SOME PHONETIC STRUCTURES OF KOASATI

MATTHEW GORDON, JACK B. MARTIN, LINDA LANGLEY

This paper presents results of the first quantitative phonetic study of Koasati (cku), a Muskogean language spoken in Louisiana and Texas. We examine vowel quality, length contrasts in vowels and consonants, the limited system of lexical tone contrasts in nouns, and the grammatical system of tone in verbs. We also study the realization of several word-final consonant clusters (fn, tl, lw, etc.) that are absent in related languages and that are typologically unusual due to their sonority reversals. Finally, we examine the cognates in related languages of the tones we document in Koasati nouns and verbs.

Keywords: Koasati, Muskogean, phonetics, phonology, consonants, vowels, tone, pitch-accent, acoustics

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1. Introduction. Koasati (cku) is a Muskogean language distantly related to Alabama (akz), Choctaw (cho), Chickasaw (cic), Mikasuki (mik), and Creek (mus). Koasati is closest to Alabama within the family, though the degree of intelligibility between the two is fairly low. The language is spoken in two locations: by approximately 25% of the 900 enrolled members within the Coushatta Tribe of Louisiana, and by another small group of members of the Alabama-Coushatta Tribe of Texas. The language is endangered in both communities. A few individuals in their 20’s understand the language and can converse, but regular use of the language is common only among those over the age of 50. This project focuses on the larger group within the Coushatta Tribe of Louisiana.

Most previous work on Koasati has focused on vocabulary, texts, and grammar. Albert Pike, Albert S. Gatschet, and John R. Swanton collected vocabulary and texts (see Kimball 1991:14-15 for discussion of this early work). Mary R. Haas conducted fieldwork in the 1930’s, collecting vocabulary, texts, and verb paradigms (Haas 1938-39) and publishing a paper on men’s and women’s speech (Haas 1944). In 1992 David Rising published a thesis on switch-reference in Koasati (Rising 1992). The most extensive documentation of Koasati has been carried out by Geoffrey D. Kimball, who has published a reference grammar (Kimball 1991), dictionary (Kimball 1994), and texts (Kimball 2010).

There has been relatively little attention paid to Koasati phonology, and no instrumental phonetic studies of any kind. This paper aims to partially remedy this lacuna by providing phonetic documentation of several properties of Koasati, including formant structure of vowels and temporal characteristics of the pervasive length contrast in
vowels and consonants. In addition, we provide a phonetic description of accent in nouns and verbs, comparing the Koasati accentual system with that found in other Muskogean languages. Finally, we explore the phonetic characteristics of a number of typologically unusual (and unique among Muskogean languages) word-final clusters displaying sonority reversals.

2. Present study. In the remainder of the paper, we present results of several phonetic studies designed to fulfill three goals: first, providing instrumental verification of a number of segmental and prosodic features of the Koasati phonological system; second, contributing to the comparative phonetic documentation of the Muskogean language family; and third, describing the phonetic realization of certain typologically unusual properties.

2.1. Methodology. The present study is based on two lists of words which our experience suggested were representative of the phonological and phonetic properties targeted for examination. The first list comprised 70 items and was recorded from fourteen speakers (eight women and six men) in the Coushatta tribal community in Elton, Louisiana. Throughout the paper, data from the eight women will be labeled FS1 (female speaker 1) through FS8 (female speaker 8) and data from the six men will be labeled MS1 (male speaker 1) though MS6 (male speaker 6). The second list contained 82 words and focused on word-final consonant length and clusters and on the accent system. Recordings of this list were analyzed for six speakers (four women and two men), of whom four (three women, FS1, FS2, and FS6, and one man, MS1) constituted a subset of
the fourteen speakers recording the first list. The remaining two speakers who recorded only the second list will be labeled FS9 and MS7 in the paper. All speakers were members of the Koasati Language Committee who use the language every day and who were felt to represent different geographical locations in the community, different ages, and different families. Recordings were made at a sampling rate of 44.1kHz and a 16 bit depth using a handheld unidirectional Sennheiser MD46 microphone (at a distance of approximately one foot from the speaker’s mouth) connected to a solidstate recorder (Marantz PMD 660/661). Some speakers were recorded individually while others were recorded in groups ranging from two to four speakers. In the case of the first corpus, speakers read twice a list of words that was randomized and counterbalanced over the two repetitions. Speakers recording the second randomized list repeated each word three times. Data were transferred to computer in preparation for acoustic analysis using Praat (Boersma & Weenink 2010).

2.2. Organization of the paper. The paper is divided into three sections: one focused on vowels, another on consonants, and a third on accent in nouns and verbs. Each section begins with a brief phonological overview of the relevant property followed by the results of the phonetic study.

Section 3 targets the vowels. First, we present results of a study of vowel formants designed to determine the extent to which phonemic short and long vowels qualitatively differ as described in previous research on Koasati and noted for other Muskogean languages. We then investigate the durational profile of phonemic length contrasts in vowels, comparing results with those of similar studies of Koasati’s Muskogean relatives
Section 4 focuses on the consonants. First, we examine the realization of length distinctions in intervocalic consonants, situating the Koasati results within the typology of phonemic contrasts in duration. We then look at two interesting features of word-final consonants resulting from a productive process of apocope occurring in statements and commands. One of these features is the phonetic realization of a number of typologically unusual final rising sonority consonant clusters, which potentially violate the Sonority Sequencing Principle (Hooper 1976, Selkirk 1984, Clements 1990, Blevins 1995). The other is the potential existence of phonemic length distinctions in final position arising through apocope following a long consonant.

Section 5 examines the realization of lexical accent contrasts in nouns and grammatical accent in verb. This phase of the study contains a phonetic study of lengthening processes associated with verb accents to determine whether lengthening neutralizes underlying length contrasts or not.

3. Vowels. We agree with Haas (1944:f.n. 2) in recognizing three phonemic vowel qualities. These may be short or long (Table 1).

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2 Kimball (1991:23) also recognizes six vowel phonemes, but argues for a more abstract analysis with just three vowels. He proposes to reduce the vowel inventory by treating vowel length (\(\ddot{a}\)) as a consonant. This would simplify the placement of infixes, which in certain verbs appear to be placed before final CCV or :CV. For this reason, he lists only
Table 1. Vowel phonemes

\[i \text{ } i:\] \hspace{1cm} \[o \text{ } o:\]

\[a \text{ } a:\]

Table 2 shows near minimal pairs for short and long vowels in initial position. The length contrast is found initially and medially, but not at the ends of words.

Table 2. Contrasts between short and long vowels in initial position

<table>
<thead>
<tr>
<th>Vowel</th>
<th>Word</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>aha</td>
<td>'sweet potato'</td>
<td>aːti</td>
</tr>
<tr>
<td>ifa</td>
<td>'dog'</td>
<td>iːsa</td>
</tr>
<tr>
<td>oki</td>
<td>'water'</td>
<td>oːla</td>
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</table>

Impressionistically, vowels tend to be increasingly centralized as they get shorter: the short vowels \(i\), \(a\), and \(o\) thus approach \([ɪ]\), \([ɐ]\), and \([ʊ]\), especially in closed syllables.\(^3\)

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three vowels \(i\), \(a\), and \(o\) in his vowel chart and includes \(:\) as a glottal glide in his consonant chart (p. 18).

\(^3\) There appear to have been additional allophones of the vowels in the 1930’s. Haas (1938-1939) transcribes short \(i\) as \([ɛ]\) in final position, where it is accompanied by falling
In addition to the vowel phonemes in Table 1, Koasati makes a distinction between oral and nasalized vowels. Haas (1944:f.n. 2) says simply, “All vowels occur also nasalized” and transcribes both long and short nasal vowels. Kimball (1991) takes the position that vowel nasalization is a “marginal” phoneme. He describes the distribution of nasal vowels this way:

Although nasalized vowels frequently occur, all word-medial nasal vowels are the result of either a nasal-fricative sequence, or the operation of the n[asalizing]-grade, which causes morphemic nasalization. Word-finally, nasalization is the result of a nasalizing phrase-terminal marker. Therefore, although nasalized vowels will be written in this work, it must be realized that nasal vowels are not autonomous phonemes in Koasati. (Kimball 1991:25)

We agree with Kimball’s basic point: nasalized vowels generally derive predictably from nasal consonants, signal grammatical meaning (‘very’, nonsubject marking, etc.), or indicate boundary phenomena (Kimball’s phrase-terminal marker). No two nouns are ever distinguished based on the oral or nasal quality of a vowel. At the same time, it is clear that speakers attend to the oral/nasal distinction in interpreting the meaning of inflected forms. It seems more straightforward to transcribe the auditory cue that signals (emphatic) intonation. She transcribes iː as [eː] in all positions. We have not observed either of these processes.
the change in meaning (whether that meaning is lexical or grammatical).\footnote{A separate question is whether it is necessary to distinguish short nasalized vowels from long nasalized vowels. Our practice is to record long nasalized vowels in the nasalizing grade, and short nasalized vowels elsewhere.}

### 3.1. Vowel quality

The frequencies of the first three formants for short and long vowels were measured over a 25 millisecond window centered in each vowel targeted for measurement. Formant values were collected using a Praat script and checked visually against a wideband spectrogram. In some cases, values had to be recalculated using different measurement parameters. Target vowels appeared word-medially in open syllables between the consonants \( k \) and \( l \). All vowels occurred in prominent syllables: either long vowels in heavy syllables, short vowels in stem-final position (in the data here before the future suffix -laho, which appears as lahõ word-finally) or an odd-numbered short vowel in a string of light CV syllables, i.e. strong syllables in trochaic feet (see 5.3 for discussion of metrical structure in Koasati). An attempt was made to compare vowels in words of roughly equivalent length: with the exception of one tetrasyllabic word, words containing the target vowels had either five or six syllables.

Table 3 shows the words used in the phonetic study of the vowels. Two speakers (MS2 and MS3) had different pronunciations of the target vowel in pakpakilahõ ‘it will bubble’: for these speakers, we measured the third vowel in atfitika ‘rope’ instead.
Table 3. Words containing the vowel (in bold) targeted for measurement

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<tr>
<th>Vowel</th>
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<th>Long</th>
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<td>a</td>
<td>walikaːalahõ ‘s/he will run’</td>
<td>atakaːilahõ ‘s/he will hang it’</td>
</tr>
<tr>
<td>i</td>
<td>pakpakilahõ ‘it will bubble’</td>
<td>paːfiːkiːilahõ ‘s/he will set (2+) down’</td>
</tr>
<tr>
<td>o</td>
<td>iskolahõ ‘s/he will drink’</td>
<td>lokəːilahõ ‘they (3+) will stand’</td>
</tr>
</tbody>
</table>

Average values for the first three vowels were taken for the fourteen speakers. Values appear in table 4. Each box delimited by thick lines contains data from a single speaker. Speakers are coded numerically and according to their gender (FS for female speakers and MS for male speakers); FS1 indicates female speaker 1, FS2 indicates female speaker 2, and so on. Formant values are for the first three formants (listed in columns) averaged over the two tokens recorded for each speaker.

Formant values for individual tokens produced by all the female speakers are plotted together in figure 1, while those uttered by the male speakers appear in figure 2.
Figure 1. Plot of the first two formants for phonemic long (on top) and short (on bottom) vowels for eight female speakers.
Figure 2. Plot of the first two formants for phonemic long (on top) and short (on bottom) vowels for six male speakers
Table 4. Formant values for Koasati short and long vowels from fourteen speakers
(two tokens averaged together for each speaker)

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<th>F2</th>
<th>F3</th>
<th>SPEAKER &amp; VOWEL</th>
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<td>366</td>
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<tr>
<td></td>
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<td>336</td>
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<td>336</td>
</tr>
<tr>
<td></td>
<td>2600</td>
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</tr>
</tbody>
</table>
As figures 1 and 2 show, both the female and male speakers clearly differentiate the three long vowels from each other. The short vowels are also distinguished, though they are centralized relative to their long counterparts. This tendency to centralize is particularly apparent in the male speaker data. Centralization is more apparent in the front-back dimension than the height dimension for the low vowel, while the two long non-low vowels are more peripheral than their short counterparts in both the height and the front-back dimensions. The front and back non-low vowels differ only slightly in height, with the front vowel being slightly higher than its back counterpart.

As noted above (f.n. 3), Haas (1938-39, 1944) transcribed the short vowels \(a, i, \) and \(o\) with more central phonetic values [ʌ] (equivalent to IPA [ɐ]), [ɪ] (but [ɛ] finally), and

<table>
<thead>
<tr>
<th></th>
<th>Short</th>
<th>Long</th>
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</tr>
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<tbody>
<tr>
<td>(a)</td>
<td>785</td>
<td>1599</td>
<td>(a)</td>
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</tr>
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<td></td>
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<tr>
<td>(o)</td>
<td>497</td>
<td>1197</td>
<td>(o)</td>
<td>470</td>
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<tr>
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<td>FS7</td>
<td></td>
<td></td>
<td>MS6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td>460</td>
<td>2057</td>
<td>(i)</td>
<td>483</td>
<td>1986</td>
</tr>
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<td></td>
<td>2912</td>
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<td>2605</td>
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</tr>
<tr>
<td>(a)</td>
<td>890</td>
<td>1656</td>
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<tr>
<td>(o)</td>
<td>535</td>
<td>1332</td>
<td>(o)</td>
<td>489</td>
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<tr>
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<table>
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<th></th>
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<th>Long</th>
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<tbody>
<tr>
<td>(a)</td>
<td>470</td>
<td>1298</td>
<td>(a)</td>
<td>650</td>
<td>1312</td>
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<td></td>
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<td>(o)</td>
<td>470</td>
<td>1298</td>
<td>(o)</td>
<td>489</td>
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<tr>
<td></td>
<td>2158</td>
<td></td>
<td></td>
<td>2377</td>
<td></td>
</tr>
</tbody>
</table>
She transcribed the long vowels \( aː, iː, oː \) with the phonetic values \([aː], [eː], \) and \([oː]\).

The closest correspondence between our data and Haas’ transcriptions is for the low vowel. In the case of the two non-low vowels, Haas’ transcriptions suggest a slightly lower quality for the long member of each pair, i.e. long \([eː]\) vs. short \([i]\) and long \([oː]\) vs. short \([ʊ]\). The centralization she describes is supported by figures 1 and 2, except that we see no lowering of \(iː\) to \([eː]\). It is also interesting that the qualitative relationship between short and long vowels differs substantially between the female speakers in figure 1 and the male speakers in figure 2. Other differences between men and women have been described for Koasati (Haas 1944, Kimball 1991), but degree of vowel centralization is not one of them.

The patterns visible in the formant plots are corroborated by statistical analyses of the data by gender. We first consider the results for the female speakers. An analysis of variance (ANOVA) with vowel quality as the independent variable and the first and second formant as the dependent factors was conducted for the long vowels produced by the female speakers. There was a significant main effect of vowel on both F1 (\(F(2, 47) = 257.412, p<.001\)) and F2 (\(F(2, 47) = 593.297, p<.001\)). Bonferroni posthoc tests indicated that all three vowels were reliably differentiated (at \(p<.001\)) in all pairwise comparisons except F1 for \(i\) vs. \(o\), which were not distinguished.

An ANOVA conducted over the short vowels showed that the three short vowels were also distinguished for the female speakers along both the F1 (main effect: \(F(2, 47) = 75.495, p<.001\)) and F2 (main effect: \(F(2, 47) = 198.228, p<.001\)) dimensions.
Bonferroni posthoc tests showed that all three vowels were reliably differentiated at the p<.001 level in all pairwise comparisons except F1 for $i$ vs. $o$, which narrowly achieved significance (p=.034).

In order to examine the effect of phonemic length on vowel quality, ANOVAs were also conducted for individual vowel qualities with phonemic length category as the independent variable and the first two formants as dependent variables. The low vowel was distinguished in both F1 ($F(1, 31) = 14.942, p=.001$) and F2 ($F(1, 31) = 96.472, p<.001$) as a function of length. The high front vowel was also differentiated based on phonemic length for both formants: for F1, $F(1, 31) = 26.390, p<.001$; for F2, $F(1, 31) = 16.051, p<.001$. Short and long back vowels also differed from each other for both formants: for F1, $F(1, 31) = 44.060, p<.001$; for F2, $F(1, 31) = 97.784, p<.001$.

Turning to the male speaker data, separate ANOVAs conducted for the short and long vowels indicated a significant effect of vowel quality on the first two formants for both phonemic lengths: for F1 for the long vowels, $F(2, 34) = 157.842, p<.001$; for F2 for the long vowels, $F(2, 34) = 490.750, p<.001$; for F1 for the short vowels, $F(2, 33) = 9.996, p<.001$; for F2 for the short vowels, $F(2, 33) = 72.752, p<.001$.

For the long vowels, Bonferroni posthoc tests showed that all three vowels were reliably differentiated at the p<.001 level in both F1 and F2 for all pairwise comparisons except for F1 in the comparison of $i$ vs. $o$, which did not reach significance. The short vowels were all reliably differentiated from each other along the F2 dimension according to pairwise posthoc tests (p<.001). For F1, $i$ vs. $o$ were not distinguished, while other pairwise comparisons reached significance at p<.01.
For the male speaker data, ANOVAs were also conducted for individual vowel qualities with phonemic length category as the independent variable and the first two formants as dependent variables. The low vowel was distinguished in both F1 (F (1, 23) = 20.383, p=.001) and F2 (F (1, 23) = 28.791, p<.001) as a function of length. The high front vowel was also differentiated based on phonemic length for both formants: for F1, F (1, 20) = 27.045, p<.001; for F2, F (1, 20) = 11.170, p=.003. Short and long back vowels also differed from each other for both formants: for F1, F (1, 23) = 26.111, p<.001; for F2, F (1, 23) = 63.816, p<.001.

In summary, long vowels are more peripheral than their short counterparts, where the effect is quite strong along both the front-back and height dimensions for the front and back vowels. For the low vowels, the centralization of short vowels is most apparent in the front-back plane, but still statistically robust in the height dimension. Nevertheless, despite the tendency for short vowels to be less peripheral than their long counterparts, they are still reliably distinguished from each other. Overall the vowel inventory is quite symmetrical, with the low vowel occupying the center of the vowel space (somewhat backer in the case of the long vowels) and the two non-low vowels differing only slightly in height (a difference which was only robust in our data for the short vowels produced by the female speakers).

The phonetic data on vowel quality from Koasati closely mirror results from related languages with similar vowel inventories. In both Creek (Johnson & Martin 2001) and Chickasaw (Gordon et al. 2000), short vowels are centralized relative to their long counterparts, a common cross-linguistic pattern (Lehiste 1970). Furthermore, the high
front vowel is slightly higher than its back counterpart in both languages, as in Koasati, though the difference in height is slightly larger in Creek than in either Koasati or Chickasaw.

3.2. Vowel duration. We also measured the duration of the target short and long vowels in the words in table 4 using a waveform in conjunction with a time-aligned wideband spectrogram. Average duration values collapsed over the 14 speakers are shown in figure 3 followed by individual speaker values in table 5.

![Figure 3. Duration (in seconds) of phonemic short and long vowels averaged over 14 Koasati speakers. Whiskers represent 95% confidence intervals.](image)
Table 5. Duration (in milliseconds) of short and long vowels by speaker

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Short</th>
<th>Long</th>
<th>Short</th>
<th>Long</th>
<th>Short</th>
<th>Long</th>
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<tbody>
<tr>
<td>FS1</td>
<td>74</td>
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<td>83</td>
<td>119</td>
<td>73</td>
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</tr>
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<tr>
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<td>71</td>
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<td>115</td>
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<td>FS7</td>
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<td>135</td>
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<td>93</td>
<td>77</td>
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<td>MS3</td>
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<td>133</td>
<td>46</td>
<td>94</td>
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<td>MS4</td>
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<td>88</td>
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<td>124</td>
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<tr>
<td>MS5</td>
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<td>47</td>
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<td>MS6</td>
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<td>90</td>
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<tr>
<td>Means</td>
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<td>134</td>
<td>68</td>
<td>108</td>
<td>56</td>
<td>127</td>
</tr>
</tbody>
</table>

The phonemic long vowels are considerably longer than the short vowels, particularly in the case of the two non-front vowels. The long low vowel and long back vowel averaged more than twice the length of their short counterparts across speakers: long \( a \): was 2.23
times as long as short \(a\), and long \(o:\) was 2.27 times as long as its short analog. The duration ratio between the short and long front vowel is not as great: 1.59:1 pooled across speakers. All speakers have a clear length distinction for all three vowel qualities, though the magnitude of the difference varies between speakers. A two-factor ANOVA (vowel quality and phonemic length) conducted over the data from both genders confirmed the robustness of the effect of phonemic length on phonetic duration: \(F(1, 166) = 533.9, p<.001\), while posthoc tests corroborated the length distinctions between pairs of vowels.

It is interesting to note that duration differences between short and long vowels observed for the two non-low vowels are considerably larger than those found in Chickasaw or Creek. Gordon et al. (2000) found that phonemic long \(a:\) in Chickasaw was 1.78 times longer than its short counterpart and phonemic long \(o:\) was 1.72 times as long as short \(o\). Chickasaw and Koasati have in common, however, that the duration ratio between long \(i:\) and short \(i\) is smaller than for the other two vowel qualities: 1.55:1 in Chickasaw and 1.59:1 in Koasati. Johnson & Martin (2001) report a 1.81:1 long:short ratio for Creek collapsed across vowel qualities, considerably shorter than that observed for the two non-front pairs in Koasati.

The ANOVA also revealed an effect of vowel quality on duration \((F(2, 166) = 3.825, p=.024)\), as well as an interaction between phonemic length and vowel quality: \(F(2, 166) = 16.603, p<.001\). This interaction was attributed to the fact that the low vowel was slightly longer than the high front vowel on average \((p=.014\) in a Bonferroni posthoc test), whereas other pairwise comparisons of vowels did not reach significance.
Interestingly, as the figure shows, the greater length of the low vowel relative to the high vowel was only found in the long vowel series and not for the short vowels.

4. Consonants. We present the consonant phonemes of Koasati in Table 6, agreeing closely with Haas (1944:f.n.2). All of the consonants have contrastive long counterparts, a property we examine in 4.1.

Table 6. The consonants of Koasati

<table>
<thead>
<tr>
<th></th>
<th>Bilabial</th>
<th>Labio-dental</th>
<th>Dental/Alveolar</th>
<th>Post Alveolar</th>
<th>Labio-velar</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stops</td>
<td>p b</td>
<td>t</td>
<td>tf</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasals</td>
<td>m</td>
<td>n</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fricatives</td>
<td>f s, ɬ</td>
<td>s, ɬ</td>
<td></td>
<td>h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approx.</td>
<td>l j w</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that, as in most related languages, there is only one voiced stop (b). Haas’s 1947 explanation of this asymmetry is that a Proto-Muskokegan labial-velar stop *kʷ developed as b in all the languages except Creek, where it yielded k or p. Thus Proto-Muskokegan *kʷihi ‘mulberry’ develops as bihi in Koasati but as kiː in Creek.
Kimball (1991:20) differs in a few details. He describes the voiceless stops and affricates as aspirated in initial and medial position. Voice-onset-time (VOT) values for initial voiceless stops in our data range from roughly 10 milliseconds to 40 milliseconds where the lower values are typical for bilabial and dental/alveolar stops and the higher values for velars. These values place Koasati in the region straddling the “unaspirated” and “slightly aspirated” categories according to Cho & Ladefoged’s (1999) classification based on a study of VOT 18 languages. Kimball describes the voiceless fricative s as palato-alveolar in his consonant chart, but says that it has dental, alveolar, and palatal allophones. We find it is generally alveolar, but post-alveolar in the sequence stʃ (pronounced [ʃʃ]).

One striking feature of Koasati phonology is the pronunciation of h. The sequence VhCV is generally pronounced VːCV when C is a voiced consonant. A form like asihli-lahõ ‘he/she will wash (something)’ is thus pronounced [ɑːsǐːlǐlɑhõ]. The h in the stem surfaces in a command, however, when the final vowel is deleted: thus, asîhl ‘wash it!’ is pronounced [ɑːsîːl].

Kimball (1991:20) describes f as bilabial. Haas (1938-39) also recorded a voiceless bilabial fricative, but the speakers we have observed closely have a labio-dental fricative (though there may be some coarticulatory rounding before o). Figure 4 shows a representative frame from a video taken of the word fo ho ‘bee’ (produced by speaker FS9, a woman in her 70s) showing contact between the upper teeth and lower lip for f.
It is plausible that the labio-dental articulation of $f$ is a relatively recent innovation. A similar shift from bilabial $f$ to labio-dental $f$ has been documented for Creek (Martin 2011).

4.1. Duration of intervocalic short and long consonants. In order to assess the robustness of consonant length contrasts, the duration of several short vs. long consonant pairs in the environment $a __ a$ was measured from a waveform with the aid of a time-aligned spectrogram. Measured pairs included $p, t, k, s, l,$ and $ʧ$. The words from which the measurements were taken appear in table 7. Of the forms with long consonants, two ($ʧahapəːkan ‘five’$ and $haffalifilaho ‘s/he will detain (one)’) are long as a result of the rising-geminating grade and thus marked with an IPA length mark. The other words are all underlying long. Long consonants of both types were included after a phonetic comparison indicated their durational equivalence (see 5.2). Two tokens of each consonant were measured for the target words in most cases except for a few exceptions. For speaker MS6, short $k$ was measured in $ostəːkan ‘four’$ instead of $atakapkalaho ‘it will$
snag’, since the k in the latter word was lenited to a voiced stop. For this same speaker as well as for speaker FS3, the long kk was measured in takka ‘catfish’ since both speakers pronounced the target word biyakka ‘chicken hawk’ with a kh cluster. One token of takka was substituted for the target word for speaker FS4, since she pronounced the target word biyakka ‘chicken hawk’ once with a kh cluster and once with a long kk.

Table 7. Words used for comparing the duration difference between short and long consonants.

<table>
<thead>
<tr>
<th>C</th>
<th>SHORT</th>
<th>LONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>apala ‘light, lamp’</td>
<td>τfahapǎːkan ‘five’ (rising-geminating grade)</td>
</tr>
<tr>
<td></td>
<td>tapatfka ‘quilt’</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>ataffo ‘grasshopper’</td>
<td>satta ‘turtle’</td>
</tr>
<tr>
<td></td>
<td>albata ‘alligator’</td>
<td></td>
</tr>
<tr>
<td>k</td>
<td>batfaka ‘ribbon’</td>
<td>biyakka ‘chicken hawk’</td>
</tr>
<tr>
<td></td>
<td>atakapkalahõ ‘it will snag’</td>
<td></td>
</tr>
<tr>
<td>s</td>
<td>asaːla ‘basket’</td>
<td>fassisi corn</td>
</tr>
<tr>
<td>l</td>
<td>palana ‘bean’</td>
<td>hallaki ‘bat (animal)’</td>
</tr>
<tr>
<td>tf</td>
<td>hafʃaːlitfilahõ ‘s/he will stand (one) up’</td>
<td>hafʃallitfilahõ ‘s/he will detain (one)’ (rising-geminating grade)</td>
</tr>
</tbody>
</table>
Duration data for the short vs. long pairs are summarized graphically in figure 5 with individual speaker data appearing in table 8. In considering the results, note that for s, the duration data may be confounded by the fact that the word containing the geminate has only two syllables whereas the word containing the singleton has three. This could increase the absolute duration difference between single and geminate consonants if the duration of individual sounds in a word is inversely correlated with the total duration of the word (see Fletcher 2010 for an overview of compression and other timing effects).

![Figure 5](image.png)

Figure 5. Consonant duration (in seconds) for six short vs. long consonant pairs (in the case of the affricate, closure plus frication) averaged over 14 speakers. Whiskers indicate 95% confidence intervals.
Table 8. Consonant duration (in milliseconds) for short vs. long consonant pairs for 14 speakers

<table>
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<tr>
<th>SPEAK</th>
<th>$p$</th>
<th>$pp$</th>
<th>$t$</th>
<th>$tt$</th>
<th>$k$</th>
<th>$kk$</th>
<th>$tʃ$</th>
<th>$tʃʃ$</th>
<th>$s$</th>
<th>$ss$</th>
<th>$l$</th>
<th>$ll$</th>
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<td>105</td>
<td>240</td>
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<td>51</td>
<td>185</td>
<td>71</td>
<td>127</td>
<td>250</td>
</tr>
<tr>
<td>FS2</td>
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<td>190</td>
<td>103</td>
<td>260</td>
<td>89</td>
<td>300</td>
<td>64</td>
<td>71</td>
<td>163</td>
<td>80</td>
<td>126</td>
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<tr>
<td>FS3</td>
<td>81</td>
<td>182</td>
<td>91</td>
<td>208</td>
<td>83</td>
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</tr>
<tr>
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<td>219</td>
<td>97</td>
<td>226</td>
<td>81</td>
<td>187</td>
<td>68</td>
<td>57</td>
<td>163</td>
<td>47</td>
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<tr>
<td>FS5</td>
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<td>158</td>
<td>105</td>
<td>161</td>
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<td>274</td>
<td>97</td>
<td>208</td>
<td>88</td>
<td>53</td>
<td>128</td>
<td>76</td>
<td>141</td>
<td>217</td>
</tr>
<tr>
<td>MS1</td>
<td>76</td>
<td>165</td>
<td>69</td>
<td>206</td>
<td>60</td>
<td>136</td>
<td>30</td>
<td>64</td>
<td>97</td>
<td>106</td>
<td>107</td>
<td>206</td>
</tr>
<tr>
<td>MS2</td>
<td>76</td>
<td>168</td>
<td>88</td>
<td>197</td>
<td>60</td>
<td>127</td>
<td>56</td>
<td>45</td>
<td>109</td>
<td>38</td>
<td>90</td>
<td>173</td>
</tr>
<tr>
<td>MS3</td>
<td>94</td>
<td>191</td>
<td>79</td>
<td>203</td>
<td>64</td>
<td>157</td>
<td>55</td>
<td>45</td>
<td>144</td>
<td>68</td>
<td>116</td>
<td>194</td>
</tr>
<tr>
<td>MS4</td>
<td>109</td>
<td>168</td>
<td>74</td>
<td>217</td>
<td>93</td>
<td>141</td>
<td>48</td>
<td>66</td>
<td>158</td>
<td>52</td>
<td>108</td>
<td>228</td>
</tr>
<tr>
<td>MS5</td>
<td>116</td>
<td>161</td>
<td>121</td>
<td>239</td>
<td>64</td>
<td>154</td>
<td>82</td>
<td>56</td>
<td>219</td>
<td>41</td>
<td>102</td>
<td>283</td>
</tr>
<tr>
<td>MS6</td>
<td>68</td>
<td>211</td>
<td>50</td>
<td>177</td>
<td>49</td>
<td>160</td>
<td>27</td>
<td>51</td>
<td>120</td>
<td>56</td>
<td>96</td>
<td>183</td>
</tr>
<tr>
<td>Means</td>
<td>98</td>
<td>180</td>
<td>93</td>
<td>221</td>
<td>76</td>
<td>177</td>
<td>61</td>
<td>56</td>
<td>147</td>
<td>65</td>
<td>115</td>
<td>218</td>
</tr>
<tr>
<td>Ratio</td>
<td>1.84:1</td>
<td>2.37:1</td>
<td>2.34:1</td>
<td>1.82:1</td>
<td>1.90:1</td>
<td>2.45:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
All the short vs. long pairs are clearly distinguished durationally, though the relative duration of the two members of each pair varies depending on the consonant and the speaker. As the figure shows, long \textit{tt}, \textit{kk}, and \textit{ll} are more than twice the length of their short counterparts averaged over all speakers. Long \textit{ʧʧ} (phonetically [tʃ]) is less than twice the length of short \textit{ʧ} averaged (1.82:1), but the closure phase of the long affricate is more than twice the duration (2.41:1) of the short affricate. The bilabial stop \textit{p} and the fricative \textit{s} also display average long:short ratios of less than 2:1. There is no obvious difference between the length of long consonants resulting from the rising-geminating grade (\textit{ʧʌhʌpːɑːkən} ‘five’ and \textit{bʌfjαlːiːfɪlɑːhə} ‘s/he will detain (one)’) and long consonants in underlying forms (see 5.2 for further analysis).

The variation between Koasati consonants in their long:short ratios is mirrored by cross-linguistic data. In many languages, phonemic long consonants are at least twice as long as short consonants, e.g. Finnish (Lehtonen 1970), Estonian (Lehiste 1966, Ojamaa 1976), Bengali (Lahiri and Hankamer 1988), Japanese (Han 1994), Italian (Farnetani and Kori 1984), Turkish (Lahiri and Hankamer 1988), Hungarian (Meyer and Gombocz 1908), Toba Batak (Cohn et al. 1999), Malayalam (Local and Simpson 1999), Thurgovian Swiss German (Kraehenmann 2001), Tashlhiyt Berber (Ridouane 2010), and Levantine Arabic (Miller 1987). In a substantial minority of languages, however, long:short ratios fall below 2:1, e.g. Dogri (Ghai 1980), Icelandic (Orešnik and Pétursson 1977), Norwegian (Fintoft 1961), Sinhala (Letterman 1994), Buginese (Cohn et al. 1999),
Madurese (Cohn et al. 1999), Maltese Arabic (Hume et al. 2010), and Cypriot Greek (Arvaniti and Tserdanelis 2000).

The differences between short and long consonants in Koasati are generally greater than those observed in Chickasaw, where most long consonants are less than twice the duration of their corresponding singletons (Gordon et al. 2000). For many consonants, Gordon et al., in fact, report long:short ratios of less than 1.5:1. Perception of the short vs. long contrast in Chickasaw, however, is facilitated in many contexts by a process of iambic vowel lengthening (absent in Koasati) that is blocked before long but not short consonants (see 5.3 for discussion of metrical structure in Muskogean).

4.2. Word-final consonant clusters. As in other Muskogean languages, most logically possible combinations of two consonants are attested in clusters word-medially.\(^5\) Word-initially, as in Creek (Martin 2011), aphaeresis has led to many sC clusters, e.g. stintijapka ‘can opener’, smokafka ‘adornments (e.g. jewelry, decorations)’, shajka ‘eraser’. These invariably include the instrumental applicative prefix, which has the form s- before consonants and st- before vowels (Kimball 1991:140). Peripheral fricative + C clusters of this type, although rare in some of the Muskogean languages, are common cross-linguistically, much like the initial and final clusters in English streets, stamps.

Particularly striking from a typological perspective is the rich array of clusters that Koasati possesses word-finally, owing to a process of final vowel deletion in statements

---

\(^5\) Kimball (1991:29) provides a chart of permissible clusters.
(1a) and commands (1b). This process is suppressed in questions (1c). Note that commands end in a sharp pitch fall indicated by $^{HL}$ in the transcription.

(1)  
   a. $hòː kf$
   
   put.on:LGR
   ‘s/he is putting (clothing) on’
   
   b.  $hokf^{HL}$
   
   put.on
   ‘put it on’!
   
   c.  $hòː kfâ$
   
   put.on:LGR
   ‘is s/he putting (clothing) on?’

Final vowel deletion potentially allows all intervocalic clusters to surface word-finally, thereby greatly expanding the possible syllable types. Of particular interest are several rising sonority clusters that constitute potential violations of the Sonority Sequencing Principle (Hooper 1976, Selkirk 1984, Clements 1990, Blevins 1995), according to which syllables are required to have a single sonority peak. In final clusters with rising sonority, the higher sonority second member of the clusters constitutes a second sonority peak in addition to the vowel preceding the cluster. In the word $bìː tl$ ‘s/he is dancing’, for example, the final lateral is higher in sonority than the preceding voiceless stop, thereby creating a second sonority maximum after the vowel nucleus. Similar rising sonority
clusters occur in words like \(hò\text{fn}\) ‘s/he is smelling it’, \(tà\text{lw}\) ‘s/he is singing’, and \(hò\text{kb}\) ‘s/he’s stringing them’.

Interestingly, our data suggest that final clusters that phonemically appear to introduce a second sonority peak create production problems for speakers and are realized phonetically in ways that reduce or eliminate the syllable-final sonority rise. One strategy for mitigating these sonority violations involves final devoicing. Clusters that consist of a voiceless stop followed by a voiced consonant spread their voicing regressively from the voiced consonant to the preceding voiceless consonant. This regressive assimilation is, in fact, a more general process affecting intervocalic clusters as well as intervocalic singleton stops and even, on rare occasion, the fricative \(s\). Thus, \(bì\text{tlil}\) ‘I am dancing’ is characteristically realized with a voiced \([d]\), i.e. \([bì\text{dlil}]\) and \(hò\text{kbil}\) ‘s/he is stringing them’ with a voiced \([g]\), i.e. \([hò\text{gbil}]\). There is an interesting twist on this voicing assimilation process in final position, where voicing spreads to the first member of the cluster but the second member of a cluster devoices either completely or partially. Thus, \(bì\text{tl}\) ‘s/he is dancing’ is typically realized as \([bì\text{d}l]\) and \(hò\text{kb}\) as \([hò\text{gp}]\).

The combination of regressive voicing coupled with final devoicing creates a voiced + voiceless cluster of falling sonority that eliminates the second sonority peak. Figures 6 and 7 depict representative examples of an intervocalic and final \(tl\) cluster, respectively.

---

6 Speakers make a clear distinction between \([l]\) and \([l]\).
Figure 6. Regressive voicing of $t$ in ʧʧ ʧʧ ʧʧ ʧʧ ‘I’m jumping’ as produced by speaker MS6.
Figure 7. Regressive voicing of $t$ and final devoicing of $l$ in $\text{ʧʧʧʧ}^{\text{HL}}$ ‘jump!’ as produced by speaker MS6.

Unlike stops, oral fricatives preceding a voiced consonant do not undergo voicing assimilation, e.g. $\text{kolōsnani}$ ‘rooster’, $\text{hōfнал}$ ‘I am smelling it’. Final devoicing still applies after fricatives, however. Thus, $\text{hōfн}$ ‘s/he is smelling it’ is typically realized with a voiceless final nasal, i.e. $\text{hōfн}$.

Another rising sonority cluster occurring word-finally is $\text{lw}$, as in $\text{tàlw}$ ‘s/he is singing’. We have observed two different speaker-dependent strategies for eliminating
the rising sonority profile of this lateral + glide cluster. One is for an epenthetic [ɜ] to be inserted between the lateral and glide. With anticipatory rounding, this sounds very much like [o], i.e. [tàlow]. The insertion of the epenthetic vowel creates an additional syllable, which serves to correct the second sonority peak.

Other speakers time the lip rounding associated with the glide such that it overlaps with virtually the entire lateral and even a portion of the preceding vowel. The result is essentially a labialized lateral, i.e. [tàl̪ʷʷ], rather than a true cluster of lateral plus glide.

Acoustic and video displays (made using an iPhone with a temporal resolution of 33 milliseconds) of two representative pronunciations of the root *talw* excerpted from the word *intalw*̂^HL ‘sing for her/him!’ , one with an epenthetic vowel and the other with a labialized glide, are shown in figures 8 and 9, respectively. Figure 8 shows a spectrogram depicting the first variant as produced by speaker FS6 along with two video frames showing the commencement of visible lip rounding (indicated by a dashed arrow) in the second half of the lateral and the phase of maximal lip rounding (indicated by a solid arrow) during the glide following the epenthetic vowel. Figure 9 illustrates a strategy employed by speaker FS9 to merge the lateral and labial-velar. The initiation of visible lip rounding in this token is nearly synchronized with the start of the lateral (considerably earlier than in the token with an epenthetic vowel in figure 8) before peak rounding is reached during the labialized lateral.
Figure 8. Excerpt showing epenthetic vowel in the final cluster in intalw<sup>HL</sup> ‘sing for her/him!’ as produced by speaker FS6. Approximate time of initial lip rounding is indicated by a dotted arrow and of maximal lip rounding by a solid arrow.
Figure 9. Excerpt showing labialized lateral in $intalw^{HL}$ ‘sing for her/him!’ as produced by speaker FS9. Approximate time of initial lip rounding is indicated by a dotted arrow and approximate time of maximal lip rounding in indicated by a solid arrow.
In summary, several strategies are used by speakers to mitigate potential violations of the Sonority Sequencing Principle. A process of final devoicing in words like hòːkb ‘s/he is stringing them’ reduces the sonority of word-final stops and nasals, while an accompanying process of regressive voicing assimilation targeting stops increases the sonority of the first member of a phonemic voiceless + voiced cluster. For final clusters like [lw], speakers may merge the lateral plus labial-velar glide into a labialized lateral or epenthesize a vowel between the liquid and glide.\(^7\)

**4.3. Word-final length distinctions.** Final vowel deletion also impressionistically leads to neutralization of length distinctions in final position, as comparison of the forms in (2) and (3) suggest:

(2) a. hàːf̩

put.on.shoes:LGR

‘is s/he putting on (shoes)’

b. hàːl

put.on.shoes:LGR

‘s/he is putting on (shoes)’

(3) a. pàːf̩̩

split:LGR

‘is s/he splitting it?’

---

\(^7\) We have also observed one speaker who simply deleted final \(w\) in final \(lw\) clusters.
b. \textit{pà:f}

\begin{verbatim}
split.LGR
's/he is splitting it'
\end{verbatim}

After final vowel deletion, a stem like \textit{{h}\textipa{a:k}}- ‘put on (shoes)’ and a stem like \textit{p\textipa{a:h}}- ‘split’ sound like \textit{h\textipa{a:f}} ‘s/he is putting (shoes) on’ and \textit{p\textipa{a:f}} ‘s/he is splitting it’: that is, the contrast between \textipa{\textit{t}} and \textipa{\textit{\textipa{h}}} is neutralized in coda position. This impression requires quantitative verification, however. The realization of length in final \textipa{\textit{b}} is of special interest, as aerodynamic forces (Westbury and Keating 1986) militate against even short final voiced obstruents (cf. languages such as German and Russian with final devoicing) let alone long final voiced obstruents.

As part of our study of length distinctions, we compared the phonetic duration of representative pairs of short and long consonants occurring in final position with their short and long counterparts in intervocalic position. The measured consonants all appeared immediately following a stressed vowel (see 5.3 on metrical structure). The words targeted for study appear in table 9. Words were analyzed for six speakers (four women and two men).
Table 9. Words used for comparing the duration of short and long consonant pairs in word-final and intervocalic positions. Final bb, ll, and þ are transcribed here to show underlying length rather than phonetic length.

<table>
<thead>
<tr>
<th>C</th>
<th>INTERVOCALIC</th>
<th>SHORT</th>
<th>LONG</th>
<th>WORD-FINAL</th>
<th>SHORT</th>
<th>LONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>ɪbil ‘I am killing it’</td>
<td>ìbbil ‘I’m punching holes’</td>
<td>ɪb ‘S/he is killing it’</td>
<td>ìbb ‘S/he is punching holes’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>palana ‘bean’</td>
<td>intàllil ‘I am building it for him’</td>
<td>tálwál ‘S/he is singing’</td>
<td>intàl ‘S/he is building it for him’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>hàːfil ‘I’m putting on (shoes)’</td>
<td>pàːfil ‘I’m splitting it’</td>
<td>hàːl ‘s/he is putting on (shoes)’</td>
<td>pàːl ‘s/he is splitting them’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Duration results pooled across speakers are shown graphically in figure 10 with individual speaker results following in table 10.
Figure 10. Duration results for three short vs. long consonant pairs in intervocalic and final position averaged over 6 speakers. Whiskers represent 95% confidence intervals.
Table 10. Duration of short vs. long consonant pairs in intervocalic and final position for 6 speakers.

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Intervocalic</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$l$</td>
<td>$b$</td>
</tr>
<tr>
<td>FS1</td>
<td>79</td>
<td>226</td>
</tr>
<tr>
<td>FS2</td>
<td>74</td>
<td>234</td>
</tr>
<tr>
<td>FS6</td>
<td>69</td>
<td>208</td>
</tr>
<tr>
<td>FS9</td>
<td>78</td>
<td>188</td>
</tr>
<tr>
<td>MS1</td>
<td>57</td>
<td>158</td>
</tr>
<tr>
<td>MS7</td>
<td>74</td>
<td>178</td>
</tr>
<tr>
<td>Means</td>
<td>75</td>
<td>199</td>
</tr>
</tbody>
</table>

As figure 10 shows, the difference in duration between short and long consonants is much smaller in final position than in intervocalic position, due primarily, at least in the case of the laterals, to an overall lengthening effect on short consonants in final position, a common cross-linguistic pattern (Wightman et al 1992). The failure of short $b$ to lengthen is perhaps not surprising since aerodynamic factors make prolonged voicing in final obstruents articulatorily difficult (Westbury and Keating 1986). There was considerable interspeaker variation with no speaker reliably distinguishing all three short vs. long pairs in final position. In fact, for certain speakers, some of the word-final short
consonants are longer than their word-final counterparts, reversals that are not observed in the case of intervocalic short vs. long pairs. In keeping with this interspeaker variability, t-tests pooled over all speakers for each pair of short and long consonants in final position failed to reveal a significant difference in length for any of the pairs, confirming impressionistic observations that consonant length contrasts are neutralized in word-final position.

5. **Prosody.** Koasati displays a complex prosodic system featuring intonation, lexical and grammatical tone, and predictable stress. Although our investigation is still not complete, several generalizations have emerged through a combination of instrumental study and impressionistic evaluation of recordings of about 2,000 words made by the second author for a digital dictionary. We begin with nouns, which are prosodically simpler than verbs.

5.1. **Accent in nouns.** In the context of elicitation, most nouns are often pronounced with high pitch on the last syllable, though other patterns are attested, including final high pattern apparently associated with slight emphasis. These different melodies are phrase-}

8. Kimball (1991:26-28) also describes a system of pitch accent, but it is quite different from what we hear. He does not distinguish the nouns in Table 11, for example.

9. The final vowel of a noun may be pronounced with glottal closure or with slight aspiration. Kimball (1991:24) states that women pronounce glottal stops after word-final vowels. We have recorded women using glottal closures and aspiration and are not sure what governs the choice.
final rather than lexical. When a noun is compounded, for example, a phrase-final high melody appears on the last word: \textit{pal\textsc{a}na}^H \textquoteleft dish\textquoteleft, \textit{pal\textsc{a}na kofoki}^H \textquoteleft bowl\textquoteleft (\textquoteleft dish\textquoteleft + \textquoteleft deep\textquoteleft).

We believe the choice of phrase-final tonal melody depends on context: in elicitation, one person may favor final low pitch, while another person might favor final high pitch. This is evident in the pitch traces in figures 11 and 12.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig11.png}
\caption{Falling intonation in \textit{pal\textsc{a}na}^L \textquoteleft dish\textquoteleft as produced by speaker FS6.}
\end{figure}
Figures 11 and 12 show the pitch of the word *palana* ‘dish’ spoken in isolation by speaker FS6 and speaker FS4, respectively. The tokens vary considerably in their pitch patterns. The token produced by speaker FS6 in figure 11 displays a gradual declination in pitch ending in a terminal fall. In contrast, the token produced by speaker FS4 in figure 12 shows a rising intonation.
is characterized by a steep terminal rise in pitch. The pitch traces in these figures support our representation of these patterns as \( \text{palan}^L \) and \( \text{palan}^H \), respectively.\(^{10}\)

Nouns may also have lexical tonal accent, however. A small number of underived nouns have rising pitch on the penult. Table 11 lists near minimal pairs for accent in this small group of nouns.

**Table 11. Pitch contrasts in nouns**

\[
\begin{array}{ll}
\text{okwaːla} & \text{‘toad’} \\
\text{okwɔːɬi} & \text{‘blueberry’} \\
\text{pa}:\text{na} & \text{‘dish’} \\
\text{pa}:\text{lə} & \text{‘popcorn’} \\
\text{shajka} & \text{‘eraser’} \\
\text{səjki} & \text{‘turkey vulture’}
\end{array}
\]

Depending on the intonation used, these may be pronounced with final high pitch, final low pitch, rising pitch, etc.

Nominalizations are a larger class of nouns commonly having rising pitch on the penult (sometimes accompanied by lengthening of the penultimate vowel):

\[
(4) \text{hopôni} \quad \text{‘a cook’ (from hopɔni- ‘cook’)}
\]

\[
\text{na}:\text{liška} \quad \text{‘speaker’ (from na}:\text{liška- ‘speak’)}
\]

\[
\text{sobajli}:\text{fə} \quad \text{‘teacher’ (from sobajli}:\text{fə- ‘teach’)}
\]

\[
\text{ahitʃə}:\text{fə} \quad \text{‘guard’ (from ahi}:\text{fə}:\text{fə- ‘take care of’)}
\]

\(^{10}\) As mentioned previously, nouns in isolation may be pronounced with final glottal closure or final aspiration.
This pattern could be considered part of the larger system of grades in Koasati, in which different pitch patterns affect the penultimate syllables of verbs to convey grammatical aspect (see discussion below).

Loan words sometimes have rising accent, presumably reflecting stress in the source language:

(5) *mobida* ‘car’ (from English *automobile*)

*pastadi* ‘Pentecostal’ (from English *apostolic*)

*kapota* ‘coat’ (from French *capote*)

Finally, some noun compounds consisting of a noun followed by a modifying verb have rising accent on the penultimate syllable of the modifying verb:

(6) *palanhomma* ‘kidney bean’ (from *palana* ‘bean’ + *homma*- ‘red’)

*tfonhatka* ‘bucket’ (from *offona* ‘metal’ + *hatka*- ‘white’)

Modifying verbs are not always accented, however: of the color terms, -*honna* ‘red’, -*hatka* ‘white’, -*lana* ‘yellow’, and -*okfakko* ‘blue, green’ are normally accented, but -*lotfa* ‘black’ is not, possibly because the penultimate syllable is light (CV).

As the examples above show, rising pitch affects vowel length. When a syllable with rising pitch is closed by a sonorant, the vowel is always short. When a syllable with rising pitch is open, the vowel is always long or lengthened (thus *sobajlitfi*- ‘teach’ is lengthened in the nominalization *sobajli:tfi* ‘teacher’). When a syllable with rising pitch is closed by an obstruent, however, the vowel may be slightly lengthened (with some
variation among speakers). A word like ʧonhǎtkə ‘bucket’ may thus be pronounced [ʧonhòɾtkə] (half long with rising pitch), or [ʧunhëtkə] (short and centralized with high pitch), depending on the speaker.

Figure 13 shows a representative pitch trace of hopo:ni ‘a cook’ as produced by speaker FS6. A comparison of FS6’s pronunciation of hopo:ni in figure 13 with the same speaker’s pronunciation of palana in figure 11 confirms our impressionistic description of a rise in accented nouns. The pitch peak in accented syllables is realized in the latter half of the accented rime (on a coda sonorant, the second half of a long vowel, or even during the onset of the next syllable as in figure 13). Pitch peak delays are longer for accents associated with a syllable containing a short vowel followed by an obstruent coda, particularly if the vowel is not lengthened.
5.2. Accent and duration in verb grades. Intonation and tone in verbs is considerably more complex than in nouns. One of the most salient features of verbs in Koasati and other Muskogeans languages is the marking of aspectual differences, termed “grades” in the Muskogeanist literature, through different tone patterns associated with the penultimate syllable of the stem.

Figure 13. Pitch accent in hopōnī^L ‘a cook’ as produced by speaker FS6.
We discuss here the phonetic realization of two of the most common grades: the lengthened/low-tone grade (l-grade) and the geminating/rising-tone grade (g-grade). Briefly, the l-grade is used for events (happenings, whether in the present or past) and is signaled by assigning low tone to the penult (with lengthening of short open penults and partial lengthening of penults with obstruent codas). The g-grade expresses resulting states and is signaled by assigning a rising pitch to the penult (with lengthening of short open penults). If the penultimate syllable begins with an intervocalic onset, the onset is noticeably lengthened. Both of these grade patterns also have high pitch on the stem-final vowel, but this accent is deleted in the g-grade at the end of a word.

Table 12 shows these patterns before the first person singular agentive suffix -li (realized as -l with final vowel deletion). A future form is also given to illustrate the “zero-grade” (corresponding to the underlying stem) counterpart to the L- and G-grades.

**Table 12. L-grade and G-grade forms of verbs**

<table>
<thead>
<tr>
<th>STEM</th>
<th>FUTURE</th>
<th>L-GRADE</th>
<th>G-GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>isi- ‘take’</td>
<td>isilahō ‘s/he will take it’</td>
<td>िसी ‘I am taking’</td>
<td>ḭसी ‘I am holding it’</td>
</tr>
<tr>
<td>halatka- ‘grab’</td>
<td>halatkalahō ‘s/he will grab it’</td>
<td>हलातका ‘I am grabbing’</td>
<td>हलातका ‘I am holding on’</td>
</tr>
<tr>
<td>sobajli- ‘learn’</td>
<td>sobajlilahō ‘s/he will learn’</td>
<td>sobājlī ‘I am learning’</td>
<td>sobājlī ‘I am knowing’</td>
</tr>
</tbody>
</table>
Figures 14 and 15 shows representative pitch traces for the l-grade form *sobàjlí-l* ‘I am learning’ and its g-grade counterpart *sobàjlil* ‘I know’, both pronounced by speaker FS6.

Figure 14. The l-grade verb *sobàjlil* ‘I am learning’ as produced by speaker FS6.
A comparison of figures 14 and 15 reveals the dramatic pitch difference between the l-grade and g-grade forms, with a fall to low pitch in the penult of the l-grade in figure 14 and a sharp rise to high pitch in the penult of the g-grade in figure 15. The lengthening of the onset of the penultimate syllable in the g-grade is also apparent.

Although lengthening effects associated with different grades are found in all the Muskogean languages, there have not been any quantitative studies of duration triggered by grade formation. It thus unclear whether grade-induced lengthening is neutralizing or
not, i.e. whether the lengthened vowels and consonants are durationally equivalent to their phonemically long counterparts. In order to explore this issue in Koasati, we compared the length of segments in accented syllables (the penultimate syllables of stems) of l-grade and g-grade verb forms. We examined the onset consonant and the vowel of the penultimate syllable of the stem in two l-grade vs. g-grade pairs of verbs. In one of the verbs, the penultimate vowel of the stem was underlying short: l-grade *halàšká-l* ‘I am grabbing hold’ vs. g-grade *hallǎtka-l* ‘I am holding on’ (cf. *halatka-lahô* ‘s/he will grab hold of it’, showing the bare stem). In the other pair, the penultimate vowel was underlying long: l-grade *balàšká-l* ‘I am getting into a lying position’ vs. g-grade *ballàška-l* ‘I am in a lying position’ (cf. *balaška-lahô* ‘s/he will get into a lying position’). In both pairs of words, the onset of the penultimate syllable of the stem contained a short *l*. Three tokens of each vowel and consonant were measured from a total of six speakers (four women and two men). The duration values were compared with their phonemic short and long counterparts not appearing in a special grade. These control sounds all appeared in trisyllabic words parallel to the l-grade and g-grade forms and with similar surrounding segments. Short *l* was measured in *palana* ‘bean’ and long *ll* in *hallaki* ‘bat’. Both short and long *a* appeared before a voiceless consonant (for most speakers, the second vowel in the word *falakʧʧ* ‘wing’ and the first vowel in the word *pasatta* ‘armadillo’) except for one speaker (FS2) for whom long *aː* appeared before a lateral in the word *asatâ* basket’. Duration results by speaker are presented in table 13.
Table 13. Duration of nucleus and onset of accented syllables (in milliseconds) in l-grade and g-grade relative to their non-grade counterparts for 6 speakers.

<table>
<thead>
<tr>
<th>SPEAKER</th>
<th>NON-Gr</th>
<th>L-Gr</th>
<th>G-Gr</th>
<th>NON-Gr</th>
<th>L-Gr</th>
<th>G-Gr</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS1</td>
<td>SH 101</td>
<td>LG 174</td>
<td>SH 106</td>
<td>LG 220</td>
<td>SH 83</td>
<td>LG 198</td>
</tr>
<tr>
<td>FS2</td>
<td>SH 59</td>
<td>LG 187</td>
<td>SH 60</td>
<td>LG 176</td>
<td>SH 43</td>
<td>LG 155</td>
</tr>
<tr>
<td>FS6</td>
<td>SH 68</td>
<td>LG 137</td>
<td>SH 114</td>
<td>LG 158</td>
<td>SH 67</td>
<td>LG 163</td>
</tr>
<tr>
<td>FS9</td>
<td>SH 60</td>
<td>LG 138</td>
<td>SH 101</td>
<td>LG 135</td>
<td>SH 61</td>
<td>LG 132</td>
</tr>
<tr>
<td>MS1</td>
<td>SH 63</td>
<td>LG 146</td>
<td>SH 120</td>
<td>LG 158</td>
<td>SH 76</td>
<td>LG 157</td>
</tr>
<tr>
<td>MS7</td>
<td>SH 82</td>
<td>LG 150</td>
<td>SH 101</td>
<td>LG 147</td>
<td>SH 77</td>
<td>LG 145</td>
</tr>
<tr>
<td>Means</td>
<td>SH 72</td>
<td>LG 153</td>
<td>SH 100</td>
<td>LG 166</td>
<td>SH 68</td>
<td>LG 158</td>
</tr>
</tbody>
</table>

Results largely confirmed impressionistic judgments about duration, especially in the case of the onset consonant. The onset of the accented penultimate syllable in the g-grade forms was substantially longer than the onset of the accented penult in the l-grade: 195 milliseconds vs. 84 milliseconds averaged across speakers. This difference was highly significant in a t-test: t (48.6) = 12.666, p<.001 (corrected for inequality of variances). In fact, the onset of the penult in the l-grade form was roughly the same (statistically equivalent) in duration to the short $l$ in *palana* ‘bean’ (75 milliseconds), while the onset of the penult in the g-grade was statistically equivalent in duration to the long $ll$ in *hallaki*
Turning to accented vowels, the l-grade exerted the greatest effect on the duration of phonemic short vowels. Thus, the phonemic short vowel in the penult of the l-grade form halāskāl (stem halatka-) averaged 100 milliseconds, while the same vowel in the penult of the g-grade form hallātkāla averaged only 68 milliseconds. The latter is statistically equivalent in a t-test to the 72 milliseconds of the short a in falakī ‘wing’ serving as a control. The difference between the short vowel in the l-grade and both its g-grade and non-grade counterparts was significant according to t-tests: for l-grade vs. g-grade, t (34)=5.243, p<.001; for L-grade vs. zero-grade, t (28) = 3.8, p=.001. The lengthening effect on short vowels in the l-grade, however, was not sufficiently large to produce a vowel that was equivalent in length to an underlying long vowel. Thus, the lengthened vowel in halāskāl was still much shorter than a phonemic long vowel (t (30) =4.072, p<.001 according to a t-test), which averaged 153 milliseconds. One potentially problematic issue in the comparison of the penultimate vowel in l-grade halāskāl with the underlying long vowel in pāsatta ‘armadillo’ is the fact that the former appears in a closed syllable and the latter in an open syllable. This difference is plausibly causing an underestimation of the lengthening effect in the l-grade since vowels in closed syllables are characteristically shorter than those in open syllables (Maddieson 1985). In order to explore this possible confound, a comparison of the penultimate long /i/ in an open syllable in the disyllabic word fīso ‘turkey’ was compared with the penultimate
lengthened /i/ (also in an open syllable) in the disyllabic l-grade form IPA-l ‘I am eating’ for the two speakers, FS9 and MS7 who provided both forms. The vowel in the former form was still slightly longer (142 milliseconds vs. 131 milliseconds) averaged over both speakers, though this lengthening effect was smaller than the one found for the comparison of halàškál and pašatta.

Finally, phonemic long vowels were virtually identical (statistically equivalent according to t-tests) in length in the l-grade (166 milliseconds), the g-grade (158 milliseconds), and non-grade forms (153 milliseconds).

Overall results indicate that lengthening under grade formation is neutralizing in the case of an accented onset consonant, which in the g-grade becomes equivalent in length to an underlying long consonant. In the case of vowel lengthening in the l-grade, however, results are less conclusive. A comparison of the lengthened vowel in the l-grade form halàškál with the phonemic long vowel in pašatta suggests that vowel lengthening is non-neutralizing. This finding may, however, be at least partially an artifact of the fact that the lengthened vowel in halàškál appears in a closed syllable, whereas the comparison long vowel in pašatta occurs in an open syllable.

5.3. Metrical structure. From the perspective of other Muskogeans languages, one of the unusual features of the Koasati prosodic system is the apparent lack of iambic rhythm. Thus, Chickasaw, Choctaw, and Creek display elements of iambic metrical structure in one of three guises: stress in Chickasaw (Gordon 2004), rhythmic vowel lengthening in Chickasaw and Choctaw (Munro and Ulrich 1984, Munro and Willmond
1994, 2005, Munro 1996, 2005, Gordon and Munro 2007, Broadwell 2005, 2006), or pitch accent in Creek (Haas 1977, Martin and Johnson 2002, Martin 2011). In Chickasaw, for example, a system of left-to-right iambs leads to stress and lengthening of the second vowel in a sequence of adjacent light (CV) syllables. The locus of stress and lengthening falls out from an analysis in which heavy syllables, which also bear stress in Chickasaw, form a monosyllabic foot and two adjacent CV syllables form an iambic foot consisting of a metrically weak syllable followed by a strong syllable. Thus Chickasaw asabikatok ‘I was sick’ has the metrical representation (a'sa·')(b'i'ka·')(tok), and tfipisalitok ‘I looked at you’ is parsed as (tf'i'pi·')(sa'li·')(tok) (Gordon and Munro 2007).

Creek nouns and zero-grade forms of verbs have a similar left-to-right iambic stress system, though the primary cue to stress is pitch rather than duration. In Creek, level high pitch spreads from the first stressed syllable to the last: (i'fa) ‘dog’, (no'ko)si ‘bear’, (no'ko) (so'tfi) ‘bear cub’, (a'wa) (na'ji)ta ‘to tie to’ (Martin 2011).

There does not appear to be evidence from stress, lengthening or tone for a productive synchronic process of iambic footing in Koasati. Rather, the first syllable of a word characteristically is most prominent in terms of duration and intensity, a prominence that is plausibly interpreted as stress (as distinct from the lexical tone accent discussed above). Impressionistically, heavy syllables (CVC and CVV), stem-final syllables, and the first in a sequence of two consecutive light syllables sound prominent, where inspection of acoustic displays suggests that this perceived prominence is a function of increased intensity and duration (and, in the case of stem-final vowels, potentially pitch).
Interestingly, the prominence on the first rather than the second syllable in a sequence of two light syllables suggests a trochaic parse for Koasati, e.g. (ˈatʃi)(ˈtika) ‘rope’, (ˈwaː)(ˈkasi) ‘calf’, (ˈok)(ˈʧos)(ˈbani) ‘type of turtle’. This analysis should be regarded as tentative, however, as we are not yet in a position to offer a definitive account of stress and its relationship to lexical accents. It is nevertheless clear that stress does not provide any evidence for iambic footing in Koasati unlike Chickasaw, Choctaw, and Creek.

6. Conclusions. This paper has provided a quantitative description of a number of phonetic properties of Koasati, some of which are typical of Muskogean languages and some of which are unusual. The phonemic contrast in length typical of both consonants and vowels within the Muskogean family was shown to be phonetically robust in Koasati. Another common feature of the family, centralization of short vowels, was also verified for Koasati through formant analysis.

More unusual within Muskogean is Koasati’s extensive inventory of word-final consonants and consonant clusters created by final vowel deletion. We documented several strategies for mitigating sonority sequencing violations in typologically rare word-final clusters. Evidence also suggested that long consonants that wind up in final position due to apocope are equivalent in length to final short consonants.
Prosodically, Koasati is typical of Muskogean languages. For example, the other Muskogean languages all distinguish eventive aspect from resultative stative aspect by means of grades. We may now add Koasati to this list:\footnote{The Chickasaw forms in (7-8) are from Munro and Willmond (1994). Other forms are based on Martin’s fieldwork. An earlier discussion of the geminating grade in Koasati and its cognates in the other languages was presented in Martin (2013).}

\begin{align*}
& (7) \quad \text{Creek} \quad \text{lejk-ís} \quad \text{‘s/he is getting seated’ (lengthened grade)} \\
& \hphantom{(7) \quad \text{Creek} \quad} \quad \text{lējk-ís} \quad \text{‘s/he is seated’ (falling tone grade)} \\
& \text{Mikasuki} \quad \text{ʧōkōl-om} \quad \text{‘s/he is getting seated’ (nasalized grade)} \\
& \hphantom{(7) \quad \text{Mikasuki} \quad} \quad \text{ʧōkōl-om} \quad \text{‘s/she is seated’ (falling-tone grade)} \\
& \text{Alabama} \quad \text{ʧōko:di} \quad \text{‘s/he is getting seated’ (zero grade)} \\
& \hphantom{(7) \quad \text{Alabama} \quad} \quad \text{ʧōkkō:di} \quad \text{‘s/she is seated’ (geminating grade)} \\
& \text{Koasati} \quad \text{ʧōkōl} \quad \text{‘s/he is getting seated’ (lengthened/low-tone grade)} \\
& \hphantom{(7) \quad \text{Koasati} \quad} \quad \text{ʧōkkōl} \quad \text{‘s/he is seated’ (geminating/rising-tone grade)} \\
& \text{Chickasaw} \quad \text{bini:di} \quad \text{‘s/he is getting seated’ (zero grade)} \\
& \hphantom{(7) \quad \text{Chickasaw} \quad} \quad \text{binni:li} \quad \text{‘s/he is seated (geminating grade)} \\
& \text{Choctaw} \quad \text{bini:di-h} \quad \text{‘s/she is getting seated’ (zero grade)} \\
& \hphantom{(7) \quad \text{Choctaw} \quad} \quad \text{binī:li-h} \quad \text{‘s/he is seated’ (nasalized grade)}
\end{align*}
As these forms show, the rising tone found on the penultimate syllable of the g-grade in Koasati is cognate with falling tone in Creek, Mikasuki, and Alabama, and with an internal glottal stop in Chickasaw.

We find a similar correspondence in nominalizations:

(8) Creek \( \text{no}^{\text{t}e}j\text{ff} \) ‘cook (verb stem)’

\( \text{no}^{\text{t}e}j\text{ff}-a \) ‘a cook’

Mikasuki \( \text{no}^{\text{h}a} : \text{fi} \) ‘cook (verb stem)’

\( \text{impi}:\text{noh}^\cdot\text{fi}-i \) ‘a cook’

Alabama \( \text{talwa} \) ‘sing (verb)’

\( \text{t}\text{a}l\text{wa} \) ‘singer’

Koasati \( \text{ho}^{\text{p}o} : \text{ni} \) ‘cook (verb stem)’

\( \text{ho}^{\text{p}o} : \text{ni} \) ‘a cook’

Chickasaw \( \text{ho}^{\text{p}o} : \text{ni} \) ‘cook (verb)’

\( \text{ih}o^{\text{p}o} : \text{ni} \) ‘a cook’

Choctaw \( \text{ho}^{\text{p}o} : \text{ni}-h \) ‘cook (verb)’

\( \text{ho}^{\text{p}o} : \text{ni} \) ‘a cook’

Here again, the rising accent we documented in Koasati is cognate with falling tone in Mikasuki and Alabama and with an internal glottal stop in Chickasaw.
The correspondences in (7-8) suggest that Proto-Muskogean used falling tone for resultative stative aspect and for nominalizations. Falling tone yielded a glottal stop in Chickasaw. In Koasati, however, the cognate of falling tone is rising tone. We believe this development was caused by peak delay: examination of the pitch trace for hopōni ‘a cook’ in figure 13 reveals that the rise on the penult is followed by a fall, as though falling tone in an earlier form *hopōni has simply shifted rightward. This change may have taken place within the last 75 years. Mary R. Haas’s fieldnotes from the 1930’s (Haas 1938-39) show falling tone on syllables where we hear rising tone.

We have attempted in this paper to document the basic properties of vowels, consonants, and word-level prosody in Koasati. Our findings show that Koasati closely resembles other Muskogean languages, but small changes over time have led to consonant clusters and tone melodies that are absent from related languages.

REFERENCES


Haas, Mary R. 1944. Men’s and women’s speech in Koasati. Language 20, 142-149.


Hume, Elizabeth; Samantha Gett; Lark Hovey; Kristen Scudieri; and Michael Spagnol. 2012. Cues to word-final geminate consonants in Maltese. Poster presented at Laboratory Phonology 12, Albuquerque, New Mexico.


KRAEHENMANN, ASTRID. 2001. Swiss German stops: geminates all over the word.

Phonology 18, 109-145.


LEHISTE, ILSE. 1966. Consonant quantity and phonological units in Estonian.

Bloomington: Indiana University Press.


RIDOUANE, RACHID. 2010. Geminates at the junction of phonetics and phonology. In
Fougeron, Cécile, Kühnert, Barbara, D’Imperio, Mariapaola, Vallée, Nathalie (eds.). Papers in Laboratory Phonology 10, pp. 61-90. New York: Mouton De Gruyter.


