ACOUSTIC PROPERTIES OF BILABIAL TRILLS IN MANGBETU

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ABSTRACT

Mangbetu (D. R. Congo) has three phonemes with bilabial trill releases: /p^{ʙ}, b^{ʙ}, ^{m}b^{ʙ}/. This study adds to previous work on Mangbetu by including VOT and more thorough stop closure duration measurements, in addition to trill vibration frequency measurements.

The key factor distinguishing /p^{ʙ}/ from /b^{ʙ}/ and /^{m}b^{ʙ}/ is the absence of voicing during the stop closure of /p^{ʙ}/. The stop closures of /b^{ʙ}/ and /^{m}b^{ʙ}/ are either entirely voiced or voicing terminates near the end of closure. The VOT of /p^{ʙ}/ is short enough that trill oscillations occur after the start of voicing. Hence, transcribing the release of /p^{ʙ}/ as voiced [^{ʙ}] is warranted.

As in other languages, the oral stop closure of /^{m}b^{ʙ}/ is short, and the failure rate of bilabial trilling increases before front vowels.

Compared to previous studies, the stop closure is longer and the frequency rate of trilling is slower, suggesting careful speech.

Keywords: bilabial trill, VOT, release, Central Sudanic, Mangbetu.

1. INTRODUCTION

Bilabial trills are speech sounds found in about 70 languages. Clusters of languages with bilabial trills are found in Papua New Guinea, Vanuatu, Cameroon, China, the Democratic Republic of the Congo (DRC), South Sudan, and Brazil. Individual languages with bilabial trills are found in Indonesia, India, and Georgia [1, 2].

Unlike [r] and [ʀ], bilabial trills are not attested as unitary phonemes. Rather, they occur in complex phonemes where they pattern as the release of a stop. The preceding stop that initiates the trill is usually bilabial, e.g. /p^{ʙ}, b^{ʙ}, ^{m}b^{ʙ}/, but it can also be coronal, e.g. /t^{p}/ [3, 4], or labial-velar, e.g. /kp^{ʙ}, gb^{ʙ}, ^{ŋ}gb^{ʙ}/. The one exception to this pattern is found in China, where bilabial trills pattern as allophones of compressed or fricative vowels following bilabial and/or coronal stops, e.g. [bβ̩, dβ̩] [2].

In northeastern DRC and South Sudan, bilabial trills are attested in five Central Sudanic languages (Mangbetu, Lombi, Asoa, Baka, and Morokodo), one Bantu language (Lika), and one Ubangian language (Dongo) [1]. Cases involving labial-velar stop closures are reported in Lombi, Baka, Morokodo, and Lika [5, 6, 7, 8, 9, 10].

Mangbetu (ISO 639-3 code: mdj) is spoken by over 650,000 people in northeastern DRC in and around the city of Isiro [11]. Several studies have documented bilabial trills in Mangbetu [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23]. In addition, Demolin has studied the acoustics of the sounds [16, 18, 19].

The Mangbetu consonant inventory includes three phonemes with bilabial trill releases: /p^{ʙ}, b^{ʙ}, ^{m}b^{ʙ}/. The following data set demonstrates contrast: [nó.pʙù] 'to bring out from within', [nó.bʙù] 'to fan', [nó.mbʙù] 'to enclose', [ná.pú] 'ashes', [nó.bù] 'to feed a fire', [né.mbó] 'have him tour (3sg hortative)', [né.mbʙó] 'clay pot' [21, 22].

Demolin reported on the frequency rate of trilling and included some measurements of stop closure duration. Besides replicating these measurements, my study builds on Demolin's work by providing more complete stop closure duration information, as well as measurements of voice onset time (VOT).

2. METHODOLOGY

2.1. Subject

An approximately 35-year-old educated male native speaker of Mangbetu (Meegye dialect) participated in this experiment. The subject lives in Isiro, DRC. He has completed some graduate school. Besides Mangbetu, he also speaks French and Lingala. His primary occupation is as a primary school director.

2.2. Procedures

We recorded a list of 73 words and short phrases spoken in isolation. These words were chosen to include bilabial trill and labiodental flap data.

The wordlist was recorded during two sessions: (1) on March 6, 2004 (items 1–43) and (2) March 27, 2004 (items 44–73). The recordings were made at the ACATBA center (Association Centrafricaine pour la Traduction de la Bible et l'Alphabétisation) in Bangui, Central African Republic. The subject was seated and read prompts on sheets of paper in orthographic transcription, which he wrote.

During the first recording session, the subject produced the gloss for each word in French and then the corresponding word in Mangbetu once. During the second session, the subject produced the word in Mangbetu once followed by the French gloss. This part of the wordlist was recorded twice.

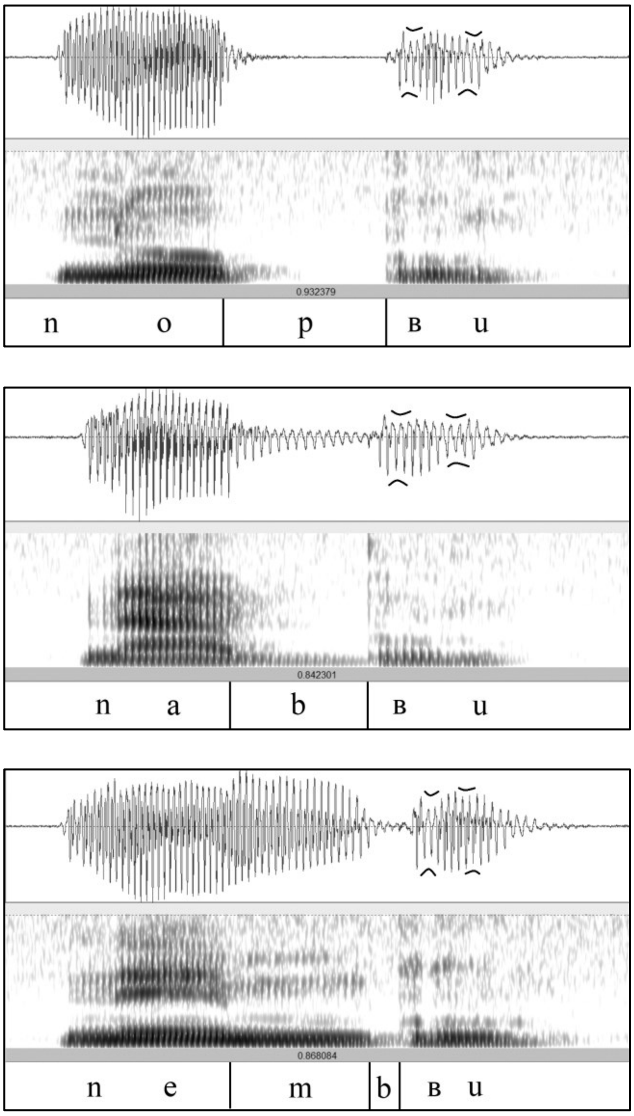

Figure 1: Waveforms and spectrograms of the words [nó.pʙù] 'to bring out from within', [ná.bʙù] 'corpse', and [né.mʙù] 'hip'.

The recording was made with a Marantz PMD 420 monaural cassette recorder and an Audio-Technica ATM 33a condenser microphone. The recording was digitized at the International Linguistics Center in Dallas, Texas in March 2005. The audio cassettes were played on a Marantz PMD 221 analog cassette recorder, and the recording was digitized onto a standard Windows XP computer using a Tascam US-122 USB Audio/Midi interface and CoolEdit 2000 for audio capture. The digitization was done at a 48 kHz sampling rate and a 24-bit quantization. The recordings were stored in non-compressed WAV format. Both a presentation form [22] and an archived form [23] of the recordings are available.

2.3. Analysis

Waveforms and spectrograms were examined using Praat [24]. Default parameters were used, except that the dynamic range of spectrograms was set at 45 dB.

First, the closure duration of the stop preceding the trill release was measured. For prenasalized stops, both the nasal closure (indicated by nasal formants) and the oral closure (indicated by a significant drop in signal amplitude) were measured.

Second, the number of trill periods [25] for each token was counted. For the speaker, the modal number of trill periods was one. In some tokens, a trill was expected but was not observed in the waveform or spectrogram. Rangelov [26, 27] refers to these as *failed trills*, as opposed to *successful trills*.

Third, trill period duration was measured. The first trill period was defined as the time from the release of the stop closure to the release of the first trill closure (or partial closure), indicated by an increase in signal amplitude [25]. Subsequent trill periods were defined as the time from the release of the trill closure to the release of the following trill closure.

Fourth, VOT was measured. This was defined as the time from the release of the stop closure to the beginning of vocal fold vibration, indicated by periodicity in the waveform and the start of vertical striations in the spectrogram. One outlier was removed.

Sample waveforms and spectrograms are given for /p^{B}, b^{B}, ^{m}b^{B}/ in Figure 1. A phonetic transcription is provided below each spectrogram, with segments demarcated where appropriate. Arcs were added to the waveform to indicate the (partial) trill closures.

3. RESULTS

3.1. Stop closure duration

The mean duration of the stop closures for /p^{B}, b^{B}, ^{m}b^{B}/ are 193 ms, 168 ms, and 190 ms, respectively, as shown in Table 1.

Phoneme	n	Closure duration ($\bar{x}$)	s.d.
/p^{B}/	43	193 ms	27.3
/b^{B}/	13	168 ms	25.0
/^{m}b^{B}/	18	190 ms	31.7

Table 1: Stop closure duration measurements for /p^{B}, b^{B}, ^{m}b^{B}/. n = number of tokens, $\bar{x}$ = sample mean, s.d. = standard deviation.

These durations are generally longer than those found in previous studies [25, 26, 28]. I consider this to be suggestive of careful speech. Rangelov [26] notes that there is substantial interspeaker variation for these measures in Ahamb. I expect that examining the speech of additional speakers in Mangbetu would likely show similar variation.

The stop closure durations of the three phonemes—in which /pᴮ/ and /ᵐbᴮ/ are similar and /bᴮ/ is somewhat shorter—harmonize with previous studies in two respects. First, Rangelov found similar stop closure durations in Ahamb for /pᴮ/ and /ᵐbᴮ/. (/pᴮ/ was slightly longer.) Second, similar patterns have been noted for the stops /p, b, ᵐb/. Lisker [29] observed that the closure duration of English /b/ is shorter than that of /p/ in intervocalic position. Maddieson [30] found that the closure duration of /p/ and /ᵐb/ are similar for Fijian. Olson [31] noted that the closure duration of /b/ is shorter than that of /ᵐb/ in Mono (DRC).

In other words, stops with bilabial trill releases appear to pattern similarly to plain bilabial stops. More work needs to be done to establish that this apparent trend occurs consistently crosslinguistically.

For /ᵐbᴮ/, the mean duration of the nasal portion of the stop closure was 148 ms (s.d. = 28.1, n = 18) and the mean duration of the oral portion of the stop closure was 41.8 ms (s.d. = 13.7, n = 18).

This short oral closure for /ᵐbᴮ/ is well attested [25, 26, 28], and a short oral closure has been documented for /ᵐb/ as well [30, 31]. In other words, the short oral closure of /ᵐbᴮ/ does not appear to be novel but is rather consistent with prenasalized stops in general [32].

For /pᴮ/, there is a rapid attenuation of voicing at the start of the oral stop closure, such that most of the closure is voiceless. Voicing does not start again until after the release of the closure.

For /bᴮ/ and /ᵐbᴮ/, voicing is maintained throughout closure in a little more than half of the tokens. In the rest of the tokens, voicing slowly attenuates until it terminates roughly 4/5 of the way through the closure. Figure 2 shows a waveform and spectrogram where this is the case for /bᴮ/.

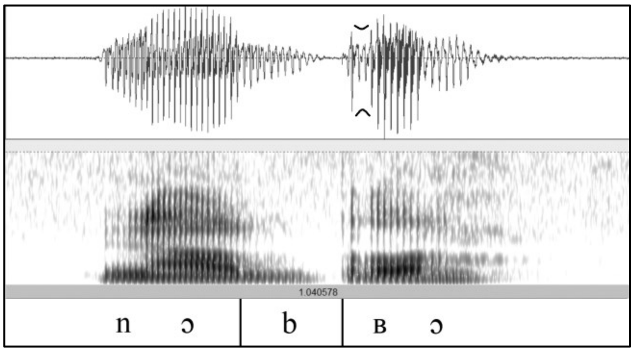

Figure 2: Waveform and spectrogram of the word [nɔ́.bʙɔ̀] 'to carry'.

It appears then, that the absence of voicing during the production of the stop closure of /pᴮ/ is a strong correlate distinguishing it from /bᴮ/ and /ᵐbᴮ/.

3.2. Number of trill periods

The number of trill periods varied from zero to three in my data. Out of 74 tokens, 36 had one trill period, 15 had two trill periods, and 2 had three trill periods. Hence, the modal number of trill periods was one. This is the same number that Maddieson [25] observed for Ngwe. The data are somewhat limited, but it appears that crosslinguistically two modal trill periods is most common, e.g. Kurti, Na?ahai, Uripiv, Ahamb [25, 26].

The remaining 15 tokens had zero trill periods, i.e. these were failed trills. Previous studies [3, 25, 26, 33] have shown that bilabial trills often do not occur when they are expected to do so, and this is also the case for Mangbetu.

Table 2 shows the number of trill periods broken down by phoneme. In my data, /bᴮ/ and /ᵐbᴮ/ occur only before back and low vowels, whereas /pᴮ/ occurs before front, back, and low vowels. To ensure a like-for-like comparison, I removed the count of tokens in which /pᴮ/ occurs before front vowels from Table 2.

Of the three phonemes, /ᵐbᴮ/ has the highest percentage of successful bilabial trills (94%). It also had the highest number of tokens with two or more trill periods (39%). This highlights the robustness of this particular phoneme [25, 32].

On the other hand, /pᴮ/ has the lowest percentage of successful trills (75%).

Phoneme	n	0 t.p.	1 t.p.	2 t.p.	3 t.p.
/pᴮ/	12	3	5	3	1
/bᴮ/	13	1	10	2	0
/ᵐbᴮ/	18	1	10	6	1

Table 2: Number of trill periods per token for /pᴮ, bᴮ, ᵐbᴮ/. Tokens with a following front vowel are not included in the count.

Another trend emerges if we examine all the tokens of /pᴮ/, including those with a following front vowel. Table 3 shows the number of trill periods per token broken down by whether the following vowel is front, back, or /a/.

The success rate of the trill release of /pᴮ/ is very high when followed by a back vowel (100%). On the other hand, the success rate drops considerably before front (48%) and low (25%) vowels. In other words, bilabial trilling is more successful before back vowels than before other vowels. This harmonizes with other studies that have shown that bilabial trilling is most robust before back vowels [25].

Voicing was not inhibited during bilabial trilling in Mangbetu, contra what is sometimes observed for apical trills [25]. However, as noted in Section 3.1, voicing was inhibited during the preceding stop closure in some tokens.

Following V	n	0 t.p.	1 t.p	2 t.p.	3 t.p.
Front V	31	16	11	4	0
/a/	4	3	1	0	0
Back V	8	0	4	3	1

Table 3: Number of trill periods per token for /p^{B}/, before front vowels, back vowels, and /a/.

3.3. Trill period duration and frequency rate of trilling

The duration of the first trill period for /p^{B}, b^{B}, ^{m}b^{B}/ is shown in Table 4. The corresponding frequency rates of trilling are shown as well.

Phon.	n	t.p. ($\bar{x}$)	s.d.	freq. ($\bar{x}$)	s.d.
/p^{B}/	24	46.4 ms	4.7	21.7 Hz	2.2
/b^{B}/	12	52.4 ms	4.4	19.2 Hz	1.6
/^{m}b^{B}/	178	56.3 ms	5.2	17.9 Hz	1.7

Table 4: Duration and frequency rate of trilling of first trill period for /p^{B}, b^{B}, ^{m}b^{B}/.

These durations are longer than those measured in previous studies [16, 18, 25, 26]. Consequently, the frequency rates of trilling are shorter than previously observed. I consider this to be indicative of careful speech on the part of the Mangbetu speaker.

There is a general decrease of frequency rate as one goes from /p^{B}/ to /b^{B}/ to /^{m}b^{B}/. This harmonizes with what Rangelov [26] found in Ahamb, where the frequency rate of /p^{B}/ is higher than that of /^{m}b^{B}/. Further research is necessary to determine if this is a crosslinguistic trend.

3.4. Voice onset time

All cases of /p^{B}/ have a measurable VOT. Importantly, the start of voicing preceded the start of the first trill closure in all but two tokens of /p^{B}/. This suggests that the transcription of the trill release as voiced [^{B}] is warranted.

For a little over half of the tokens of /b^{B}/ and /^{m}b^{B}/, there is no break in voicing between the closure and the trill. Consequently, there was no principled way to measure VOT for these tokens.

For the remaining tokens, voicing attenuated gradually until it ceased completely, typically about 4/5 of the way through the stop closure. In those cases, I was able to measure the delay between release of closure and the commencement of voicing during the first trill period. The results for these measurements are shown in Table 5.

Phoneme	n	VOT ($\bar{x}$)	s.d.
/p^{B}/	42	23.2 ms	10.1
/b^{B}/	7	17.7 ms	10.5
/^{m}b^{B}/	6	17.4 ms	8.32

Table 5: Voice onset time duration measurements for /p^{B}, b^{B}, ^{m}b^{B}/.

4. DISCUSSION

As discussed in Section 3.4, the trill release of /p^{B}/ is nearly always voiced. This not only leads us to transcribe the release with a raised small cap b [^{B}] to indicate voicing, but it raises a question concerning the practice of calling this phoneme a “voiceless bilabial trill,” since the voicelessness occurs during the stop closure, not during the trill release.

It would be hasty to generalize that all cases crosslinguistically of a voiceless stop followed by a bilabial trill release involve a voiced release. Coupe [4] and Rangelov [26] include spectrograms of such phonemes that clearly indicate voicelessness during the trill release. My study indicates that voicing during the trill release is a feature worth examining more carefully in future studies.

There is much room for future work on bilabial trills in Mangbetu. This includes:

- Examining the behavior of /b^{B}/ and /^{m}b^{B}/ before front vowels,
- Comparing the stop closure duration of the three trill phonemes with their non-trill counterparts /p, b, ^{m}b/,
- Comparing the behavior of /p^{B}, b^{B}, ^{m}b^{B}/ with the Mangbetu coronal trills /t^{r}, d^{r}, ^{n}d^{r}, r/,
- Using earbuds to measure more precisely the nasal stop closure of /^{m}b^{B}/ [26, 34],
- Studying more speakers of Mangbetu; Ladefoged [35] recommends recording at least six speakers of each sex,
- Video recordings to examine lip oscillation.

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7. REFERENCES

[1] Keating, C. A. 2007. *A Cross-Linguistic Overview of Bilabial Trills*. Graduate Institute of Applied Linguistics M.A. Thesis.

[2] Olson, K. S. 2022. The non-existence of the plain bilabial trill phoneme. *Proc. 96th Ling. Soc. Amer.* Washington, 5239. DOI: 10.3765/plsa.v7i1.5239.

[3] Ladefoged, P., Everett, D. 1996. The status of phonetic rarities. *Lg.* 72, 794–800. DOI: 10.2307/416103.

[4] Coupe, A. R. 2015. Prestopped bilabial trills in Sangtam. *Proc. 18th ICPhS* Glasgow. https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2015/Papers/ICPHS0734.pdf

[5] Kutsch Lojenga, C. 2013. Exotic consonants in Congolese languages. Paper presented at: The Phonetics and Phonology of Sub-Saharan Languages, Johannesburg, 7–10 July 2013.

[6] Parker, K. H. 1985. Baka phonology. *Occasional Papers in the Study of Sudanese Languages* 4, 63–85. https://www.sil.org/resources/archives/35934.

[7] Sampson, D. L. 1997. Update on Baka phonology and orthography, as of 1996. *Occasional Papers in the Study of Sudanese Languages* 7, 114–120. https://www.sil.org/resources/archives/35985.

[8] Persson, J. 2001. The Morokodo language. Ms. SIL International.

[9] Persson, J. 2004. Bongo-Bagirmi languages in Sudan. *Occasional Papers in the Study of Sudanese Languages* 9, 77–84. https://www.sil.org/resources/archives/35968.

[10] de Wit, G. 2010. Lika phonologie. *SIL Electronic Working Papers* 2010-002. https://www.sil.org/resources/archives/7818.

[11] Eberhard, D. M., Simons, G. F., Fennig, C. D. 2023. *Ethnologue*. SIL International. www.ethnologue.com.

[12] Larochette, J. 1958. *Grammaire des dialectes mangbetu et medje suivi d'un manuel de conversation et d'un lexique*. Musée Royal du Congo Belge.

[13] Tucker, A. N., Bryan, M. A. 1966. *Linguistic Analyses: The Non-Bantu Languages of North-Eastern Africa*. Oxford University Press.

[14] Thomas, J. M.-C., Bouquiaux, L., Cloarec-Heiss, F. 1976. *Initiation à la phonétique: Phonétique articulatoire et phonétique distinctive*. Presses Universitaires de France.

[15] Demolin, D. 1988. Some problems of phonological reconstruction in Central Sudanic. *Belgian J. Linguistics* 3, 53–95. DOI: 10.1075/bjl.3.06dem.

[16] Demolin, D. 1990. Les trilles bilabiales du mangbetu. *Pholia* 5, 67–90. http://www.ddl.cnrs.fr/Download/Pholia/Pholia_N-5.pdf.

[17] Demolin, D. 1991. L'analyse des segments, de la syllabe et des tons dans un jeu de langage mangbetu. *Langages* 25, 30–50. DOI: 10.3406/lgge.1991.1800.

[18] Demolin, D. 1992. *Le mangbetu: Étude phonétique et phonologique*. Université Libre de Bruxelles dissertation.

[19] Demolin, D. 2013. The phonetics of bilabial trills in Mangbetu. Paper presented at: The Phonetics and Phonology of Sub-Saharan Languages, Johannesburg, 7–10 July 2013.

[20] McKee, R. G. 1991. The interpretation of consonants with semi-vowel release in Meje (Zaire) stems. In: Rottland, F., Omondi, L. N. (eds), *Proceedings of the Third Nilo-Saharan Linguistics Colloquium*. H. Buske, 181–195.

[21] McKee, R. G. 2007. Concerning Meegye and Mangbetu's bilabial trills. In: Payne, D., Reh, M. (eds), *Advances in Nilo-Saharan Linguistics. Proceedings of the 8th Nilo-Saharan Linguistics Colloquium, University of Hamburg, August 22–25 2001*. Rüdiger Köppe, 181–189.

[22] Olson, K. S., Mbiri, D. 2013. Labial vibrants in Mangbetu. *Afrikanistik Online 2013*. https://nbn-resolving.de/urn:nbn:de:0009-10-38517.

[23] Olson, K. S., Mbiri, D., Olson, R. E., Kuntz, J., Simons, G. F. 2013. Labial vibrants in Mangbetu: Archival form. *ORTOLANG*. https://hdl.handle.net/11403/sldr000829/v1.

[24] Boersma, P., Weenink, D. 2022. Praat: Doing phonetics by computer [Computer program]. Version 6.2.21. www.praat.org.

[25] Maddieson, I. 1989. Aerodynamic constraints on sound change: The case of bilabial trills. *UCLA Working Papers in Phonetics* 72, 91–115. https://escholarship.org/uc/item/52014440.

[26] Rangelov, T. 2019. The bilabial trills of Ahamb (Vanuatu): Acoustic and articulatory properties. *Proc. 19th ICPhS* Melbourne, 1292–1296. https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2019/papers/ICPhS_1341.pdf.

[27] Rangelov, T., Walworth, M., Barbour, J. 2023. A multifaceted approach to understanding unexpected sound change: The bilabial trills of Vanuatu's Malekula Island. *Diachronica*. DOI: 10.1075/dia.21051.ran.

[28] Olson, K. S., Meynadier, Y. 2015. On Medumba bilabial trills and vowels. *Proc. 18th ICPhS* Glasgow. https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2015/Papers/ICPHS0522.pdf

[29] Lisker, L. 1957. Closure duration and the intervocalic voiced-voiceless distinction in English. *Lg.* 33, 42–49. DOI: 10.2307/410949.

[30] Maddieson, I. 1989. Prenasalized stops and speech timing. *J. Int. Phonetic Assn.* 19, 57–66. DOI: 10.1017/S0025100300003856.

[31] Olson, K. S. 2005. *The Phonology of Mono*. SIL International and the University of Texas at Arlington.

[32] Ladefoged, P., Maddieson, I. 1996. *The Sounds of the World's Languages*. Blackwell.

[33] Yoder, B. 2010. Prenasalization and trilled release of two consonants in Nias. *Work Papers of the Summer Institute of Linguistics, University of North Dakota Session 50*. DOI: 10.31356/silwp.vol50.03.

[34] Stewart, J., Kohlberger, M. 2017. Earbuds: A new method for measuring nasality in the field. *Language Documentation & Conservation* 11, 49–80. http://hdl.handle.net/10125/24724.

[35] Ladefoged, P. 2003. *Phonetic Data Analysis*. Blackwell.