we provide acoustic comparisons to show that the fricative rhotics are not necessarily sibilants.

Evidence from other Tibeto-Burman languages is presented to demonstrate the challenges faced in transcribing non-sibilant fricative rhotics in the alveolar area. Whitley (2003) outlines the problems faced in Hispanic linguistics for transcribing **r** using current IPA diacritics and conventions. This paper furthers the case made by Whitley in presenting a similar set of problems faced in transcribing alveolar rhotic fricatives in Tibeto-Burman languages like Nusu. We are unaware of any languages where fricatives and approximants at the labiodental, palatal, or velar place of articulation are contrastive, yet there are separate phonetic symbols for them, illustrating their phonetic characteristics (e.g. v vs. ʋ, j vs. j̞, ɣ vs. ɰ). Aside from laterals, non-sibilant fricatives in the alveolar and post-alveolar region do not have separate symbols. We therefore argue that alveolar fricative rhotics should be distinguished from sibilant fricatives to underline their independent phonetic and phonological status.

Data for this paper are drawn from recorded wordlists with 461 basic vocabulary items recorded in five varieties. Speakers reside in Kachin State, Myanmar. There was one male speaker for each variety recorded near Myitkyina town: Myagu (Aungmye), Wawa, Zileng, Yotolo. One male speaker of Topya was recorded in Ngwaphakha (Chipwe township). In Tsawlaw township, a male speaker of Topya (Zibankha) and Myagu (Shishidukhu) were recorded. The wordlists were elicited in Lisu and roughly transcribed in situ by an M.A. linguistics student (speaker of Burmese, Lisu, Anong, Rawang). Transcriptions were confirmed or adjusted by the authors. Rhotic consonants were identified in three ways: a rhotic consonant occurred in the corresponding word across Nusu varieties in our wordlists; the word was spelled with grapheme <R> by native speakers; or the word was transcribed with a rhotic consonant [ɹ] in one of the previous linguistic descriptions of Nusu. A selection of 103 words that include rhotics were transcribed in Excel for comparison across varieties (n = 103). The Myagu (Shishidukhu) and Topya (Zibankha) wordlists were imported into Phonology Assistant 3.3.3 software (SIL 2011) to compare environments. Speech Analyzer 2.7 (SIL 2005) software was used for waveform and spectrogram analysis of the Topya (Zibankha) and Myagu

(Shishidukhu) data. For spectral analysis, the .wav file was converted from stereo to mono in Audacity 2.1.2 and the relevant segment was selected and saved. The Topya word list was also filtered using noise reduction in Audacity due to eliminate some of the background noise. In Sigview32 2.8.0, the segment was high-pass-filtered at 700 Hz so that any spectral peaks due to voicing would be removed from the spectrum (see Evers et al. 1998). Forty milliseconds were selected at the center of the fricative, and an FFT spectrum analysis was computed, then the magnitude and frequency of the maximum spectral peak was measured.

2. Phonological evidence for a Nusu rhotic

Previous descriptions of Nusu do not agree on whether there is a rhotic phoneme. Unlike other sound classes, rhotics defy description based on articulatory features. Cross-linguistic evidence regarding rhotics demonstrates that rhotics can be identified on the basis of phonotactics and shared phonetic features. Applying these criteria to Nusu suggests that Nusu has a rhotic phoneme. The fact that Nusu allows a wide range in the degree of constriction in the realization of /ɹ/, including sibilant allophones, makes it highly unlikely that a phonemic distinction between /ɹ/ and /ʐ/ could be maintained. The question for Nusu is not about a possible phonological contrast of sibilant vs. non-sibilant fricatives at the same place of articulation but about their phonological category.

Commonly, rhotics are sounds that have been associated orthographically with the letter <R> or the Greek letter rho and pattern together in synchronic and diachronic variation (Ladefoged & Maddieson 1996: 245). Over two thousand years ago, Indian phoneticians used a term for the sound class coined as rhotics by Wells (1970). According to Deshpande (1978), they noticed that two sounds, one alveolar and one velar, both induced retroflexion in following consonants and called it “ra-çruti”, or a ‘sound heard as r’.

The phonological classification of rhotics is challenging because their phonetic realizations vary so greatly (Lindau 1985). Places of articulation range from apicoalveolar (Czech) to postalveolar (Malayalam), to uvular (French), with rhotics in the dental-alveolar area being the most common ones, and retroflex rhotics not being unusual (Ladefoged & Maddieson 1996). For Swedish, dialectal rhotic variation in medial position ranges from prealveolar, postalveolar, retroflex and ‘back’, with the latter category ranging from pre-velar to uvular (Muninovic & Engstrand 2001). The manner of articulation ranges on a spectrum from retroflex sibilant in Chinese (Svantesson 1986) to fricative in French, to approximant in Chinese (Lee-Kim 2014), to vocalic in British English and German. The vocalized final /r/ in British English can only occur as a ‘linking r’ in its consonantal form when followed by vowels as in /‘far a’we/ (Wells 1970). In Standard German final /ʁ/ is realized as a near-open central vowel [ɐ] which changes to an approximant or fricative if followed by vowel-initial suffixes (Kohler 1990).

In Maddieson’s (1984) survey of 317 languages, the most frequent types of rhotic were trills (47.5%) and taps/flaps (38.3%). Approximants (9.9%) and fricatives (3.5%) were quite rare. These fricatives need to be taken seriously, though, as they are often linked to other types of rhotics through synchronic and diachronic variation, especially in languages such as German, French, or Portuguese which have a uvular rhotic (Wiese 2001: 341). Indeed, rhotics cannot be united together as a class on the basis of articulatory properties. Rather, it is phonotactics and shared phonetic features of rhotic subsets that constitute the main arguments for grouping rhotics together.

Regarding phonological status, fricative rhotics do not necessarily form minimal pairs with non-rhotic fricatives that share the same place of articulation. Eastern Armenian distinguishes a voiced retroflex non-sibilant fricative and palato-alveolar sibilant fricative (Maddieson 1984). On the other hand, the Mandarin rhotic can be realized as a voiced retroflex sibilant (Svantesson 1986) or an approximant, traditionally described as a fricative vowel or syllabic sibilant ʅ (Lee-Kim 2014). Yet it does not form a contrast with a non-sibilant fricative; the only contrastive fricative is a voiceless retroflex sibilant. Svantesson’s comparisons of Mandarin sibilants (1986) show that voiceless sibilants are produced rather consistently, whereas the voiced rhotic sibilant productions show a wide degree of variation, consistent with the behaviour of rhotics in other non-related languages. Similarly, there is no contrast for rhotic and non-rhotic velar fricatives in French or German. As for English varieties, the historical final /r/ preserved in Scots, Irish and American varieties is realized as a trill or an approximant, respectively; it has no frication and therefore differs in more than one feature from the voiced alveolar sibilant. Russian has a dental palatalized trill /r̪ʲ/ and dental palatalized fricative /z̪ʲ/, but not a fricative rhotic (Maddieson 1984). The other three languages that were included in Maddieson 1984 as having a voiced non-sibilant retroflex fricative were Araucanian, Burushaski, and Chukchi. None of these three languages has voiced sibilants.

2.1 Phonotactic evidence

Perhaps the most important factor justifying rhotics as a class is syllable prosody. In many languages, the only type of consonant cluster allowed is a cluster with a rhotic in medial position (Ladefoged & Maddieson 1996: 216). Their position within a syllable is not limited by their degree of constriction, as observed by Wiese (2001) for Dutch and German. Divergent types of /r/ form a phonological class in

Dutch. It has rVr avoidance which does not depend on the type of /r/. The rhotics can be alveolar or uvular and realized by various manners of articulation but they all share unity with respect to *rVr (Wiese 2001: 359). For a German dialect from the Lower Rhine area, Wiese (2001) notices that even a uvular fricative can precede syllable-final sonorants /l/ and /n/, although fricatives are usually considered lower in sonority than laterals and nasals. This illustrates that sonority is a phonological, and therefore abstract ranking property, not an auditory or acoustic trait. Accordingly, Wiese links this phenomenon to the sonority hierarchy but points out that sonority is not based on the commonly conceived segmental class features: obstruent <nasal <liquid <glide <vowel (Clements 1990). Obstruents are considered lowest in sonority and vowels are highest, but rhotics can exhibit features of all sonority classes. Since even fricative rhotics can appear closer to the center of the syllable than laterals and nasals, Wiese proposes an extended sonority hierarchy for German where he splits up the 'liquid' category into laterals and rhotics: obstruent <nasal <lateral < /r/ <glide <vowel. This distinction is feasible for many other languages, e.g. American or Irish English 'brink' or 'blink' vs. 'curl' or 'corn'. Wiese further argues that "/r/ is non-arbitrary in terms of its phonotactic patterning. Its constant appearance between vowels and other consonants leads to the conclusion that /r/ is a prosody" (2001: 360). Ballard and Starks (2004: 2) also observe that rhotics can have frication and still pattern as sonorants:

> as voiced fricatives, these rhotics involve stricture close enough to create friction, so they are phonetically more obstruent-like than sonorant. Nonetheless these fricatives are classified as sonorants in both French (Tranel 1987) and Czech (Kučera 1961) because they pattern phonologically as sonorant consonants in most cases for these languages.

For example, French allows devoiced or fricative /r/ in positions which are restricted to sonorants. French has clusters with obstruents and fricative /r/ but not other obstruent-fricative clusters (Wiese 2001: 351). Rhotics and laterals are called liquids based on their similar phonotactic behavior. Colantoni and Steele (2005) give evidence that despite divergent phonetic realizations, French and Spanish rhotics pattern like laterals as the second member in clusters with obstruents. Rhotics also alternated with laterals in the evolution of French and Spanish. But in contrast to Wiese's findings for German and Dutch, French and Spanish rhotics seem to be less sonorant in nature than laterals. For example, Colantoni and Steele find that in Spanish clusters with /b, d, g/, rhotics are distinguished from the adjacent consonant by an epenthetic vowel, but laterals are not (2005: 8–9). In addition, the French fricative rhotic patterns with other voiced fricatives in terms of vowel lengthening. Colantoni and Steele suggest that rhotics may be in a stage of evolution in which they are "fluctuating between more or less sonorous segments" in these Romance languages (2005: 12). In Nusu, the rhotic /ɹ/ as well as semivowels /j/ and /w/ are allowed as the second member in a consonant cluster. Thus, they are ranked higher in sonority whether they are realized with or without constriction. Furthermore, despite the lack of rhotics in modern Loloish languages, Bradley (1978) reconstructed labial-rhotic and velar-rhotic clusters *pr *br *kr *gr for Proto-Loloish. These clusters account for correspondences among the Loloish languages and the Burmish languages. Burmese inscriptions include both types of clusters.

Syllable structure is rather limited in Loloish languages, and Nusu is no exception. The most common syllable-types are V^T, CV^T and CCV^T where ^{T} denotes tone. Syllable-initial consonant clusters are formed with the semi-vowels /j/ and /w/ between the initial consonant and the vowel, as seen in the examples [ɧa:˧] 'tongue' and [kʰwi˥] 'dog' from Myagu Nusu. The two previous analyses of Nusu treat these semi-vowels as a part of dipthongs, but Bradley (1978) includes them with **l** and **r** as 'resonants' in Proto-Loloish. For Nusu, the only other consonant that can occur in this position is an alveolar approximant or fricative [ɹ]. According to the previous accounts of Nusu, a rhotic consonant can follow /m, m̥, p, pʰ, b, f, v, k, kʰ, g, x/, and possibly /ɣ/. The Nusu themselves represent all of these clusters with <R> as the second consonant. Table 1 includes examples of labial-rhotic clusters in Topya Nusu.

Table 1. Labial-rhotic clusters in Topya Nusu

Topya Nusu	Gloss
mɹɔ˥.kwa˩	'arrow'
m̥ɹɨ˧.ɔ˧	'tall'
pɹu˧	'porcupine'
bu˧.pʰɹɔ˧	'cockroach'
bɹɔ˩.ɔ˥	'to shine (for flashlight)'
vɹi˧	'snake'

The phenomenon of preglottalization reveals further evidence regarding the sonority of Nusu /ɹ/. Preglottalization is contrastive in Nusu, seen in [ˀɳi̱˥] 'twist' vs. [ɳi̱˥] 'far inside'. This consonant modification is very common in Austroasiatic languages such as Khmu (Osborne 2009), Sui, and Maonan, and also found in Tibeto-Burman Karen (Solnit 1997) where it is realized as parallel or sequential glottal closure, see also Roengpitya (1997) for Lai (Kuki-Chin-Naga). Since there are no other unambiguous clusters formed by stops and nasals, preglottalized sonorants are interpreted as unitary segments. The only other segments that occur preglottalized in Nusu are clearly sonorants /ˀm, ˀn, ˀɳ̥ ˀl, ˀj, ˀw/, see Table 2 for examples. Since Nusu /ɹ/ can be preglottalized, it should be treated as a sonorant.

Table 2. Preglottalization in Nusu

Preglottalized sonorant	Myagu Nusu	Gloss
ˀɹ	ˀɹɯ^{33}	'to retract'
ˀm	ɑ^{21}ˀmɯ$^{\underset{\sim\sim}{53}}$	'corn'
ˀn	ˀni$^{\underset{\sim\sim}{53}}$	'to twist'
ˀɳ̥	ˀɳ̥u^{55}	'that'
ˀl	ˀla$^{\underset{\sim\sim}{53}}$	'to turn a page'
ˀj	ˀju$^{\underset{\sim\sim}{53}}$	'a person' (classifier)
ˀw	ˀwə$^{r\underset{\sim\sim}{53}}$	'to be wet'

2.2 Shared phonetic features

Section 4 will demonstrate the range of phonetic realizations of the Nusu rhotic, varying from alveolar and palatalized-alveolar approximants to voiced and voiceless non-sibilant fricatives to occasional sibilants. Cross-linguistically, rhotics vary widely in terms of place and manner of articulation, so this variation in the Nusu rhotic should come as no surprise. Ladefoged and Maddieson (1996) provide an acoustic description of the wide range of rhotic realizations. Rhotics can often be associated with lowering of the third formant, suggested by data from English, Izon, Italian, and Toda. This is seen in the transitions from and to adjoining vowels, in the steady-state formant structure of approximants, and in the formant structure of the intervals between the closures of trills. Other rhotics have high third formants, with different places of constriction like the Hausa and Arrernte retroflex approximant, the Czech fricative rhotic, and the uvular rhotics found in Swedish, French and German.

Rhotics in a language can share the same manner of articulation but vary in place of articulation. For example, trills share similar pulsing patterns, whether alveolar or uvular. The acoustic similarity is so high that South Swedish speakers are not aware that some members in their families use an alveolar trill while the others use a uvular trill (Lindau 1985).

Furthermore, rhotics can be maintained in the same place of articulation with variations in the manner of articulation. An acoustic similarity is found between taps and trills; the latter are basically a series of taps. Trilling accompanied by frication has also been observed in French and Edo. Ladefoged and Maddieson point out that in the trills they investigated, the opening phases of several of them were prolonged into an approximant instead of further short openings and closures. This is a natural explanation for why trills vary with or change into approximants, observed as the most common medial rhotic realization for Swedish (Muninovic & Engstrand 2001). Recasens and Espinosa (2007) similarly report a burst with a possible friction release for fully voiced postconsonantal trills in Catalan, and that the first contact in intervocalic trills is not always entirely closed.

Rhotic tongue bunching with molar contact of the sides of the tongue has been observed in palatographic records for the retroflex, velar, and uvular fricative plus trill (Catford 2001).

To summarize this, it is not that the various subgroups of sounds forming rhotics share the same feature. It is the fact that one feature from one subgroup, e.g. 'uvular' for trills, is shared with another rhotic subgroup, e.g. 'uvular' for fricatives, and allows the rhotic to change phonetic class. Thus, the segment under investigation in Nusu can be regarded as a rhotic whether it is realized as an approximant or fricative, including palatalized forms. Furthermore, fricativization is a widespread phenomenon in Tibeto-Burman languages, frequently affecting high vowels and glides /j/ and /w/ (cf. Chirkova & Handel 2013).

Synchronic comparison shows that the Nusu rhotic varies significantly in both manner and place of articulation, all of which are possible rhotic realizations: alveolar approximants, laterals, velar and uvular fricatives, and retroflex sibilants. In the word 'to be swollen', there is a transition from approximant to fricative for the initial consonant of the Myagu speaker from Shishidukhu (first token) as well as the Zileng speaker, though the Myagu speaker has a rhotic and the Zileng speaker has a lateral approximant transitioning into a lateral fricative. The Wawa speaker and the Yotolo speaker from Ngwaphakha both have uvular fricatives which sound very similar to a German voiced uvular fricative rhotic. The tokens uttered by the Topya speaker from Ngwaphakha contain a sequence of a velar fricative and alveolar approximant cluster.

Table 3. Comparison of 'to be swollen' across Nusu varieties

Myagu (Shishidukhu)	Zileng	Wawa	Topya (Ngwaphakha)	Topya (Zibankha)	Yotolo
ɹʲɹ̝a˨	lɬua˧˨[1]	ʁam˩˥	ɣɹe˥	(ɹ̝/ʐ)e˥	ʁɔa˥˩

These forms bear similarities to the word *roŋ* 'swollen' in written Burmese (Benedict 1976). This invites further study, which would extend the framework of this paper and therefore is left for future investigations.

1. In this table, we transcribe two initial consonants in sequence to represent a transition between approximant and fricative manners. We use parentheses and slash (ɹ/ɹ̝) to represent alternation across tokens.

3. Acoustic distinctions of approximants, fricatives, and sibilants

As shown in the preceding sections, there is plenty of cross-linguistic evidence for fricative rhotics. These are mainly distinguished from approximants by their degree of constriction as shown in 3.1. In addition, fricatives are distinguished between non-sibilant fricatives and sibilants (cf. Ladefoged and Maddieson 1996; Whitley 2003). Some of the transcriptions for Tibeto-Burman rhotics include sibilant symbols, especially [ʐ]. Therefore, it seems necessary to investigate the phonetic distinctions between fricative rhotics and sibilants.

3.1 Approximant vs. fricative

Colantoni (2006: 22) argues that the principal difference between approximant and fricative rhotics in Argentinian Spanish is the turbulent airstream for fricatives, caused by a higher degree of constriction. Following Ladefoged and Maddieson (1996), Martínez-Celdrán observes that fricatives require a greater degree of articulatory precision than stops, whereas approximants, in addition to a wider vocal tract, have an even lower degree of articulatory precision (2004: 204). The class of sounds he refers to as approximants are central approximants, as opposed to lateral approximants and glides, and defines as follows:

> Approximants are segments that, having a certain degree of constriction, lack a turbulent airstream, either due to the non-existence of the necessary articulatory precision required to produce it, or because the vocal tract is not narrow enough, or because both these conditions occur simultaneously.
>
> (Martínez-Celdrán 2004: 208)

This lack of articulatory precision and/or lack of turbulent airstream would distinguish central approximants from fricatives.

Ladefoged and Maddieson (1996: 242) provide spectrograms for Edo words contrasting an alveolar approximant [ɹ], a voiced alveolar fricative [ɹ̝], and a voiceless alveolar fricative [ɹ̝̊]. The approximant involves only a small reduction in intensity when compared to surrounding vowels. For the voiced fricative, there is a greater amplitude drop but very little frication. Both the voiced and voiceless fricative are marked by a lowering of the higher formants whereas the approximant shows a lowering of the first formant, suggesting a different place of articulation than the fricatives. In Colantoni's (2006) acoustic analysis of Argentinian Spanish rhotics, the 'trilled' rhotics in certain dialect areas were often approximants, and the 'assibilated' or fricative variant common in other dialect areas could occur as an alveolar voiced or voiceless non-sibilant fricative. As expected, the waveform and spectrogram examples for the approximants and fricatives provided by

Colantoni show that approximant realizations are higher in periodicity than fricative variations. In other words, the disturbances shown on the wavefore display repeated patterns of vibration in more regular time intervals and more consistent shape. Similarly, Bradley (2006) finds periodicity to be a significant feature in distinguishing rhotic approximants from fricatives in seven Latin American varieties of Spanish. The approximant [ɹ] has minimal aperiodic noise in the upper spectrum, as well as a discernible formant structure, whereas the fricatives both show substantial aperiodic noise in the upper spectrum, distinguished only by the presence of F_0 for the voiced fricative (5–6). Data from other languages suggest that voiced fricative rhotics may retain formant structure (Magnuson 2007; Ladefoged & Maddieson 1996 on Edo).

3.2 Fricative vs. sibilant

Ladefoged and Maddieson (1996: 137) made several observations about the production of fricatives. The turbulent airstream which defines fricatives depends on a very precisely shaped channel for air to flow through. Even a millimeter of difference in the degree of constriction can make a difference in the target sound. In the case of sibilants, the turbulence is produced by "a high velocity jet of air formed at a narrow constriction going on to strike the edge of some obstruction such as the teeth" (1996: 138). This is exemplified through Icelandic which distinguishes between a voiceless alveolar fricative /θ̠/, a voiced alveolar fricative /ð̠/, and an alveolar sibilant /s/. X-ray tracings show that the tongue position for all three is slightly different, but the teeth are close together only in the sibilant fricative (1996: 145). Similarly, x-ray tracings of Mandarin Chinese sibilants also show that the upper and lower teeth are close together (1996: 150). MRI images of Polish, which distinguishes alveolar /s/ and alveolo-palatal /ɕ/ reveal a tight teeth constriction in addition to a tongue constriction (Toda et al. 2010). Thus, both sibilants and fricatives involve a narrow constriction creating turbulence, but sibilants require a secondary obstruction, the teeth, which form a downstream obstacle (cf. Shadle 1990).

Many acoustic studies involving sibilants have focused on differentiating various sibilants from each other such as /s, z/ vs. /ʃ, ʒ/ in English or /s, ʂ, ɕ/ in Chinese, Polish, and Japanese. What they have in common is that their spectral moment analysis shows high dynamic amplitudes, i.e. the difference between maximum and minimum amplitudes (Shadle & Mair 1996; Ladefoged & Maddieson 1996; Jongman et al. 2000; Gordon et al. 2002). The concentration of noise in the upper frequencies is usually above 3000 Hz (cf. Colantoni 2006). Lee (2011) performed a spectral analysis of [s̠], [ʂ], and [ɕ] in Chinese and Polish, the spectral center of gravity was lower for [ʂ] than for the other two sibilants in Chinese, but not in Polish. For Lee's three male Chinese speakers, the spectral center of gravity for [s̺] ranged between 6000–1000 Hz, for [ʂ] between 3000–6000 Hz, and for [ɕ] between 5000–6500 Hz. Whitley (2003: 83) provides the only discussion that differentiates a postalveolar fricative allophone of /ɾ/ in Chilean Spanish from the sibilants [ʃ ʒ] and [ʂ ʐ] of other languages. He states that the rhotic fricative lacks the higher frequency turbulences expected of a grooved tongue.

Acoustic studies differentiating coronal non-sibilant fricatives from sibilants are lacking, perhaps in part because such a distinction is rare and difficult to maintain due to of perceptual and acoustic similarity. In order to discriminate between fricatives [ɹ̝, ɹ̝̊] and sibilants [ʐ, ʂ], it would be important to have acoustic data from a language that has both non-sibilant alveolar fricatives and sibilants. Colantoni (2006) notes that the location of the concentration of energy for fricative rhotics in the Argentinian Spanish varieties that do not also have palato-alveolar sibilants was almost identical to what has been reported for English /ʃ, ʒ/. She calls for further acoustic studies in varieties of Spanish that have a stable opposition between alveolar fricative rhotics and palato-alveolar sibilants.

Li et. al (2007) mention that the retroflex sibilant /ʂ/ in Mandarin Chinese involves a short slack constriction which results in a low-frequency prominence. The authors do not use slack in terms of phonation contrast with stiff voice, so it is not clear whether slack relates to articulatory effort or tension. They use two spectral measures to differentiate sibilant fricatives; one assesses the degree of palatalization and the other interprets place of articulation. This complicates the acoustic distinction between non-sibilant fricatives [ɹ̝, ɹ̝̊] and sibilants [ʂ, ʐ], since both could show a low-frequency prominence. For sibilants, the energy would be expected to be greater in the higher frequencies. From what is known so far, the distinguishing factor could be the overall spectral shape, with sibilants [ʂ, ʐ] showing regions of higher magnitude above 3000 Hz. Post-alveolar sibilants are expected to have spectral peaks between 3000 and 5000 Hz, with high magnitudes anywhere between 1600–7000 Hz. Alveolar sibilants usually have spectral peaks from above 3500 Hz to above 8000 Hz (Colantoni 2006; Evers et al. 1998).

This study attempts to emphasize that the alveolar fricatives in Nusu are rhotics, but not always sibilants. It does not include an investigation of acoustic features found for the bunched or molar rhotic (cf. Catford 2001), or for the simultaneous involvement of the pharyngeal tract (e.g. Magnuson 2007) due to lack of instruments. In order to determine whether Nusu rhotics involve a secondary obstruction at the teeth, bunching of the dorsum, or adjustment of the pharyngeal tract, instrumental data are needed (cf Catford 2001; Zhou et al. 2008).

Table 4 outlines the acoustic features that distinguish the sounds under consideration.

Table 4. Acoustic features

	Approximant rhotics	**Fricative rhotics**	**Sibilants**
Intensity	amplitude similar to surrounding vowels	greater drop in amplitude	high amplitude in higher frequency range
Periodicity	periodic	aperiodic noise; if voiced, an aperiodic layer on the periodic cycle	aperiodic noise
Spectral shape	discernible structure	spectral peak below 3000 Hz, lower energy above 3000 Hz, lowering of higher formants.	clear spectral peaks at higher frequencies (3000–8000 Hz), greater amplitude in higher frequencies than in the lower frequencies.

4. Phonetic realizations of the Nusu rhotic

Cross-linguistic evidence reveals the extreme variability associated with rhotics. They change place and manner of articulation quite easily. Alveolar fricative rhotics can appear as phonemes or allophones. And this variability can even lead to processes whereby sibilants change into rhotics and rhotics change into sibilants. The preceding section highlights the phonetic similarity between approximants, fricatives, and sibilants. Approximants and fricatives are separated by only a small difference in the degree of constriction. Non-sibilant fricatives and sibilants might be distinguished only by the closeness of the teeth. The following sections will present and discuss the acoustic properties of the rhotic in Nusu. In addition to approximant realizations, the Nusu rhotic can be realized as a voiced or voiceless fricative, including occasional [ʐ].

4.1 Approximants

The acoustic representation of rhotic examples from Topya and Myagu Nusu reveals both alveolar and palatalized alveolar approximant variants of /ɹ/.

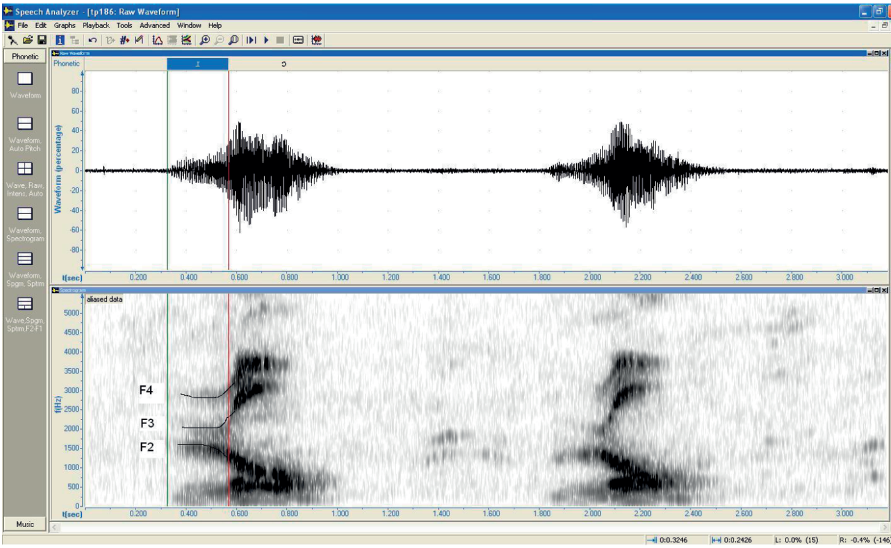

Figure 1. Waveform and spectrogram of approximant [ɹ] (Topya) in [ɹɔ̃] 'rib'

The spectrogram for the Topya speaker onset shows an approximant realization with no turbulence; the signal is similar in periodicity to the following vowel but lower in intensity. The waveform is shown in Figure 2. Both of the third and fourth formants are lowered, which is associated with rhotics (Ladefoged & Maddieson 1996: 244). The acoustic data does not indicate whether the [ɹ] is alveolar or retroflex, with tongue tip raised or bunched. The auditory impression is alveolar, as indicated in the transcription.

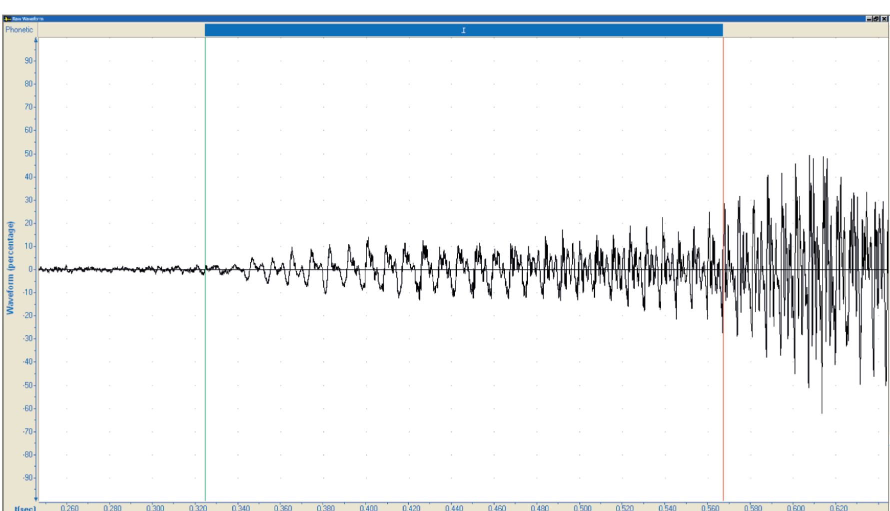

Figure 2. Close-up waveform approximant [ɹ] (Topya) in [ɹɔ̃] 'rib'

For rhotics appearing in clusters, periodicity and formant patterns are consistent with those found in the word initial [ɹ]. An approximant also appears in some consonant clusters in the Myagu variety, where the palatalized variety [ɹʲ] is common in initial, medial, and intervocalic position. Data from four Myagu speakers, two Wawa speakers, and one Zileng speaker suggest that palatalization is not contrastive; [ɹʲ] is in free variation with the alveolar [ɹ]. For some speakers it is even more common than [ɹ]. The [ɹʲ] variant is also characterized by third formant lowering. The distinguishing aspect of this variant is the high second formant, suggesting that some part of the tongue is raised close to the palate. From this we infer that the dorsum was raised closer to the palate, responsible for the auditory impression of a simultaneous [j] and [ɹ].

Figure 3 below compares the palatalized approximant [ɹʲ] approximant in Myagu (left) with the alveolar approximant in Topya (right) in the word /pɹɔ̱/ 'fly'.

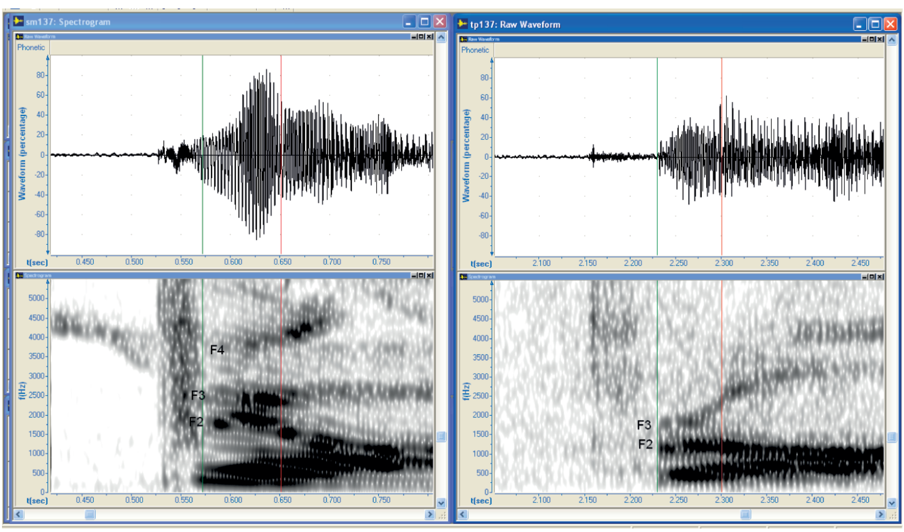

Figure 3. Comparison of Myagu and Topya approximant variants in /pɹɔ̱/ 'fly'

The Myagu approximant [ɹʲ] on the left side (preceded by a bird chirp) is produced with greater intensity than the following vowel, probably because the word is spoken with stiff voice which involves a raised larynx and a build-up of pressure. The Topya syllable to the right is produced with creaky phonation, with the individual pulses of the glottis reflected in the spectrogram. The approximant formant patterns are noticeably different from each other. While the third formant is set at a low level in the Myagu [ɹʲ], the F3 lowering is much more dramatic in the Topya example. This suggests that the tongue tip is more retracted for the Topya speaker. In addition, F2 begins quite high for the Myagu speaker and comes down for the open back vowel [ɔ]. This may indicate that some part of the tongue, probably the dorsum, is raised close to the palate during the rhotic approximant, and then it is pulled down and back for the vowel. Acoustically, the two approximant variants are quite distinct from each other, but they both are rhotic. This is seen when comparing the palatalized alveolar approximant with the palatal approximant /j/ in the Myagu variety. The following images show the waveforms and spectrograms in a contrastive environment. The first word is <*BYA*> [bja˧] 'to fly' and the second is <*BRA BRA*> [bɹʲa˥ bɹʲa˩ xa˧] 'to shine (a flashlight)'. Only the second syllable of <*BRA BRA*> [bɹʲa˥ bɹʲa˩ xa˧] is displayed because the first syllable was clipped due to excessive volume. Both F2 and F3 are much higher and more [i]-like in [j] than in the palatalized rhotic [ɹʲ]. For 'to shine (a flashlight)', this speaker used reduplication and a post-verbal particle, whereas some other speakers produced only the initial syllable.

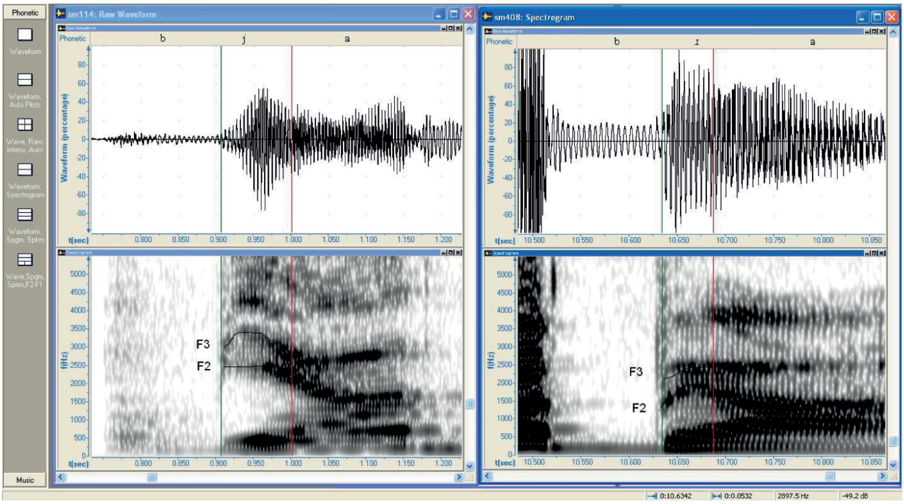

Figure 4. Comparing [bja] and [bɹʲa] in Myagu Nusu

This section has demonstrated that Nusu has approximant rhotic variants with clearly non-turbulant periodic signals and F3 lowering. The Myagu [ɹʲ] differs in auditory cues and acoustic properties from the Topya [ɹ], suggesting a different configuration of the vocal tract. The higher F2 for the palatalized variant indicates that the tongue dorsum is raised towards the pre- or medio-palatal zones. The higher F3 for the palatalized alveolar approximant suggests that retraction of the tongue-tip is less pronounced than in the alveolar approximant.

4.2 Fricatives

The Nusu rhotic also occurs as voiced and voiceless alveolar fricatives. This section compares fricative and approximant realizations of the rhotic across tokens of the same word by the same speaker and across varieties.

In the next example, the Topya speaker happens to alternate between an approximant and a fricative realization of the /ɹ/ in the word 'rat': [ɹ̝uʔ pɔ˩] and [ɹuʔ pɔ˩]. Figure 5 provides a comparison of the first syllable in both tokens. There is a distinct difference in the two realizations of /ɹ/, showing turbulence for the fricated rhotic on the left in addition to the periodic signal.

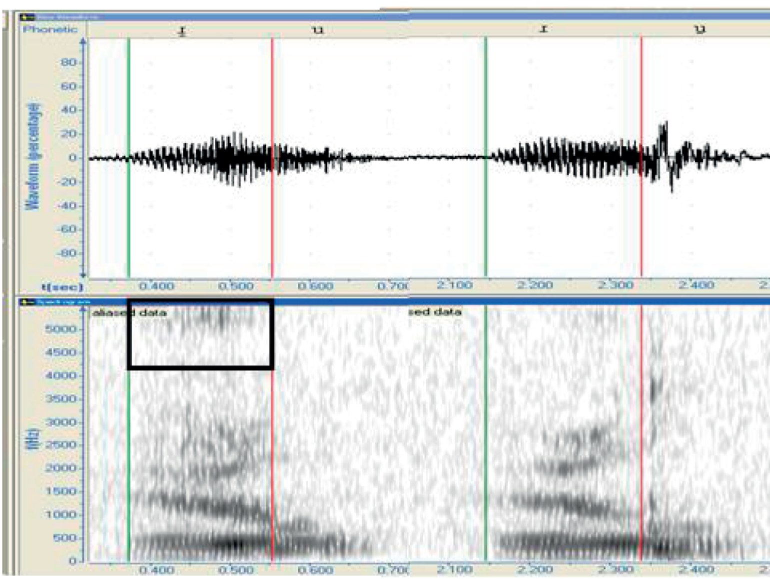

Figure 5. Fricative and Approximant variants of /ɹ/ in 'rat' (Topya)

There are also instances of voiced alveolar fricatives [ɹ̝] occurring in Cr clusters between voiced initials and high vowels. The following example, [ŋu.bɹ̝i˞.do] 'Nu. river.at', is taken from a recording of a picture dictionary by a speaker of the Myagu variety. The rhotic has a periodic waveform, with additional turbulence revealed in the spectrogram. The highest intensity is in the middle frequencies, not the upper frequencies. These are indicators of friction, but not sibilance. The third formant stays low throughout the rhotic and the vowel, indicating a retroflexed or retracted tongue.

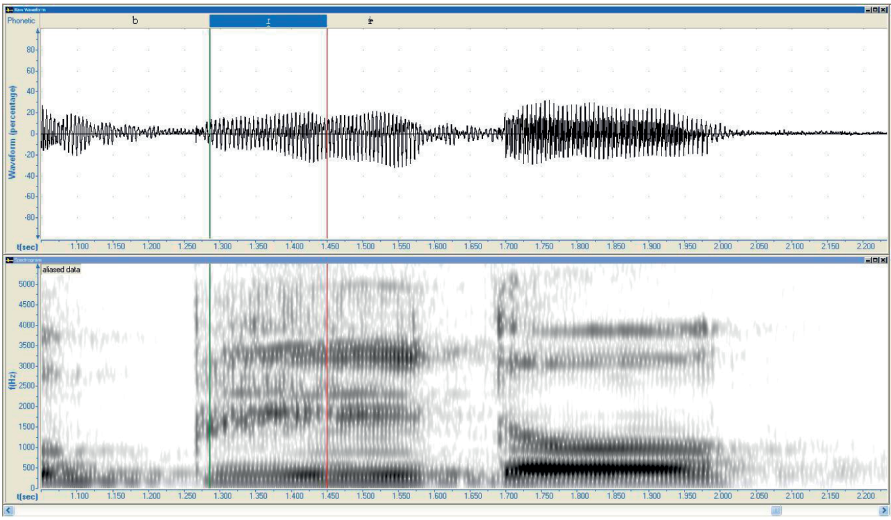

Figure 6. Voiced fricative [ɹ̝] in /bɹi/ 'river' (Myagu)

Voiced fricative realizations of the rhotic tend to occur before closed vowels [i, ɨ, u, e] in both the Myagu and Topya varieties especially in syllable-initial position. The following example illustrates how the degree of constriction can vary across varieties for the same word. Table 5 illustrates 'to laugh' 笑, Proto-Loloish *ray^{1}. The examples for Central/Southern and Northern Nusu are taken from Sun & Lu (1986). Topya is part of Southern Nusu, Myagu is part of Central Nusu, and Wawa is part of Northern Nusu.

Table 5. Varying degree of constriction across Nusu varieties for 'to laugh'

Topya	Myagu	Wawa	Central/ Southern	Northern	Proto-Loloish
ɹ̝e˧ɔ˩	ɹʲe˞˦ʃwɔ˥˩	e˞ ˧˥˧	ɹe˥	ɹi˥	*ray^{1}
Non-sibilant fricative	Palatalized Approximant	Rhotacized Vowel	Approximant	Approximant	

In the Myagu variety, the approximant /ɹ/ has a voiceless fricative allophone in Cr clusters with [p^{h}], as in [bɔ˧ p^{h}ɹ̥a˧] 'cockroach' shown in Figure 7. In Topya, this is an approximant as indicated in Table 1. The waveform for the Myagu token displays aperiodic friction, and the spectrogram shows less intensity during the rhotic than during the surrounding sounds. There is a hint of the peak frequencies at about 1600 Hz (close to F2) and 2400 Hz (close to F3) but no clear indication of sibilance.

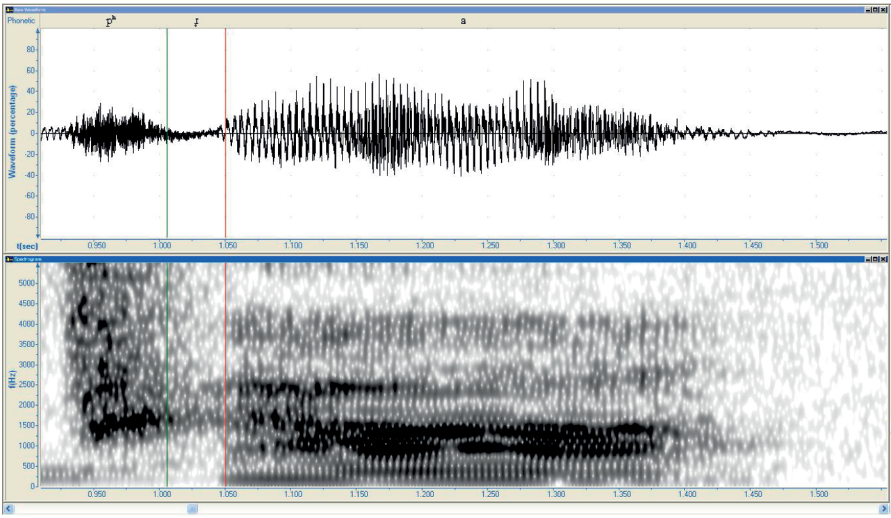

Figure 7. Voiceless fricative [ɹ̝̊] in [bɔ˧ pʰɹ̝̊a˧] 'cockroach' (Myagu)

In summary, the voiced fricative [ɹ̝] displays intra-speaker variation across varieties. It occurs most frequently before closed vowels or the mid front vowel but is not limited to this environment. This is seen for the Topya speaker varying between approximant and fricative before an open-mid back vowel in [ɹɔʔxa˥] and [ɹ̝ɔʔxa˥] 'to weave'.

4.3 Distinction from sibilants

Previous descriptions of Nusu include voiced sibilants /z, ʐ, ʑ/. We argue that /ʐ/ is not a separate phoneme. Fu (1991) described a cluster [ɣɹ] as pronounced by applying a relatively slight friction at the tongue root but a heavier friction of retroflexion. She maintains that the phonetic value is close to [ʐ], and her [ɣɹ] often corresponds to initial [ɹ] in Sun and Lu's transcriptions. This section attempts to distinguish the Nusu fricative rhotic from true sibilants /z/ and /ʑ/. Both descriptions of Nusu include five voiced fricatives as shown in Table 6. The three fricatives in the rectangle are transcribed as sibilants. In addition to the voiced fricatives, Sun and Lu posit a semi-vowel /ɹ/.

Table 6. Voiced fricatives according to previous analyses of Nusu

labial	dental/alveolar	'retroflex'	palatal	velar
v	z	ʐ	ʑ	ɣ

From a phonological perspective, we argue that /ɹ/ can be distinguished from /z/ and /ʑ/, but there is no evidence for a further contrast with /ʐ/.

Table 7. Lexical contrasts involving the rhotic and voiced sibilants in Myagu Nusu

/z/	/ɹ/	/ʑ/
/za˥ ŋe˧/ 'child'	/ɹa˥˧/ 'swollen'	/ʑa˥˧/ 'difficult'
	/ɹi˥/ 'big'	/ʑi˥/ 'urine', /ʑi˧/ 'liquor'
/zɔ̃˧ kʰɹa˧/ 'lesson'	/ɹɔ̃˧/ 'rib'	/ʑõ˥˧/ 'elephant'

Previous studies have used [ʐ] in transcriptions of words from both the /ɹ/ and /ʑ/ columns. Examples are given in Table 8.

Table 8. Varying transcriptions for fricative segments in identical words

English gloss	Nusu (Bijiang)	Nusu (Central)	Nusu (Northern)	Nusu (Southern)
	Sun et al. 1991	**Sun & Lu 1986**	**Sun & Lu 1986**	**Sun & Lu 1986**
difficult	ʐa^{55} a^{31}	ʐa^{55}	ʐa^{35}	ʑɔ^{55}
liquor	ʐi^{55}	ʐi^{33}	ʐʅ^{31}	ʑi^{35}
big	ʐi^{55} a^{31}	ɣɹi^{55} (Huang & Dai 1992)	ɹʅ^{35}	ɹi^{55}
urine	ʑi^{55}	ʐi^{55} (cf. Dai 1989 ʑi^{53} Zhizhiluo NusA; ʐi^{55} NusB)	ʐʅ^{55}	ʑi^{53}

The examples in Table 8 show that even in previous studies, the initial in 'big' was transcribed as a [ʐ] or [ɹ]. The initial in 'urine' was transcribed with [ʐ] and [ʑ]. In their description of Nusu initials, Sun and Lu (1986) provide the following as examples for each sound, /z/ 'son', /ɹ/ 'laugh', /ʐ/ 'to be big', /ʑ/ 'urine.' There is a paucity of evidence for the phonemic status of /ʐ/, and we would argue that both 'laugh' and 'to be big' begin with an /ɹ/ that can be realized variably as an approximant, a non-sibilant fricative rhotic, or a voiced sibilant. Though the sound transcribed in the previous analyses of Nusu as [ʐ] may sound very similar to a sibilant fricative (as often described for the Mandarin Chinese rhotic), intra-speaker and inter-speaker evidence suggest that in some words it is an allophone of the rhotic /ɹ/ and in others an allophone of the voiced alveolopalatal sibilant /ʑ/ (cf. Table 7). Sibilant transcriptions with [ʐ] therefore do not necessarily indicate an obstruent but sometimes a sibilant rhotic. We argue that [ʐ] is not a distinctive phoneme of Nusu. Sun and Lu selected "big, large" 大 as an example of /ʐ/, but the consonant precedes a closed vowel, /i/, one of the environments where /ɹ/ is often realized as a fricative [ɹ̝]. Therefore, we will take a closer look at further spectral features.

As mentioned in Section 3.2, sibilants are characterized by a hissing sound created when the teeth are brought close together thereby forming a secondary obstruction to the turbulent airflow. Acoustically, this results in the loudest noise, or spectral peak, being found in the highest frequencies. Figures 8 to 12 display spectral analysis samples for each of the voiced fricatives as produced by the Myagu speaker from Shishidukhu. Frequency (0–15 kHz) is shown on the x-axis and magnitude on the y-axis. Each graph represents a mathematical transformation of the waveform into the components of its frequency spectrum, thus revealing which frequencies are associated with the most noise relative to other frequencies in the spectrum. The example words do not involve stiff syllables in order to ensure that the comparison of voiced fricatives is not affected by differences in syllable phonation. The examples given for [ɹ̝] and [ʑ] are taken from words that Sun and Lu used to postulate /ʐ/ and /ʑ/ as distinctive consonants for Nusu.

Intense turbulence in the higher frequencies is a hallmark of sibilant fricatives. This is seen only in the examples of [z] and [ʑ]. Peak frequencies for [z] are observed between 4000–9000 Hz at magnitudes of 60 to 132 (see Figure 8). The maximum peak frequency is at 5049.5 Hz. This matches the description of [s] by Evers et al. 1998. For [ʑ] spectral peaks are observed between 2000–8000 Hz at magnitudes of 80 to 575 (see Figure 9). The maximum peak frequency is 3106.2 Hz. This is also consistent with the description of [ʃ] in Evers et al. 1998. In both of these sibilant tokens, peaks above 3000 Hz reach magnitudes much greater than 80. In contrast, all three of the other voiced fricatives, [ɹ̝, v, ɣ] show a maximum peak frequency below 3000 Hz (see Figures 10–12). Above 3000 Hz, magnitudes do not rise above 80. The maximum peak frequency for [ɹ̝] is 2061.8 Hz (Figure 10). In this respect, and in its overal spectral shape [ɹ̝] is more similar to the non-sibilants [v, ɣ] than the sibilants [z, ʑ] despite their closeness in place of articulation. It should be noted that the Myagu (Shishidukhu) speaker's production of the initial rhotic in 'to be big' varies, but with [rʲ], not a sibilant.

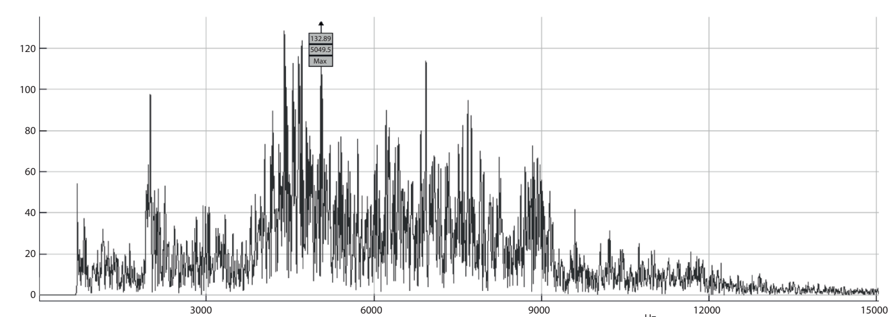

Figure 8. FFT spectrum analysis of [z] in /za˥ ŋe˧/ 'child' (Myagu)

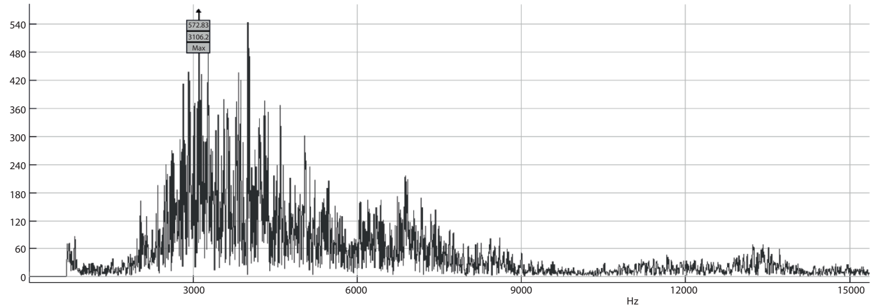

Figure 9. FFT spectrum analysis of [z̡] in /z̡i˥/ urine’ (Myagu)

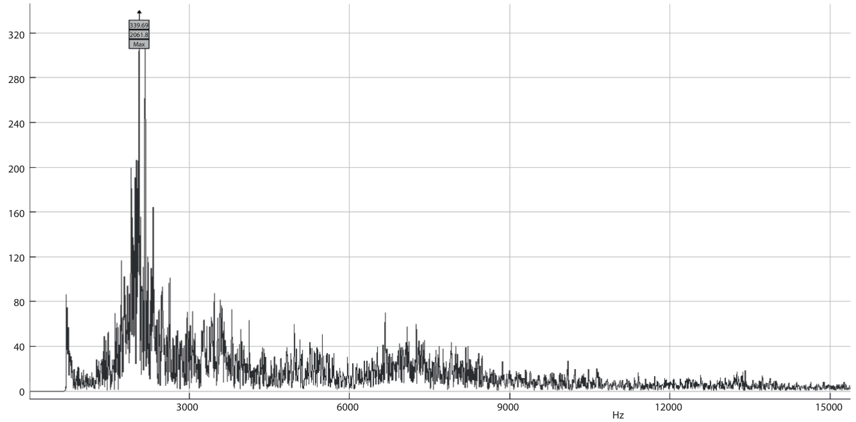

Figure 10. FFT spectrum analysis of [ɹ̝] in /ɹi˥/ ‘to be big’ (Myagu)

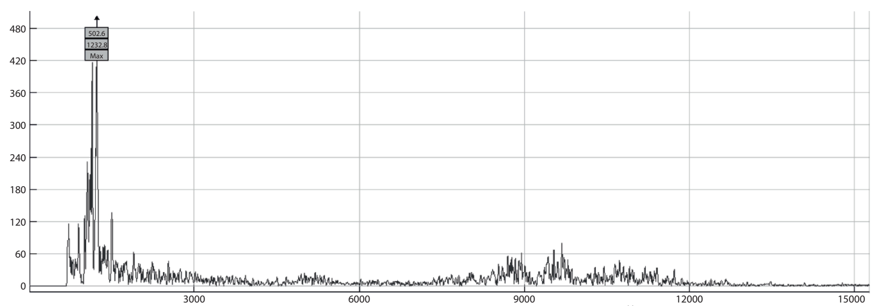

Figure 11. FFT spectrum analysis of [v] in /vɑ˩ lɔ˧˥/‘belly’ (Myagu)

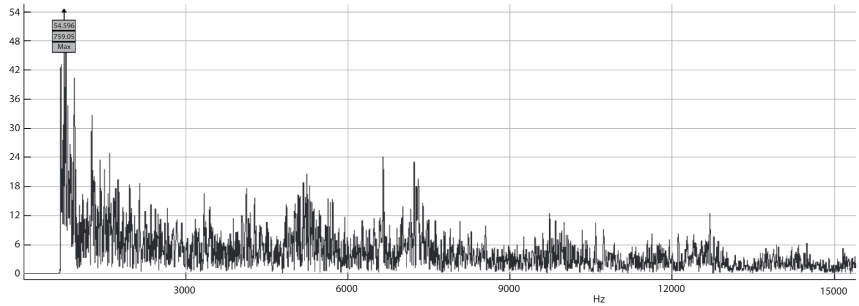

Figure 12. FFT spectrum analysis of [ɣ] in /ɣɨ˧/ 'pigeon' (Myagu)

It is crucial to recognize the wide range of variation in constriction allowed for /ɹ/. The rhotic shows a broad range of intra-speaker variation from an approximant to a non-sibilant fricative to even a sibilant fricative. For /ɹi˥/ 'to be big', the Shishidukhu Myagu speaker pronounced three tokens, with initials [ɹ̝] on the first token and [ɹ^{j}] on the second and third tokens. An FFT spectrum analysis of the first token is given in Figure 10. Figure 13 below provides an FFT spectrum analysis of the second token. Similar to fricative [ɹ̝], the palatalized approximant shows a maximum peak frequency of 2417.1 Hz and all frequencies above 3000 Hz do not exceed a magnitude of 80.

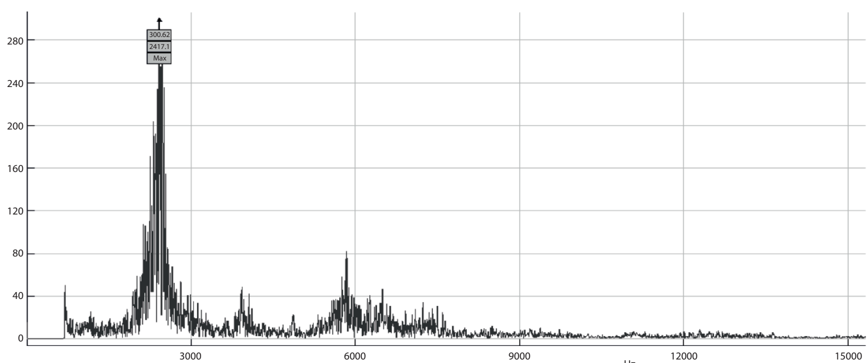

Figure 13. FFT spectrum analysis of [ɹ^{j}] 'to be big' (Myagu)

The Topya speaker on the other hand, displays a continuum of constriction for /ɹ/ that can be realized as either a non-sibilant fricative rhotic or a sibilant-like fricative. Figure 14 provides an FFT spectrum analysis of the initial [ɹ̝] in the first token of 'to be swollen'/ɹa˥˧/. Consistent with non-sibilant fricatives, the highest magnitudes are all below 3000 Hz; above 3000 Hz magnitudes do not exceed 80. The second token shown in Figure 15 shows lower spectral peaks characteristic of a non-sibilant fricative, but also higher spectral peaks that come closer to a sibilant. This points at the speaker bringing the teeth closer together than in the first token, creating a second occlusion responsible for sibilance. If the tongue is brought close enough to the alveolar ridge (or pre-palate) to produce the turbulent airstream of an alveolar non-sibilant fricative, it is only a small articulatory movement to bring the teeth even closer together to form a voiced sibilant fricative.

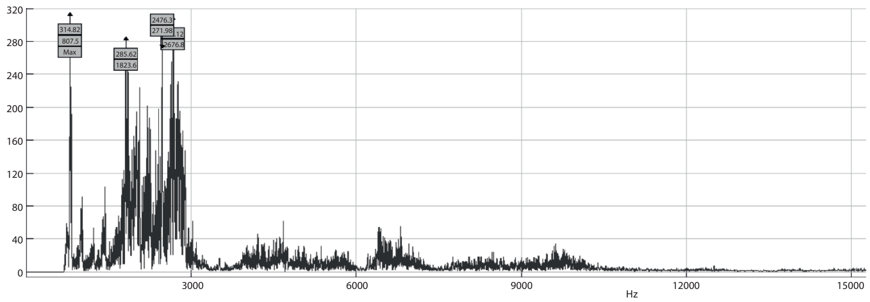

Figure 14. FFT spectrum analysis of the first token of [ɹ̝] 'to be swollen' (Topya)

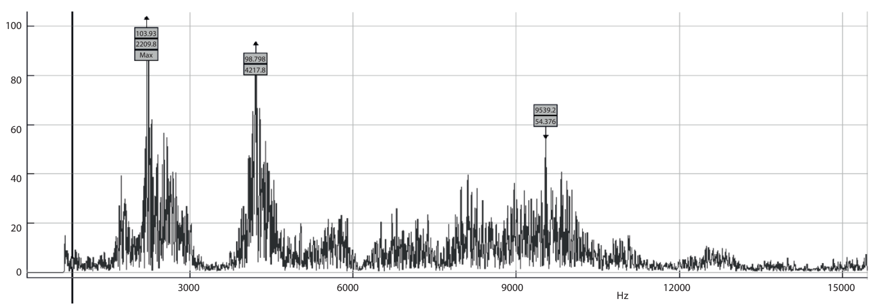

Figure 15. FFT spectrum analysis of the second token of [z̡] 'to be swollen' (Topya)

Figure 15 shows a greater amount of turbulence in the upper frequencies between 4000–1000 Hz than can be seen in either Figure 10 or Figure 14 for [ɹ̝]. Above 3000 Hz there is only one frequency peak above 80, at 4217.8 Hz. In addition, the maximum peak frequency is below 3000 Hz, and the overall shape still does not show the same concentration of energy above 3000 Hz that can be seen in Figures 8 and 9 for sibilants [z] and [ʑ].

The Topya speaker's range of variation is even wider for the initial in 'to be big'. The first token is pronounced with a fricative which might be characterized as [z̡]. Figure 16 provides an FFT spectrum analysis of the fricative. The maximum peak frequency is at 1814.2 Hz, and there are even higher spectral peaks in the range above 3000 Hz than was observed in Figure 15. Significantly, peaks that exceed 100 can be observed as high as 9000 Hz. Thus, the overall spectral shape is more similar to a sibilant. However, the initial in the second token is an approximant [ɹ], with no evidence of spectral peaks in the range above 3000 Hz (see Figure 19).

This illustrates that the retroflex sibilant [ʐ] does not form contrast with [ɹ] but is an allophonic sibilant realization of the rhotic.

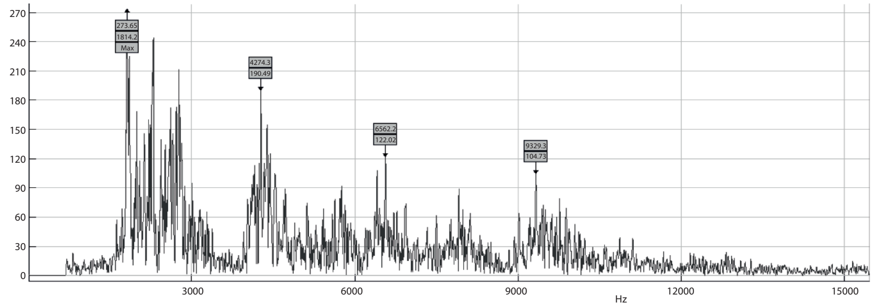

Figure 16. FFT spectrum analysis of the first token of [ʐ] ‘to be big’ (Topya)

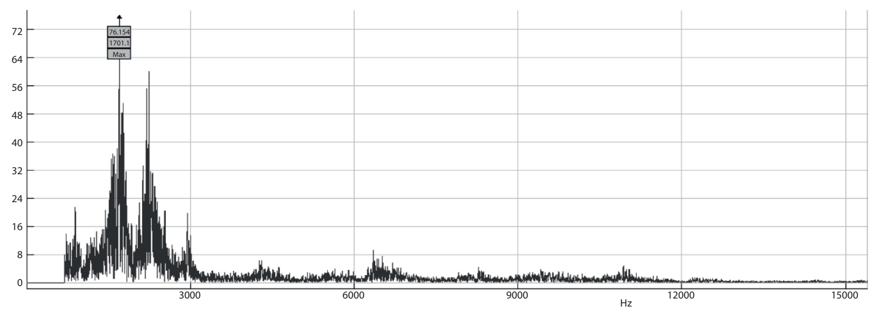

Figure 17. FFT spectrum analysis of the second token of [ɹ] ‘to be big’ (Topya)

Thus, the Shishidukhu speaker’s initial /ɹ/ shows a range of constriction from [ɹʲ] to [ɹ̝], and the Topya speaker’s initial /ɹ/ ranges in constriction from approximant [ɹ] (see Figures 5 and 17), to non-sibilant fricative [ɹ̝] (Figure 14), to sibilant [ʐ] (Figures 15 and 16). This wide range of phonetic realizations displayed by both speakers reveals a continuum in the degree of constriction permissible for Nusu speakers. Symbolically, it may be useful to characterize the allophones of /ɹ/ as [ɹ, ɹʲ, ɹ̝, ʐ]. It is important to recognize, however, the point on the continuum where the voiced fricative allophone [ɹ̝] is non-sibilant (see Figures 12 and 14).

Colantoni’s (2006) study of alveolar fricative rhotic allophones clarifies the relationship between fricative rhotics and sibilants by documenting the unexpected process of dissimilation occurring in Argentinian Spanish. The most influential variety, Buenos Aires, has only trills for the rhotics, but the post-alveolar ‘double l’ as in *calle* ‘street’, is pronounced as a sibilant [ʒ]. Colantoni mentions the acoustic and perceptual similarity between fricative rhotics and post-alveolar sibilants. While all of the locations included in Colantoni’s study have fricative realizations of /r/, the ones that are acquiring the Buenos Aires-style [ʒ] for *calle* also show a process of ‘de-assibilating’ the rhotics. In other words, to distinguish the post-alveolar sibilant [ʒ] and the rhotics, speakers in these locations decrease the degree of constriction on the rhotic and produce an alveolar approximant [ɹ] instead of an alveolar fricative rhotic. So while the Latin-American alveolar fricative rhotics are not sibilants, there is a dispreference for having both alveolar fricative rhotics and post-alveolar sibilants. Applied to Nusu, this would explain why the sibilant allophone of /ɹ/ is so rare.

In 1984, Maddieson argued that "the criteria for reporting a sound as 'some kind of r' rather than, say, as a voiced retroflex sibilant /ẓ/ are obscure and may not reflect a phonetic difference between /ẓ/ and /ɹ̆/, but instead be based on phonotactic considerations or other non-phonetic characteristics (including orthographic convention)" (1984: 80). By 1996, he characterized a few languages as having non-sibilant alveolar fricative rhotics. In the case of Nusu, the argument for a non-sibilant fricative rhotic can be made on the basis of phonotactics, phonological variation, and acoustic distinction. Maddieson's original argument related to the low frequency of voiced alveolar fricative rhotic *phonemes* found among the world's languages. In Nusu, [ʐ] appears to be one of the phonetic realizations of /ɹ/, but not the primary one. The similarity to other variants such as the fricative [ɹ̝] should not inhibit the precision with which we describe phonetic realizations of Nusu /ɹ/.

5. Further evidence for fricative rhotics in Tibeto-Burman

Evidence from other Asian languages indicate that coronal fricative rhotics deserve more recognition. There are hints that alveolar fricatives [ɹ̝, ɹ̥] or fricative versions of [ɻ] may appear at least as allophones in several other languages. It is commonly reported that an initial retroflex rhotic /ɻ̝/ can be realized as sibilant [ʐ] in Beijing Chinese. Duanmu (2007) states that Standard Chinese has an approximant, and David Bradley (p.c.) has mentioned that there is less friction in most varieties, depending on the following vowel. Many Tibeto-Burman languages, including Nusu, have been described by Chinese scholars who seem to associate retroflex sibilants with allophones of /ɹ/.

Fu (1991: 241) provides data that may suggest a voiced fricative rhotic in Achang, a Tibeto-Burman language in the Burmish subgroup, spoken in Southwest Yunnan. In her comparison of Nusu and Achang consonant clusters, Nusu [ɹ] correlates with [ʐ] in Achang, as seen in Table 9.

The source of her Achang data is unclear, and the exact phonetic character of the Achang [ʐ] is not described in detail. Both Dai (1992) and Sun et al. (1991) also include clusters of [mʐ] in their Achang transcriptions. Whereas rhotics, laterals, and semivowels /w/ and /j/ can occur as the second member of consonant clusters in Burmish languages, a consonant-sibilant cluster would be surprising.

Table 9. Achang consonant clusters

Nusu	Achang
Cɹ	Cʐ
pɹe^{55}	phʐə^{31}
mɹɨ^{55}	mʐau^{31}
khɹu̬^{53}	kʐuat^{55}
gɹa̬^{53}	kʐuat^{55}

The phonotactics of this data either suggest that the Achang sound transcribed in this data as [ʐ] could possibly represent a non-sibilant fricative rhotic, as observed in Nusu, or that the sibilant has the phonological status of a rhotic, as in some descriptions for Chinese (cf. Duanmu 2007).

Fricatives have been recorded as rhotic allophone realizations in other Tibeto-Burman languages. Limi Tibetan (a dialect of Humla Bhotia, NW Nepal) has two rhotic phonemes /r/ and /r̥/ (Wilde 2001: 28–30). /r/ is often realized as a voiced apico-alveolar fricative [ɹ̝], (therefore, sounding almost apical retroflex like Indo-Aryan languages in the region), and varies freely with a tap. Wilde describes the voiceless apico-alveolar fricative /r̥/ as forming 'a fairly loose constriction at the alveolar ridge' and specifically distinguishes [ɹ̝] from [ʐ] and [ɹ̝̊] from [s] and [ʃ] on the basis that Limi sounds are not grooved.

Jejara (Para Naga), a Tibeto-Burman language spoken in Northwest Myanmar is reported to have both voiced and voiceless alveolar fricative allophones (Lubbe 2007). Lubbe describes a voiced alveolar fricative rhotic that alternates with an alveolar flap allophone [ɾ]. A voiceless alveolar fricative transcribed as [r̥ʰ] is listed as a separate phoneme though it may be simply an allophone (p.c. Barkman).

Sprigg (1972: 550) includes data from consonant clusters in Tibetan dialects which he designates as (i) plosive-fricative (Pr/r̥) or (ii) plosive-plosive-fricative (ptr/r̥) sequences; e.g. (i) Balti (Khapalu) [kru] 'corner', [kr̥u] 'cubit', [gri] 'knife'; Golok [tr̥ɪt] 'lead', [trɔ̃ː] 'village'; Lhasa [¯l̥ʌ¯briː¯bə] 'artist'; (ii) Golok [ptr̥ugu] 'offspring', [ptriː] 'wrote'; Lhasa [¯kjɪ¯ptr/r̥uː] *khyi-phrug* 'puppy'.

Voiced and voiceless retroflex fricatives also occur in Mongsen Ao, a Tibeto-Burman language spoken in Nagaland, India. Coupe (2007: 43) provides wave-forms and spectrograms. He identifies them as apical post-alveolar approximants /ɹ/ and /hɹ/, but specifies that both the voiced and voiceless phonemes generate a great deal of friction. Phonetically, he describes them as retroflex fricatives and uses the symbols [ʐ] and [ʂ]. The spectrograms show the most intensity between 2000–3000 Hz for the voiced phoneme and between 3000–5000 Hz for the voiceless phoneme. These samples imply frication for both examples, but sibilance only for the latter.

We have heard a voiceless fricative rhotic [ɹ̥] in [ə.ɹ̥ə́ŋ.gù] 'to be tall' in a Rawang variety (Tangsar as spoken in Nangsing along the lower Langdaqgong); David Sangdong, a native speaker of Rawang who has personally collected wordlists in over 30 Nungish varieties, interpreted this sound as a consonant cluster in Tangsar (Nangsing) [əxrə́ŋ.gù] and Trung (Dazingdam, Dalammai, and Khrongdam) [ʔəhraŋ]; c.f. Rawang (Matwang) [əhaŋe] *vhange*.

Finally, Matisoff's (2003: 76) discussion of the retroflex affricates in the Dayang variety of Pumi, spoken in Sichuan, underscores the importance of resolving transcription problems for representing rhotics in Tibeto-Burman. Dayang Pumi has both a retroflex and palatal affricate series that developed from clusters of *labial-plus-liquid. The retroflex affricates are characterized by what he transcribes as sibilant off-glides /pʐ/ [př], /pʂh/, and /bʐ/. He mentions that in the first, "the off-glide *varies* between [ʐ] and a fricative **r**-sound similar to Czech /ř/." Moreover, these affricates can be distinguished from **r**-clusters that derive from the optional elision of schwa in a sesquisyllabic word (e.g. [br] 'snake' *brá~bərá)*. The schwa returns in careful speech. Here Matisoff wants to distinguish between a retroflex sibilant and a non-sibilant rhotic fricative, and what is lacking is an accepted transcription convention for a retroflex "fricative **r**-sound." Matisoff is not the first to observe the similarity between the Czech rhotic fricative trill and Tibeto-Burman rhotic fricatives. Van Driem (1990: 83) reported that the phoneme /r/ has "a palatal realization [ɽ] virtually identical to the Czech *ř*" in Dumi, a Tibeto-Burman language of the Eastern Kiranti group spoken in Nepal.

6. Conclusion

Data from Nusu demonstrate that its rhotic phoneme /ɹ/ can be realized as voiced and voiceless non-sibilant fricatives. These fricative variations should not be assumed to be sibilant [ʐ], though this is a possible allophone. Evidence from a number of other Tibeto-Burman languages suggest that non-sibilant fricative rhotics are more widespread. Tibetan varieties, Jejara, and Mongsen Ao provide evidence for both voiced and voiceless alveolar non-sibilant fricative rhotics. Consistent with the previous literature on rhotics, the best evidence for classifying these fricatives as rhotics derives from phonotactics and phonological patterning. Nusu, Achang, Tibetan varieties, and Dayang Pumi have voiced fricatives occurring in Cr clusters. Nusu, Limi Tibetan, and Jejara all have fricative rhotics in phonological variation with other rhotic forms, whether approximant, tap, or flap. Finally, acoustic data can represent the degree and type of friction that occur in realizations of rhotic phonemes. Such phonetic evidence can help to distinguish these fricatives from sibilants.

By introducing the alveolar fricative rhotics in Nusu, this paper calls for systematic acoustic and instrumental analyses of fricative rhotics in Nusu as well as other Tibeto-Burman languages. Spectral moment comparisons would shed light on whether the fricative rhotic [ɹ̝] is a sibilant or not. X-ray or MRI studies would be useful for this purpose and also for identifying exact articulatory gestures involved in the /ɹ/ variants of Nusu discussed here {ɹ, ɹ̝, ɹ̝ʲ, ʐ, ɹ̥}. Such studies would reveal (1) whether a secondary obstruction is caused by adducting the teeth; (2) whether the tongue tip is raised or bunched; (3) which parts of the tongue are involved (tip-blade and/or dorsum); (4) the constriction location (alveolar ridge, pre-palatal, medio-palatal, post-palatal); and (5) whether any sort of pharyngeal constriction comes into play. Palatograms and linguagrams would not answer all of these questions, but they could provide limited data about which part of the tongue comes into contact with the teeth and/or palate and where that constriction is located.

In the meantime, Tibeto-Burman scholars struggle to transcribe non-sibilant fricatives. Resorting simply to [r] or [ɹ] does not allow for specification of the kind of environmental and dialectal variation exhibited in Nusu or other languages like Dayang Pumi. In Tibeto-Burman descriptions, voiced alveolar fricatives have been transcribed most commonly as [r] and [ʐ], but also as [ɹ], and following Czech convention, [ř]. The IPA [ɹ̝] is not very reader-friendly and hardly used. The common practice of transcribing [ʐ], especially in consonant clusters erases the rhotic aspect of the voiced fricative. Voiceless alveolar non-sibilant rhotic fricatives are also challenging, with various transcribers resorting to [rh], [hr], [xr], [ʂ] and [r̥ʰ]. Current IPA standards for representing a voiceless rhotic fricative would engage two diacritics that are usually positioned under the letter: [̥] and [̝] (as seen in Ladefoged and Maddieson 1996: 242 as well as Wilde 2001: 28–30). This double diacritic below the symbol is not even possible in some word processing environments, especially when a retroflex symbol [ɻ] is used. In this paper, we have used [ɹ̥] which captures the voiceless feature, but not necessarily fricative manner. Following Whitley's proposed [ɹ̌] and [ɻ̌] for non-sibilant voiced fricatives would allow for a less awkward representation of the voiceless fricatives: [ɹ̥̌] and/or [ɻ̊̌]. It would have the added benefit of utilizing the Czech convention which has already surfaced in Tibeto-Burman literature (cf Matisoff 2003). On the other hand, rhotics can bear tone in some languages, so there could be confusion with tone marking. The old symbol for the Czech fricative trill [ɼ] could be utilized. It was approved as a replacement of [ř] in 1945 and withdrawn by IPA in 1989 because it can be written with diacritics. As Dvořák (2010) points out, the Czech fricative trill (which has a voiceless allophone) is the only consonant phoneme that does not have its own symbol in the IPA alphabet. It would be beneficial for scholars to find a generally acceptable way to represent non-sibilant rhotic fricatives which preserves the rhotic aspect as well as the fricative manner, especially when additional diacritics are needed (e.g. voicelessness, syllabicity, tone).

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Appendix

Variety location	Myagu Aungmye	Myagu Shishi-dukhu	Zileng Shwezet	Wawa 8 Miles	Topya Ngwa-phakha	Topya Zibankha	Yotolo Shwezet
alcohol	ʐ̩˩pʰɔʔ	ʐ̩˩ pʰɔʔ	tswa˥˧ʔ ʐɿ˧	tsʰɔm˥ ʐɿ˧˩	ʝi˩ pʰɑ˥˧ʔ	ʐi˩ pʰɔʔ	lja˥˧ʔ (j/ʐ̩/ʝ̩)˩
chicken	ɹʲaʔ	ɹʲa˥	ɹaʔ	ɹaʔ	ɹɔʔ	ɹɔʔ	ɹaʔ
crest (of chicken or bird)	ɹʲaʔ via˥	ɹ̝ɑ̰˥ vja˥	via˥	jea˧	dɔʔ	ɹɔʔ dɔʔ	tɔ˥ gjɔŋ˩ a˥
to shave (beard)	ɹʲo̰ʔ˥	hũ˥.tʂʰæʳ˥.ɹʲṵ˥˧ʔ	ɹʲu˥˧ʔ	ɹo˥˧	ɹu˥˧	ɹ̝u˥˧ʔ	ɹʲu˥˧ʔ
elbow	laʔ tsʰiɑ̰ʔ ˥	laʔ tʰɔ̃˧	ɹʲɔ˥ tʰɔŋ˧	laʔ sɨa˥˧	ɹa˥ tʰɔŋ˧	ɹɔ˥ tʰɔŋ˧	ɹʲɔ˧ tɔ̃˧
bone	ɹʲu˥	ɹ̝ɨ˥	ɹʲɨ˥	ɹu˧˥	ɹʲɨ˥˧	ɹ̝ɨ˥	ɹʲɨ˧˥
rib	(ɹʲ/ɹ̝)ɔ̃˧	ɹɔ̃˧	ɹʲã˧	ɹaŋ˩ ŋaʔ	ɹʲɔ̃˧	ɹɔ̃˧	ɹaŋ˩ ŋa˧
wall of house	pja˧	pja˧	pja˧	ca˧˥	ɹɛʔ	ɹ̌e˥	pja˧˥
clothing	wɔʔ kʰwe˧	wɔʔ kʰwe˧	wɔʔ kʰwe˧	wɛʔ ji˩ wɛʔ ga˧˥	waʔ tʷi˥	waʔ(ɹ/ɹ̌)i˥wɛʔ kʰwe˩	
to weave (cloth)	ɹʲa˩ ɹʲaʔ˥	ɹ̝aʔ	ɹaʔ	ɹaʔ	ɹɔʔ	(ɹ/ɹ̌)ɔʔ xa˥	ɹa˧ɹaʔ
to look at	ɹ̝ʲu˧ ja˥˧	ɹ̝u˩	ɹu˩ aneʔ	ɹu˧	ʃɔ˥˧ ɹo˩	ɹ̝u˩.ɔ˧	ɹʲu˥.a˧.dɔ˩
to smile	ɹʲe˩ ʃɛ˩ ʃɛ˥˧	ɹ̝e˩ si˩ se˥	ɹe˩ sɛ˩ se˥	ɹi˩ bɛʔ	ɹe˩ se˥	ɹe˩ sɛ˩ sɛ˥	bɛʔ mɛ˧
to laugh	ɹʲe˧ ʃwɔ˧	ɹʲe˞˥˧ʃwɔ˧˩	ɹaʔ	e˞˥˧	ɹe˧˥	ɹ̝e˧ɔ˩	ɣɨ˩ a˧ dɔ˩
that	wɛ̹˥ ku˩	wi˧ ku˩	ɹʲu˥ kʰo˧	wɛ̹˩ ku˥	ɹa˥ kʰu˩	ɹa˥ kʰu˩/ɰɹa˥ kʰu˩	o˩ ku˧
to be swollen	ɹʲa˥˧	ɹʲɹ̝a˥˧	ɬɨa˥˧	ʁam˧˥	ɣɹe˥	(ɹ̝/ʐ)e˥	ʁɔa˧˥
rat	ɹʲwa̰ʔ˥	wʳɑ̰˥˧ˀpɔ̰˩	ɹʲa˥˧ pɔ˩	ɹoʔ	ɹʲu˥˧ʔ	ɹ̝uʔ pɔ˩/ɹuʔ pɔ˩	wɹaʔ

Variety location	Myagu Aungmye	Myagu Shishi-dukhu	Zileng Shwezet	Wawa 8 Miles	Topya Ngwa-phakha	Topya Zibankha	Yotolo Shwezet
river	ɹʲoŋ˩ bɹʲia˧	ʳɔ̃˧ bʷi̯a˥˩	ɹʲõŋ˧ bi̯˧	ɹ̠̊ŋ˩ bɹ̠̊ŋ˧a˩	ja˧ bʷi˧	ja˧ bɹi˧	ɔ̃˩ bɹ̠i˧
pus	bæ̃ʳ˧	bɑ̃ʳ˧	bæ̃ʳ˧	bɨ˧ lu˩ pju˧	li˥ bɘa˧	li˥ bɹɘ˧	bɘ˩
to be full (container)	bæ̃ʳ˧ ga˩˥	bɑ̰ʳ˥˩	bæ	bein˧	bɹɘa˩	bɹɘa˩ ɔ˥	bɘa˩˥
to shine (flashlight)	bɹʲa˦ bɹʲa˥˦	bɹʲa˦ bɹʲa˩ xa˧	bɹʲa˩	bɹa˥	bɹɔ˩	bɹɔ˩ ɔ˥	bɹa˧ dɔ˩
rainbow	tʰõ˩ gi̯˥aʔ	tɔ̃˧ giaʔ	tsʰõ˩ gɹiaʔ	tʰɔŋ˩ giaʔ	tʃʰõ˩ dʒi˥	tʃʰõ˩ dʐi˥	tuk gwia˥˩
thunder	mɨ˩ gʲɨ˥ gʲɨ˥	mɨ˩ gɹia˥˩	mɨa˥˩ gɹia˥˨	maŋ˦ gɹi˩˥	mɨ˦ dɨ˥	mi˥˩ zi˥	mɨa˩˥ gɨa˩˥
water	i˩ gɹʲa˥	i˩ gɹʲa˥ˀ	i˩ gɹʲa˥ˀ	ji˩ gɹʲa˥ˀ	i˩dɹɔ˥	e˩dʐɔ˥ʔ	i˩ gɹʲa˥ʔ
to be cold (person)	gɹʲaʔ˥ la˩	g̟ɹɑ̰ʔ˥/g̟ɹɑ̰˥	gɹʲa˥ʔ	gɹaʔ	(ɖ/d)ɔʔ ɕɔʔ	dʐɔ˥ʔ lɛ˩	gɹʲa˥ʔ a˥ dɔ˩
root (tree)	siʔ gɹʲɨ˥	si̯˧ gɘ˦	tsyʔ gɹi˥	tsɨ˧ ɹaŋ˩ a˧	si˧ˀ dɨ˥	siʔ ɟɨ˥	si˧ gri˦
pestle (for peppers)	pʰɨ˥gi̯˧	pʰi g̟ɹi˧	pʰɨ˥ gɹi˧	pʰu˥ gɹi˩	pʰɨ˥ dʒi˧	pʰɨ˥ ɟɹi˧	pʰɨ˥ gɹi˩
gong	gi̯˥ bæ̃˧	g̟ɹi˥ bæ˧	gɹi˥ ba˧	dʒein˩	gɹi˥ ba˧	dʐi˥ ba˧	ga˩
to be full (after eating)	wa˩ gɹʲaʔ˥ a˩˥	va˩ g̟ɹa˥	va˧ gɹʲa˧	bu˧	vɛ˩ dʒɔ˥	ve˩ dʐɔ˥	vɔ˦ bu˥ ta˥
to be afraid	gɹʲuʔ˦ a˧ la˩	gɹuʔ	gɹuʔ a˧	gɹuʔ	dʐɹuʔ	ɟɹuʔ	gruʔ˥ dɔ˩
to fall (from a height)	gɹʲa˩ je˧ ga˥˨	gaʳ˩ kʰxa˩	gʲa jaʔ	gɹa˧	ɖɔ˧ tʂʰɔ˧	tʂʰɔ˧ ka̰ʔ	gra˥ lia˧
to swim	i˩ gɹʲaʔ væʔ ga	i˩ g̟ɹaʔ væʔ	i˩gɹʳa˥ʔ væ̃ʳ˥ʔ	i˩ grãʔgu˩˥	i˩ ɖɔ˥ʔ wi˥ʔ	tʂʰṵ̃˥ ɹḭ˩ʔ	ji˩ tsɨ˩gua˩˥
to float	dɨ˧biɛ˧xi˧ði˥ga˩	i˩ g̟ɹaʔ dɨ(a)˧ hwe˧	i˩ɟaʔdɨa˩xea	zwi˩	xwe˩	li˧ zwi˧	zwɛ˩ nia˧
to rub/scrub	kɹʲaʔ kʰɹʲa˩ ga˩˥	gɹṵ˥ʔ kʰɹa˩	gɹʲṳ˥	ja˥	xɹ̥iʔ	ɹ̥ɪʔ	ʃeʔ gɹɘʔa˧

Variety location	Myagu Aungmye	Myagu Shishi-dukhu	Zileng Shwezet	Wawa 8 Miles	Topya Ngwa-phakha	Topya Zibankha	Yotolo Shwezet
horn (of buffalo)	kʰɨ˩ a˥	kʰia˧˩	kʰɹi˧	kʰə˧a˥˧	tʂʰɨ˧	tʃʰɹi˧	kʰɹia˧˩
frog	kʰ(x/ɹ̥)a˩ tsʰɔ̃˧	kʰʳa˩ tsɔ̃˧/kʰɹ̥a˩ tsəŋ˧	kʰɹa˩ sɔ̃˥˧	kaʔ saŋ˥	pɔ˧	pɔ˧	gaʔ tsəŋ˥
armpit	ɲaʔ ɹʲũ˥ kʰ(x/ɹ̥)õ˧	laʔ ʳõ˥ kʰhõ˧	ɲaʔ u˥ kʰjɔŋ˧	tʃe˥ vaʔ kɹoŋ˩	ɹʲu˩ ɹʲõ˥ tʂũ˥	ɹuʔ u˥ tʃʰun˧	tʃa˥ vɛʔ kʰɹɔŋ˩
leg	kʰxi˞˧	kʰxi˞˧	kʰxi˞˧	kʰɹi˩	tɹi˧	tɹi˧	tʃʰi˩
calf	kʰɹ̥ə˧pʰɔ˩	kʰxi˞˧ pʰɔ˩	kʰxi˞˧ pʰɔʔ	kɹi˩ pʰɛ˧	tɹi˧ pʰa˩	tɹi˧ pʰa˩	tʃʰi˩ pʰwɛ˧
shin	kʰɹi˥ kɔŋ˧	kʰxi˞˧ kɔ̃˧	kʰxi˞˧ kã˧	kʰɹi˩ kaŋ˧ ŋaʔ	tɹi˧ kɔŋ˧	tɹi˧ kɔ̃˧	tʃʰi˩ kak a˥
heel	kʰɹi˧ tʰɔ̃˧	kʰxi˞˧ tʰɔ̃˧	kʰxi˞˧ tʰã˧	pʰa˥ tʰaŋ	pʰɹa˥ tʰɔ̃˧	pʰɹɔ˥ tʰɔŋ˧	tʃʰi˧ tʰaŋ˧
marrow	kʰɹ̥ʲɔ̃˧	kʰʳɔ̃˥˧	kʰxã˥	kʰɹaŋ˩	tʃʰɔ̃˧˩	tʃʰɔ̃˧	kʰɹəŋ˩
excre-ment	kʰxi˞˥	kʰxi˞i˥	kʰxi˥	kʰɹi˥	tʰɹi˧	tɹi˥	tʃʰi˥
road/path	kʰɹ̥ʲa˧ pʰɹɔ̃˧	kʰɹ̥a˧ pʰɹɔŋ˧/ kʳʰa˧ pʰɹɔŋ˧	kʰɹa˧ pʰjoŋ˧	kʰɹ̥a˧˩	tʃʰɹe˧ pʰɹoŋ˧	tʰe˧ pʰɹoŋ˧	kʰɹa˧ pʰɹɔŋ˧
to sew	ga˥ kʰɹ̥ʲɔ̃ʔ	kʰhɔʔ	kʰɹɔʔ	kʰɹ̥əm˥˧	tʃʰɔ̃ʔ	tʃʰɔ˩	kʰɹɔʔ a˧ dɔ˩
to walk	kʰɹ̥ʲa˧ pʰa˧ swa˥	kʰha˧ pʰɹɔŋ˧ swa˥	kʲa˧pʲɔŋ swa˥	kʰ(ɹ̥ʲ)a˧ sʰo˥	tʃʰɹe˧ pʰɹɔ̃˧ su˥	tʰɹe˧ pʰroŋ˧ so˥	kʰɹa˧ pɹɔŋ˧ sua˥ dɔ˩
to split	kʰɹ̥ʲa˥ ga˥˧	kʰɹ̥a˥	kʰja	kʰɹ̥am˥	tʰɹe˥	tʂʰe˥	kʰrɔa˧
to stab	kʰɹ̥ʲaʔ ga˥˧	kʰxa̰ʔ	kʲaʔ	kʰɹ̥am˥˧	tɹɛʔ	tʂʰeʔ	kʰrɔʔa˧
six (persons)	kʰṵʔ˥ ˀjoʔ˥	kʰxuʔ iuʔ	kʲuʔ juʔ	kʰɹu˩ juʔ˥	tʃʰo˩ iuʔ	tʂʰu˩ iuʔ	kʰɹu˥ iuʔ
mosquito	kjɔ̃˧	kɹɔ̃˧/kə˞ɔ̃	tʃə˧	kjaŋ˩	dʒɔ̃ŋ˧	dʒɔ˧	kjək
to scratch oneself	ɣe˧ la˩	kɹa̰ʔ jɨ˧/ka̰ʔ jɨ˧/	kʲaʔ	ɣe˧˩	xɨʔ	xɨʔ	kraʔ
soil (earth)	mi̥˥ mi̥˧	mɹi˥˧ mɹi˧	mɨ˥˧ mi̥˧	mɹi˩	mɹi˥˧ mɹi˧	mɹi˥˧ mɹi˧	mri˥˧ mri˩

Variety location	Myagu Aungmye	Myagu Shishi-dukhu	Zileng Shwezet	Wawa 8 Miles	Topya Ngwa-phakha	Topya Zibankha	Yotolo Shwezet
mud	mi̥˥ mi̥˧ dʒɔ˥	mɣ˞i˥ ɲ̊ia˧	mi̥˧˥ mja˩	m̥ɹi˩ pʰəin˩ tʰwin˩ aʔ	mɹi˩ nja˥˧ʔ	mɹi˩ dʑ̊ɔ˧˥	mɹi˩ tʷa˧˥
dust	mi̥˥ mi̥˧	mɣ˞i˥mɔ˧ dʷi˩mɹi˥mɔ˧ dʷi˩	mæʳ˩ tʷi˧˥ aʔ	mri˩ tsɨ˧ bein˧ aʔ	mɹi˩ sɔ˥		mɹi˩ ma˥ tʷia˧˥
grass (field/jungle)	mjaʔ ga˩˥	mɹa̰˥	mɹæʔ	mɹaʔ	mɹɔʔ	mɹɔ̰	mɹɛʔ
horse	mɨ˧	mɨ̟˥	mɹʲɔ˧	mɹɔ˩˥	mɹɨ˧	mɹɨ˥	mɹɨ˩˥
eyebrow	mɹʲə˥˧mɨ̥˥	mɹaʔ mɨ̥˥	mɹʲa˥˧ʔ m̥a˧	ɲeʔ dʒi˥ bɨa˥˧	mja˩ mu˥˧ʔ	mja̰˩ʔ kɔ˧	ɲaʔ bəa˩
arrow	væ˧	mɹa˥	mja˥	mɹa˧˥	mɹɔ̃˥ kwa˩	mɹɔ˥ kwa˩	mɹa˧˥
knife/blade	m(j/ɹʲ)ɨ˥	mɹu˥/mu̥˥	mɹʲɨ˥	mɹʲaŋ˩˥	mɹɨŋ˧	mɹɨ˥	mɹəŋ˧˥
to dig (with a tool)	tua˥˧ ne˥	me̥˥ me̥˧ du˥	dua˥˩˥	du˩˥	du˥	du˥	dua˧
to be sharp	tʰua˥˩˥	tʰua˥˩˥	liaʔ	tʰu˥	mɹɨ˩ so˥	mɹɨ˥ ɬjɨ˩	tʰua˥˧
sand							
yam	gwa˩ lɔ˥	m̥ɹuʔ	m̥ɹuʔ	m̥ãũp	m̥uʔ	m̥u˧	m̥jõk
to be ripe	m̥a˩	mjɔ̃˥	m̥æ̃ʔ	m̥ia˧	ɲɨʔ ɔ̃˥˧	m̥ɨ ɔ	m̥a˧
name	pʰæ̃ʳ˧	m̥a˧	m̥æ˧	m̥i˩	m̥rɨ˧	m̥ɹə˧	m̥a˩
to be tall	m̥ɨa˩˥ la˩	mɨ˥ m̥hũ˩ xa˧	mɨa	m̥ɹ̥ɔ˩	m̥ɹɨ˧˥	m̥ɹɨo˧	m̥ɨa˩˥
cockroach	bo˧ pʰ ɹ̥a˧	bɔ˧ pʰɹ̥a˧	bɔ̃˧ pʰ(ɹ̥/ɹʲ)a˧	pʰɹ̥a˩	bo˧ pʰɹɔ˧	bu˧ pʰɹɔ˧	bə˩ pʰɹ̥ʲa˩
face	pʰɹ̥ən˥ n̥a˧	pʰɹ̥ɔ̃˥ n̥a˧	pʰɹ̥ɔ̃˥ n̥a˧	pʰɹ̥ʲan˥ n̥a˩	pʰɔ˥ nɔ̃˧	pʰɔ˥ n̥ɔ̃˧	pʰɛ˥ na˧
to be spicy	pʰ (ɹ̥)æ̃˥˧	pʰaʳ˧ pʰɹ̥a˥ xa˧	pʰæ	p̥ʰein	pʰɹə˧	pʰɹə˧	pʰa˥ dɔ˩
porcupine	pɹʲo˧	pɹ̟u˧	pɹʲu˧	pɹu˩	pɹu˧	pɹu˧	pɹuʔ

Variety location	Myagu Aungmye	Myagu Shishi-dukhu	Zileng Shwezet	Wawa 8 Miles	Topya Ngwa-phakha	Topya Zibankha	Yotolo Shwezet
fly	pɹʲɔ̰ʔ˧˩	pɹʲɔ˥ʔ	pɹʲɔ̰ʔ˧˩	pɹʲɔ̱n˧˩	pɹɔ̃ʔ	pɹɔ̰	pɹɔʔ
comb	pe̹˧˩	pø˞e˥	pe˥	pe̱˧	pe˥	pɹe˥	pe˦
ant	la˥ ɹʲaʔ˧˩	la˥ ɹwaʔ	la˥ ɹwaʔ	bɔ˩ ɹʲɔ˥ʔ	pʰɔ˥ lɛ˧	ɔ˥ ɹiuʔ	la˧ ɹwaʔ
rain	mɨa˧˩ ɹwa˥	mɨ˥ wʳa˧	mɨ˥ ɹua˧	maŋ˩˨ ɹo˩	mɨ˥ ɹo˩	mɨ˧˩ ɹo˦	mɨ˥ va˩
to wash (hands)	laʔ tʃʰia˧˩	tʃʰi˥ kʰɹa˩	tʃia˧˩	tʃʰɹ˥	syʔ	lɔʔ tʃʰi˥	laʔ tʃʰi˥
day	a˥ ɲi˩	a˥ɲi˩	ɲia˩	ɲuo˦ ɲi˧	a˧ɲi˧	ɲi˩ ɨ̆˩	nia˧
year	kʰɹu˧ ɹuʔ	kʰɣ ɹ̟ṳa̰ʔ	kʰxɨ˥ ju̱˥ʔ	kʰṳ˥ʔ ɹʲu˥ʔ	kʰṳ˩ ɹʲu˥ʔ	kʰu˩ ɹu˥ʔ	kʰu˥ ɹʲu̱˥ʔ
jungle/forest	mɛʔ˦ bɔŋ˧	ʂə̃ʳ˦ naʔ˥ lja˧	mɨ˩ te˦ lia˩˨	maŋ˥ θeiŋ˥ ɹa˩	siʔ tɹeʔ	mɨ˩tɨ˥ɹɔ˧	mɨ˧ta˥ɹa˩
to bark	lɔŋ˩ a˥	kʰwi˥ lɔ̃˧	lɔa˩˨	lɔŋ˩	ɹɛʔ o˧	kʰwi ɹḛʔ	lɔŋ˩ a˧dɔ˩
snake	v(i/i̯)a˧	vɹ̟ɤa/vi̯a̰˧˩	vi̯a̰˩˨	vɹ̩˧ aʔ	ɹi˧	vɹi˧	via˩˨
eyelid	mɹʲɛʔ˧˩ kʰuʔ˧˩ ɹ̟i˧	mja̰ʔ kʰṳ ɹ̟i˞˧	mja˥ʔ kʰu˥ʔ ɹʲi˧	0	mja˩ kʰu˥ʔ ɹʲi˧	mja̰ʔ kʰṳ˥ ɹi˧	ɲa˥ʔkʰu˥ʔ (j/i̯) a˧
arm	laʔ˧˩	laʔ ɹ̟ɔ̃˥	laʔ bɔŋ˥	laʔ ɹam˩˨	lɔ˩ʔ ɹʲa˥	lɔʔ ɹɔ˥	la˥ʔ ɹʲɔ˥
skin	kʰuʔ ɹ̟i˥	kʰṳ˥ɹ̟i˞˦	kʰu˥ʔ ɹʲi˧	kʰuʔ ɹi˩		kʰuʔ ɹ̟i˥/kʰuʔ ɹi˥	kʰu˥ʔ i̯˩
to see	vɛ̹˩ ga˩˨	vɹɔ̃˧	vɹʲã˧	ɹaŋ˩	ɹʲɔ˧ ɔ̃˧	ɹɔ̃.ˀɔ̃˩	vɹaŋ˩ a˧ dɔ˩
to think	zwi˩dɔʔ la˩	zya˧˩	zɤa˧	zɹ˩ ɲi˩	mi˦ ru˩	mi˧ɹu˩/mi˧ɹ̟u˩	sy˧ nia˥
to hate	ɹʲu˩ni˩˨ma˥ʃi˧tʰõ væ	tʰõ˧ vɹɔ˧	ɲiʔ pʰuʔ a˧	tʰo˩ ɹaŋ˩	sɔ˥ jɨ˩	tʰu˧ ɹɔ˧	0
four (persons)	ve˩ joʔ	vy˞˩ iuʔ	vi̯˩ ˀju˥ʔ	vɹ̩˩ juʔ˧˩	vɹi˩ iuʔ	vɹi˧ jṳ˥	vɹi iuʔ
to be soft (cotton)	n̥a˧n̥aʔ a˩	n̥a˧ naʔ xa˩	ɲiaʔ	n̥am˧˩	ɹɔk	vɹɔʔ ɔ˧	ʑɔ̃˧ wa˧˩
to be blind	ma˥ væ̃ʳ˧	ma˥ vɹɔ̃˧	mjæʔ mɨ˥	ɲeʔ dʒeʔ	mja˩ dʒaʔ	mjaʔ dʒaʔ	mjaʔ mɨa˩˨

Variety location	Myagu Aungmye	Myagu Shishi-dukhu	Zileng Shwezet	Wawa 8 Miles	Topya Ngwa-phakha	Topya Zibankha	Yotolo Shwezet
sleeping area	jɔʔ˦ ɹʲa˥˩	jɔʔ ɹ̥a˧	jɔʔ za˧	jaᵐp ɹa˩	jaʔ ɹɔ˧˥	jɔʔ ɹɔ	ɟɔʔ dʒɛ˩
to cut (hair)	tsʰa˧ ɹʲuʔ˦ kʰɹ̥ʲa˩	tsa˧ dɨʔ	tsa˧˥ ju̱˥ a˩	o˩ pʰu˥ ɹʲu̱ʔ˦	ɔ˩ pʰu˥ (ɹ/ɹʲ)u˦ʔ	tse˥ ɹuʔ/tse˥ ɹ̥uʔ	tsɔ˩ bɹɔ˧
otter	ɹ̥a˧	ɹ̥a˧	ɹ̥a˧˥	ɹ̥am˩	ɹ̥e˦	ɹ̥ɛ˧	kɹɔʔ
sweat	ɹ̥ia˥˩	ɹ̥ia˥˩	ɹ̥ia˥˩	ɹ̥i̯˥	ʈwi˦ tʰuʔ	tɹi˦	ko˩ kɨ˥
to shout	kʰɨ˩ ɲia˧˥	kʰɨ˩	kʰəa˥˩	kʰɨ˥	dʒɨ˧˥˧	(dʐ/d)ɨɔ˧	ta˧ gɨa˧ a˧ dɔ˩
to sing	gwa˧	0	mæ˧ kʰwe˧ mæ˧	ga˥	xũ˧ ʃi˥	pʰɨ˩ ɹ̥i˥	mə˧ kʰwɛ˧ ma˥dɔ˩
to count	ɹ̥ɨ˩ ɲi˥ ɟa˩	ɹ̥̊ɨ˩	ɹ̥ɨa˥˩	ɹ̥u˥	ɹ̥ɨ˩ ɹu˨	ɹ̥ɨ˩	kɹə˧ nia˧ dɔ˩
to scare/frighten	kɹʲ(ɨ/u)ʔ la˥˩ la˩	kɹ̥uʔ	kʰɹuʔ a˧	kɹʲuʔ	tɹuʔ	dʒuʔ	kɹʲuʔ dɔ˩
to die	ʃia˧ ga˦	ɹ̥i˧	ʃɹa˥˩	ʃɹ˩	ʃi˧a˩õ˧	ʃi˧a˩õ˥˩	ɕa˩ da˧
to sit (remain)	oʔ ɲi˧ ga˧˥˧	ɲi a˧˥	ɹʲõʔ˦	ṵ̃˥	ɹu˩ tɔ˥	ɲi˧ tɔʔ	ɲõʔ ni˩
to be long	mɨ˥ ɹ̥a˧˥˧	mɨ˥ ɹ̥ɨ˩ᵃ xa˧	ɹ̥ɨ˥a˦	ɹ̥o˩	ɹ̥ə˧	(ɹ̥/ʃ)ɹɔ˧o˧	kɔʔa˧
to be fat (person)	tsʰwa˦	mɨ˥ ɹ̥i˩ xa˧	tsu˧ la	pʰɔm˥	tsõ˧ gɔ˥	twaʔ ɔ˧	tsua˩ dɔ˩
yellow	mi̯˧˥ mia̯˧˥˧	ɹ̥i˧˥˧ ɹ̥i˩ xa˧	ɹʲaʔ˦ ũhiʔ˥	0	ɹ̥i˧˥ ɹ̥i˩	ɹ̥i˧˥ ɹ̥i˩	ɹ̥i˧˥˧ ɹ̥i˩
to be big	ɹʲi˥a˥˩	mɨ˥ ɹ̥i˩ xa˧/mɨ˥ ɹʲi˩ xa˧	ɹʲi˥a˥˩	ɹ̥e̯˧˥	ɹi˥	(ʐ/ɹ)i˥o˧	ɹia˧˥˧

[a] Substantial increase in speaking volume, sound recording clipped near the critical segment.

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