The Phonetic Properties of Voiced Stops Descended from Nasals in Ditidaht*

John Sylak-Glassman
University of California, Berkeley

Introduction

Five genetically diverse languages in the Pacific Northwest underwent an extremely rare sound change in which all the nasal consonants of each language became voiced oral stops (Haas 1969:112, Thompson and Thompson 1972). Sound changes sometimes leave behind relics indicating the former status of segments. For example, in Amharic, the phonemic distinction between the vowels /ə/ and /a/ is generally neutralized when they occur in syllables with /h/. Whether neutralization occurs can be predicted on the basis of the historical origin of /h/. In cases in which /h/ descended from earlier *χ, *$\hbar$, or *h, neutralization occurs, but neutralization does not occur when /h/ descends from *k.

In these languages, one might predict that the voiced oral stops would retain some phonetic characteristics from being nasal consonants previously. For example, their duration may be the same as nasal consonants or they may have greater prevoicing than is cross-linguistically normal due to nasals being voiced throughout their duration.[1] Confirming or disconfirming the existence of these phonetic "relics" leads to a better understanding of how sound change operates and how it can be discovered in languages without a long written tradition. However, despite the rarity of the nasal to voiced oral stop sound change and its implications for historical linguistics, no study has yet determined the phonetic properties of the resulting voiced oral stops in any language that

*I wish to thank the Ditidaht First Nation and especially my consultants for sharing their language and culture with me. This work was made possible by the Robert L. Oswalt Graduate Student Support Endowment for Endangered Language Documentation and the University of California, Berkeley, Graduate Division Summer Grant. Thank you to Deborah Mack, Adam Werle, and Randy Bouchard for helping me start to work with members of the Ditidaht First Nation, and thank you to Andrew Garrett, Keith Johnson, Melinda Fricke, Clara Cohen, the members of the Pacific Northwest Languages Working Group, and the audience at the Linguistic Society of America's 2013 Annual Meeting for insightful comments. Any errors in this work are my own.

[1] Prevoicing, or negative VOT, refers to the voicing that is considered part of the voiced plosive that occurs before the following stop release burst.

has undergone the change. This study shows that in Ditidaht (Wakashan), one of the languages that underwent the sound change, voiced oral stops have the same duration as the few instances of nasals remaining in the language and that the voiced oral stops have a cross-linguistically normal amount of prevoicing.

The first section (§1) discusses the details of the nasal to voiced oral stop sound change that is claimed to have spread through an area of the Pacific Northwest. The next section (§2) presents a typology of languages that lack nasal consonant phonemes, identifying three relevant types. The third section (§3) is an acoustic study of voiced oral stops and the few remaining instances of nasals in Ditidaht. The conclusion (§4) assesses the impact of the results of the study for historical linguistics.

1 The Nasal to Voiced Oral Stop Sound Change in the Pacific Northwest

1.1 Linguistic and Structural Description

The sound change that affected five languages of the Pacific Northwest changed each language's nasal consonants to voiced oral stops. In these languages, the change operated as a process of denasalization. This can be thought of as a change from [NASAL] to ∅ in a privative feature system, or as [+nasal] to [−nasal] in an equipollent system.[2] Before the change, nasal consonants contrasted with voiceless stops mainly by a difference in nasality since voicing was predictable from other features (such as [+son]) and never needed to be actively specified. However, after the change, voicing was no longer predictable and became contrastive. This denasalizing sound change, then, created a voicing distinction that was not present before. The change from the historical system to the contemporary system is schematized in (1).

(1)

Historical						*Contemporary*					
[−voi]	p	t	k	q	→	[−voi]	p	t	k	q
[+nas]	m	n				[−nas, +voi]	b	d		

The sound change had the overall effect of preserving the previously existing contrast between nasal stops and (voiceless) oral stops, but shifted the means of making the contrast from nasality to voicing. This change created a new featural contrast in the phonologies of these languages. However, their lexicons were not structurally affected by the change since it neither created homophony (i.e. neutralized contrasts) nor gave rise to new contrasts.

[2] It has been argued that a feature specifying nasality is always privative, but purely for ease of exposition, I use an equipollent system here.

The phonetic starting point of the change was either fully nasal consonants or sounds that were only partially nasal (either by being consistently realized with only a partially lowered velum or by being variably realized as oral or nasal). The standard point of view is that the starting point was fully nasal consonants, such as /m/ and /n/, since these consonants are extremely cross-linguistically common (Thompson and Thompson 1972).

However, based on descriptions of Makah and Lower Chinook by Boas (1911:17,565), Kinkade (1985) proposes that the starting point may have been a sound that was only partially nasal. Kinkade notes that occurrences of such intermediately nasal sounds are noted in older descriptive work, such as Boas (1911). Boas writes that "lower Chinook has a sound which is readily perceived as a *b*, *m*, or *w*. As a matter of fact, it is a *b* sound, produced by a very weak closure of the lips and with open nose, the breath passing weakly both through the mouth and through the nose, and accompanied by a faint intonation of the vocal chords" (17). Boas goes on to describe a similar sound for Makah, which is in the Southern Wakashan subgroup with Ditidaht, writing that "... the *b* sound ... is produced with a half-closed nose by the Indians of the Strait of Fuca, in the State of Washington. In this case the characteristic trait of the sound is a semiclosure of the nose, similar to the effect produced by a cold in the head" (17). These descriptions point to a sound that was consistently realized as intermediately nasal, most likely with only partial lowering of the velum.

While such an intermediate sound may have been the starting point of the change, the standard view would hold that the intermediate sound was only a step on the way to the sound becoming oral. The choice of what the phonetic starting point of the change was has important consequences for how the sound change can be understood to have spread.

1.2 Geography

1.2.1 Origin of the Sound Change

The geographic origin for the sound change is uncertain, but Thompson and Thompson (1972:447-448) provide evidence that it began in Lushootseed (Salish). They show that there was a historical tendency in Lushootseed for sonorants in general, not just nasals, to occlusivize to voiced stops. Lushootseed has a voiced stop and affricate inventory that extends beyond the /b, d/ that occur in the other languages that underwent the sound change and includes /b, d, d^z, $\widehat{dʒ}$, g/ and /g^w/. Citing Swadesh (1952), Thompson and Thompson (1972:447) show that in Lushootseed, */w/ > /g^w/ and */y/ > /$\widehat{dʒ}$/. This latter change is said to have continued to give rise to /d^z/, which is still present "as a result of morphophonemic patterns which are not yet fully understood" (ibid.). Furthermore, /g/ is described as being "the result of dissimilation from /g^w/" (ibid.). In Lushootseed, then, the development of voiced stops from nasals can be viewed as a subpart of a change that occurred throughout a larger portion of the inventory. Because the denasalizing sound change is a subset of

this larger change, Lushootseed is posited as the first language to have undergone the change.

1.2.2 Spread of the Sound Change

The most important geographic aspect of the sound change to be accounted for is the fact that the territories of the languages involved are not all adjacent. The five languages of the Pacific Northwest that underwent the sound change are Quileute (Chimakuan), Lushootseed, Twana (both Salish), Makah, and Ditidaht (both Wakashan).

Figure 1: Languages of the Pacific Northwest (from Thompson and Kinkade 1990:32)

From the map in Figure 1, it is apparent that Lushootseed and Twana are directly adjacent, as are Quileute, Makah, and Ditidaht.[3] However, these two groups of languages are geographically non-

[3]The Strait of Fuca was an impediment, but not a barrier, between the Ditidaht and Makah. Substantial historical contact, both friendly and inimical, occurred between the two groups, as indicated by consultants themselves and by stories collected in Arima et al. (1991).

adjacent, with Twana being separated from Quileute by Clallam and Quinault.

To account for this fact, one must either: 1) posit two independent sound changes which each result in an inventory-wide loss of nasality, 2) demonstrate that Twana and Quileute had sufficient contact to spread the change, 3) show that the change somehow spread through an intervening language, such as Clallam or Quinault, or 4) show that the geographic split between the two groups of languages is somehow inaccurate. Neither this study nor any previous work attempts to defend the position that there were two independent sound changes (Option 1). Thompson and Thompson (1972:444-445, fn. 6; citing Elmendorf 1960) also deny that significant contact (Option 2) existed between the Quileute, Makah, or Ditidaht with Twana. In the same passage, Thompson and Thompson remark that there was contact between the Twana and Makah with the Clallam as intermediaries, "but probably this contact was not of any great historical depth." In addition, Elmendorf (1949:58-59) rules out significant contact between Twana and Quinault. Any other intermediary paths would have been less direct, so it is unlikely that the sound change was transmitted via an intermediary language (Option 3). If the areal spreading account is to be maintained, then, it must be done through a re-examination of the distribution of the languages or the sound in question (Option 4).

Thompson and Thompson (1972) and Kinkade (1985) both assume that the sound change spread areally, but their accounts of how such a spread occurred differ according to their views on the phonetic starting point of the change. Thompson and Thompson (1972), who assume that the starting point of the change was fully nasal consonants, state that "we may suspect that Chemakum and Quileute (already split into separate langauges, but perhaps still in contact) presented a nasal-less block . . ." (450). However, this is incorrect according to Powell (1975:33), who reconstructs nasals for the Chimakuan stock based on internal evidence, namely that Quileute voiced stops have conditioned prenasalized allophones (23) and that the voiced stops pattern with continuants as if they were nasals (45).[4] In addition, Powell shows that Chemakum had nasal consonants throughout the time in which it was attested.[5] With a historically nasal-less Chimakuan block ruled out, we might suppose that Twana and Quileute were in contact before the arrival of Clallam speakers, who are said to have "moved from Vancouver Island to the north shores of the Olympic Peninsula in relatively recent times" (Thompson and Thompson 1972:449). However, there is no archaeological or linguistic evidence to substantiate any claim of more than sporadic contact between the Quileute and Twana. Despite this, it seems necessary to assume that this contact did

[4]The standard featural representation of nasal consonants, which is maintained here, asserts that they are not continuants (i.e. that they are [−cont]) because they have a complete oral obstruction. However, since air flows continuously out of the nasal passage during their articulation, it is conceivable that they would pattern with continuants.

[5]Powell considers the possibility noted by Thompson and Thompson (1972) that Chemakum lost nasals and then regained them later under pressure from Clallam (44), but refrains from investigating it further since it ultimately cannot be proven based on the available historical evidence.

occur if an areal spreading account is to be maintained under the assumption of Thompson and Thompson (1972) that the phonetic starting point of the change was fully nasal consonants. The path of the spread of the sound change would then have been from Lushootseed westward to Twana, then to Quileute, then to Makah, and finally to Ditidaht.

The account given by Kinkade (1985) is quite different. He argues that a geographically contiguous group of languages along the borders of the inside coastline from approximately central Vancouver Island to southern Puget Sound and out the Strait of Juan de Fuca had an intermediately nasal sound (or sounds) that he proposes was the starting point of the sound change (478).[6] His view, then, is that the sound change was not strictly denasalization, but a leveling of the variation in realizations of the intermediately nasal sound. In each language under his view, the intermediately nasal sound came to be categorically and consistently realized as either a fully nasal consonant or a voiced oral stop (479). The languages for which the sound became a voiced oral stop were not geographically contiguous, but the languages with the intermediately nasal sound that served as the phonetic starting point for the sound change were. The sound change then spread across that geographically continuous range, but its results created a split between the languages which came to have voiced oral stops to the exclusion of nasal consonants.

1.3 Chronology

The precise chronology of the sound change is uncertain, but there is evidence that the occurrence and spread of the sound change occurred quite recently, even into the 20th century. Early descriptive accounts (by F. Boas, G. Gibbs, C. Hill-Tout, E. Sapir, W. Fraser Tolmie, and others) from the 1840s until approximately 1915 describe sounds that are intermediate in nasality or that vary between nasal and voiced oral stop realizations (Kinkade 1985:478-479). After this period, the intermediate or varying sound seems to have settled into being realized categorically as either a nasal consonant or a voiced oral stop since there is less variability in descriptions. However, Kinkade (1985:479) notes that "fieldworkers have reported indeterminate or varying sounds even within the past ten to twenty years."[7] Under the view that the phonetic starting point was a fully nasal consonant, the sound change may be considered to be older than it would be if the starting point were an intermediately nasal sound. This follows from the idea that the process of the change would have to have been *n $>$ *n/d $>$ d instead of *n/d $>$ d, and that the process of change from *n $>$ *n/d must have taken additional time.[8]

[6] It is not clear whether that sound would have been a phoneme that was consistently realized with a partially lowered velum or a phoneme that was variably realized as oral or nasal.

[7] Unfortunately, he does not note which fieldworkers or which languages are being referred to.

[8] A trajectory of *n $>$ d should also be considered, but perhaps only for languages in which there is no attestation of intermediately nasal sounds by fieldworkers.

2 Typology of Languages Without Nasal Consonant Phonemes

2.1 A Possible Linguistic Universal

Ferguson (1963:56) proposed an absolute universal that "Every language has at least one P[rimary] N[asal] C[onsonant] in its inventory." He defined a Primary Nasal Consonant (PNC) as "a phoneme of which the most characteristic allophone is a voiced nasal stop, that is, a sound produced by a complete oral stoppage (e.g., apical, labial), velic opening, and vibration of the vocal chords." This proposed universal has numerous counterexamples, including four of the five languages of the Pacific Northwest that have been discussed. However, a weakened version of that universal may still hold true.

(2) Every language uses nasality for a linguistic purpose.

Most absolute universals end up being disproven, but of the languages that have been proposed as counterexamples to Ferguson's universal, every one conforms to this weakened universal. While Primary Nasal Consonants can be eliminated from the core phonemic inventory of some languages, every language seems to use nasality or nasal consonants either in loanwords or for some socio-/meta-linguistic purpose, such as signaling formality by the use of archaic forms with nasals as in Quileute (Powell and Woodruff 1976), or representing specific kinds of characters in storytelling (e.g. in accounts of foreigners trying to speak Rotokas, Rotokas speakers use nasal forms in the foreigners' Rotokas; Firchow and Firchow 1969:274). Languages that lack Primary Nasal Consonants can be grouped into three broad types based on the degree to which they make use of nasality.

2.2 Type I: Only Lexical or Metalinguistic Nasality

In Type I languages, none of the consonants have nasal free-variants or conditioned nasal allophones. Nasality is used only in miscellaneous lexical items, primarily loanwords, or for socio-/meta-linguistic purposes (e.g. in storytelling). Type I languages use nasality to the least extent of languages that lack Primary Nasal Consonants.

Four of the five languages of the Pacific Northwest are Type I languages. (It will be shown that Quileute is a Type III language.) To show this, examples of the use of nasals are provided for each language. Makah and Ditidaht use nasals in loanwords such as /ˈna:ni:/ 'grizzly bear,' which occurs in both languages (Davidson 2002:75, Werle 2007:84). Nasals are also used in some words with a diminutive meaning (Ditidaht /ni:t͡sʼ/ `short'). In Lushootseed, loanwords and some words with diminutive meaning also contain nasals, such as the word /miʔmaʔd/ 'small' (Thompson and Thompson 1972:448). In Twana, loanwords from English and Chinook Jargon contain nasals, as does the word /kʼaˈkʼeʔmaɬ/ 'small,' which is noted specifically as not being a loan from Lushootseed (or presumably any other language; Drachman 1969:188-189,198-199).

2.3 Type II: Nasal Free-Variants

Type II languages have at least one consonant with a nasal free-variant, but no consonants with a conditioned nasal allophone. Languages of this type include languages like Pawnee, where "in word-initial position many speakers frequently pronounce the [phoneme /ɾ/] as a nasal [n] and some speakers even pronounce it occasionally as a lateral [l]" (Parks and Pratt 2008:13-14). The interspeaker variation is what makes this free variation, even though there is some phonological conditioning.

A particularly interesting case of a Type II language is the Central dialect of Rotokas, a Papuan language spoken on central Bougainville Island. The voiced bilabial phoneme of Rotokas "is variously realized as [β], [b], and [m]" (Robinson 2006:207). Robinson (2006) shows that Central Rotokas lost its nasals, making it the only language outside of the Pacific Northwest known to have undergone a complete loss of nasals throughout its inventory. Through new fieldwork, Robinson (2006) showed that the Aita dialect of Rotokas has both a voiced stop and nasal series, which suggests that the denasalizing sound change in Central Rotokas merged the nasals with the voiced stops. That sound change therefore would have had structural effects, possibly creating homophony, whereas the denasalizing sound change did not have structural effects in the five languages of the Pacific Northwest.

2.4 Type III: Conditioned Nasal Allophones

Type III languages have at least one consonant with a conditioned and consistently realized nasal allophone. While Type III languages lack a Primary Nasal Consonant underlyingly, nasality is used as a phonemically contrastive element and nasal consonants are commonly encountered in surface forms. For example, many Tukanoan languages have nasal harmony systems in which nasal consonants are not underlyingly distinct from oral ones, but the presence of nasalization in the morpheme is contrastive. In the Western Tukanoan language Máíjɨki, the underlying voiced obstruents /b, d, d͡ʒ/ surface under nasal consonant harmony as [m, n, ɲ], as in /[NAS] bába/ → [mámá] 'new.'[9] In this example, [b] does not minimally contrast with [m], rather the presence of nasality on the morpheme is apparent from the nasalization of both the consonants.

As noted above, Quileute (Chimakuan) is a Type III language. Its voiced stops are realized as prenasalized when they occur as syllable onsets in reduplicated forms, e.g. [^{m}bə́t͡s^{m}bət͡s] /bat͡sbat͡s/ `chipmunk' and [$^{n}$déq'$^{n}$deq'] /díq'diq'/ `mallard duck' (Powell 1975:23; acute accent marks stress).

[9] The acute accents indicate level high tone. See Farmer (In prep).

3 Acoustic Study of Voiced Oral Stops and Nasal Consonants in Ditidaht

The complete loss of nasal consonants in a language is such a rare phenomenon that its phonetic results are not well understood. It is possible that the voiced oral stops that resulted from such a change are different somehow from voiced oral stops without such a history. Specifically, one might question whether any of the characteristics of the resulting voiced oral stops are holdovers or "relics" of their former status as nasals. The goal of this study was to determine whether any holdover effects existed by investigating some of the acoustic characteristics of the voiced oral stops. The language of focus was Ditidaht (Wakashan), which is a Type I language that underwent an inventory-wide loss of nasality as a result of the denasalizing sound change that spread through the Pacific Northwest.

To determine whether any holdover effects existed, the voiced oral stops of Ditidaht were compared to the language's few existing tokens of nasal consonants. These nasal consonants occur in loanwords, some words with diminutive meaning, and other miscellaneous lexical items. For a full list, see the Appendix. Under the view of Kinkade (1985) that an intermediately nasal sound was the phonetic starting point of the sound change, comparing the voiced oral stops to the existing tokens of fully nasal consonants is meaningless. However, it is still a valid comparison if the starting point of the change is assumed to have been fully nasal consonants (as is the view of Thompson and Thompson 1972) and if one assumes that these would not have differed significantly from the few remaining tokens of fully nasal consonants. The fact that it would be articulatorily difficult to consistently produce and maintain only partial velic lowering in a sound lends credence to the idea that fully nasal consonants were the starting point of the change.[10] Moreover, fully nasal consonants are reconstructed for the Wakashan, Salish, and Chimakuan stocks (Fortescue 2007, Kroeber 1999, and Powell 1975, respectively). This study adopts this point of view on the phonetic starting point of the sound change, but with significant reservations based on the difficulty of plausibly establishing a path for the change's geographic spread.

Duration and prevoicing were the two acoustic characteristics that were examined for holdover effects. Because the voiced oral stops occupy the same segmental positions and timing slots as the former nasal consonants, an identical or similar duration to contemporary nasal consonants could be interpreted as a holdover effect. Nasal consonants are, cross-linguistically, usually voiced throughout most of their duration.[11] This raises the possibility that the voiced stops in Ditidaht might exhibit more prevoicing than is cross-linguistically normal as a result of retaining some of the voicing from their former incarnation as nasal consonants.

[10] Many thanks to Chris Carignan for pointing this out.

[11] The contemporary nasal consonants in Ditidaht are fully voiced throughout their entire duration.

Before proceeding to the study, it is useful to present the Ditidaht phonemic inventory. This is shown in Tables 1 and 2, adapted from Werle (2007:76-77). Forms in parentheses are marginal as a result of sound changes.[12]

	Bilabial	Alveolar	Postalv.	Palatal	Velar	Uvular	Phar.	Glottal
Plosive	p b	t d			k k^w	q q^w		ʔ
Glottalized Plos.	p’ ˀb	t’ ˀd			k’ $k’^w$	(q’ $q’^w$)		
Nasal	(m ˀm)	(n ˀn)						
Fricative		s	ʃ		x x^w	χ $χ^w$	ʕ	h
Affricate		t͡s t͡s’	t͡ʃ t͡ʃ’					
Lateral Fric.		ɬ						
Lateral Affric.		t͡ɬ t͡ɬ’						
Approximant	w ˀw			j ˀj				
Lateral Approx.		l ˀl						

Table 1: Consonant phonemes

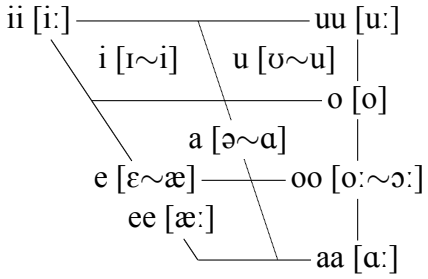

Table 2: Vowel phonemes

Due to the absence of voiced oral stops or nasal consonants at the velar and uvular places of articulation, only bilabial and alveolar stops were examined in this study. Also of note is that long vowels have a consistent quality, while short vowels exhibit some free variation and are most frequently realized with the first of the two variants listed.

[12]The uvular ejectives */q’, $q’^w$/ merged as /ʕ/ (Jacobsen 1969), whose active articulator is most likely the epiglottis. It is realized as a stop prevocalically and as a glide in other positions (Werle 2007:75). Words with /q’, $q’^w$/ are still present in the language as a result of the morphological Hardening process (Werle 2007:80-82) and contact. Cultural vocabulary shared with neighbors (e.g. /$q’^w$eːtij/ `Mink, the Trickster') and some toponyms of Makah origin (e.g. q’iːquːws `Caycuse River') have these phonemes.

3.1 Consultants and Methods

3.1.1 Consultants

To investigate whether any of these holdover effects exist in Ditidaht, data were collected from three native speakers (2 F, 1 M) in Malachan, British Columbia, during May and June 2012.[13]

3.1.2 Materials

All tokens were recorded using a Zoom® Handy H4N digital recorder with an Audio Technica® AT-803 lavalier microphone.

The author compiled a wordlist from a working dictionary that included all the 36 known words that contain nasal consonants in Ditidaht along with tokens for voiced oral stops in a variety of segmental contexts.[14] The wordlist listed the Ditidaht word followed by an English gloss.

All of the nasal consonants attested in Ditidaht, /m, ʔm, n, ʔn/, were represented in the list.[15] These words can all be interpreted as the results of contact with English, Chinook Jargon, Nuu-chah-nulth, or Salish languages, or as instances of sound symbolism, generally conveying smallness. The words with nasals are not always morphologically independent. For a list of all the words with nasals accompanied by glosses and possible origins, see the Appendix.

The wordlist also contained words with all the voiced oral stops, /b, ʔb, d, ʔd/.[16] The segmental contexts for voiced oral stops were chosen to provide the maximum variety of positions in the word, in the syllable, with respect to stress, and with respect to vowel length. To control for possible effects of coarticulation, the vowel in contact or surrounding the consonant of interest was kept as /a/ whenever possible. Not all the phonologically possible contexts were attested in words in the working dictionary. For example, there were no tokens positioned between two long, unstressed vowels (VV__VV). This was an accidental gap.

Some of the gaps in the data, however, were systematic. The stress system and phonotactic restrictions of Ditidaht limit the combinatorial possibilities for segmental contexts with voiced stops next to short and long vowels, both stressed and unstressed. Primary stress falls on the first syllable

[13] This is the official name for the Reserve on maps, but it is locally called Nitinat/Nitinaht (both variants are pronounced [ˈnɪtnæt]) or Nitinaht Lake. The occurrence of nasals in toponyms can ultimately be attributed to Nuu-chah-nulth influence (possibly via English speakers adopting Nuu-chah-nulth pronunciations). The native Ditidaht place names do not contain nasals.

[14] Thank you to Adam Werle for compiling the working dictionary for the Ditidaht Studies Program at the Ditidaht Community School and providing me with a copy. The full wordlist used in this study is available by request.

[15] All the traditional sonorant consonants and voiced stops have plain realizations and have corresponding pre-glottalized variants that are also phonemic (ʔm, ʔn, ʔl, ʔj, ʔw, ʔb, ʔd). These pre-glottalized phonemes are realized exactly like their plain counterparts except for some preceding creaky voicing or laryngealization evident in spectrograms. The sounds ʔl and ʔm are exceedingly rare.

[16] Because there is no velar or uvular nasal or any velar or uvular voiced oral stops, velar and uvular consonants were not included in the wordlist.

if its vowel is long, otherwise on the second syllable whether it is long or short (Werle 2007:91).

Phonotactic restrictions limit the distribution of voiced and pre-glottalized consonants. The plain voiced consonants, /b, d, m, n, l, j, w/, can occur word-initially and adjacent to a vowel, so long as they are not post-consonantal. However, the pre-glottalized consonants, /ˀb, ˀd, ˀm, ˀn, ˀl, ˀj, ˀw/, can only occur directly following a vowel (and possibly with other consonants following them; Werle 2007:83). The restricted distribution of the pre-glottalized consonants must be for perceptual reasons: the restriction to post-vocalic positions is because otherwise the preceding laryngealization could not be heard. Historically, initial pre-glottalized consonants were deglottalized, but those following a vowel were usually not (Haas 1969:115-118).

Table 3 shows the segmental contexts in words that were elicited in order to obtain tokens of a voiced oral stop where it was in contact with only one vowel. These segmental contexts were in word-initial onset, word-medial coda (by definition pre-consonantal), and absolute word-final positions. Table 4 shows the segmental contexts in words that were elicited in order to obtain tokens of a voiced oral stop where it was in intervocalic onset position, in contact with two vowels.

Word Position	*Syllable Position*	*Contact V Length*	*Contact V Stress*	*Consonants Recorded*				*Environment*
Initial	Onset	Short	Unstr.	b		d		#__V
		Long	Str.	b		d		#__V́V
Medial	Coda	Short	Unstr.	b		d	ˀd	V__(.)C
			Str.	b	ˀb	d	ˀd	V́__(.)C
		Long	Unstr.	b	ˀb	d	ˀd	VV__(.)C
			Str.	b	ˀb	d	ˀd	V́V__(.)C
Final	Coda	Short	Unstr.	b	ˀb	d		V__#
			Str.	b		d	ˀd	V́__#
		Long	Unstr.			d	ˀd	VV__#
			Str.	b		d	ˀd	V́V__#

Table 3: Segmental structures in words meant to elicit voiced oral stops in all non-intervocalic contexts

V_1 Length	*V_1 Stress*	*V_2 Length*	*V_2 Stress*	*Consonants Recorded*				*Environment*
Short	Unstr.	Short	Unstr.	b	ʔb	d	ʔd	V__V
			Str.	b	ʔb	d	ʔd	V__Ṽ
		Long	Unstr.	b	ʔb	d		V__VV
			Str.	b		d		V__ṼV
	Str.	Short	Unstr.	b	ʔb	d	ʔd	Ṽ__V
		Long	Unstr.	b		d	ʔd	Ṽ__VV
Long	Unstr.	Short	Unstr.	b		d	ʔd	VV__V
		Long	Unstr.					VV__VV
	Str.	Short	Unstr.	b	ʔb	d	ʔd	ṼV__V
		Long	Unstr.	b	ʔb	d	ʔd	ṼV__V

Table 4: Segmental structures in words meant to elicit voiced oral stops in intervocalic contexts

3.1.3 Elicitation

Using the wordlist, the author first tried to elicit the Ditidaht word by asking the speaker for it using the English gloss. This was successful for the majority of lexical items. In cases when speakers could not recall a word, the author read the Ditidaht word. If the speaker clearly recognized the word, she or he was then asked to repeat it for the recording. All recordings were done in quiet rooms without any noise in the tokens that were measured.

3.2 Data, Analysis, and Results

3.2.1 Segmentation

Recordings were labeled in Praat (Boersma and Weenink 2001) using an ASCII equivalent of Ditidaht orthography in order to obtain tokens of the nasal consonants and voiced oral stops. When multiple tokens of the elicited word were provided, the one with a declarative intonation and the clearest spectrogram was used. In words with multiple instances of the consonant of interest, only the one in the desired environment or adjacent to a stressed vowel was used. For example, in the word /ˈna:ni:/ 'grizzly bear,' only the first /n/ was used as a token.

Nasals were labeled according to where F2 and F3 were noticeably weakened and voicing still occurred with a strong F1. This was visually obvious in the spectrogram and correlated exactly with the audio. Included in the duration of nasals were occasional "nasal bursts," which were structures visible in the spectrogram that looked similar to stop bursts. These occurred at the end of nasal consonants and did not seem to be auditorily associated with the following vowel.

Voiced oral stops were labeled from the onset of closure (in cases where it was apparent) to the onset of the following vowel. In the absence of a following vowel, the end of release noise was taken to be the end of the voiced oral stop. Prevoicing in voiced oral stops was labeled from the onset of any voicing until that voicing ended based on pulses identified by Praat and verified by visual inspection. In tokens following a vowel, prevoicing was judged to start where the vowel formants were weakened but voicing continued.

The pre-glottalized nasals and voiced oral stops (/ˀm, ˀn, ˀb, ˀd/) were transcribed like their plain counterparts. The laryngealization that occurs on vowels preceding these consonants was not included in their duration.[17]

To make sure that duration contrasts existed between stops of different voicing categories, voiceless stops and ejectives were labeled. Where possible, the closure period was included for voiceless stops and ejectives. This was usually not possible when the segment was word-initial. Voice onset time (VOT) was measured from the stop burst to the onset of voicing in the following vowel.

3.2.2 Data

Table 5 summarizes the total number of tokens for nasal consonants, voiced oral stops, plain voiceless stops, and ejectives. The total number for each category signifies all the tokens that were available for acoustic analysis across speakers and across phonemes within that category. Counts are given for the number of tokens by phoneme and by speaker.

Token Type	*Nasals*				*Voiced Oral Stops*				*Plain Voiceless Stops*			*Ejective Stops*		
Total Tokens	89				194				106			55		
By Phoneme	m	ˀm	n	ˀn	b	ˀb	d	ˀd	p	t		p’	t’	
	21	2	57	9	59	27	69	39	54	52		27	28	
By Speaker	M	F_1	F_2		M	F_1	F_2		M	F_1	F_2	M	F_1	F_2
	31	23	35		66	65	63		36	32	38	18	19	18

Table 5: Token counts by phoneme, by speaker, and total

3.2.3 Analysis

The goal of the study was to determine whether any of the acoustic properties of the voiced oral stops could be attributed to their former status as nasals. Specifically, segmental duration and

[17] Because of this, their durations as measured were not significantly different from that of their plain counterparts. Voiced oral stops: $t(171) = -0.54$, $p = 0.588$; Nasals: $t(48) = 1.72$, $p = 0.091$.

prevoicing were thought to be acoustic parameters in which holdover effects might be evident. To determine whether there were holdover effects, the duration of voiced oral stops was compared with the nasals that currently remain in a few words of Ditidaht. To help understand the results of this comparison, the duration of voiced oral stops was also compared with plain voiceless stops and ejective stops. Prevoicing was measured for the voiced oral stops and compared to cross-linguistic measurements from Lisker and Abramson (1964).

Two-tailed t-tests were used to compare the durations of voiced oral stops with nasals, plain voiceless stops, and ejective stops. A t-test was also used to compare the VOT measurements for plain voiceless stops and ejective stops. Two t-tests were also used to compare the durations of pre-glottalized consonants (as transcribed, see fn. 8) and their plain counterparts. This yields six t-tests total. To control for errors arising from multiple comparisons, an initial α-level of 0.05 was adjusted to 0.00834 (= 0.05/6) using a standard Bonferroni correction.

3.2.4 Results

The results of the comparisons of duration are reported in Table 6.

Segment Type	*Mean Duration*	*Segment Type*	*Mean Duration*	t	p	
Voiced Oral Stop	111 ms	Nasals	115 ms	t(137) = 0.53	p = 0.591	
		Plain Voiceless Stops	140 ms	t(298) = -4.99	$p < 0.001$	***
		Ejective Stops	106 ms	t(247) = 0.63	p = 0.525	

Table 6: Duration of voiced oral stops in comparison with other segment types

The mean durations of voiced oral stops and nasals are not significantly different, nor are the mean durations of voiced oral stops and ejectives.

Nasals were strongly voiced throughout their entire durations, and the mean prevoicing for all voiced oral stops was 90 ms. Given the mean duration of voiced oral stops (111 ms), prevoicing accounts for approximately 81% of their total mean duration. The mean prevoicing accounted for 87% of the pre-release duration for labials and 76% for alveolars.

The mean VOT of plain voiceless stops was 28 ms as opposed to 54 ms for ejective stops. The dimension of VOT is, as would be predicted, a relevant factor in distinguishing these stops (t(159) = -5.25, $p < 0.001$).

3.3 Discussion

3.3.1 Duration

At first, the fact that the mean durations of nasals and voiced oral stops are not significantly different seems to provide evidence that the duration of the voiced oral stops is a holdover effect from their historical status as nasals. However, there is reason to doubt that conclusion.

Typological evidence suggests that it may be more common than is usually thought for voiced oral stops to have nearly the same duration as nasal consonants. Dmitrieva (2012:79,124) showed that the durations of /d/ and /n/ were extremely similar in the production of nonce words in both Russian and Italian. Trigui et al. (2010:104) show that in Modern Standard Arabic, the durations of /b/ and /m/ are very similar, but the durations of /d/ and /n/ are less so. Byrd (1993:3,6,12), however, shows that the durations of voiced oral stops in English were 20-21 ms longer than the durations of nasals in the TIMIT corpus, which consists of read speech (Zue et al. 1990:352). A summary of the quantitative aspects of this typological evidence is presented in Table 7.

	/b/	/m/	/d/	/n/	/b/ & /d/	/m/ & /n/
Arabic	58	62	69	60	63.5	61
English	82	62	76	55	79	58.5
Italian			78	71		
Russian			84	86		

Table 7: Mean duration (in ms) of segments and segment classes in four languages

Because the durations of voiced oral stops and their nasal counterparts can be very similar in languages in which the voiced oral stops did not arise historically from the nasals (or vice versa), the durational similarity of voiced oral stops and contemporary nasals in Ditidaht cannot be said to be a phonetic holdover effect or "relic" with any certainty.

3.3.2 Prevoicing

Because the contemporary nasals of Ditidaht are voiced throughout their entire duration, one might expect the voiced oral stops to have greater prevoicing than is cross-linguistically normal (assuming that contemporary nasals reflect the historical nasals). In addition, the sound change that shifted nasals to voiced oral stops introduced a voicing distinction into the language, which is another reason to expect that greater than normal prevoicing might occur. However, the amount of prevoicing exhibited by Ditidaht voiced oral stops fits well with languages with a three-way voicing distinction

according to data from Lisker and Abramson (1964).[18]

Language	*Voicing Categories*	*Mean Prevoicing of /b, d/*
Hungarian	2	89 ms
Dutch	2	83 ms
Puerto Rican Spanish	2	124 ms
Tamil	2	76 ms
English	*2*	*0 or negative*
Eastern Armenian	3	99 ms
Ditidaht	**3**	**90 ms**
Thai	3	88 ms

Table 8: Data from Lisker and Abramson (1964), sorted by number of voicing categories

Ditidaht voiced oral stops do not seem to exhibit a cross-linguistically unusual amount of prevoicing. However, the fact that Ditidaht does exhibit consistent and substantial prevoicing shows that even in the face of severe language endangerment and pressure from English, speakers of the language still maintain subtle phonetic characteristics in Ditidaht instead of adopting a more English-like pronunciation. This is in contrast to the kind of adaptation reported to occur for Brazilian Portuguese VOT in Sancier and Fowler (1997).

4 Conclusion

This study has described the acoustic characteristics of Ditidaht's voiced oral stops, which are the result of an inventory-wide historical loss of nasality. The loss of nasality to this extent is an extremely cross-linguistically rare sound change, and is attested only in one other language, the Central dialect of Rotokas. The study reported here is the first to examine the phonetic consequences of that sound change. Similar studies on Lushootseed and Rotokas, the only two living languages that have also undergone such a loss, would substantially contribute to understanding this rare sound change.

The results of this study have shown that no acoustic characteristics of the Ditidaht voiced oral stops can reliably be attributed to their former status as nasal consonants. For historical linguistics, this finding shows that the origins of a sound change need not be present, even at a sub-phonemic level, in the current language. Similarly, if holdover effects or "relics" are not found, that is not evidence against a sound change having taken place. Evidence from regular correspondences shows

[18]The data cited from Lisker and Abramson (1964) are from words read in isolation from a wordlist. Because the data are from words uttered in isolation, they are assumed to be comparable to the Ditidaht data.

that the nasal to voiced oral stop change took place (Haas 1969:112,116), yet there is no residual sub-phonemic evidence of the change that is apparent in the voiced oral stops in Ditidaht.

References

Arima, Eugene Yuji; Denis St. Claire; Louis Clamhouse; Joshua Edgar; Charles Jones; and John Thomas. 1991. *Between Ports Alberni and Renfrew: Notes on West Coast Peoples*, *Mercury Series*, vol. 121. Hull, Quebec: Canadian Museum of Civilization.

Boas, Franz. 1911. *Handbook of American Indian Languages*. Bureau of American Ethnology Bulletin no. 40, Washington, D.C.: Government Printing Office.

Boersma, Paul and David Weenink. 2001. Praat, a system for doing phonetics by computer. *Glot International* 5(9/10):341--345. Includes review by Vincent van Heuven.

Byrd, Dani. 1993. 54,000 American stops. *UCLA Working Papers in Phonetics* 83:97--116.

Davidson, Matthew. 2002. *Studies in Southern Wakashan (Nootkan) Grammar*. Ph.D. thesis, SUNY Buffalo, Buffalo, NY.

Dmitrieva, Olga. 2012. *Geminate Typology and the Perception of Consonant Duration*. Ph.D. thesis, Stanford University, Palo Alto, CA.

Drachman, Gaberell. 1969. *Twana Phonology*, *Ohio State University Working Papers in Linguistics*, vol. 5. Columbus, OH: Department of Linguistics, Ohio State University.

Elmendorf, William W. 1949. *The Structure of Twana Culture*. Ph.D. thesis, University of California, Berkeley, Berkeley, CA.

Elmendorf, William W. 1960. *The Structure of Twana Culture*. Washington State University Research Studies, Monographic Supplement No. 2, Pullman, WA: Washington State University.

Farmer, Stephanie. In prep. Tone in Máíjɨki. Ms. University of California, Berkeley.

Ferguson, Charles A. 1963. Assumptions about nasals: A sample study in phonological universals. *Universals of Language*, edited by Joseph H. Greenberg, Cambridge, MA: MIT Press, 53--60.

Firchow, Irwin and Jacqueline Firchow. 1969. An abbreviated phoneme inventory [of Rotokas]. *Anthropological Linguistics* 11(9):271--276.

Fortescue, Michael. 2007. *Comparative Wakashan Dictionary*. Munich: Lincom Europa.

Haas, Mary R. 1969. Internal reconstruction of the Nootka-Nitinat pronominal suffixes. *International Journal of American Linguistics* 35:108--135.

Jacobsen, William H. 1969. Origin of the Nootka pharyngeals. *International Journal of American Linguistics* 35(2):125--153.

Jacobsen, William H. 1994. Nootkan vocative vocalism and its implications. *Sound Symbolism*, edited by John J. Ohala; Leanne Hinton; and Johanna Nichols, Cambridge, UK: Cambridge University Press, 23--39.

Kinkade, M. Dale. 1985. More on nasal loss on the Northwest Coast. *International Journal of American Linguistics* 51:478--480.

Kroeber, Paul D. 1999. *The Salish Language Family: Reconstructing Syntax*. Lincoln, NE: University of Nebraska Press.

Lisker, Leigh and Arthur S. Abramson. 1964. A cross-language study of voicing in initial stops: Acoustical measurements. *Word* 20(3):384--422.

Parks, Douglas R. and Lula Nora Pratt. 2008. *A Dictionary of Skiri Pawnee*. Studies in the Anthropology of North American Indians, Omaha, NE: University of Nebraska Press.

Powell, James V. 1975. Proto-Chimakuan: Materials for a reconstruction. *University of Hawaii Working Papers in Linguistics* 7(2):i--202.

Powell, James V. and Fred Woodruff, Sr. 1976. *Quileute Dictionary*. Moscow, ID: JONA.

Robinson, Stuart. 2006. The phoneme inventory of the Aita dialect of Rotokas. *Oceanic Linguistics* 45(1):206--209.

Sancier, Michele L. and Carol A. Fowler. 1997. Gestural drift in a bilingual speaker of Brazilian Portuguese and English. *Journal of Phonetics* 25:421--436.

Swadesh, Morris. 1952. Salish phonologic geography. *Language* 28(2):232--248.

Thompson, Laurence C. and M. Dale Kinkade. 1990. *Languages*, Washington, D.C.: Smithsonian Institution, *Handbook of North American Indians: Northwest Coast*, vol. 7, chap. 3, 30--51.

Thompson, Laurence C. and M. Terry Thompson. 1972. Language universals, nasals, and the Northwest Coast. *Studies in Linguistics in Honor of George L. Trager*, edited by M. Estellie Smith, The Hague: Mouton, Janua Linguarum, 441--456.

Trigui, Aymen; Mohsen Maraoui; and Mounir Zrigui. 2010. The gemination effect on consonant and vowel duration in Standard Arabic speech. *11th ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing*, London, 102--105.

Werle, Adam. 2007. Ditidaht vowel alternations and prosody. *The Canadian Journal of Linguistics* 52(1/2):71--104.

Zenk, Henry. 1993. A basic Chinook Jargon lexicon. *International Conference on Salish and Neighbouring Languages*, vol. 28, Vancouver, BC: UBC Working Papers in Linguistics, vol. 28, 363--388.

Zue, Victor; Stephanie Seneff; and James Glass. 1990. Speech database development at MIT: TIMIT and beyond. *Speech Communication* 9:351--356.

Appendix

Ditidaht Words with Nasal Consonants

The table below shows the Ditidaht lexical items that have nasal consonants (stress is marked with an acute accent). These can all plausibly be attributed to contact or diminutive sound symbolism. In many cases, the exact explanation is known.

/m/

Word	*Gloss*	*Word Origin*
ʔamáʃ	breasts, to breastfeed, milk (n)	Also ʔadáb `breasts.' Related placename for ``breast mountain'' SE of Malachan is /ʔadábas/. Reconstructed for Proto-Southern Wakashan as *ʔanma `breast, suckle' by Fortescue (2007:253). Makah has ʔadáab(a) `breast, milk, sucking breast' and Nuu-chah-nulth has ʔinma `breast, milk, suckling milk'
ham	excrement	loaned via Nuu-chah-nulth or kept intact; reconstructed for Proto-Wakashan in Fortescue (2007:38)

hamʕé:jqt͡ɬ	have to poop	
hamúʔɬ	toilet, washroom, women's bathroom	
mitú:li:	Victoria	loan from English
lijó:m	devil	Chinook Jargon from French *diable*
mú:kʷa:wis	smokehouse	loan from English
mú:smus	cow	Chinook Jargon (Zenk 1993)
t͡s'ú:mʕas	Port Alberni	probable loan from Tseshaht Nuu-chah-nulth

/n/

Word	*Gloss*	*Word Origin*
hiɬnájukʃt͡ɬ	a fart (female)	Baby talk? Diminutive sound symbolism?
nat͡ɬkíje:	to kick something to somebody	?
nat͡ɬkʃít͡ɬ	to kick	Nuu-chah-nulth
ná:t͡ɬkapiʔɬ	to put one's feet up (indoors)	?
ná:ni:	grizzly bear	Nuu-chah-nulth
sá:nti:	Sunday	Loan from English
sá:sa:nte:tχ	Saturday	Morphologically derived from /sa:nti:/
ne:n	Grandma! (direct address)	baby talk, diminutive (Jacobsen 1994:29)
t͡s'iníp'uʔ	squirrel	Diminutive sound symbolism? Note that this is /t͡simt'u:/ in Tseshaht, Hupacasath Nuu-chah-nulth according to Jacobsen (1994:29)
sá:sin	hummingbird	Nuu-chah-nulth
té:kin	socks	Loan from English, ultimately. Chinook Jargon is /stakin/ (Zenk 1993:383).
ʔí:ʔinxʷaʔp	too small (to do something)	Diminutive sound symbolism? Compare English *eensy-weensy* to Ditidaht root /ʔin/ or /nii/ for ``small, little, few''
ʕinqt͡ʃú:	dumplings, boiled bread	Diminutive sound symbolism?
ni:t͡s'	short	Diminutive sound symbolism?
ní:t͡s'akʷt͡ʃ	to wear shorts or something short	Diminutive sound symbolism?
qʷiní:	seagull	Nuu-chah-nulth

ʔiní:q	a few, a little bit	Diminutive sound symbolism?
ʔisáno:	pee (female)	Diminutive sound symbolism for nasal. Note Fortescue (2007:150), ``PW /ʔi(ʔ)asa/ `urinate (woman)'"
ʔinú:wiʃt͡ʃt͡ɬ	to become small	Diminutive sound symbolism?
ʔinú:we:jaʔp	to make something small	Diminutive sound symbolism?

/ˀn/

Word	*Gloss*	*Word Origin*
ná:ˀnsaʔ	robin	Diminutive sound symbolism?
piˀnó:	kitten	Diminutive sound symbolism?
ʔiˀníts’	a short time	Diminutive sound symbolism?
ní:ˀni:ts’aqabɬ	short hair	Diminutive sound symbolism?

John Sylak-Glassman
University of California, Berkeley
Department of Linguistics
1203 Dwinelle Hall
Berkeley, CA 94720-2650
sylak@berkeley.edu
http://linguistics.berkeley.edu/∼sylak