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Tone, stress, and their interactions in Cushillococha Ticuna

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Ticuna (ISO: tca; Peru, Colombia, Brazil) displays a larger tone inventory – five level tones – than any other Indigenous American language outside Oto-Manguean. Based on recent fieldwork, this article argues that, in addition to these tone properties, the Cushillococha variety of Ticuna also displays stress. Stress corresponds to morphological structure, licenses additional tonal and segmental contrasts, conditions many phonological processes, and plays a central role in grammatical tone processes marking clause type. Empirically, these findings expand our understanding of word prosody in tone languages in general and Amazonian languages in particular. Theoretically, they challenge current models of stress-conditioned phonology and grammatical tone.

Keywords: tone; stress; prosody; stress-conditioned phonology; Amazonian languages

1 Introduction

The purpose of this paper is to describe and analyze the word-prosodic system of Ticuna – a language isolate spoken in the northwestern Amazon Basin – through data gathered in recent fieldwork in the town of Cushillococha, Peru. The study makes two primary contributions.

First, I provide evidence that the Cushillococha variety of Ticuna displays five level tones, with eight surface tone melodies, including contours, on monosyllables. My analysis of the tone inventory supports previous analyses by L. Anderson (1959) and D. Anderson (1962), and opposes Montes Rodriguez's (1995, 2004) argument for only three level tones.

Second, I argue that in addition to tone, the Cushillococha variety of Ticuna also displays fixed stress on the initial syllable of the Prosodic Word (PrWd). Stress affects almost every aspect of this variety's phonology, including segmental and tonal contrast licensing; segmental and tonal phonological processes; and grammatical tone. With this close relationship between tone and stress, the prosodic system of

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Cushillococha Ticuna strongly resembles the prosodic systems of other languages with large tone inventories, such as San Martín Itunyoso Trique (Oto-Manguean; DiCanio 2008) and Thai (Tai-Kadai; Potisuk et al. 1996). As such, data from this language offers a new, genetically unrelated testing ground for theories developed to account for tone-stress interactions in other language families.

This paper is organized as follows. §2 provides background information about the Ticuna language and people, as well as the fieldwork conducted for this study. §3 describes the phonological inventory of Cushillococha Ticuna, including the inventory of tones. Next, I turn to stress. In §4, I argue that the language displays fixed, PrWd-initial stress realized acoustically as increased vowel duration. Over the following three sections, I then show that stress licenses additional tone and segmental alternations (§5); triggers tonal (§6) and segmental (§7) phonological processes; and conditions the outcome of grammatical tone alternations (§8). In §9 I discuss theoretical implications of the findings, and in §10 I conclude.

2 Language background

2.1 Classification and dialects

Ticuna is an Indigenous language isolate spoken in about 160 communities along the Amazon River in Peru, Colombia, and Brazil. The current western extreme of Ticuna settlement is the town of Cushillococha, Peru, and the eastern extreme is approximately the mouth of the river Jutaí in Amazonas state, Brazil. Figure 1 shows the location of this territory within South America. The Amazon River is highlighted in white.

Figure 1: Location of Ticuna territory and of Cushillococha, the field site for this research, within northern South America (Base map via Google Earth)

Ticuna is spoken by between 38,000 (Lewis et al. 2014) and 70,000 (Instituto Socio-Ambiental 2021) people. The language continues to be acquired by children in Peru and Brazil, but not in most communities in Colombia (Santos Angarita 2005).

Based on segmental sound changes, varieties of Ticuna can be divided into three groups: eastern, western, and inland (Santos Angarita 2005; Montes Rodriguez 2005). Eastern and western varieties are spoken on the main course of the Amazon River – western ones predominantly in Peru, and eastern ones in Brazil. Based on my own observations of communication between speakers of eastern and western varieties, these two groups are completely mutually intelligible. Inland varieties of Ticuna, in contrast, are spoken in the interfluvial area between the Amazon and Putumayo rivers, which is located entirely in Colombia. Santos Angarita (2005: 10, 27), who is a native-speaker linguist from an eastern dialect area, suggests that inland varieties are not completely mutually intelligible with the eastern and western groups.

Among previous analyses of Ticuna prosody, Montes Rodriguez (1995) and Bertet (2020, 2021) examine the same inland variety, with substantial differences; Soares (2000) describes an eastern variety; and Santos Angarita (2005) compares varieties from several groups spoken within the national territory of Colombia. Lambert and Doris Anderson, two SIL members, have worked for several decades with the variety of Ticuna spoken in the town of Cushillococha, Peru, which belongs to the western dialect group (Santos Angarita 2005: 10). While the Andersons' primary goal was to produce a Ticuna translation of the Bible (Anderson & Anderson 1984), they also published an article describing the language's tone inventory, a textbook intended to teach Ticuna to English-speaking missionaries, and a Ticuna-Spanish dictionary (L. Anderson 1959; D. Anderson 1962; Anderson and Anderson 2017).

Like the Andersons, I conduct fieldwork with the Cushillococha variety, and I lack data on any other variety of Ticuna. As such, I am only able to evaluate the Andersons' works. These publications contain very accurate phonetic transcriptions. However, neither author had any substantial training in linguistics, and this is evident in the publications. They are essentially wordlists, offering little phonological or morphological analysis beyond statements of the phonemic inventory. Where the Andersons do offer an explicit phonological analysis, I compare it with mine.

2.2 Fieldwork and participants

I collected the data in this paper over approximately 15 months of fieldwork in Cushillococha between 2015 and 2022. This town is a land-titled Indigenous community with about 5,000 residents, almost all of whom are Ticuna and speak Ticuna as their first and dominant language.

During fieldwork, I collected phonological data on tone and stress with 15 speakers, aged 18 to about 75 years, who were born in Cushillococha or nearby. Most examples in this paper come from interviews with two people, Deoclesio Guerrero Gómez (DGG) and Lilia Witancourt Guerrero (LWG). A smaller number of examples are from interviews with three other speakers: Ling Cándido Serra (LCS), Katia Lucero Salate Cándido (KSC), and an anonymous speaker. DGG and LCS are male, while LWG, KSC, and the anonymous consultant are female. DGG was in his early seventies at the time of research; the anonymous speaker was in her late fifties; LCS and LWG were in their late thirties; and KSC was in her late teens.

All of the interviewees were sequential Cushillococha Ticuna-Spanish bilinguals and very fluent in Spanish. They spoke both languages regularly. The anonymous speaker reported speaking Spanish more often than Ticuna; all other participants reported speaking Ticuna more often. KSC had received her entire education up to age 12 in Ticuna-medium classrooms, and all other interviewees had taught in Ticuna-medium classrooms and worked as interpreters or translators. They therefore possessed high Ticuna literacy and metalinguistic awareness. I did not observe significant differences between the interviewees, or between the interviewees and the other 10 speakers who participated in data collection, in any of the prosodic phenomena described here. I did observe variation between participants in the distribution of nasality, which is discussed in §3.4.

The data and analysis in this paper concern only the variety of Ticuna spoken in contemporary Cushillococha. As a result, I refer to the study language throughout as 'Cushillococha Ticuna,' using the unmodified name 'Ticuna' only for the ethnic group and the language as a whole. Descriptions of other varieties of Ticuna report somewhat different prosodic systems (Bertet 2020, 2021; Montes Rodriguez 1995; Soares 2000; Santos Angarita 2005). Additionally, due to sound changes, earlier descriptions of the Cushillococha variety report a different segmental inventory (L. Anderson 1959, D. Anderson 1962).

2.3 Recording methods

I collected data with the consultants via elicitation sessions in their homes or in my accommodations in Peru, using both Spanish and Cushillococha Ticuna as contact languages. Items cited in this paper were generally recorded in carrier sentences of the forms given in (1) or (2).[1] Different carrier sentences were used for the phonetic analysis in §3.2.2. Some items, which are not used to illustrate minimal tone differences, were recorded in isolation.

(1)	nɨ^{31}ma^{2}	rɨ^{1}	X	ɲa^{4}a^{2}ʔɨ̃^{4}
	3.TOP	TOP	X	3SBJ.SC.QUOT
	‘s/he said X’			

(2)	tʃo^{1}ma^{1}	rɨ^{1}	X	ɲa^{4}tʃa^{3}gɨ^{3}rɨ^{1}
	1SG.TOP	TOP	X	1SGSBJ.QUOT
	‘I said X’			

Recordings were made with a Zoom H4N recorder sampling at 44.1kHz, generally connected to a Shure SM10A head-mounted microphone.

Apart from elicitation, I have also collected a corpus of about 116,000 words of connected speech in Cushillococha Ticuna, representing roughly 150 speakers. This corpus, described in Skilton (2021), consists mostly of recordings of informal conversation and child-caregiver interaction. Like the elicited phonological data, the corpus reflects significant between-speaker variation in the distribution of nasality. However, it conforms to the generalizations presented here about word prosody.

3 Phonological inventory

This section describes the language’s segmental inventory (§3.1); tone inventory (§3.2); inventory of other suprasegmental features, including contrastive creaky voice (§3.3) and nasality (§3.4); and syllable structure (§3.5).

3.1 Segmental inventory

Cushillococha Ticuna displays 16 consonant and 6 vowel phonemes. Table 1 displays the consonants.

Table 1: Phonological inventory of consonants

Manner	Labial	Alveolar	Palatal	Velar	Glottal
Voiceless Stop/Affricate	p	t	tʃ	k	ʔ
Voiced Stop	b	d	ɟ	g	
Nasal	m	n	ɲ	ŋ	
Fricative	ɸ				
Approximant		ɾ		w	

The phonemes represented in Table 1 as /ɸ/ and /ŋ/ are subject to changes in progress, both of which have also been observed in other varieties of the language.

The phoneme shown in Table 1 as /ɸ/ has recently undergone a change in manner. It is described as a labialized velar stop [k^{w}] in sources from the 1950s, such as L. Anderson (1959) and D. Anderson (1962). Cushillococha speakers born before about 1960, including DGG, still usually produce the phoneme as [k^{w}]. However, by 2019 most Cushillococha people, including LWG and KSC, produced this phoneme in all environments as a fricative or approximant [ɸ, ʍ] rather than a stop. I therefore represent it as /ɸ/. This change is also observed in other eastern and western varieties (Santos Angarita 2005: 89).

Additionally, the phoneme shown in Table 1 as /ŋ/ is undergoing a typologically unusual split. In the speech of people born in Cushillococha before about 1980, /ŋ/ occurs before both oral and nasal vowels and is realized as [ŋ] in both environments (see §3.4 on vowel nasality). As a result, minimal pairs such as [ŋõ̰^{1}] ‘eat, bite’ and [ŋo̰^{1}] ‘appear’ differ only in the nasality of the vowel. By contrast, most Cushillococha

[1] Examples use IPA, except that <r> represents the tap. Nasality is transcribed as described in §3.4. Glosses follow the Leipzig glossing rules, with the following additional abbreviations: AL = alienable; DEINTENS = deintensifier ‘sort of’; DFLT = default (possessor); DIR = directional; DISTRIB = distributive; I, II, III, IV = concord for noun classes I, II, III, IV; IBEN = beneficiary case with intransitive verb; LNK = linker/determiner; MULTI = multifunctional demonstrative; QUOT = quotative; SC = subordinate clause type (inflectional category); SUB = subordinator.

people born after about 1980 produce this segment as [ŋ] before nasal vowels and an approximant [ʎ] before oral vowels. For them, [ŋõ̰^{1}] 'eat, bite' and [ʎo̰^{1}] 'appear' are phonetically different in both the manner of the initial segment and the quality of the vowel.[2]

Among the primary consultants for this study, in elicitation DGG and LCS produced the segment undergoing the split as [ŋ] in all environments. LWG occasionally produced forms with the split, but more often produced the segment as [ŋ] in all environments. KSC always produced forms with the split. Since the majority of consultants do not have the split, I represent the phoneme as /ŋ/ throughout. This choice is not intended as a claim about the representation of this sound by speakers who do have the split.

Turning to vowels, there are six vowel qualities /i u e o a ɨ/ and two rising diphthongs, /au/ and /ai/. Diphthongs and monophthongs behave identically in most phonological processes. I justify the treatment of /au/ and /ai/ as diphthongs in my discussion of the syllable template (§3.5).

3.2 Tone inventory

3.2.1 Level and contour tones and their distribution

Phonetically, Cushillococha Ticuna displays four level tones and three contour tones which can appear on monosyllabic words. An additional level tone appears only on polysyllabic words, giving a total of eight contrasting tone categories. In describing the tone inventory, I assume that the TBU is the syllable. This claim is justified in §8.3.

I represent tone using numbers 1-5, where 5 represents the high end of the speaker's pitch range.[3] Under this scheme, the seven tone categories possible on monosyllabic words are level tones 1, 2, 3, and 4, and contour tones 31, 43, and 51. (3) shows the seven contrasts on monosyllabic words with the nucleus /u/.[4] In (3a), the diaresis marks creaky voice, discussed further in §3.3; tone 5 is not included in (3) because it virtually never occurs on monosyllables.

(3)
- a. mṵ^{1} 'eat (fruit)' b. mu^{2} 'send'
- c. mu^{3} 'weave' d. mu^{4} 'be many'
- e. mu^{31} 'pierce with pointed weapon' f. ũ^{43} 'go (singular subject)'
- g. tu^{51} 'pull'

(4) shows six of the contrasts on monosyllabic words with the nucleus /a/. There is no example of tone 51 in (4) because there are no monosyllabic words of the form /(C)a^{51}/ (tone 51 is very infrequent in the lexicon).

(4)
- a. pa̰^{1} 'hug' b. pa^{1} 'be tired' (modal voice)
- c. ã^{2} 'mosquito' d. ã^{3} 'give (inanimate singular object)'
- e. pa^{4} 'be a young adult' f. a^{31} 'be thin'
- g. pa^{43} 'be dry'

Tone 5, the superhigh tone, has a restricted distribution. The only two monosyllables with tone 5 are the function word *nai^{5}* 'other, noun class III' and the possibly onomatopoeic verb *pe^{5}* 'slap.' These two words both belong to minimal tone sets, as shown in (5) and (6).

[2] Other varieties of Ticuna also have splits in *ŋ conditioned by the nasality of the following vowel, but in all other described varieties with splits, the reflex of *ŋ before oral vowels is [ŋʰ], [g], [h], or zero, rather than an approximant (Santos 2005: 78-79; Montes Rodriguez 2005: 109; Bertet 2020: 70).

[3] Readers who compare examples in this work to L. Anderson (1959) and D. Anderson (1962) should be aware that the Andersons use a tone notation system where 5 is the *low* end of the pitch range.

[4] Audio clips of each word in the phonological examples appear in the supplementary materials. All audio clips are from recordings publicly available in the California Language Archive, Collection 2015-06. Please consult the text documents in the supplementary materials for archival citations for each example.

(5) a. na̰ḭ^{1} ‘untie’ b. nai^{1} ‘other (noun class II)’
c. nai^{2} ‘fart’ d. nai^{31} ‘tree, generic’
e. nai^{4} ‘hot’ f. nai^{5} ‘other (noun class III)’

(6) a. pe^{43} ‘sleep’ b. pe^{5} ‘slap’

Tone 5 more often appears in polysyllabic words, where it may occur on any syllable. The minimal set in (7) demonstrates the contrastiveness of tone 5 on the first syllable of disyllabic words, and the minimal and near-minimal sets in (8)–(10) demonstrate the contrast on the second syllable.

(7) a. ŋẽ^{2}ʔma^{4} ‘there (anaphoric/addressee-proximal, locative case)’
b. ŋẽ^{3}ma^{2} ‘that (anaphoric/addressee-proximal/invisible, noun class IV)’
c. ŋẽ^{4}ma^{2} ‘that (anaphoric/addressee-proximal/invisible, noun class V)’
d. ŋẽ^{5}ma^{2} ‘there (anaphoric/addressee-proximal, allative case)’

(8) a. ɟu^{3}ra^{1} ‘palm species; floor’ b. ɟo^{3}ra^{5} ‘owner, boss’

(9) a. de^{43}ʔa^{2} ‘talk (v., n.)’ b. de^{43}ʔa^{5} ‘water’

(10) a. ma^{3}rɨ^{3} ‘already’ b. e^{3}rɨ^{4} ‘because’
c. pi^{3}ri^{5} ‘fry (v.); fried food (n.)’ (< Spanish *freir*)

Even in polysyllabic words, the distribution of tone 5 is still subject to some morpheme structure constraints. Tone 5 can appear on any syllable of a noun or adverb; any syllable of a suffix or enclitic which attaches to nouns (or adverbs or interjections); or non-final syllables in a verb root, verbal suffix, or verbal enclitic. However, tone 5 *never* appears on the final syllable of any suffix or enclitic which attaches to verbs. With the exception of the verbs *pe^{5}* ‘slap’ and *pi^{3}ri^{5}* ‘fry,’ it also never appears on the final syllable of verb roots. These constraints mean that, except in these two roots, tone 5 never appears on the final syllable of a verb stem.

3.2.2 Phonetic realization of tones on monosyllabic words

Auditorily, the tones that I label as ‘level’ – tones 1, 2, 3, 4, and 5 – vary between level tones at superlow, low, mid, high, and superhigh pitch, and rising tones which begin at a superlow, low, mid, high, or superhigh pitch and display a slight rise. Thus tone 1 could be equally well described as 11 or 12, tone 2 as 22 or 23, and so on, and it would be as accurate to call these tones ‘rising’ as to call them ‘level.’ In contrast to the level/rising tones, the ‘contour’ tones 31, 43, and 51 are always phonetically falling.

To describe the acoustics of the five level tones, I recorded two speakers – LWG and the anonymous female consultant – producing each of the words in (3)–(6) in isolation and in three different carrier sentences, where the target word was followed by either tone 1 (11), tone 3 (12), or tone 4 (13). All of the target words except for (4c) and (5b, d, f) are verbs and syntactically require subject proclitics. The speakers produced all verbs with the same subject proclitic, the third-person main clause form *na^{4}=/ni^{4}=*. This proclitic was used in all carrier sentences as well as in isolation.

(11) (na^{4}=)X rɨ^{1} na^{4}me^{43}
(na^{4}=)X rɨ^{1} na^{4}=me^{43}
(3SBJ=)X TOP 3SBJ=good
‘s/he Xed, it’s fine’ (reading with verbs); ‘the X, it’s good’ (reading with nouns)

(12) (na^{4}=)X ʔa^{3}rɨ^{1} ni^{41}ʔĩ
(na^{4}=)X ʔa^{3}rɨ^{1} ni^{41}ʔĩ
(3SBJ=)X again 3SBJ.COP
‘s/he/it Xed again’ (reading with verbs); ‘it’s an X again’ (reading with nouns)

(13) (na^4=)X ɲa^{4}a^{2}ʔĩ^4
(na^4=)X ɲa^{4}a^{2}ʔĩ^4
(3SBJ=)X 3SBJ.SC.QUOT
's/he said X'

Each speaker produced each carrier sentence and each word in isolation at least twice. Some words in isolation were produced up to eight times; some carrier sentences were produced up to six times. All tokens were analyzed unless they contained noise or disfluencies. In total, 235 tokens were usable for the anonymous speaker and 208 tokens for LWG.

For each vowel token analyzed, F0 was measured at ten equally spaced intervals from 0% to 100% of the duration of the vowel using Praat (v. 6.2; Boersma and Weenink 2022) and scripts written by DiCanio (2022). Following the measurement of F0, tone 1 vowels with creaky voice in words such as *mṵ^{1}* 'eat fruit' were excluded from this and all subsequent analyses because their nonmodal phonation prevented reliable measurement of F0. This excluded 47 tokens, leaving 396 in the data set. All other F0 values were transformed to log scores and a by-speaker z-score normalization was applied. F0 could not be measured at the first timepoint for 22.2% of tokens and at the final timepoint for 16.2%. This was typically due to low amplitude, nonmodal phonation caused by an adjacent glottal stop, or for words produced in isolation, vowel post-aspiration (phrase-final oral vowels are post-aspirated). All other timepoints had <7% missing data. Missing F0 values were disregarded in the z-score normalization.

Acoustically, Figure 2 shows z-score normalized log F0, which measures the distance of an F0 value from the center of the speaker's F0 space, vs. normalized time for of each of the five level tones. The left panels in Figure 2 show data from the anonymous female consultant, and the right panels show data from LWG.

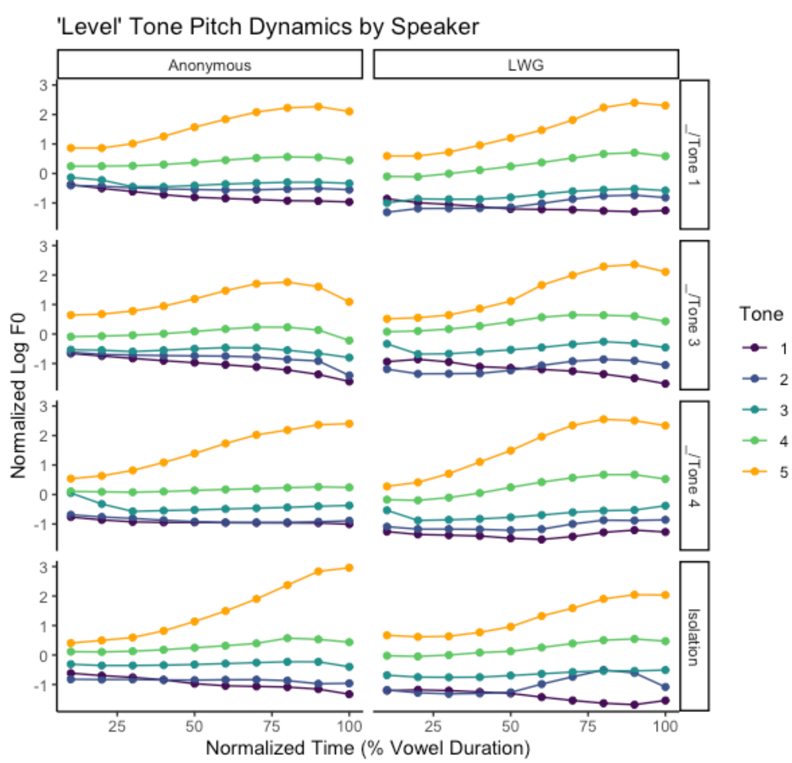


Figure 2: Normalized log F0 vs. normalized time for 'level' tones on monosyllabic words

Figure 3 shows the same data for the contour tones. Data manipulation, analysis and visualization were performed in R (v. 4.1.2; R Core Team 2020) using tidyverse, lme4 and lmerTest packages (Wickham et al. 2019; Bates et al. 2015; Kuznetsova et al. 2017).

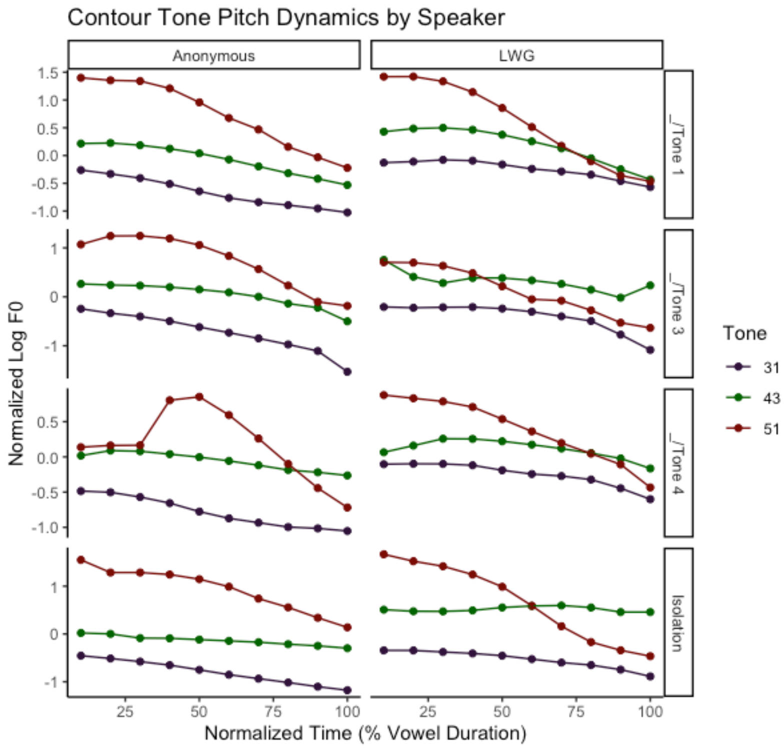


Figure 3: Normalized log F0 vs. normalized time for 'contour' tones on monosyllabic words

As Figures 2 and 3 illustrate, the language's tones – especially the level tones – are not equally dispersed through the pitch range. Some tones display a large separation in pitch from their nearest phonetic neighbors: for example, in LWG's data, level tone 5 is 1.3 to 6.0 semitones (14.8 to 79.7 Hz) higher than level tone 4 at each time point. But other tones crowd together within a small range – in comparison to the large tone 4-tone 5 difference, LWG's pairwise differences among tones 1, 2, and 3 never exceed 1.46 semitones (13 Hz).

Since some tones are so similar in pitch, and others so dispersed, it is reasonable to ask whether the tone contrasts described above concern only F0. Kuang (2013) argues that as well as F0, systems with five level tones always recruit some additional acoustic cue to tone, such as phonation type or duration. To assess the role of these additional cues in Cushillcocha Ticuna, I analyzed the relationships between tone, F0, vowel duration, and phonation type in the set of monosyllabic words used to construct Figure 2 and Figure 3. As the main purpose of this article is to describe relationships between tone and stress, not the phonetics of tone, this discussion is brief; more detailed study is necessary to untangle all of the acoustic cues to tone in Ticuna.

First, to determine whether there was a relationship between tone category and F0, I fit a series of linear mixed models with F0 in semitones as the outcome, tone category as a fixed effect, and speaker as a random effect. The data for these models was the 443 vowel tokens used to construct Figure 2 and Figure 3. A separate model was fit for each of the ten timepoints, and each was compared to a model which included no random effect of speaker. Models with random effects were selected whenever they explained significantly more variance than models without them. In all models, Tone 3 was used as the reference level because it had the smallest number of tokens. Full model specifications and results for each F0 timepoint are given in the supplementary materials.

For F0 at timepoints 1 through 6, the final models selected included both a fixed effect of tone and a random effect of speaker, and for F0 at timepoints 7 through 10, they included only a fixed effect of tone. These final models observed an effect of tone category on F0 at every timepoint, and for every tone, except for the following: tone 31, at timepoints 1, 4, 5, 6, and 7; tone 43, at timepoint 10; and tone 51, at timepoint 10. Thus, model results confirmed that, as shown in Figure 2 and Figure 3, tones differ throughout their timecourse in F0.

Second, I evaluated the relationship between tone and vowel duration by fitting a linear mixed model with duration as the outcome, tone category as a fixed effect, and speaker as a random effect. Data and reference levels were the same as in the models of F0. The mixed-effects model explained significantly more variance than a model with no random effect of speaker ($\chi^2[1] = 4.37$, $p = 0.036$). The model observed a significant effect of tone category on duration for all tones other than tone 43. Table 2 provides the model summary, and Figure 4 visualizes the duration data for words produced in the frame preceding tone 3.

Table 2: Linear mixed model fit by REML for relationship between tone and vowel duration. Tone 3 was used as the reference level. Formula: dur ~ Tone + (1|Speaker)

	Estimate	SE	*t*	*p* (Sattherthwaite)
Intercept	0.158	0.012	12.861	<0.001
Tone 1	0.052	0.012	4.462	<0.001
Tone 2	0.050	0.013	3.986	<0.001
Tone 31	0.040	0.012	3.285	0.001
Tone 4	0.030	0.012	2.593	0.010
Tone 43	0.011	0.012	0.935	0.350
Tone 5	0.044	0.012	3.780	<0.001
Tone 51	0.064	0.013	5.004	<0.001

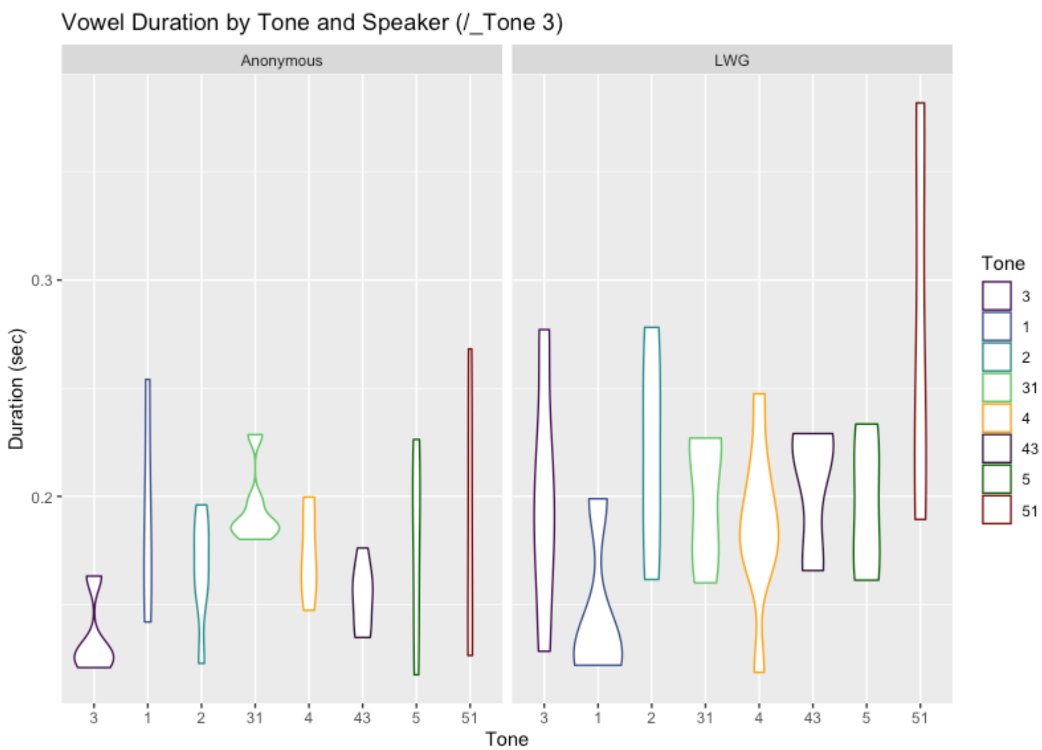


Figure 4: Vowel duration vs. tone category on monosyllabic words preceding tone 3

Following the duration analysis, I evaluated the association between tone and phonation type. Again using scripts by DiCanio (2022), I took eleven measures of spectral tilt – H1, H2, HNR, H1-H2, H1-A1, H1-A2, H1-A3, and intensity of H1, H2, and A1 to A3 – at three equally spaced timepoints per vowel. Two tone 1 tokens produced by LWG were excluded from these analyses because of inconsistently measurable F0. All other data was identical to the data in the F0 and duration analysis, and tone 3 continued to be used as the reference level.

As in the F0 analysis, I fit a separate model for each spectral tilt measure at each timepoint, with the measure as the outcome, tone as the fixed effect and speaker as a random effect. Each model was compared to a model with the fixed effect of tone, but no random effect of speaker. Models with random effects were selected whenever they explained significantly more variance than models with fixed effects only. Full model specifications and results for each spectral tilt measure at each timepoint appear in the supplementary materials.

The spectral tilt models failed to identify any spectral tilt measures which displayed a significant relationship with every tone at every timepoint. The measures which most often displayed a consistent (every timepoint) relationship to a given tone were A3 and H1-A3. These two measures displayed significant, consistent effects of tone for five tone categories – tones 1, 31, 4, 43, and 5. The similarity of the results for A3 and H1-A3 are unsurprising given the strong correlation between the two measures, which ranged in absolute value from 0.88 to 0.92. The only other spectral tilt measures which displayed significant, consistent effects of more than two tones were H1-A2 and H2 intensity. For H1-A2, there was an effect of tone at every timepoint for tones 1, 31, and 43. For H2 intensity, there was an effect of tones 1, 43 and 51.

Figure 5 visualizes the time dynamics of the consistently tone-related spectral tilt measures for each tone category. The top plot displays the A3 track; due to the strong correlation between A3 and H1-A3, I do not plot H1-A3. The middle plot displays H1-A2 tracks, and the bottom plot displays H2 intensity tracks.

As visual comparison of Figure 5 with the F0 tracks in Figures 2 and 3 suggests, the spectral tilt measures affected by tone in this data are not highly correlated with F0 (correlations between these measures and F0 at the closest timepoint never exceeded 0.33). This suggests that, as well as F0, phonation type may also act as a cue to tone on monosyllabic words in Ticuna, even words without contrastive creaky voice. Exactly how the phonation cues should be characterized is a question for further research. H1-A2 and H1-A3 have often been identified as cues to contrastive breathy voice (Esposito & Khan 2020: 7-8), but A3 and H2 intensity are not widely discussed as correlates of phonation type in the literature.

To conclude, Table 3 summarizes the F0, duration, and spectral tilt measures displaying significant effects of each tone category in the above analyses.

Table 3: Tone categories and the acoustic measures which they significantly affect in linear and linear mixed models. Spectral tilt masures are reported only if there is a significant effect at every timepoint.

Tone	Effect on F0	Effect on spectral tilt measures	Other effects
Tone 1	All timepoints	A3, H1-A3, H1-H2, H2 intensity	Duration
Tone 2	All timepoints	H1-H2	Duration
Tone 3	(reference level)		
Tone 31	Timepoints 2, 3, 8-10	A3, H1-A3	Duration
Tone 4	All timepoints	A3, H1-A3, H1 frequency, H2 frequency	Duration
Tone 43	Timepoints 1-9	A1, A2, A3, H1-A1, H1-A2, H1-A3, H2	
Tone 5	All timepoints	A1, A3, H1-A3, H1 intensity, H1 frequency, H2 frequency	Duration
Tone 51	Timepoints 1-9	A1, H1-A1, H1-H2, H2 intensity	Duration

3.2.3 Distribution of tones in non-monosyllabic words

Most of the examples so far, as well as the data in Figures 2 and 3, have come from monosyllabic words. However, tone contrasts are mostly maintained in larger words.

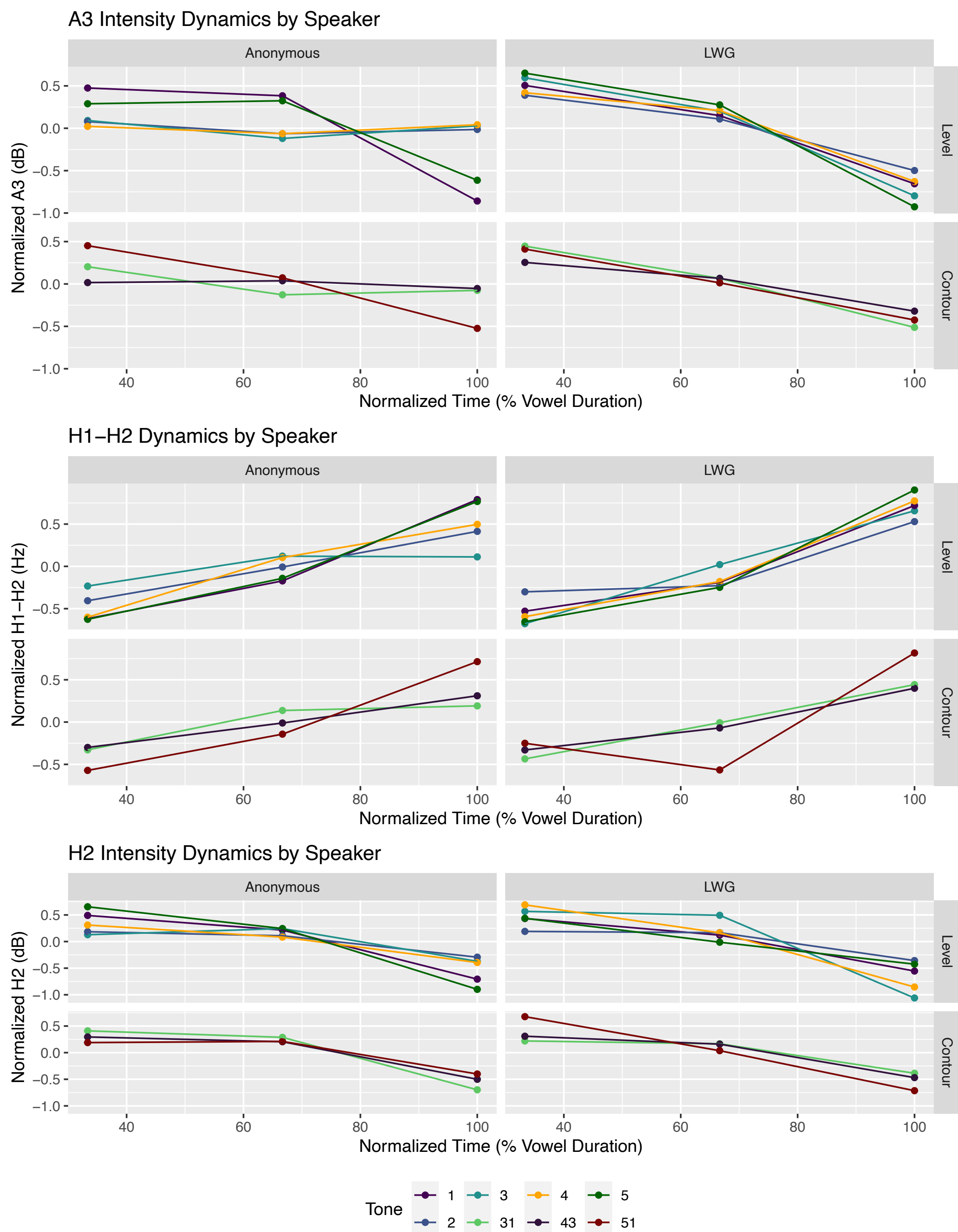


Figure 5: Spectral tilt measures displaying significant effects of >3 tones at every timepoint measured

To investigate the maintenance of tone contrasts in disyllabic and larger words, I constructed a lexical database of 378 nominal and verbal roots. This database consisted of all roots listed in the wordlist of D. Anderson (1962) which contemporary speakers recognized and 157 additional roots that I had elicited in lexical elicitation interviews or recorded in texts. It included loanwords, but excluded morphologically complex stems, as well as inalienable nouns (which are not prosodically independent words). DGG, LCS, and KSC then recorded all of the lexical items in the database in the utterance frames given in (1) and (2).

The lexical database is a convenience sample and by no means represents the entire root lexicon of the language. Despite this incompleteness, the database clearly shows that tone contrasts are maintained in disyllabic roots. In the 378 items, 22 of the 25 possible disyllabic melodies involving only level tones are attested. Table 4 presents example disyllabic roots with all of the attested melodies involving only level tones.

Table 4: Tone melodies on disyllabic words with only level tones

Tone 1 on first syllable			Tone 2 on first syllable		
1.1	wi^{1}ʔɟa^{1}	urinate (v.)	2.1	tɨ^{2}ʔe^{1}	manioc (n.)
1.2	ŋai^{1}ka^{2}	nearby (loc.) (n.)	2.2	ɟi^{2}ma^{2}	DEM:MULTI, noun class III (n.)
1.3	ɲa^{1}ʔtɨ^{3}	under (n.)	2.3	ɨ^{2}ʔɨ^{3}	firewood (n.)
1.4	(n.att.)		2.4	ɟi^{2}ma^{4}	DEM:MULTI, noun class II (n.)
1.5	i^{1}ru^{5}	plantain variety (n.)	2.5	(n.att.)	
Tone 3 on first syllable			**Tone 4 on first syllable**		
3.1	tɨ^{3}re^{1}	port (n.)	4.1	pe^{4}ʔtʃi^{1}	basket, generic (n.)
3.2	ŋẽ^{3}ma^{2}	DEM:MULTI, noun class IV (n.)	4.2	ɲa^{4}a^{2}	DEM:SPKR.PROX, noun class IV (n.)
3.3	ĩ^{3}nɨ^{3}	listen (v.)	4.3	o^{4}ʔta^{3}	brain (n.)
3.4	e^{3}ga^{4}	if (conj.)	4.4	o^{4}ʔgɨ^{4}	vomit (v.)
3.5	wɨ^{3}ra^{5}	bow and arrow (n.)	4.5	dɨ^{4}ʔwa^{5}	at last (adv.)
Tone 5 on first syllable					
5.1	a^{5}we^{1}	bird sp. (n.)			
5.2	nu^{5}a^{2}	DEM:SPKR.PROX.ALL (n.)			
5.3	ko^{5}mɨ^{3}	bright white (v.)			
5.4	wai^{5}ra^{4}	açaí, *Euterpe precatoria* (n.)			
5.5	(n.att.)				

As described in further detail in §5.2, the contour tones 31, 43, and 51 occur only on the first syllable of roots. Of the 15 possible disyllabic tone melodies with a contour on the first syllable, 11 are attested, as shown in Table 5. Three of the four unattested melodies involve tone 51, which is very rare in the lexicon (it appears in only 10 total words in the lexical database).

Table 5: Tone melodies on disyllabic words with a contour tone on the first syllable

Tone 31 on first syllable			Tone 43 on first syllable		
31.1	ɟa^{31}tɨ^{1}	be male (v.), man (n.)	43.1	o^{43}na^{1}	food, generic (n.)
31.2	tai^{31}ɟa^{2}	hungry (v.)	43.2	de^{43}ʔa^{2}	talk (v.)
31.3	ta^{31}ʔɨ^{3}	fruit sp., *Pouteria caimito* (n.)	43.3	be^{43}re^{3}	fruit sp., *Solanum sessiliflorum* (n.)
31.4	(n.att.)		43.4	wɨ^{43}ʔi^{4}	one (n.)
31.5	no^{31}ʔri^{5}	at first (adv.)	43.5	de^{43}ʔa^{5}	water (n.)
Tone 51 on first syllable					
51.1	i^{51}ra^{1}	small (v.)	51.3	ŋĩ^{51}ã^{3}	let's go! (intj.)
51.2, 51.4, 51.5 (n.att.)					

I do not attempt to construct equivalents to Tables 4 and 5 for trisyllabic and larger roots, as roots of that size are usually either (a) loans or (b) diachronically derived from morphologically complex stems.

3.2.4 Tone inventory: Interim summary

Tables 4 and 5 demonstrate that all five tone contrasts persist on the initial syllable of disyllabic roots, as well as in monosyllables. Additionally, all of the tones found on monosyllables pattern separately in the grammatical tone process described in §8. In light of these facts, I analyze all five level tones as phonemic, yielding five tonemes /1 2 3 4 5/. I treat contour tones as composed of a sequence of two level tones which have been assigned to the same TBU (syllable).

3.3 Creaky voice

Creaky voice is contrastive on syllables with tone 1. (14) and (15) provide minimal pairs illustrating the contrast between modal voice and creaky voice on monosyllabic words with tone 1.

(14) a. na̰^{1} 'fall into trap' b. na^{1} 'stop crying'

(15) a. to̰^{1} 'Night Monkey (Aotus sp.)' b. to^{1} 'other (form for noun class IV)'

All vowels except for /ɨ/ can bear underlying creaky voice, as shown by (16).

(16) a. ŋḭ̃^{1} 'steal' b. ŋḛ^{1} 'drop'
c. ŋṵ^{1} 'learn' d. ŋa̰ḭ^{1} 'sew'
e. ga̰ṵ^{1} 'be cold'

While /ɨ/ never bears underlying creaky voice, it can display creaky voice on the surface due to assimilation from an adjacent creaky vowel. For example, the enclitic *=kɨ^{1}ã̰^{1}* 'from, originating from' is often pronounced [kɨ̰^{1}ã̰^{1}]. This restriction against creaky voice with /ɨ/ is the language's only limitation on the co-occurrence of segmental and suprasegmental features. /ɨ/ can have all values of other suprasegmental features (i.e., tone and nasality), and other suprasegmental features can occur on all vowels.

In addition to creaky voice, Cushillococha Ticuna also has syllables closed by glottal stop (§3.5). It is clear that creaky voice is distinct from coda glottal stop because voice quality remains contrastive even in syllables closed by glottal stop. This is shown by the pair of derived words in (17). (See §7.1 on the change of /ɨ/ to [o] in (17).)

(17) a. to^{1}ʔo^{5}tʃi^{2}
/to^{1}=ʔɨ^{5}tʃi^{2}/
other=real
'really different'

b. to̰^{1}ʔo^{5}tʃi^{2}
/to̰^{1}=ʔɨ^{5}tʃi^{2}/
Night.Monkey=real
'real Night Monkey'

As well as appearing on tone 1 syllables, creaky voice also appears on tone 2 syllables in a small number of words (I am aware of less than 10). One of these words is in a minimal pair with a tone 1 word (18).

(18) a. tʃo̰^{2} 'break, crack, speaking of something three-dimensional'
b. tʃo̰^{1} 'be white'

Additional roots containing creaky voice on tone 2 appear in (19). The varying word class of these roots indicates that creaky voice on tone 2 is not restricted to any specific, phonologically marked word class.

(19) a. Verb: tʃa̰^{2} 'spread out, smooth out (e.g. fabric)'
b. Pronoun: ta̰^{2}kɨ^{4} 'what? (interrogative pronoun), something (indefinite pronoun)'
c. Noun: bḛ^{2}ru^{5} 'butterfly'

As (18) and (19) suggest, creaky voice on tone 2 is associated with syllables containing coronal onsets (18a, 19a, b), though it can occur with non-coronals (19c). Creaky voice on tone 2 also seems to occur only on stressed syllables, though its rarity makes it hard to evaluate whether it is exclusively stress-licensed.

Outside of this small number of underived words, creaky voice on tone 2 appears primarily as an allotone of tones 1 and 2. Syllables with tone 1 and modal voice change to tone 2 with creaky voice in one of the language's grammatical tone processes (§8). Additionally, syllables with tone 2 and modal voice change to creaky voice when they bear the conditional antecedent enclitic *=(ʔ)gu^{2}* (20). As well as demonstrating this alternation, (20) also shows that, while underlying creaky voice is prohibited on /ɨ/, derived creaky voice is allowed.

(20) a. tʃa^{3}ʔɨ^{2}
/tʃa^{3}=ɨ^{2}/
1SG.SBJ=make
'I make'

b. tʃa^{1}ʔɨ̰^{2}ʔgu^{2}
/tʃa^{1}=ɨ^{2}=ʔgu^{2}/
1SG.SBJ.SC=make=SUB
'if I make'

While the conditional antecedent enclitic triggers creaky voice on tone 2, it does not trigger it on tone 1, as shown by (21), or on any higher tone.

(21) tʃi^{1}pa^{1}ʔgu^{2}
/tʃi^{1}=pa^{1}=ʔgu^{2}/
1SG.SBJ.SC=tired=SUB
'if I get tired'

Tone 1 syllables with creaky voice pattern apart from tone 1 syllables with modal voice in many phonological alternations affecting tone, such as tone sandhi (§6.1) and the main grammatical tone process (§8). And voice quality is involved in these alternations as a target, as well as a trigger: in both tone sandhi and grammatical tone, tone 1 syllables with creaky voice become tone 5 syllables with modal voice. Tone 2 syllables with creaky voice also behave differently from modal voice counterparts in the grammatical tone process, though – because of the small number of words displaying creaky voice on tone 2 – the differences are less clear.

The processes that treat creaky vs. modal voice syllables differently are not conditioned by, and do not affect, any segmental feature. This suggests that voice quality is a prosodic rather than segmental feature. Additionally, voice quality is not contrastive on syllables with tones other than 1 and 2, which indicates that voice quality and tone are not fully independent parameters of contrast in the language's prosodic system. Thus, I analyze syllables with creaky voice and tone 1 as displaying a different toneme from syllables with modal voice and tone 1, and I refer to this toneme as 'tone 1̰' in the rest of this study. I also analyze creaky voice tone 2 as a distinct phoneme from modal voice tone 2, referring to it as 'tone 2̰.' This analysis yields a total of seven tonemes: /1 1̰ 2 2̰ 3 4 5/. This the same inventory proposed by L. Anderson (1959) and D. Anderson (1962), except that the Andersons do not include tone 2̰.

3.4 Nasality

Nasality is contrastive on vowels in onsetless syllables, as shown by (22), and on vowels in syllables with the onsets /ʔ w ɾ ŋ/, as shown for /ŋ/ in (23).

(22) a. a^{5}we^{1} 'pava, bird species' b. ã^{5}we^{1} 'charcoal'

(23) a. ŋo̰^{1} 'appear' b. ŋõ̰^{1} 'eat, bite'

In syllables with onsets other than /ʔ w ɾ ŋ/, nasality is predictable. The vowel of a syllable with a (voiced or voiceless) obstruent onset is always phonetically oral, and the vowel of a syllable with a nasal onset other than /ŋ/ is always phonetically nasal. In other words, syllables may have the surface forms [TV], [DV], or [NṼ], but not [*TṼ], [*DṼ], or [*NV] with a nasal other than /ŋ/. Due to this predictable distribution, my transcription does not mark nasality on vowels following nasals unless the nasal is /ŋ/.

Given this distribution, if /ŋ/ patterned with the other nasals in allowing only a nasal nucleus, nasality would be appropriately described as a property of the entire syllable (in line with many other Amazonian languages; Walker 2000; Singerman 2016: 463). It would then be possible to treat the surface nasal stops as allophones of the voiced oral stops, conditioned by the nasality of the nucleus or by a syllable-level [+nasal] feature.

However, per (23), nasality *is* contrastive in syllables with /ŋ/ onsets, meaning that some NV syllables do exist. I therefore treat nasality as a binary feature of vowels, encoded as [+nasal], rather than a feature of syllables. To account for the absence of TṼ, DṼ, and NV syllables with onsets other than /ŋ/, I posit that the phonology includes a set of morpheme structure constraints against obstruent-nasal vowel sequences (*TṼ, *DṼ) and against nasal stop-oral vowel sequences involving nasals other than /ŋ/ (*mV, *nV, *ɲV).

For speakers who have the *ŋ > ʎ sound change before oral vowels described in §3.1 – i.e., most Cushillococha people born after 1980 – this analysis is inappropriate. Due to the split, these speakers have only nasal vowels following /ŋ/. For them, it is best supported to analyze nasal stops as allophones of the oral voiced stops conditioned by a following nasal vowel, or to treat nasality as a feature of the syllable (cf. Bertet 2020: 86-90).

Nasality is compatible with all tones, all vowel qualities, and both modal and creaky voice. Since creaky nasal vowels are not widely reported in the literature on contrastive creaky voice, (24) provides examples of creaky nasal vowels of several qualities.

(24) a. ã̰ṵ̃^{1} 'stay, singular subject' b. na̰ḭ^{1} 'tie, singular object'
c. ŋḭ̃^{1} 'steal' d. mṵ^1 'eat (fruit)'
e. ma̰^{1} 'hit/kill, singular object'

3.5 Syllable structure

The Cushillococha Ticuna syllable template is (C)V1(V2)(ʔ). There are no complex onsets. Glottal stop is the only possible coda. Its distribution is restricted: glottal codas are allowed word-finally only in derived words.

Complex nuclei are only allowed if V1 is /a/ and V2 is /i/ or /u/. The complex nuclei (diphthongs) /ai/ and /au/ behave as a single vowel for the distribution of tone, nasality, and creaky voice. Diphthongs pattern apart from monophthongs in that they have a restricted distribution in the word (§5.1) and behave differently in phonological processes involving vowel quality assimilation (§7.1). However, diphthongs behave identically to monophthongs in other phonological processes, such as stress-conditioned tone alternations (§6) and grammatical tone (§8). I treat /ai/ and /au/ as diphthongs, rather than vowel-glide sequences /aj/ and /aw/, because of their behavior in vowel quality assimilation (§7.1) and because there is no other evidence of /j/.

Vowel sequences other than /ai/ and /au/ also exist, as examples earlier in this paper have already illustrated (e.g., *nu^{5}a^2* 'here: Allative' in Table 4). However, these vowel sequences behave as disyllabic with respect to the distribution of suprasegmental features: they may have two different tones, values of nasality, and values of creaky voice. Vowel sequences other than /ai/ and /au/ also pattern away from monophthongs in tone alternations and grammatical tone. Thus, I analyze all vowel sequences other than /ai/ and /au/ as heterosyllabic.

4 Stress

Stress in Cushillococha Ticuna is fixed on the initial syllable of the Prosodic Word, which is – for most word classes – the initial syllable of the root (§4.1-4.6). The primary acoustic correlate of stress is duration (§4.7). Phonological consequences of stress are far-reaching, affecting contrast licensing (§5), lexical phonology (§§6-7), and grammatical tone (§8).

Other research on varieties of Ticuna describes different stress-tone interactions. For the Cushillococha variety, L. Anderson (1959) and D. Anderson (1962) do not recognize the existence of stress. For the San Martín de Amacayacu variety, Bertet (2020, 2021) describes similar stress placement facts but does not analyze them in terms of a prosodic hierarchy. Additionally, due to somewhat different surface facts, Bertet (2020, 2021) argues that the Amacayacu variety displays 16 tonemes: ten tonemes are licensed only in stressed syllables, while the other six are licensed only in unstressed syllables. He attributes differences in the phonological behavior of stressed vs. unstressed syllables to this difference in inventory.

4.1 Stress and word class

In Cushillococha Ticuna, the relationship between the syntactic and prosodic word differs between word classes. Understanding stress therefore requires understanding the morphology of each word class. The language has four content word classes: verbs, nouns, adverbs, and interjections. (There is no evidence for adjectives or ideophones.) I describe the relationship between the syntactic vs. prosodic word, and the stress pattern, for each word class.

4.2 Verbs

Verb roots are most often monosyllabic. They are stressed on the initial syllable (25).

(25) a. tʃa^{3}ˈɸa̰^{1}
/tʃa^{3}=ɸa̰^{1}/
1SG.SBJ=know
'I know'

b. tʃa^{3}rɨ^{3}ˈmo^{4}ẽ^{2}
/tʃa^{3}rɨ^{3}= mo^{4}ẽ^{2}/
1SG.SBJ=greet
'I say hello'

c. tʃa^{3}ˈŋe^{4}tʃa^{1}ɨ̃^{1}
/tʃa^{3}=ŋe^{4}tʃa^{1}ɨ̃^{1}/
1SG.SBJ=sad
'I am sad'

d. tʃa^{3}ʔˈo^{2}e^{5}ga^{1}ã^{5}ẽ^{2}
/tʃa^{3}=o^{2}e^{5}ga^{1}ã^{5}ẽ^{2}/
1SG.SBJ=worried
'I am worried'

Verb roots typically appear with subject proclitics, such as the proclitics *tʃa^{3}(ʔ)=* and *tʃa^{3}rɨ^{3}=* in (25). (These proclitics are associated with different conjugation classes.) I refer to these morphemes as 'proclitics' rather than 'prefixes' because they can also appear on nouns in nonverbal predication, as shown by the nonverbal predicate in (26).

(26) tʃa^{3}ˈtɨ^{3}re^{1}gu^{2}
/tʃa^{3}=tɨ^{3}re^{1}=gu^{2}/
1SG.SBJ=port=LOC
'I am in the port'

In addition to subject proclitics, verbs can also bear additional proclitics marking object agreement, aspect, and motion-related meanings. (27) provides examples of verbs with aspectual proclitics (a) and associated motion proclitics (b) in addition to subject proclitics.

(27) a. i^{5}tʃa^{3}ˈwi^{1}ʔɟa^{1}
/i^{5}=tʃa^{3}=wi^{1}ʔɟa^{1}/
IMPF=1SG.SBJ=urinate
'I am urinating'

b. tʃa^{3}ɟa^{3}ˈwi^{1}ʔɟa^{1}
/tʃa^{3}ɟa^{3}ˈwi^{1}ʔɟa^{1}/
1SG.SBJ=go.and=urinate
'I go and urinate'

As (25)–(27) illustrate, verbal proclitics are never stressed. The initial stress on the root is the only stress in the verbal word. In other words, stress marks the boundary between the proclitic material and the verb stem.

4.3 Nouns

Cushillococha Ticuna nouns are divided into two morphological categories: inalienably possessed and alienably possessed. Both categories of nouns are generally disyllabic.

Alienable nouns are semantically diverse and make up the majority of the nominal lexicon. Like verb roots, they bear initial stress (28).

(28) a. ˈde^{31} 'liquor' b. ˈpo^{3}ʔi^{5} 'plantain, generic'
c. ˈwai^{3}ɟu^{3}ri^{5} 'collective labor' d. ˈtʃi^{3}ri^{3}ma^{4}ta^{1} 'fish sp., *Prochilodus nigricans*'

Pronouns bear obligatory case enclitics and undergo extensive case-based suppletion. While these properties make it difficult to identify pronominal roots, pronominal *stems* behave like alienable nouns, displaying initial stress (29).

(29) a. ˈnɨ^{31}ʔna^{1} 'third person pronoun (noun classes II, III, IV), recipient case form'
b. ˈtʃo^{1}gɨ^{1} 'first person singular pronoun, reflexive form'
c. ˈtɨ^{31}ma^{2} 'third person pronoun (noun class I), topic form'

In contrast to the semantic range of alienable nouns, inalienable nouns are generally part terms (e.g., *mḛ^{1}* 'hand', *a^{5}tɨ^{2}* 'leaf'), kinship terms (e.g., *ta^{4}a^{2}* 'grandchild,' *e^{3}ɟa̰^{1}* 'sister'), landscape terms (e.g., *ta^{4}a^{2}* 'lake') or terms for close personal possessions (e.g., *ʔtʃi^{5}ru^{2}* 'clothes'). Inalienable nouns are unacceptable in isolation (30).

(30) *ta^{4}a^{2}
*grandchild
(attempted reading: 'grandchild')

Rather than appear in isolation, inalienable nouns must be licensed by either possession or noun incorporation. Both of these processes are forms of compounding, involving the combination of two lexical stems into a single prosodic word. As the structures of possession (noun-noun compounding) and incorporation (verb-noun compounding) are almost identical, I describe only possession.

When inalienable nouns are possessed, they cliticize to the final element of the possessor noun phrase. The initial syllable of the possessor is stressed; the inalienable noun is not (31).

(31) ˈɟa^{31}tɨ^{3}ta^{4}a^{2}
/ɟa^{31}tɨ^{3}=ta^{4}a^{2}/
man=grandchild
'man's grandchild'

If the possessor of an inalienable noun is a pronoun, it appears in a suppletive form specific to inalienable possession. The initial syllable of the pronoun is stressed, as in other pronoun forms (29), and the inalienable noun is unstressed (32).

(32) ˈna^{4}ta^{4}a^{2}
/na^{4}=ta^{4}a^{2}/
3(IV)POSS=grandchild
'his/her/their grandchild'

The possessive construction for alienable nouns is different and does not involve compounding. In possession of an alienable noun, such as *o̰^{1}ʔi^{5}* 'grandfather, old man,' the possessor bears the enclitic *=a^{1}rɨ^{3}* if it is a noun (33a) and appears in a suppletive form, specific to alienable possession, if it is a pronoun (33b). Both possessor and possessed retain their initial stress. This is the evidence that in alienable possession, but not inalienable possession, the possessor and possessed are independent prosodic words.

(33) a. ˈɟa^{31}tɨ^{1}a^{1}rɨ^{3} ˈo̰^{1}ʔi^{5}
/ɟa^{31}tɨ^{1}=a^{1}rɨ^{3} o̰^{1}ʔi^{5}/
man=AL.POSS grandfather
'man's grandfather'

b. ˈno^{51}rɨ^{3} ˈo̰^{1}ʔi^{5}
/no^{51}rɨ^{3} o̰^{1}ʔi^{5}/
3(IV).AL.POSS grandfather
'his/her/their grandfather'

To summarize, because of their morphological requirements, inalienable nouns only appear as the second stem in noun-noun and noun-verb compounds. Since stress is initial, including in compounds, this means that they are never stressed.

4.4 Adverbs and interjections

Adverbs and interjections have similar phonological properties, and many roots can be used in both functions. Phonologically, adverbs and interjections behave like alienable nouns. They are generally disyllabic, are acceptable in isolation, and bear stress on the initial syllable (34). Unlike verbs, they do not have subject proclitics.

(34) a. ˈbai^{51} ‘no! (emphatic answer to polar questions), not at all (emphatic negation)’
b. ˈta^{4}ma^{3} ‘no (standard answer to polar questions), not (standard negation)’
c. ˈta^{4}gu^{2}ma^{3} ‘never’
d. ˈwo^{5}e^{3}ta^{2}ma^{4} ‘exactly’

4.5 Enclitics

Adverbs, alienable nouns, and verbs can all bear enclitics, which do not have a characteristic prosodic size. Many enclitics are acceptable across word classes, as shown in the examples of the enclitic *=ʔɨ^{5}tʃĩ^{2}* ‘really’ in (35).

(35) a. Verb: ta^{43}=ʔɨ^{5}tʃĩ^{2} (big=really) ‘really big’
b. Noun: ɟo^{3}ra^{5}=ʔɨ^{5}tʃĩ^{2} (owner=really) ‘real owner’
c. Adverb: po^{2}ra^{4}ã^{1}kɨ^{2}=ʔɨ^{5}tʃĩ^{2} (fast=really) ‘very quickly, very intensely’

Some enclitics are restricted to just one type of constituent (e.g., case markers always cliticize to the final element of the noun phrase). While these markers could be analyzed as suffixes given their distribution, their phonological behavior is identical to that of multi-categorial markers such as *=ʔɨ^{5}tʃĩ^{2}* ‘really.’ Since this means there is no motivation for a distinction between enclitics and suffixes, I treat all post-root markers as enclitics. Enclitics are not stressed and do not affect the stress pattern of their host (36).

(36) a. na^{4}ˈmu^{4}
/na^{4}=mu^{4}/
3SBJ=be.many
‘there are many’

b. na^{4}ˈmu^{4}ʔũ^{5}tʃĩ^{2}
/na^{4}=mu^{4}=ʔɨ^{5}tʃĩ^{2}/
3SBJ=be.many=really
‘there are really many’ (see §7.1 on /ɨ/ → [u])

c. ni^{4}ˈmu^{4}tʃĩ^{1}gɨ^{1}
/ni^{4}=mu^{4}=tʃĩ^{1}gɨ^{1}/
3SBJ=be.many=DISTRIB
‘there are more and more’

With their lack of stress and requirement for a clitic host, enclitics are morphophonologically identical to inalienable nouns. Instead, the distinction between inalienable nouns and enclitics is syntactic. Inalienable nouns can be the head of a phrase – for example, they can trigger noun class concord – and enclitics cannot.

4.6 The prosodic word

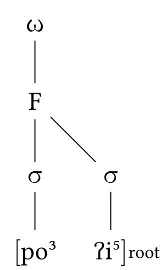
As described in the preceding subsection, Cushillococha Ticuna verb stems, alienable nouns, adverbs, and interjections can occur in isolation and always bear initial stress. Inalienable nouns occur only as the second stems in compounds, and as a result, they never bear stress. Enclitics and subject proclitics also cannot occur in isolation and are never stressed.

I analyze this pattern as indicating that the relationship between the syntactic and prosodic word varies with morpheme class. Verb stems, alienable nouns, adverbs, and interjections project an independent prosodic word (PrWd). Inalienable nouns, enclitics, and proclitics do not. This prosodic weakness is what prevents inalienable nouns, enclitics, and proclitics from appearing in isolation or as the initial morpheme of a PrWd.[5]

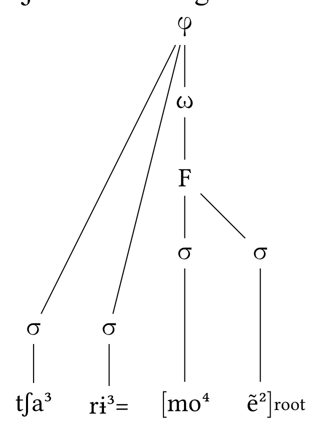
Among the prosodically dependent morphemes, inalienable nouns and enclitics display many phonological interactions with their hosts, such as vowel quality assimilation and tone 1̰ dissimilation (§6-7). By contrast, subject proclitics' only interaction with their hosts is that a glottal stop is epenthesized between vowel-final subject proclitics and vowel-initial stems (e.g., 25d). To capture this asymmetry, I posit that inalienable nouns and enclitics form a single PrWd with the clitic host. Subject proclitics do not: they are instead dominated directly by the phonological phrase. In other words, inalienable nouns and enclitics cannot head a PrWd, but can be parsed into one; subject proclitics can neither head nor be dominated by the PrWd.

With this analysis of prosodic wordhood, we can state the stress generalization for Cushillococha Ticuna very simply: stress always falls on the first syllable of the PrWd. The prosodic trees in (37) illustrate how this accounts for the stress patterns observed in various classes of morphosyntactic words: alienable noun roots with no proclitics or enclitics (a), verbal words consisting of a proclitic and root (b), noun-noun compounds consisting of a possessor and inalienable noun (c), and verbal words consisting of a root and enclitic (d). As further sections will explore, this language has no evidence of foot structure beyond the first two syllables of the Prosodic Word; I therefore represent later syllables as dominated directly by the PrWd in (37c,d).

(37) a. ˈpo^{3}ʔi^{5} 'plantain'

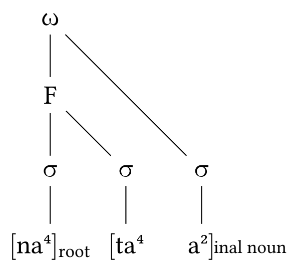


b. tʃa^{3}rɨ^{3}ˈmo^{4}ẽ^{2} 'I greet'

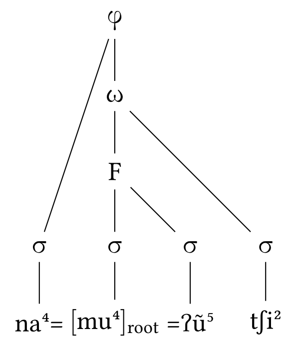


[5] This analysis is inconsistent with phonological theories that posit that underlying representations have no prosodic structure (e.g., Kiparsky 1979). The alternative analysis is that the lexical entries of inalienable nouns and clitics include the morphological information that they are bound, but no information about PrWd projection. In this analysis, the unstressability of inalienable nouns and enclitics arises from the fact that they are never first in the morphosyntactic word. But because subject *proclitics* are first in the morphosyntactic word, they will require a different explanation for their extrametricality, such as a rule or constraint penalizing assignment of stress to non-root constituents. Thus, compared to this 'prosody-first' analysis, a 'morphology-first' analysis does not produce simpler representations and requires more complex stress rules.

c. ˈna^{4}ta^{4}a^2 ‘his/her/their grandchild’



d. na^{4}ˈmu^{4}ʔũ^{5}tʃĩ^2 ‘there are really many’



Because of the variable relationship between the syntactic word and PrWd shown in (37), there are some syntactic words which appear to be minimal stress pairs, such as (38).

(38) a. na^{4}ˈpa^1
/na^4=pa^1/
3SBJ=smell.strong
‘it smells’

b. ˈna^{4}pa^1
/na^4=pa^1/
3(IV)POSS=hammock
‘his/her/their hammock’

The syntactic words in (38) contrast in stress placement because they have different morphological, and therefore prosodic, constituency. In (38a), the morpheme *na*^{4} is a subject proclitic. It is outside of the PrWd projected by the verb stem *pa*^{1} ‘smell’ and therefore is unstressed. In (38b), on the other hand, the morpheme *na*^{4} is a free pronoun (which happens to be homophonous with a subject proclitic; this is not the case for other pronouns). When the pronoun is compounded with the inalienable noun *pa*^{1} ‘hammock’, it projects its own PrWd, occupies the first syllable of that PrWd, and therefore is stressed. Thus, while stress placement is never contrastive *within* a word class in Cushillococha Ticuna, on the surface it does contrast *between* word classes (cf. Smith 2011).

4.7 Acoustic correlates of stress

The primary acoustic correlate of stress is vowel duration. To assess the difference in duration between unstressed and stressed syllables, I measured the duration of all vowels in 130 tokens of 27 verb stems (16 monosyllabic, 6 disyllabic, and 5 trisyllabic) produced by DGG (n word tokens = 66) and LWG (n word tokens = 64). The verb stems were produced in utterance frames as described in §1. Closed syllables occurred in some of the disyllabic and trisyllabic stems, but their vowels were excluded from analysis to control for effects of the glottal coda. This exclusion yielded a data set of 187 vowel tokens.

Within this data set, the average stressed vowel of a monosyllabic word lasted 201ms (SD = 52ms), the average stressed vowel of a non-monosyllabic word lasted 159ms (SD = 37ms), and the average unstressed vowel lasted 123ms (SD = 39ms). An analysis of variance indicated that both stress and word length had significant effects on vowel duration. Stressed syllables were longer than unstressed syllables ($F[1,184] = 89.376$, $p < 0.001$). The stressed (i.e. only) syllables of monosyllabic words were also longer than the stressed syllables of non-monosyllabic words ($F[1,184] = 23.425$, $p < 0.001$). In light of the cross-linguistically greater duration of contour tones, I repeated these analyses considering only level tone syllables. The average duration of a stressed level tone syllable was 189ms (SD = 55ms) in a monosyllabic word and 149ms (SD = 34ms) in a non-monosyllabic word. The ANOVA results were unchanged.

5 Contrast licensing in stressed syllables

Stressed syllables license additional segments (§5.1) and tones (§5.2) not found in unstressed syllables.

5.1 Segmental contrasts in the stressed syllable

Recall from §3.1 above that the segmental inventory of Cushillococha Ticuna consists of 16 phonemes. In native-vocabulary words, six phonemes –/ɸ ~ k^w/, /ŋ/, /ɲ/, /d/, /ai/, and /au/ – occur only in stressed syllables. That is, they appear in the first syllable of roots, but never in the non-initial syllables of roots, and never in inalienable nouns, suffixes, enclitics, or proclitics.

The distribution of /o/ is also conditioned by stress, but is slightly more complex than that of the other stress-licensed segments. /o/ appears in root-initial syllables and never appears in suffixes, enclitics, or proclitics. However, unlike the other stress-licensed segments, /o/ *can* appear in non-initial root syllables. Specifically, unstressed /o/ may appear in the second syllable of a root if and only if (a) the first root syllable also has the nucleus /o/ and (b) the second syllable has no supralaryngeal onset. That is, words of the form (C)o(ʔ)o exist, such as *o^{2}ʔõ^4* 'baby,' but there are no words of the form (C_1)oC_2o with a supralaryngeal C_2 (e.g. **o^{2}to^4*).

I take the second syllable [o] in underived words like *o^{2}ʔõ^4* 'baby' to be derived from underlying /a/ by a regular phonological process described in §7.2.[6] Under this analysis, underlying /o/ has exactly the same distribution as the other stress-licensed phonemes: it occurs only in stressed syllables.

The distributional restrictions on /ɸ/, /ŋ/, /ɲ/ /d/, /ai/, /au/, and /o/ are specific to native-vocabulary words. Loanwords, regardless of origin, can display the stress-licensed segments in non-initial syllables. Two examples are *na^{3}ra^{3}ɲa^1* 'orange (fruit)' (< Spanish *naranja* 'orange') and *tu^{3}pau^{3}ka^1* 'church' (Omagua [Tupi-Guaraní] *tupa* 'Christian God' + *uka* 'house').

Some loanwords display phonological adaptation driven by the restrictions on the stress-licensed segments. Adaptation applies mainly to /d/, which is borrowed as the tap, and /o/, which is borrowed as /u/ (among other adaptations). The noun *tʃu^{3}ra^{3}ra^1* 'soldier, army' (< Spanish *soldado* 'soldier') exemplifies the /d/ → [ɾ] adaptation, while the common noun *a^{3}ru^{4}tʃu^1* 'rice' (< Spanish *arroz*) and the personal name *Bi^{3}tu^5* (< Spanish *Victoria*) exemplify the /o/-raising adaptation. Not all loanwords with /d/ and /o/ in non-initial positions display adaptation, however. For example, on morphological criteria the loan *mo^{3}to^1* 'motorcycle' (< Spanish *motocicleta*) is highly integrated as a word of Cushillococha Ticuna, yet it retains its non-initial /o/.

5.2 Tone contrasts in the stressed syllable

Three tones occur only on stressed syllables: tones 51, 43, and 31. This is a natural class of the language's contour or falling tones. Per §3.2.1, the remaining tones – those which are not stress-licensed – are either level in pitch or phonetically rising.

Tones 51, 43, and 31 have similar distribution to the segments discussed in §5.1. They appear on the initial syllables of roots only, and do not appear on non-initial root syllables or on any syllable of inalienable nouns, enclitics, or suffixes. Unlike the stress-licensed segments, tones 31 and 43 do appear on verb proclitics, though they are at least sometimes derived by fusion of an underlying disyllabic /3.1/ or /4.3/ sequence. This licensing relationship between contour tones and stress is cross-linguistically common and may arise from the increased duration of stressed syllables (Zhang 2004).

6 Stress-conditioned tone processes

Stress conditions the application of many phonological processes in Cushillococha Ticuna. In the following sections, I describe and analyze four stress-conditioned phonological processes – two affecting tone, and two affecting segments. I begin with the processes affecting tone: tone 1̰ dissimilation and tone 43 assimilation.[7]

[6] Surface /o/ can also be derived from underlying /ɨ/ by a regular process, but that process does not apply within morphemes (§7.1). The underlying second vowel of forms like *o^{2}ʔõ^4* 'baby' is therefore /a/, not /ɨ/.

[7] For the analogous processes in San Martín de Amacayacu Ticuna, see Bertet (2020: 138-140).

6.1 Tone 1̰ dissimilation

Tone 1̰ syllables are subject to a stress-conditioned dissimilation process in which they are realized as tone 5. This process is stress-conditioned because it applies only to stressed syllables.

6.1.1 Tone 1̰ dissimilation applies in stressed syllables

When an underlying tone 1̰ syllable bears stress and is followed by either (a) another tone 1̰ syllable or (b) a syllable with modal tone 1, the stressed tone 1̰ dissimilates to tone 5.

(39) provides an example of tone 1̰ dissimilation in a verb which is tone 1̰ in isolation (39a). The verb undergoes dissimilation triggered by a creaky 1̰ syllable in (39b) and triggered by a modal 1 syllable in (39c) and (39d). (See §7.2 on the change of /a/ to [o] in 39-41.)

(39) a. na^{4}ˈtʃo̰^{1}
/na^{4}=tʃo̰^{1}/
3SBJ=white
‘she/he/it is white’

b. na^{4}ˈtʃo^{5}õ̰^{1}tɨ^{3}
/na^{4}=tʃo̰^{1}=ã̰^{1}tɨ^{3}/
3SBJ=white=yard
‘s/he/it has a white (i.e. sandy) yard’

c. ni^{4}ˈtʃo^{5}tʃi^{1}gɨ^{1}
/na^{4}=tʃo̰^{1}=tʃi^{1}gɨ^{1}/
3SBJ=white=DISTRIB
‘it keeps turning white’

d. na^{4}ˈtʃo^{5}gɨ^{1}
/na^{4}=tʃo̰^{1}=gɨ^{1}/
3SBJ=white=blood
‘it has white sap’ (of a tree)

Because most Cushillococha Ticuna nouns are disyllabic or larger, it is hard to observe tone 1̰ dissimilation in nouns. However, the process does occur, as shown by (40). In this example, a monosyllabic noun which is tone 1̰ in isolation (40a) undergoes dissimilation triggered by a creaky 1̰ syllable (40b) and by a modal 1 syllable (40c, 40d).

(40) a. ˈto̰^{1}
/to̰^{1}/
‘Night Monkey (*Aotus* sp.)’

b. ˈto^{5}õ̰^{1}tɨ^{3}
/to̰^{1}=ã̰^{1}tɨ^{3}/
Night.Monkey=yard
‘Night Monkey’s yard’

c. ˈto^{5}mɨ^{1}kɨ^{3}
/to̰^{1}=mɨ^{1}kɨ^{3}/
Night.Monkey=companion
‘Night Monkey’s companion’

d. ˈto^{5}gɨ^{1}
/to̰^{1}=gɨ^{1}/
Night.Monkey=blood
‘Night Monkey’s blood’

Modal voice tone 1 syllables are triggers, but not targets, of tone 1̰ dissimilation. This is shown in (41), where the modal voice tone 1 noun *to^{1}* ‘other (Class IV)’ fails to undergo dissimilation in the same environments shown in (40).

(41) a. ˈto^{1}
/to^{1}/
‘other’

b. ˈto^{1}o̰^{1}
/to^{1}=a̰^{1}/
other=mouth
‘other one’s mouth’

c. ˈto^{1}mɨ^{1}kɨ^{3}
/to^{1}=mɨ^{1}kɨ^{3}/
other=companion
‘other one’s companion’

d. ˈto^{1}gɨ^{1}
/to^{1}=gɨ^{1}/
other=blood
‘other one’s blood’

Creaky tone 2 also does not undergo the dissimilation (42, cf. 39c). Because tone 2̰ occurs only on stressed syllables (§3.3), it is never in the environment to trigger dissimilation.

(42) ni^{4}ˈtʃo̰^{2}tʃĩ^{1}gɨ^{1}
/ni^{4}=tʃo̰^{2}=tʃĩ^{1}gɨ^{1}/
3sbj=crack=DISTRIB
'it keeps cracking'

6.1.2 Tone 1̰ dissimilation fails to apply in unstressed syllables

Tone 1̰ dissimilation is exclusive to stressed syllables. The process does not apply if the target tone 1̰ syllable is unstressed. This is shown for immediately post-tonic tone 1̰ syllables in (43), where the tone 1̰ is part of a disyllabic root, and (44), where the tone 1̰ syllable is the noun in a verb-noun compound.[8]

(43) a. ˈko^{2}rḛ^{1}
/ko^{2}rḛ^{1}/
'sweet potato'

b. ˈko^{2}rḛ^{1}ã̰^{1}tɨ^{3}
/ko^{2}rḛ^{1}=ã̰^{1}tɨ^{3}/
sweet.potato=yard
'yard planted with sweet potatoes'

c. ˈko^{2}rḛ^{1}a^{1}ne^{1}
/ko^{2}rḛ^{1}=a^{1}ne^{1}/
sweet.potato=land
'garden of sweet potatoes'

d. ˈko^{2}rḛ^{1}gɨ^{1}
/ko^{2}rḛ^{1}=gɨ^{1}/
sweet.potato=blood
'sweet potato sap'

(44) a. na^{4}ˈpa^{1}a̰^{1}
/na^{4}=pa^{1}=a̰^{1}/
3SBJ=smell.bad=mouth
'its mouth smells bad'

b. na^{4}ˈpa^{1}a̰^{1}tʃĩ^{1}gɨ^{1}
/na^{4}=pa^{1}=a̰^{1}=tʃĩ^{1}gɨ^{1}/
3SBJ=smell.bad=mouth=DISTRIB
'its mouth keeps smelling bad'

Based on the data introduced so far, tone 1̰ dissimilation could be analyzed as either stress-conditioned or foot-conditioned. If it is stress-conditioned, the process is predicted to apply only to stressed (i.e., PrWd-initial) syllables. On the other hand, suppose that all syllables are parsed into binary feet, and tone dissimilation is foot-conditioned. Dissimilation should then apply in unstressed but odd-numbered syllables.

(45) and (46) support the prediction of the stress-conditioned analysis. They show that tone dissimilation does not apply to the third syllable of a trisyllabic stem, whether the stem is a noun (45) or a verb (46).

(45) a. ˈna^{4}e^{3}ɟa̰^{1}
/na^{4}=e^{3}ɟa̰^{1}/
3(IV)POSS=sister
'his/her/their sister'

b. ˈna^{4}e^{3}ɟa̰^{1}ã̰^{1}tɨ^{3}
/na^{4}=e^{3}ɟa̰^{1}=ã̰^{1}tɨ^{3}/
3(IV)POSS=sister=yard
'his/her/their sister's yard'

c. ˈna^{4}e^{3}ɟa̰^{1}gɨ^{1}
/na^{4}=e^{3}ɟa̰^{1}=gɨ^{1}/
3POSS=sister=blood
'his/her/their sister's blood'

(46) a. na^{4}ˈtʃo̰^{1}e^{3}ɟa̰^{1}
/na^{4}=tʃo̰^{1}=e^{3}ɟa̰^{1}/
3SBJ=white=sister
's/he has a white (i.e. light-skinned) sister'

b. na^{4}ˈtʃo̰^{1}e^{3}ɟa̰^{1}tʃa^{1}ĩ^{1}
/na^{4}=tʃo̰^{1}=e^{3}ɟa̰^{1}=tʃa^{1}ĩ^{1}/
3SBJ=white=sister=PROSP
's/he is going to have a white sister'

[8] (44)–(46) use derived stems because, as far as I know, there are no disyllabic verb roots and no trisyllabic roots of any category which end in tone 1̰.

Since the dissimilation process treats all unstressed syllables equally, it is better analyzed as stress-conditioned than foot-conditioned. This is one example of the generalization in §4.6 that there is no evidence for iterative footing in the PrWd.

Additionally, the lexical database described in §3.2.3 contains no roots which violate tone 1̰ dissimilation (i.e., display an initial 1̰1 sequence). Thus, the rule producing tone 1̰ dissimilation does not need to include a specification that it applies only across morpheme boundaries. With this background, (47) formally states the rule producing tone 1̰ dissimilation. I take the feature [+superlow] as defining the natural class of tones 1 and 1̰; the rule states that when tone 1̰ occurs on a stressed syllable and the following syllable has a superlow tone, the stressed tone 1̰ is realized as tone 5.

(47) Tone 1̰ dissimilation: 1̰ → 5 / ˈ_σ[+superlow]

6.2 Tone 43 assimilation

The same tones that trigger tone 1̰ dissimilation – modal tone 1 and creaky 1̰ – also trigger a process of tone assimilation. Stressed syllables with underlying tone 43 are realized as tone 31 when they are followed by a tone 1̰ or 1 syllable.

(48) shows this for the morpheme *na*^{43}, a pronoun which acts as the default grammatical possessor of inalienable nouns that are semantically unpossessed. Like all possessive pronouns in the language, it projects a PrWd and bears stress (§4.3). The default possessor is realized with tone 43 when it is followed by a syllable with tones 4 or 5 (48a,b). But when the pronoun is followed by a syllable with tone 1̰ or modal 1, it is realized as 31 (48c, d).

(48) a. ˈna^{43}a^{5}tɨ^{1}
/na^{43}=a^{5}tɨ^{1}/
DFLT.POSS=leaf
'leaf'

b. ˈna^{43}tɨ^{4}
/na^{43}=tɨ^{4}/
DFLT.POSS=river
'river'

c. ˈna^{31}ã̰^{1}tɨ^{3}
/na^{43}=ã̰^{1}tɨ^{3}/
DFLT.POSS=yard
'yard'

d. ˈna^{31}a^{1}ne^{1}
/na^{43}=a^{1}ne^{1}/
DFLT.POSS=land
'land'

Tones 1̰ and 1 are not the only triggers of tone 43 assimilation. Tone 3 also triggers the process, as shown in (49).

(49) a. ˈna^{31}e^{3}ĩ^{1}
/na^{43}=e^{3}ĩ^{1}/
DFLT.POSS=prey
'game animal'

b. ˈna^{31}tɨ^{3}we^{3}
/na^{43}=tɨ^{3}we^{3}/
DFLT.POSS=half.sphere
'half (of something spherical)'

In contrast to tones 1̰, 1, and 3, tone 2 does not trigger tone 43 assimilation (50). Thus, the triggers of assimilation cannot be treated as a natural class of the low or low/mid tones.

(50) ˈna^{43}tɨ^{2}
/na^{43}=tɨ^{2}/
DFLT.POSS=weeds
'weeds'

Since tone 3 patterns with tones 1̰ and 1 as a trigger of the /43/ → [31] change, one might expect that it would also pattern with these tones in tone 1̰ dissimilation, acting as another trigger for this process. However, tone 3 does *not* trigger tone 1̰ dissimilation (51).

(51) a. na⁴ˈtʃo̰¹e³ɟa̰¹
/na⁴=tʃo̰¹=e³ɟa̰¹/
3SBJ=white=sister
's/he has a white sister'

b. na⁴ˈtʃo̰¹ne³
/na⁴=tʃo̰¹=ne³/
3SBJ=white=son
's/he has a white son'

c. na⁴ˈtʃo̰¹pa³tɨ⁴
/na⁴=tʃo̰¹=pa³tɨ⁴/
3SBJ=white=claw
'it has white claws'

My lexical database includes roots which display the environment for tone 43 dissimilation, but where it fails to apply. They include both 43.1 roots such as *o⁴³na¹* 'food' and 43.3 roots such as *be⁴³re³* 'cocona, plant species (*Solanum sessiliflorum)*.' These roots indicate that tone 43 assimilation applies only across morpheme boundaries, meaning that the formal statement of tone 43 assimilation must include a morpheme boundary in the environment. The rule does *not*, however, need to include stress as part of the environment. While tone 43 assimilation is stress-conditioned in that it only targets stressed syllables, this 'stress-conditioning' is epiphenomenal on the fact that tone 43 – like the other contour tones – only occurs in stressed syllables (§5.2).

With this background, (52) provides a formal statement of the rule producing tone 43 assimilation. Note that, as discussed above, there is no external motivation for positing that the triggers of this process (tones 1 and 3) share phonological features. In (52), I therefore represent the environment of this rule as disjunctive: when a syllable bears tone 43, and the following syllable belongs to a different morpheme and bears a superlow tone or tone 3, the tone 43 syllable is realized with tone 31.

(52) Tone 43 assimilation: $43 \rightarrow 31$ / $\_]_{\text{morpheme}}\sigma$[+superlow], $\_]_{\text{morpheme}}\sigma^{3}$

6.3 Interim summary

I showed in §5 that the stressed syllable licenses segments and tones not found in other syllables. In this section, I demonstrated that the stressed syllable also undergoes tone alternations – tone 1̰ dissimilation (§6.1) and tone 43 assimilation (§6.2) – that unstressed syllables do not undergo.

The two tone processes observed only on stressed syllables relate to stress in different ways. Tone 1̰ dissimilation interacts with stress via classic stress-conditioning. Tone 1̰ can occur on both stressed and unstressed syllables, but it undergoes dissimilation to tone 5 only when it occurs on stressed syllables (§6.1). There is no relationship with licensing; stress is simply part of the environment for the process. In contrast, tone 43 assimilation interacts with stress exclusively via stress-licensing. Because tone 43 occurs only on stressed syllables, tone 43 assimilation can occur only on stressed syllables (§6.2). Due to this relationship with licensing, it is unnecessary to include stress in the environment for the process.

7 Stress-conditioned segmental processes

In this section, I analyze two stress-conditioned segmental processes: vowel quality assimilation targeting /ɨ/ and vowel quality assimilation targeting /oa/ sequences.

7.1 /ɨ/ assimilation

The oral vowel /ɨ/ is subject to a stress-conditioned assimilation process in which it assimilates completely to the quality of a preceding non-central vowel. This process is stress-conditioned because it is *triggered* only by stressed vowels.

The entries for morphemes with underlying /ɨ/ in Anderson and Anderson's (2017) dictionary describe this allomorphy, but do not include a generalization about the conditioning environment. Similarly, Montes Rodriguez (2004: 155) notes the process in the Amacayacu variety, but describes it as conditioned only by vowel quality. As the following data show, stress also conditions the alternation.

7.1.1 /ɨ/ assimilation is triggered by stressed syllables

When the *stressed* syllable contains a front or back vowel, and the *following* syllable of the PrWd contains underlying oral /ɨ/ and lacks a supra-laryngeal onset, the token of /ɨ/ assimilates completely in quality and nasality to the vowel of the stressed syllable.

All vowel qualities other than /a/ and /ɨ/ trigger /ɨ/ assimilation. (53) shows a set of monosyllabic verbs with vowels of all the possible vowel qualities, followed by the enclitic /=ʔɨ^{1}ra^1/ 'sort of.' Front vowels (53a, b), back vowels (53c, d), and diphthongs (53e, f) trigger assimilation of the /ɨ/ in /=ʔɨ^{1}ra^1/. /a/ and /ɨ/ do not trigger assimilation (53f, g).

As shown in (53e, f), diphthongs differ from other vowel qualities in their behavior in /ɨ/ assimilation. While monophthongal vowel qualities other than /a/ trigger complete assimilation of /ɨ/, diphthongs display fusion with /ɨ/. The first vowel of the diphthong becomes the sole vowel of its (stressed) syllable, while the second vowel of the diphthong becomes the sole vowel of the syllable with the underlying /ɨ/.

(53) a. na^{4}ˈtʃi^4**ʔi**^{1}ra^1
/na^4=tʃi^4=ʔɨ^{1}ra^1/
3SBJ=stand=DEINTENS
's/he sort of stands up'

b. na^{4}ˈme^{31}**ʔẽ**^{1}ra^1
/na^4=me^{43}=ʔɨ^{1}ra^1/
3SBJ=good=DEINTENS
'it's sort of good'[9]

c. na^{4}na^{3}ˈmu^2**ʔũ**^{1}ra^1
/na^4=na^3=mu^2=ʔɨ^{1}ra^1/
3SBJ=3OBJ=send=DEINTENS
's/he sort of sends it'

d. na^{4}ˈdo^{31}**ʔo**^{1}ra^1
/na^4=do^{43}=ʔɨ^{1}ra^1/
3SBJ=soft=DEINTENS
'it's sort of soft'

e. na^{4}ˈna^4**ʔĩ**^{1}ra^1
/na^4=nai^4=ʔɨ^{1}ra^1/
3SBJ=be.hot=DEINTENS
'it's sort of hot'

f. na^{4}ˈda^2**ʔu**^{1}ra^1
/na^4=dau^2=ʔɨ^{1}ra^1/
3SBJ=see=DEINTENS
's/he sort of sees'

g. na^{4}ˈɟa^2**ʔɨ**^{1}ra^1
/na^4=ɟa^2=ʔɨ^{1}ra^1/
3SBJ=mature=DEINTENS
'it's sort of mature'

h. na^{4}na^{3}ˈʔɨ^2**ʔɨ**^{1}ra^1
/na^4=na^3=ɨ^2=ʔɨ^{1}ra^1/
3SBJ=3OBJ=do=DEINTENS
's/he sort of makes it'

/ɨ/ assimilation behaves the same in nouns, as shown by (54): it is triggered by front vowels (54a, b), back vowels (54c, d), and diphthongs (54e), but not by /a/ or /ɨ/ (54f).

(54) a. ˈŋi^1**ʔi**^{4}ne^1
/ŋi^1=ʔɨ^{4}ne^1/
3(V)POSS=body
'her (Class V) entire body'[10]

b. ˈe^4**ʔe**^{5}tʃi^2
/e^4=ʔɨ^{5}tʃi^2/
G.americana=really
'real *Genipa americana* (plant sp.)'

c. ˈŋu^2**ʔu**^{5}tʃi^2
/ŋu^2=ʔɨ^{5}tʃi^2/
T.bicolor=really
'real *Theobroma bicolor* (fruit sp.)'

d. ˈto^1**ʔo**^{5}tʃi^2
/to^1=ʔɨ^{5}tʃi^2/
other=really
'really different'

[9] This form exemplifies tone 43 assimilation (§6.2).

[10] The inalienable noun *ʔɨ^{4}ne^1* appears in many examples throughout this section because it is one of the small number of enclitics and alienable nouns beginning with /ɨ/. While I gloss *ɨ^{4}ne^1* as 'body,' this gloss is inadequate, because it suggests a mind-body dualism which is not part of the word's meaning. See Santos Angarita (2013) for a Ticuna linguist's definition of *ɨ^{4}ne^1*.

e. ˈtʃa¹**ʔu**⁴ne¹
/tʃau¹=ʔɨ⁴ne¹/
1SG.POSS=body
'my entire body'

f. ˈna⁴**ʔɨ**⁴ne¹
/na⁴=ʔɨ⁴ne¹/
3(IV)POSS=body
'his/her/their/its (Class IV) entire body'

7.1.2 /ɨ/ assimilation is not triggered by unstressed syllables

/ɨ/ assimilation does not apply unless the target /ɨ/ segment is adjacent to the stressed syllable. The exception is when the process is triggered by /u/, as assimilation of /ɨ/ to /u/ is not conditioned by stress.

The failure of unstressed syllables to trigger /ɨ/ assimilation is shown in (55), a verb, and (56), a noun. (55) has a sequence of unstressed /e/ followed by unstressed /ɨ/. If the /e/ token was stressed, it would trigger complete assimilation of the /ɨ/, as in (53b) and (54b). But as the /e/ is unstressed, the /ɨ/ does not assimilate. The same applies to the sequence of /i/ and /ɨ/ in (56).

(55) na⁴ˈtʃi³¹e²ʔɨ⁵tʃi²
/na⁴=tʃi³¹e²=ʔɨ⁵tʃi²/
3SBJ=bad=really
'it's really bad'

(56) ˈo̰¹ʔi⁵ʔɨ⁵tʃi²
/o̰¹ʔi⁵=ʔɨ⁵tʃi²/
grandfather=really
'real grandfather'

Like tone 1̰ dissimilation, /ɨ/ assimilation is stress-conditioned, not foot-conditioned. A stress-conditioned analysis of /ɨ/ assimilation predicts that the process applies only if the target syllable is adjacent to the stress. By contrast, a foot-conditioned analysis predicts that the process applies in all even-numbered syllables, including those that are not adjacent to the stress.

(57) and (58) support the stress-conditioned analysis. Contrary to the foot-conditioned analysis, they illustrate that /ɨ/ assimilation does not apply in the fourth syllable of the PrWd (an even-numbered syllable that is not adjacent to a stress). This is another piece of evidence that foot formation is not iterative (§4.6).

(57) na⁴ˈwi³ɟa³e³ʔɨ⁵tʃi²
/na⁴=wi³ɟa³e³=ʔɨ⁵tʃi²/
3SBJ=sing=really
's/he really sings'

(58) ˈka³ru¹ne³ʔɨ̃⁵tʃi²
/ka³ru¹=ne³=ʔɨ⁵tʃi²/
Carlos=son=really
'Carlos' real son'

While unstressed /i/ and /e/ do not trigger /ɨ/ assimilation, unstressed /u/ *does* trigger the process.

(59) ˈu³ku¹ʔu⁵tʃi²
/u³ku¹=ʔɨ⁵tʃi²/
needle=really
'real needle'

(60) tʃa³tɨ³re¹gu²ʔu⁵tʃi²
/tʃa³=tɨ³re¹=gu²=ʔɨ⁵tʃi²/
1SG.SBJ=port=LOC=really
'I'm right in the port'

Besides /u/, the other back vowel, /o/, is restricted in distribution to the first two syllables of the PrWd (§5.1). While stressed (first syllable) /o/ triggers /ɨ/ assimilation (53d, 54d), unstressed (second syllable) /o/ does not (61). /o/ thus patterns with the front vowels and diphthongs, not with /u/, in its behavior as a trigger of /ɨ/ assimilation.

(61) ˈo²ʔõ⁴ʔɨ⁴ne¹
/o²ʔõ⁴=ʔɨ⁴ne¹/
baby=body
'baby's body'

Recall from §5.1 that all underived words with /o/ in the second syllable have the form [(C)o(ʔ)o]. Since /ɨ/ assimilation derives words of this same form, it is attractive to posit that underived words with /o/ in the second syllable, like *o²ʔõ⁴* 'baby,' have the underlying form /(C)o(ʔ)ɨ/, with the final /o/ in the surface form derived by /ɨ/ assimilation. However, this analysis is impossible because there are underived words of the form [(C)o(ʔ)ɨ]. Two examples are the nouns *o¹ʔɨ³* 'shuyo, fish species (*Hoplerythrinus unitaeniatus*)' and *to^{2}ʔɨ^{3}* ‘isula, ant species (*Paraponera clavata*).’ Since the /ɨ/ tokens in these words do not undergo assimilation, /ɨ/ assimilation, like tone 43 assimilation, must be a derived environment effect.

With this data in hand, we can state the rule governing /ɨ/ assimilation as in (62): when /ɨ/ comes after a non-low stressed vowel, across a morpheme boundary, it assimilates completely in quality to that vowel.

(62) /ɨ/ assimilation:
/ɨ/ → V[α-high -low α-front α-back α-nasal] / ˈV[α-high -low α-front α-back α-nasal]]$_{\text{morpheme}}$(ʔ)_

The /ɨ/ assimilation rule as stated in (62) produces the correct output for assimilation of /ɨ/ to monophthongs, but not for assimilation to diphthongs. Specifically, (62) predicts that assimilation of /ɨ/ to a diphthong will produce a sequence of the form [V1V2.V2], while the outcome is actually [V1.V2] in forms such as (53b). In order to produce the fusion, we need the additional diphthong-monophthong fusion rule given in (63): when a diphthong comes before a monophthong with the same quality as the second vowel in the diphthong, the second vowel of the diphthong deletes.

(63) Diphthong-monophthong fusion: Vβ → ∅ / Vα_(ʔ)Vβ

Since the environment in (63) does not include a morpheme boundary, it predicts that there will be no roots with a diphthong followed by a high vowel with the same quality as the second member of the diphthong (*ai.i, *au.u). In the lexical database, this prediction is correct: there are no roots of this form.

Last, assimilation of /ɨ/ to /u/ is not stress-conditioned, and no roots violate it, meaning that it is likely not a derived environment effect. I posit the additional rule given in (64) to produce assimilation of /u/-/ɨ/ sequences anywhere in the word, including root-internally. This rule states simply that /i/ is realized as [u] when it comes after /u/.

(64) /u/-/ɨ/ assimilation: /ɨ/ → [u] / u(ʔ)_

Bertet (2020: 125-126) describes a similar process to /ɨ/ assimilation in the Amacayacu variety, but analyzes it as copying of the stem vowel to an underspecified vowel slot in the following enclitic. I reject the copying analysis because of the behavior of stressed /a/. Following /ˈa/, morphemes involved in this alternation are not realized with [a], as predicted by copying, but with [ɨ] (53g), as predicted by my analysis.

7.2 A related process: /oa/ assimilation

In addition to /ɨ/ assimilation, the lexical phonology displays another vowel assimilation process which is limited to the first two syllables of the PrWd. This is assimilation of /oa/ sequences, which also occurs in the Amacayacu variety (Bertet 2020: 126).

When the first syllable of the PrWd contains /o/, and the second syllable contains /a/ and lacks a supralaryngeal onset, the /a/ of the second syllable assimilates completely to the /o/ in quality. (65) shows the process in two verbs, (66) in a noun.

(65)	a.	na^{4}ˈtʃo^{5}**o**^{1}ne^{1} /na^{4}=tʃo̰^{1}=a^{1}ne^{1}/ 3SBJ=white=land ‘s/he/it has white (i.e. sandy) land’	b.	na^{4}ˈdo^{43}ʔ**o**^{5}tɨ^{1} /na^{4}=do^{43}=a^{5}tɨ^{1}/ 3SBJ=soft=leaf ‘it has soft leaves’
(66)	a.	ˈto^{1}**o̰**^{1} /to^{1}=a̰^{1}/ other=mouth ‘other one’s mouth’	b.	ˈto^{1}**o**^{1}ʔɨ̃^{5} /to^{1}=a^{1}ʔɨ̃^{5}/ other=IBEN ‘for the other one’

/oa/ assimilation is absent when /o/ occurs in the second syllable and /a/ occurs in the third syllable of the PrWd (67). Since [o] never occurs after the second syllable of the PrWd, this is the latest position where an /oa/ sequence can appear.

(67) a. ˈo^{2}ʔõ^{4}a̰^{1}
/o^{2}ʔõ^{4}=a̰^{1}/
baby=mouth
'baby's mouth'

b. ˈbo^{2}ʔo^{3}a^{1}ʔɨ̃^{5}, *[ˈbo^{2}ʔo^{3}o^{1}ʔɨ̃^{5}]
/bo^{2}ʔo^{3}=a^{1}ʔɨ̃^{5}/
grub.sp=IBEN
'for grubs'

The lexical database described in §3.2.3 does not contain any underived words of the form [Co(ʔ)a]. As such, and as with /uɨ/ assimilation, there is no evidence that /oa/ assimilation is limited to derived environments. Thus, I posit that all surface [(C)o(ʔ)o] words have underlying /a/ in the second syllable and display surface [o] in the second syllable due to /oa/ assimilation. On this account, for example, the underlying form of the word 'baby' is /o^{2}ʔã^{4}/, and its surface form [o^{2}ʔõ^{4}] reflects the outcome of /oa/ assimilation. Per §5.1, this permits the generalization that in native-vocabulary words, /o/ occurs only in the stressed syllable.

With this background, /oa/ assimilation can be modeled with the rule shown in (68), which states that when /a/ comes after stressed /o/, /a/ is realized as [o].

(68) /oa/ assimilation: /a/ → [o] / ˈo(ʔ)_

7.3 Interim summary

§6 described how the stressed syllable undergoes processes – tone 1̰ dissimilation and tone 43 assimilation – which no other syllable undergoes. This section further showed that the stressed syllable also triggers processes – /ɨ/ and /oa/ assimilation – that no other syllable triggers. The processes which the stressed syllable uniquely triggers are segmental, while the processes which it uniquely undergoes are tonal (§6).

This section and §6 have concentrated on phonological alternations. However, the stressed syllable also behaves exceptionally with respect to grammatical tone alternations. The following section therefore turns to the language's most important grammatical tone process – where, again, the stressed syllable patterns apart from all other syllables.

8 Stress-conditioned grammatical tone processes

Cushillococha Ticuna displays an extensive set of grammatical tone alternations affecting the final syllables of verb stems. These alternations involve circle and chain shift patterns similar to the well-known tone circles found in Taiwanese Southern Min and other Sino-Tibetan languages (Mortensen 2006). Because the circle-like alternations are triggered mostly by nominalizing constructions, I refer to them collectively as the *nominalizer tone circle.*

Exactly like the phonological processes described in the previous two sections, the nominalizer tone circle is also stress-conditioned. In §8.1, I introduce the circle and the morphosyntactic contexts where it applies. Then, I lay out the alternations caused by the circle on stressed syllables (§8.2) and unstressed syllables (§8.3). In §8.4 I discuss interactions between the nominalizer tone circle and other tone processes, and in §8.5 I give an interim summary.

My analysis is informed by D. Anderson's (1963: 369) initial description of the tone circle. Anderson's statements of the alternations are generally accurate; however, her list of conditioning environments is not accurate, at least for contemporary Cushillococha Ticuna, and she does not identify the circle as stress-conditioned. Bertet (2020: 130-138) states a similar list of surface alternations, but because he treats the stressed and unstressed syllable toneme inventories as unrelated, he identifies the alternations as affecting different tonemes, not as stress-conditioned.

8.1 Triggers of the nominalizer tone circle

Several morphemes trigger the nominalizer tone circle. The most common triggers are nominalizing enclitics, which appear on verbs to derive relative clauses. I refer to these morphemes as 'nominalizers' because the constituents which they derive have the external syntax of nouns (e.g., can bear case and possess other nouns).

The nominalizers agree in noun class with the head noun of the relative clause that they derive. They are listed, together with their noun classes, in (69).

(69) a. =e^{3} NMLZ:I
b. =kɨ^{3} NMLZ:II
c. =ʔɨ̃^{5}ne^{1} ~ =ne^{1} NMLZ:III[11]
d. =ʔɨ̃^{4} NMLZ:IV

Not all nominalizers trigger the nominalizer tone circle. Specifically, the nominalizer for noun class V is syntactically identical to the nominalizers in (69), deriving relative clauses. It is also segmentally identical to the class II nominalizer, with the segmental form *=kɨ^{3}*. However, the noun class V nominalizer does *not* induce the nominalizer tone circle on its host, while the noun class II nominalizer does.

(70) illustrates the nominalizer tone circle, including its non-application in class V nominalizations, by comparing relative clauses formed with the nominalizers in (69) vs. with the class V nominalizer. Each example in (70) has the same verb, *mṵ^{1}* 'eat (raw fruit).' This verb is underlyingly tone 1̰. In (70a-c), when the root bears the Class I, II, and IV nominalizers, it is realized as tone 5 – one of the tone circle alternations. But when the root bears the class V nominalizer in (70d), it is realized with its underlying tone. This same pattern holds regardless of verb stem properties: the class V nominalizer never affects stem tone.

(70) a. bu^{3}e^{3} ɟa^{4} ta^{31}ʔɨ^{3} **mu^{5}e^{3}**
/bu^{3}e^{3} ɟa^{4} ta^{31}ʔɨ^{3} **mṵ^{1}**=e^{3}/
baby(I) LNK(I) *Pouteria.caimito* **eat.fruit**=NMLZ(I)
'the baby (class I) that ate *P. caimito* (fruit species)'

b. ŋe^{3}ʔtɨ^{1}ɨ^{3}kɨ^{3} ɟa^{4} ta^{31}ʔɨ^{3} **mu^{5}kɨ^{3}**
/ŋe^{3}ʔtɨ^{1}ɨ^{3}kɨ^{3} ɟa^{4} ta^{31}ʔɨ^{3} **mṵ^{1}**=kɨ^{3}/
young.man(II) LNK(II) *P.caimito* **eat.fruit**=NMLZ(II)
'the young man (class II) that ate *P. caimito*'

c. du^{1}ɨ̃^{3}ʔɨ̃^{4} i^{4} ta^{31}ʔɨ^{3} **mu^{5}ʔɨ̃^{4}**
/du^{1}ɨ̃^{3}ʔɨ̃^{4} i^{4} ta^{31}ʔɨ^{3} **mṵ^{1}**=ʔɨ̃^{4}/
person(IV) LNK(IV) *P.caimito* **eat.fruit**=NMLZ(IV)
'the person (class IV) that ate *P. caimito*'

d. pa^{4}kɨ^{3} i^{4} ta^{31}ʔɨ^{3} **mṵ^{1}kɨ^{3}**
/pa^{4}kɨ^{3} i^{4} ta^{31}ʔɨ^{3} **mṵ^{1}**=kɨ^{3}/
young.woman(V) LNK(V) *P.caimito* **eat.fruit**=NMLZ(V)
'the young woman (class V) that ate *P. caimito*'

I take the failure of the Class V nominalizer to induce the tone circle – as represented by the contrast between (70a-c) and (70d) – as evidence that it is neither syntactic status as nominalizers nor phonological form that causes the Class I, II, III, and IV nominalizers to induce the nominalizer tone circle. Instead, I assume that triggering the circle is a lexical property of the Class I, II, III, and IV nominalizers (69).

As well as these nominalizers, at least two other morphosyntactic constructions also trigger the nominalizer tone circle.

[11] This morpheme displays stress-conditioned segmental allomorphy. It is realized as *=ʔɨ̃^{5}ne^{1}* when adjacent to the stressed syllable and *=ne^{1}* elswhere.

First, the subordinating enclitic *=ʔ(ĩ^{4})* appears in focus constructions, purpose clauses, and complement clauses. It triggers the nominalizer tone circle on the final syllable of the verb stem to which it attaches, as shown for a tone 1̰ verb in (71).

(71) na^{1}**te^{5}ʔĩ^{4}**ka̰^{1}
/na^{1}=**tḛ^{1}**=ʔĩ^{4}=ka̰^{1}/
3SBJ.SC=**sharp**=SUB=PURP
'so that it is sharp'

While the subordinator *=ʔ(ĩ^{4})* resembles the class IV nominalizer, the two morphemes are synchronically distinct. The subordinator can be realized without a vowel in utterance-final position, but the nominalizer always has a vowel.

Second, the adverb *ɲṵ^{1}ʔma^{5}ta^{4}(ta^{1})* 'until,' which introduces a temporal subordinate clause, triggers the nominalizer tone circle on the final syllable of the subordinate clause verb. This trigger differs from all other tone circle triggers because the verb which undergoes the circle does not bear any segmental subordinating morphology. Nevertheless, the tone circle alternations still take place, changing tone 1̰ to 5 in (72a) and tone 3 to 2 in (72b).

(72) a. ɲṵ^{1}ʔma^{5}ta^{4}ta^{1} i^{5}tʃa^{1}na^{3}**ta^{5}**
ɲṵ^{1}ʔma^{5}ta^{4}ta^{1} i^{5}=tʃa^{1}= na^{3}=**ta̰^{1}**
until DIR=1SG.SBJ.SC=3OBJ=**discard**
'until I left him/her'

b. ɲṵ^{1}ʔma^{5}ta^{4}ta^{1} nɨ^{31}ʔĩ^{3} na^{1}**ʔĩ^{3}nɨ^{2}**
ɲṵ^{1}ʔma^{5}ta^{4}ta^{1} nɨ^{31}=ʔĩ^{3} na^{1}ʔ=**ĩ^{3}nɨ^{3}**
until 3(IV)=ACC 3SBJ.SC=**hear**
'until she/he heard it'

In sum, the nominalizer tone circle applies in a variety of morphological constructions and syntactic environments that involve subordination. Through the rest of this section, I exemplify the tone circle alternations exclusively with the nominalizers shown in (69). However, the alternations are the same whether the tone circle is triggered by one of the nominalizers in (69), the subordinator, or *ɲṵ^{1}ʔma^{5}ta^{4}(ta^{1})* 'until.' Furthermore, the circle occurs only on the final syllable of verb stems. It never applies to adverbs, verb arguments, or other material.

8.2 The nominalizer tone circle on stressed syllables

The circle has different outcomes on stressed syllables than unstressed syllables. This section describes the stressed syllable changes; §8.3 describes the changes on unstressed syllables.

On stressed syllables – that is, monosyllabic verb roots – the tone circle causes the eight alternations in (73). Tone 5 is not included as a target in (73) because it occurs on only one monosyllabic word (§5).[12]

(73)

a.	/1̰/ → 5	b.	/1/ → 2̰	c.	/2/ → 2, 5[13]
d.	/2̰/ → 2̰	e.	/3/ → 2	f.	/4/ → 1
g.	/31/ → 3	h.	/43/ → 31	i.	/51/ → 51

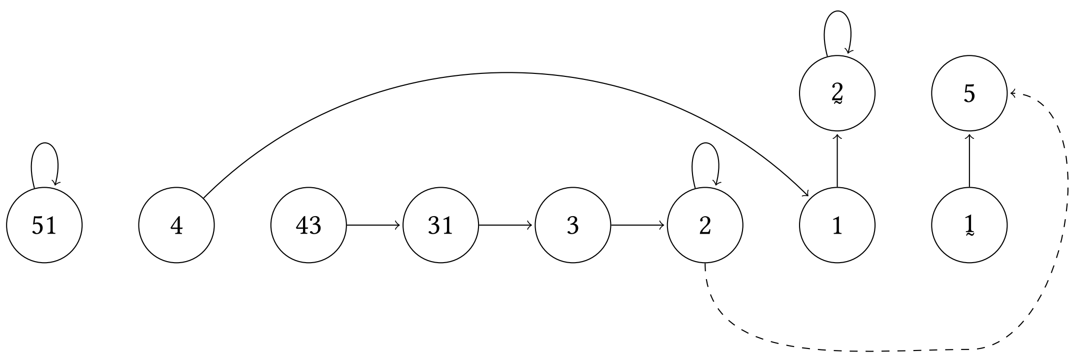
(74) depicts the changes in (73) graphically. In the figure, the solid lines represent changes that take place in all tone circle environments, while the dashed line connecting tones 2 and 5 represents a change

[12] This word, *pe^{5}* 'slap,' remains tone 5 when subject to the circle. I do not include it in (73) because it is impossible – given the lack of other tone 5 monosyllables – to determine if this alternation generalizes.

[13] Stressed syllables with tone 2 are realized as tone 5 before the Class I nominalizer *=e^{3}*, but tone 2 before other triggers of the tone circle (77).

triggered only by the Class I nominalizer (cf. note 13). Following (74), (75)–(83) provide example verb roots of each tone undergoing the circle. Examples are given with nominalizers for noun classes I, II, and IV. Class III is left out for semantic reasons: because this class does not contain any animate nouns, Class III subject relative clauses tend to be semantically unacceptable.

(74)



(75) Tone 1̰

a. /pa̰^{1}/ (hug) →
ˈpa^{5}e^{3} 'the one (Class I) that hugs'
ˈpa^{5}kɨ^{3} 'the one (Class II) that hugs'
ˈpa^{5}ʔĩ^{4} 'the one (Class IV) that hugs'

b. /mṵ^{1}/ (eat fruit) →
ˈmu^{5}e^{3} 'the one (Class I) that eats (fruit)'
ˈmu^{5}kɨ^{3} 'the one (Class II) that eats (fruit)'
ˈmu^{5}ʔĩ^{4} 'the one (Class IV) that eats (fruit)'

(76) Tone 1

/pa^{1}/ (be tired) →
ˈpa̰^{2}e^{3} 'the one (Class I) that's tired'
ˈpa̰^{2}kɨ^{3} 'the one (Class II) that's tired'
ˈpa̰^{2}ʔĩ^{4} 'the one (Class IV) that's tired'

(77) Tone 2

a. /ɟa^{2}/ (be mature) →
ˈɟa^{5}e^{3} 'the one (Class I) that's mature'
ˈɟa^{2}kɨ^{3} 'the one (Class II) that's mature'
ˈɟa^{2}ʔĩ^{4} 'the one (Class IV) that's mature'

b. /mu^{2}/ (send) →
ˈmu^{5}e^{3} 'the one (Class I) that sends'
ˈmu^{2}kɨ^{3} 'the one (Class II) that sends'
ˈmu^{2}ʔĩ^{4} 'the one (Class IV) that sends'

(78) Tone 2̰

a. /tʃo̰^{2}/ (crack) →
ˈtʃo̰^{2}e^{3} 'the one (Class I) that cracked'
ˈtʃo̰^{2}kɨ^{3} 'the one (Class II) that cracked'
ˈtʃo̰^{2}ʔĩ^{4} 'the one (Class IV) that cracked'

b. /tʃa̰^{2}/ (spread out fabric, trans.) →
ˈtʃa̰^{2}e^{3} 'the one (Class I) that spreads'
ˈtʃa̰^{2}kɨ^{3} 'the one (Class II) that spreads'
ˈtʃa̰^{2}ʔĩ^{4} 'the one (Class IV) that spreads'

(79) Tone 3

a. /ã^{3}/ (give, inanimate singular object) →
ˈã^{2}e^{3} 'the one (Class I) that gives (it)'
ˈã^{2}kɨ^{3} 'the one (Class II) that gives (it)'
ˈã^{2}ʔĩ^{4} 'the one (Class IV) that gives (it)'

b. /mu^{3}/ (weave) →
ˈmu^{2}e^{3} 'the one (Class I) that wove'
ˈmu^{2}kɨ^{3} 'the one (Class II) that wove'
ˈmu^{2}ʔĩ^{4} 'the one (Class IV) that wove'

(80) Tone 4

a. /pa^{4}/ (be a young adult) →
ˈpa^{1}e^{3} ‘the one (Class I) that’s young’
ˈpa^{1}ʔĩ^{4} ‘the one (Class IV) that’s young’[14]

b. /mu^{4}/ (be many) →
ˈmu^{1}e^{3} ‘many (Class I)’
ˈmu^{1}kɨ^{3} ‘many (Class II)’
ˈmu^{1}ʔĩ^{4} ‘many (Class IV)’

(81) Tone 31

a. /a^{31}/ (be thin) →
ˈa^{3}e^{3} ‘the one (Class I) that’s thin’
ˈa^{3}kɨ^{3} ‘the one (Class II) that’s thin’
ˈa^{3}ʔĩ^{4} ‘the one (Class IV) that’s thin’

b. /mu^{31}/ (pierce) →
ˈmu^{3}e^{3} ‘the one (Class I) that pierces’
ˈmu^{3}kɨ^{3} ‘the one (Class II) that pierces’
ˈmu^{3}ʔĩ^{4} ‘the one (Class IV) that pierces’

(82) Tone 43

a. /pa^{43}/ (be dry) →
ˈpa^{31}e^{3} ‘the one (Class I) that’s dry’
ˈpa^{31}kɨ^{3} ‘the one (Class II) that’s dry’
ˈpa^{31}ʔĩ^{4} ‘the one (Class IV) that’s dry’

b. /ũ^{43}/ (go, singular subject) →
ˈũ^{31}e^{3} ‘the one (Class I) that goes’
ˈũ^{31}kɨ^{3} ‘the one (Class II) that goes’
ˈũ^{31}ʔĩ^{4} ‘the one (Class IV) that goes’

(83) Tone 51

a. /ko^{51}/ (tease) →
ˈko^{51}e^{3} ‘the one (Class I) that teases’
ˈko^{51}kɨ^{3} ‘the one (Class II) that teases’
ˈko^{51}ʔĩ^{4} ‘the one (Class IV) that teases’

b. /tu^{51}/ (pull) →
ˈtu^{51}e^{3} ‘the one (Class I) that pulls’
ˈtu^{51}kɨ^{3} ‘the one (Class II) that pulls’
ˈtu^{51}ʔĩ^{4} ‘the one (Class IV) that pulls’

8.3 The nominalizer tone circle on unstressed syllables

On unstressed syllables, the nominalizer tone circle causes a different – though partially overlapping – set of alternations than on stressed syllables. The tone circle alternations which occur on unstressed syllables are shown in (84). Tones 31, 43, 51, 2̰, and 5 are not included as targets in (84) because they never occur on unstressed syllables (tones 31, 43, 51, and 2̰) or never occur on the final syllable of a verb stem (tone 5).[15]

(84) a. /1̰/ → 5 b. /1/ → 3 c. /2/ → 2, 5[16]
d. /3/ → 2 e. /4/ → 5

The differences between the nominalizer tone circle on unstressed syllables (in 84) and stressed syllables (in 73) come down to the behavior of tones 1 and 4. Stressed tone 1 syllables are realized as tone 2̰ in the circle, but unstressed ones are realized as tone 3. Likewise, stressed tone 4 syllables are realized as tone 1 in the circle, but unstressed ones are realized as tone 5. Other differences between the stressed and unstressed alternations are epiphenomenal on differences in the tone inventory of the two syllable types.

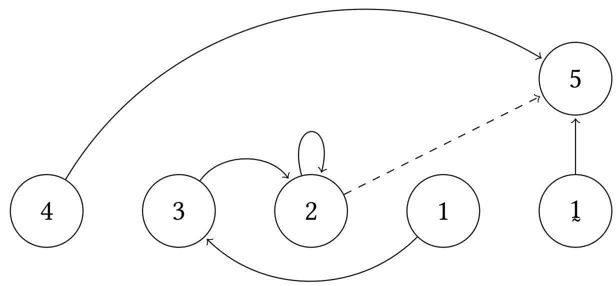
(85) depicts the changes on unstressed syllables graphically. As in (74), the solid lines represent alternations occurring with all tone circle triggers, and the dashed line represents the alternation occurring only with the Class I nominalizer.[16] Below (85), (86)–(90) provide examples of the circle on disyllabic verb stems with each possible stem-final tone.

[14] Participants find the predicted Class II form *pa^{1}kɨ^{3}* semantically unacceptable. All human referents in Class II are men/boys, and this verb cannot be predicated of individual men.

[15] The loan verb *pi^{3}ri^{5}* ‘fry’ is the only polysyllabic verb that ends in tone 5. The tone 5 is unchanged when the word is subject to the circle, but as there are no other verbs of this form, we cannot know if the alternation generalizes.

[16] As with stressed syllables, unstressed syllables with tone 2 are realized as tone 5 before the Class I nominalizer, but as tone 2 with all other circle triggers.

(85)



(86) Disyllabic ending in Tone 1̰
/ŋṵ^{1}=a̰^{1}/ (hurt=mouth) →
ˈŋu^{5}a^{5}e^{3} ‘the one (Class I) whose mouth hurts’[17]
ˈŋu^{5}a^{5}kɨ^{3} ‘the one (Class II) whose mouth hurts’
ˈŋu^{5}a^{5}ʔɨ̃^{4} ‘the one (Class IV) whose mouth hurts’

(87) Disyllabic ending in Tone 1
/wi^{1}ʔɟa^{1}/ (urinate) →
ˈwi^{1}ʔɟa^{3}e^{3} ‘the one (Class I) that urinates’
ˈwi^{1}ʔɟa^{3}kɨ^{3} ‘the one (Class II) that urinates’
ˈwi^{1}ʔɟa^{3}ʔɨ̃^{4} ‘the one (Class IV) that urinates’

(88) Disyllabic ending in Tone 2
/de^{43}ʔa^{2}/ (talk) →
ˈde^{43}ʔa^{5}e^{3} ‘the one (Class I) that talks’
ˈde^{43}ʔa^{2}kɨ^{3} ‘the one (Class II) that talks’
ˈde^{43}ʔa^{2}ʔɨ̃^{4} ‘the one (Class IV) that talks’

(89) Disyllabic ending in Tone 3
/ĩ^{3}nɨ^{3}/ (listen) →
ˈĩ^{3}nɨ^{2}e^{3} ‘the one (Class I) that listens’
ˈĩ^{3}nɨ^{2}kɨ^{3} ‘the one (Class II) that listens’
ˈĩ^{3}nɨ^{2}ʔɨ̃^{4} ‘the one (Class IV) that listens’

(90) Disyllabic ending in Tone 4
/o^{4}ʔgɨ^{4}/ (vomit) →
ˈo^{4}ʔgɨ^{5}e^{3} ‘the one (Class I) that vomits’
ˈo^{4}ʔgɨ^{5}kɨ^{3} ‘the one (Class II) that vomits’
ˈo^{4}ʔgɨ^{5}ʔɨ̃^{4} ‘the one (Class IV) that vomits’

Trisyllabic verb stems display exactly the same alternations in the circle as disyllabic ones. Outcomes of the circle on trisyllabic stems are shown in (91)–(95).

[17] The realization of the verb root as tone 5 is in these examples is due to tone 1̰ dissimilation, not the tone circle. The realization of the second stem syllable as tone 5 is due to the tone circle; dissimilation cannot apply here because the syllable is not stressed. See §8.4 for further discussion of the interaction between the circle and other tone processes.

(91) Trisyllabic ending in Tone 1̰
/ɟu^{2}=e^{3}ɟa̰^{1}/ (die=sister) →
ˈɟu^{2}e^{3}ɟa^{5}e^{3} ‘the one (Class I) whose sister died’
ˈɟu^{2}e^{3}ɟa^{5}kɨ^{3} ‘the one (Class II) whose sister died’
ˈɟu^{2}e^{3}ɟa^{5}ʔĩ^{4} ‘the one (Class IV) whose sister died’

(92) Trisyllabic ending in Tone 1
/tʃi^{31}e^{2}=ga^{1}/ (bad=voice) →
ˈtʃi^{31}e^{2}ga^{3}e^{3} ‘the one (Class I) that sounds bad’
ˈtʃi^{31}e^{2}ga^{3}kɨ^{3} ‘the one (Class II) that sounds bad’
ˈtʃi^{31}e^{2}ga^{3}ʔĩ^{4} ‘the one (Class IV) that sounds bad’

(93) Trisyllabic ending in Tone 2
/ta^{43}=ʔɨ^{5}tʃi^{2}/ (big=really) →
ˈta^{43}ʔɨ^{5}tʃi^{5}e^{3} ‘the one (Class I) that’s really big’
ˈta^{43}ʔɨ^{5}tʃi^{2}kɨ^{3} ‘the one (Class II) that’s really big’
ˈta^{43}ʔɨ^{5}tʃi^{2}ʔĩ^{4} ‘the one (Class IV) that’s really big’

(94) Trisyllabic ending in Tone 3
/wi^{3}ɟa^{3}e^{3}/ (sing) →
ˈwi^{3}ɟa^{3}e^{2}e^{3} ‘the one (Class I) that sings’
ˈwi^{3}ɟa^{3}e^{2}kɨ^{3} ‘the one (Class II) that sings’
ˈwi^{3}ɟa^{3}e^{2}ʔĩ^{4} ‘the one (Class IV) that sings’

(95) Trisyllabic ending in Tone 4
/pu^{3}ra^{3}kɨ^{4}/ (work) →
ˈpu^{3}ra^{3}kɨ^{5}e^{3} ‘the one (Class I) that works’
ˈpu^{3}ra^{3}kɨ^{5}kɨ^{3} ‘the one (Class II) that works’
ˈpu^{3}ra^{3}kɨ^{5}ʔĩ^{4} ‘the one (Class IV) that works’

The fact that disyllabic and trisyllabic stems behave the same in (86)–(95) shows that the nominalizer tone circle is not sensitive to the syllable count of the stem, only to the distinction between the stressed syllable and the other stem syllables. Thus, as in the processes discussed in §§6-7, the prosodic factor conditioning the circle is stress, not foot structure.

The polysyllabic stem examples also show that the tone circle is insensitive to the morphological composition of the stem. For example, compare the underived disyllabic stem *wi^{1}ʔɟa^{1}* ‘urinate,’ in (87) with the derived trisyllabic stem *tʃi^{31}e^{2}=ga^{1}* (bad=voice) ‘sound bad’ in (92). Under the circle, the final tone 1 syllables in (87), an underived stem, and (92), a derived stem, behave exactly the same. Both are realized as tone 3, while a stressed tone 1 syllable subject to the circle (i.e. a monosyllabic verb root) would be realized as tone 2̰.

Last, the outcomes of the tone circle on polysyllabic stems demonstrate that the process does not display effects of the Obligatory Contour Principle (OCP) (Leben 1973; Odden 1986). If the OCP applied at the lexical level in Cushillococha Ticuna, polysyllabic stems with level tone melodies – such as the /11/ stem in (87), /33/ stem in (89), /44/ stem in (90), and /333/ stem in (94) – would be modeled as involving a single tone associated with multiple TBUs (syllables). Assuming that the nominalizer tone circle affects the identity of this single tone, the circle is predicted to change the tone of every stem syllable. Thus, a /44/ stem such as *o^{4}ʔgɨ^{4}* ‘vomit’ should be realized as 55 when subject to the circle, while a /333/ stem such as *wi^{3}ɟa^{3}e^{3}* ‘sing’ should be realized as 22. In fact, only the last syllable changes under the circle. This is true for both disyllabic stems, as shown by (87), (89) and (90), and trisyllabic stems, as shown by (94). Thus, the /44/ stem *o^{4}ʔgɨ^{4}* ‘vomit’ is realized as 45 (*o^{4}ʔgɨ^{5}*), not 55, and the /333/ stem *wi^{3}ɟa^{3}e^{3}* ‘sing’ is realized as 332 (*wi^{3}ɟa^{3}e^{2}*), not 222 as predicted by the OCP analysis.

This indicates that the OCP does not apply at the lexical level in Cushillococha Ticuna. Stems with level tone melodies, such as /44/ and /333/, should be represented as involving multiple tones with the same value – each linked to a distinct TBU – rather than a single tone linked to multiple TBUs.

8.4 Interactions of the nominalizer tone circle and other tone alternations

The nominalizer tone circle is ordered after and counterbleeds the process of tone 1̰ dissimilation in disyllabic stems with the underlying tone melodies /1̰1̰/ and /1̰1/. It is also ordered after and counterbleeds tone 43 assimilation in disyllabic stems with the underlying melodies /43.1̰/ and /43.1/.

Recall from §6.1 that tone 1̰ dissimilation applies to stressed tone 1̰ syllables which are immediately followed by another tone 1̰ or modal 1 syllable. The nominalizer circle also applies to these trigger (tone 1̰ and 1) syllables, causing tone 1̰ syllables to be realized with tone 5, and tone 1 syllables to be realized with tone 3. Tones 3 and 5 are not triggers of tone 1̰ dissimilation. Thus, when the tone circle applies to the second syllable of a /1̰1̰/ or /1̰1/ stem, it eliminates the tone which would trigger dissimilation.

This raises the question of whether tone 1̰ dissimilation still occurs when the trigger syllable is subject to the nominalizer tone circle. It does: when a /1̰1̰/ or /1̰1/ stem undergoes the circle, both the tone 1̰ dissimilation and the tone circle apply. As shown in (96) and (97), the initial syllable is realized as tone 5, undergoing the same tone 1̰ dissimilation process as if the stem were not nominalized. The second syllable is realized with the tone assigned by the circle: tone 5 if it is underlyingly tone 1̰ (96) and tone 3 if it is underlyingly modal 1 (97).

(96) ˈtʃo⁵o⁵ʔĩ⁴
/tʃo̰¹=a̰¹=ʔĩ¹/
white=mouth=NMLZ:IV
'the one (Class IV) that has a white mouth'

(97) ˈtʃo⁵gɨ³ʔĩ⁴
/tʃo̰¹=gɨ¹=ʔĩ⁴/
white=blood=NMLZ:IV
'the one (Class IV) that has white sap'

The tone circle also interacts with tone 43 assimilation. Per §6.2, tone 43 assimilation applies to tone 43 syllables followed by a syllable with the tones 1̰, 1, or 3. When the tone circle applies to tones 1̰ and 3, they are respectively realized with tones 5 and 2, making them no longer triggers of the assimilation process. On the other hand, when the circle applies to tone 1 in an unstressed syllable, it is realized with tone 3, remaining a trigger of assimilation.

The interaction between tone 43 assimilation and the tone circle therefore occurs only in stems with the underlying form /43.1̰ or /43.3/. When such stems are subject to the tone circle, both tone 43 assimilation and the circle apply. The stem-initial syllable is realized with tone 31, undergoing the assimilation. The second syllable is realized with the tone assigned by the circle; in (98), since the second syllable is underlyingly tone 1̰, it is realized with tone 5.

(98) ˈme³¹me⁵kɨ³
/me⁴³=mḛ¹=kɨ³/
good=hand=NMLZ:II
'the one (Class II) that has pretty hands'

In other words, the tone circle displays exactly the same opaque, counterbleeding relationship with tone 43 assimilation as with tone 1̰ dissimilation.

8.5 Interim summary

The nominalizer tone circle is a morpho-tonological process targeting verb stems, triggered by certain morphosyntactic constructions involving subordination or relativization. Because the constructions that trigger the circle are not a natural class, I treat the nominalizer tone circle as a lexical property of some subordinating morphemes, rather than a grammatical tone process directly marking subordination.

The nominalizer tone circle applies to the final syllable of the verb stem. It fails to affect any tones on syllables to the left of the final syllable. If the final syllable is also the stressed syllable – that is, if the verb stem is monosyllabic – then the nominalizer tone circle causes the tone alternations shown in (73) (§8.2). If the verb stem is not monosyllabic, and the tone circle therefore applies to a unstressed syllable, then the circle causes the alternations shown in (84) (§8.3). Among the five tones that can occur on both stressed and unstressed syllables (tones 1̰, 1, 2, 3, and 4), the circle causes different changes on stressed vs. unstressed syllables for two – tones 1 and 4. It causes the same changes on two other tones – tones 1̰ and 3 – and generally fails to cause changes to tone 2.

While the nominalizer tone circle is sensitive to the phonological distinction between stressed and unstressed syllables, it is not sensitive to any other properties of the verb stem, such as its prosodic size or morphological composition (§8.3). Additionally, the nominalizer tone circle never affects any syllable other than the stem-final syllable. Contrary to the predictions of the OCP (§8.3), in stems with a sequence of syllables with the same tone, it affects only the tone of the final syllable, not the tone of preceding syllables with the same tone. Likewise, in verb stems where the underlying representation meets the environment for tone 1̰ dissimilation or tone 43 assimilation, the circle fails to bleed the other tone processes (§8.4). Thus, non-final syllables of a verb subject to the circle are always realized with exactly the same tones which they would display elsewhere.

9 General discussion

In the preceding sections, we have seen that in Cushillococha Ticuna, stress licenses additional segmental and tonal contrasts (§5), conditions phonological processes involving both segments and tones (§§6, 7), and conditions the outcome of the primary grammatical tone process (§8). In this section, I discuss broader implications of these phenomena – first, how they affect our understanding of word prosody in Amazonia as a geographic area (§9.1), and second, how they impact theoretical understanding of stress-tone interactions and grammatical tone (§9.2).

9.1 Areal implications

As described here, the prosodic system of Cushillococha Ticuna is radically different from the prosodic system of all other Amazonian languages. In order to contextualize this description for readers who are not familiar with Amazonian languages, here I note some of the most important differences between Ticuna and other languages of the region.

While many other Amazonian languages have contrastive tone, no other language in the region has more than two underlying tone levels (Hyman 2010; Epps and Salanova 2013: 2). As such, the tonal inventory of Cushillococha Ticuna – with five level tones and three contours (§3.2) – is substantially larger than the inventory of any other language in the region. This remains true even if some of the tones, such as level 5 or the contours, are seen as marginal because of their restricted distribution.

Related to the differences in inventory size are differences in the relationship between tone and stress. Although tone and stress coexist in a number of Amazonian languages, their interactions are unlike those seen in Cushillococha Ticuna. For example, in Kashibo-Kakataibo (Panoan; Zariquiey Biondi 2018), lexical tone and stress coexist and are both realized as high pitch; this contrasts with Cushillococha Ticuna, where tone and stress have separate phonetic realizations (§4.7). A more comparable kind of tone-stress interaction appears in Hup (Naduhup; Epps 2008: 86), where only stressed syllables bear contrastive tone (i.e., stress licenses tone). But while stress plays a role in tone licensing in Cushillococha Ticuna (§5.2), it licenses not the presence of tone, but the availability of additional tone contrasts. There are no other Amazonian languages where stress expands the tone inventory in this way. Since other languages also have fewer tone contrasts to license, this difference can be seen as epiphenomenal on inventory size.

Last, and again related to inventory size, grammatical tone has been described in other Amazonian languages, such as Bora (Bora-Muinane; Thiesen and Weber 2012) and several Tukanoan languages, including Kotiria (Stenzel 2013), Barasana (Gomez-Imbert and Kenstowicz 2000), and Máíhɨ̃ki (Farmer

2015). (Bora is in current and historical contact with Ticuna; Tukanoan languages are not.) As in Cushillococha Ticuna, grammatical tone in other Amazonian languages tends to apply to verbs and mark nominalization or subordination, categories that often overlap. For example, the most productive grammatical tone process in Bora marks subordination (Thiesen and Weber 2012: 89-92) and grammatical tone in Máíhĩ̃ki arguably marks nominalization (Farmer 2015: 21-24).

Despite this similar grammatical function, the Cushillococha Ticuna nominalizer tone circle is phonologically very different from the nominalizing and subordinating grammatical tone processes seen in Bora and Tukanoan languages. The nominalizing/subordinating tone processes in those languages have relatively simple additive or subtractive effects, such as linking a high tone to the left edge of the verb in Bora or deleting all non-root tones in Máíhĩ̃ki. In contrast, the nominalizer tone circle does not simply add or remove tones from the verb stem. Instead, it subjects the verb stem to a set of alternations which includes both chain shift and circle shift components. Though chain and circle tone shifts are well attested in other tone areas, such as Southeast Asia (Mortensen 2006) and West Africa (Sande 2018), I am not aware of grammatical tone processes with chain/circle shift components in any other Amazonian language. As with the differences in contrast licensing, this difference can be seen as epiphenomenal on the tonal inventory. Chain and circle shifts are only logically possible in systems with more than two values – otherwise, they are toggles (Baerman 2007) – and outside Ticuna, Amazonian tone systems only have two values.

Last, this comparative discussion raises the question of how the Cushillococha Ticuna tone system came into being. Answering this question would offer insights both for Amazonian historical linguistics and for understanding of the genesis of complex tone systems. But given our current tools, the question cannot be answered. Since Ticuna is an isolate and does not have written historical records, little can be known about its historical phonology.

One explanation for tonogenesis, however, can be eliminated: language contact. Documents by the Jesuit priest Samuel Fritz (1691) carefully described the colonial-era distribution of Indigenous groups in the lower Amazon area. All of these groups can be identified with a documented language family: they spoke Arawakan, Panoan, Peba-Yaguan, and Tupi-Guaraní languages (O'Hagan 2023). Many members of these language families – and others that have been in contact with Ticuna, such as Bora – display tone, but none have more than two levels. Thus, while the prosodic system of Ticuna has developed under contact with other tone languages, those languages' inventories were probably far smaller; they are unlikely to have exerted pressure toward greater tonal complexity.

9.2 Theoretical implications

The data presented in this paper bears on several basic questions about the phonology of tone. These questions include how tone and stress can interact (§9.2.1); whether stress-tone interactions can be analyzed with existing theories of stress-conditioned phonology (§9.2.2); and how grammatical tone and tone sandhi processes should be modeled (§9.2.3).

9.2.1 Interactions between tone and stress

Cushillococha Ticuna clearly displays both tone and stress, combining a large tone inventory with a large number of stress-conditioned phonological processes. Stress and tone interact in two ways: stress licenses additional tone contrasts, and it conditions certain tone processes.

Stress and tone have several logically possible licensing relationships across languages. Stress can license tone – either the presence of tone or the availability of additional tone contrasts. Where stress licenses the presence of tone, unstressed syllables either have no lexical tones (as in Hup; Epps 2008) or undergo phonetic neutralization or reduction of their tones (as in many East and Southeast Asian languages; Brunelle 2017). Neither of these licensing relationships appears in Cushillococha Ticuna: unstressed syllables have lexical tones, and their tones are not phonetically reduced. But as discussed above, stress does license additional tone contrasts, with contour tones and perhaps tone 2̰ appearing only on stressed syllables (§5.2). This restriction of contour tones to stressed syllables is cross-linguistically common and can be attributed to the increased duration of stressed syllables (Zhang 2004).

While interactions where stress licenses tone are most common, other types of interactions are also attested cross-linguistically. Tone and stress can be independently contrastive (Remijsen 2002; Remijsen & van Heuven 2005), and lexical tone can affect stress placement (de Lacy 2002). These less common types of tone-stress interaction, however, are absent in Cushillococha Ticuna. Stress is fixed and initial in the Prosodic Word (§4). Variance in stress placement within the morphosyntactic word in this language is due to variable relationships between the morphosyntactic word and PrWd, not due to lexical stress – unless one views a morpheme's ability to project a PrWd as a form of lexical stress – or effects of tone.

In the extent and nature of these licensing interactions between tone and stress, the prosodic system of Cushillococha Ticuna looks most similar to Oto-Manguean languages, especially Mixtecan and Trique languages such as San Martín Itunyoso Trique (DiCanio 2008). Exactly like Cushillococha Ticuna, Itunyoso Trique displays fixed stress, a large inventory of lexical tones, and a prominent role for stress in contrast licensing for both segments and tones. While Cushillococha Ticuna stress is word-initial and Itunyoso stress is word-final (DiCanio 2008: 20), stress has almost identical effects on contrast licensing in the two languages. In both, stressed syllables license additional consonants (DiCanio 2008: 42; §5.1) and the vowel /o/ (DiCanio 2008: 48; §5.1), as well as contour tones (DiCanio 2008: 157; §5.2).

But though the effects of stress on tone licensing in Cushillococha Ticuna are typologically expected, the effects of stress on tone processes are not. Many other languages across families, notably Oto-Manguean and Sino-Tibetan, have stress, tone, and large inventories of tone processes – all the ingredients for stress-conditioned tonology. But these other tone languages still generally do not display stress-conditioned tone processes other than neutralization. Cushillococha Ticuna, on the other hand, has many stress-conditioned tone processes, most of which are not neutralizing (§6, §8). This may reflect differences in morphological typology, as Ticuna is much more agglutinating than other languages represented in the tone literature.

9.2.2 Models of stress-conditioned phonology

Stress-conditioned phonological processes are generally analyzed in terms of positional faithfulness (Beckman 1998). Since positional faithfulness is a very general concept, the stress-conditioned phonology seen in Cushillococha Ticuna could be modeled using the theory. However, I argue that positional faithfulness is not analytically useful for all stress-conditioned phenomena in the language.

More specifically, while positional faithfulness is helpful for understanding stress-conditioned segmental phonology in Cushillococha Ticuna, it does not aid analysis of stress-conditioned tone processes. The segmental processes of /ɨ/ and /oa/ assimilation (§7) do represent an example of positional faithfulness (i.e., increased faithfulness to stressed syllables), since they preserve the vowel quality of the stressed syllable and apply assimilation to other syllables. In contrast, the tonal processes of tone 1̰ dissimilation and tone 43 assimilation represent the precise opposite of positional faithfulness. They repair marked tonal sequences by changing the tone of the stressed syllable, rather than those of unstressed syllables (§6). Similarly, the nominalizer tone circle causes tone alternations on both stressed and unstressed syllables. Where the circle's alternations vary with stress, as on tone 4 syllables, they are phonetically larger (i.e., less faithful) on stressed syllables (§8), again opposite the expected pattern.

So while the tone phonology of Cushillococha Ticuna is clearly stress-conditioned, that stress-conditioning involves prioritizing faithfulness to the tones of *unstressed* syllables. When morphology creates a marked tonal sequence, the tones of *stressed* syllables change to repair it, and when grammatical processes cause tone change, that change is larger (less faithful) on *stressed* syllables. This high ranking of unstressed syllable faithfulness is exactly opposite the typological pattern of greater faithfulness to stressed syllables (Beckman 1998) and reduction of unstressed syllables (González 2003).

With this context, modeling the stress-conditioned tone processes using positional faithfulness is possible. We only need to rank faithfulness to tone in unstressed syllables above general faithfulness to tone. But using positional faithfulness to analyze this phenomenon is not necessarily insightful. It provides no explanation for why Cushillococha Ticuna reverses the strong cross-linguistic pattern toward increased faithfulness to stressed syllables, or for why this reversal in positional faithfulness is found only for tone processes, not segmental ones. In a similar inversion of typological trends, Rolle (2018: 93) argues that 'dominant' grammatical tone processes, such as replacive grammatical tone, always prioritize affix faithfulness over root faithfulness. Together with what I have shown about unstressed syllable faithfulness in tone processes, this finding suggests that typological generalizations about positional faithfulness – whether to roots or to stressed syllables – may not apply to tone.

The stress-conditioned tone processes here, then, require a different model. Positional markedness (Zoll 2004), though less prominent in the literature than positional faithfulness, could easily be used to model tone 1̰ dissimilation and tone 43 assimilation. Constraints in this analysis would penalize marked structures on stressed syllables (e.g., tone 1̰ on a stressed syllable), possibly with phonetic motivations (e.g., the decreased airflow of creaky vowels conflicts with the increased duration of stressed syllables). On the other hand, while positional markedness may accommodate the simpler tone alternations, it is unclear whether this theory can model the stress-conditioned portions of the nominalizer tone circle, which I discuss next.

9.2.3 Models of tone sandhi and grammatical tone

Most phonological processes described in this paper are fairly phonetically natural – assimilatory or dissimilatory – even when the repairs they make are phonetically unexpected, as with tone 1̰ dissimilation. The tone circle, in contrast, is strikingly unnatural. It appears unmotivated by markedness, eliminating structures which are otherwise phonologically unmarked in the language. It is minimally constrained by faithfulness, making repairs that involve large phonetic changes to the underlying tone. And it eludes natural class analysis, giving disparate treatment to phonetically and (otherwise) phonologically similar tones.

Because of this unnaturalness, the tone circle cannot be modeled under any of the most recent theories of grammatical tone, such as those articulated by Mortensen (2006), McPherson and Heath (2016), or Sande (2018). The accounts of Mortensen (2006), McPherson and Heath (2016), and Sande (2018) are not appropriate to the tone circle because they are specific to grammatical tone phenomena that have different basic characteristics. Mortensen (2006) models tone circles that have the same number of input and output tonemes, while the input and output inventories of the nominalizer tone circle differ in both size and content. McPherson and Heath's (2016) account examines invariant replacive grammatical tone assigned by one constituent to another (e.g., L tone assigned by nominal possessors to the nouns they possess), while the nominalizer tone circle's melodies are variable and not entirely replacive. And Sande (2018) models scalar tone shifts, while the nominalizer tone circle lacks the internal consistency of a scalar shift.

Given its phonetic unnaturalness, the alternations of the nominalizer tone circle look more like tone sandhi in Sino-Tibetan languages than classic "grammatical tone." McPherson (2019) describes a similarly arbitrary set of grammatically conditioned tone alternations in Seenku (Mande; Burkina Faso), and argues that they are best analyzed in morphological terms – as selection among a set of phonologically conditioned suppletive allomorphs (Paster 2006) of the alternating morpheme. Her allomorph selection analysis follows analyses of phonetically arbitrary tone sandhi in Chinese languages developed by Zhang and Lai (2008).

The Cushillococha Ticuna tone circle does resemble some Chinese tone sandhi circles, especially the "right-dominant" sandhi found in Southern Min, Southern Wu, and Northern dialects (Zhang 2014). In both sets of alternations, the trigger is always to the right of the target, and the alternations are arbitrary and paradigmatic (i.e., based only on the target tone). The difference is that, unlike all of the Chinese tone sandhi circles described by Zhang (2014), the Ticuna tone circle can occur in the absence of a local phonological or morphological trigger – for example, in "until" clauses (§8.1). Since sandhi is defined as occurring at morphological or phonological junctures, analyzing this phenomenon as sandhi would expand the boundaries of the concept.

But leaving aside whether it is sandhi, can the tone circle be analyzed like sandhi, using allomorph selection? The allomorph-selection architecture is very general, and therefore also very powerful. To use it to produce the facts in §8, all we need to do is posit that the lexical entries for all verbs include two suppletive allomorphs: the allomorph that occurs in isolation and in constructions that do not induce the circle, and the allomorph that occurs in the tone circle. Since the tone circle can apply to any verb-stem-final syllable, these two allomorphs must be listed both for verb roots and for all other morphemes – such as verbal suffixes, enclitics, and inalienable nouns – which can occur as the final element of a verb stem. (99) and (100) give the lexical entries for the verb root 'eat fruit' and the inalienable noun 'sister' under this analysis.

(99) EAT FRUIT (v.)
 a. mṵ^{1} (non-circle)
 b. mu^{5} (circle)

(100) SISTER (n. inal.)
 a. e^{3}ɟa̰^{1} (non-circle)
 b. e^{3}ɟa^{5} (circle)

An alternative analysis of the tone circle based on allomorph selection, but not invoking the concept of sandhi, comes from Rolle's (2018) account of grammatical tone. Rolle analyzes all grammatical tone as floating tones, associated with morphemes that potentially also have segments and their own tones. Whether the floating tone of a grammatical morpheme replaces underlying tones, or combines with them according to general rules of the language's tonology, is determined by a morpheme-specific constraint ranking (Rolle 2018: ch. 3).

To model the tone circle using Rolle's theory, we must add is the statement that grammatical tone morphemes may undergo phonologically conditioned suppletive allomorphy – that is, that the floating tones of a grammatical tone morpheme may undergo allomorphy conditioned by the tone and/or stress of another syllable in the environment. We can then restate the alternations of the circle by listing as many allomorphs of the floating grammatical tones as we observe unique input-output tone pairs. (101) shows how this list of allomorphs would begin, assuming for the purposes of argument that the morpheme which triggers the tone circle has no segmental content.

(101)
 a. [5] / 1̰_ Accounts for /1̰/ → 5 in stressed and unstressed syllables
 b. [2 [+creaky voice]] / ˈ1_ Accounts for /1/ → 2̰ in stressed syllables
 c. [3] / 1_ Accounts for /1/ → 3 in unstressed syllables

Yet effectively, the McPherson- and Rolle-style analyses of the tone circle in (99)–(101) differ from the simple lists of alternations given in (74) and (85) only in notation. (74) and (85) represent the tone circle as a change to a tone that is already present in the underlying representation of the stem, while these analyses represent the circle as suppletive allomorphy of a stem morpheme (McPherson) or of the morpheme triggering the circle (Rolle). Analyzing the tone circle within this model, like analyzing the stress-conditioned phenomena using positional faithfulness, is possible. But it does not lead to different or greater insights about the circle than modeling it through rules. An additional weakness shared by both rule-based and allomorphy-based analyses is that they do not explain why phonologically conditioned tone alternations in the language involve the same inputs and outputs as the tone circle (e.g., why tone 1̰ becomes tone 5 in both dissimilation and the circle).

In sum, most existing approaches to tone sandhi and grammatical tone cannot describe the nominalizer tone circle. McPherson (2019) and Rolle's (2018) theories can, with some adaptation; however, these suppletion-based analyses are not much different from a list of the surface alternations. These issues show that the nominalizer tone circle demands either (a) a new theoretical approach to grammatical tone, or (b) an analysis as something besides grammatical tone or sandhi.

10 Conclusion

At first glance, tone (§3.2) is much more conspicuous than stress in the phonology of Cushillococha Ticuna. Yet stress is still present, as shown by the increased duration of stressed syllables (§4), the increased number of segments and tones licensed in stressed syllables (§5), and the large number of phonological processes conditioned by stress (§§6-8). Stress-conditioned processes are present in the segmental phonology (§6), general tone phonology (§7), and grammatical tone (§8), as well as in other domains, such as morphology, not covered in this paper. Because this system is profoundly different from the prosodic systems of all other South American languages, these findings significantly enrich our understanding of phonology on this continent (§9.1). Many of the results are also challenging to model under current phonological theories. They represent important new data for theories of stress-conditioned phonology in general, stress-tone interactions, tone sandhi, and grammatical tone (§9.2).

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