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Untangling cultural inheritance: language diversity and long-house architecture on the Pacific northwest coast

Peter Jordan[1,2] **and Sean O'Neill**[1,2,*]

[1]*Department of Archaeology, University of Aberdeen, St Mary's Building, Elphinstone Road, Aberdeen AB24 3UF, UK*
[2]*AHRC Centre for the Evolution of Cultural Diversity, Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY, UK*

Many recent studies of cultural inheritance have focused on small-scale craft traditions practised by single individuals, which do not require coordinated participation by larger social collectives. In this paper, we address this gap in the cultural transmission literature by investigating diversity in the vernacular architecture of the Pacific northwest coast, where communities of hunter–fisher–gatherers constructed immense wooden long-houses at their main winter villages. Quantitative analyses of long-house styles along the coastline draw on a range of models and methods from the biological sciences and are employed to test hypotheses relating to basic patterns of macro-scale cultural diversification, and the degree to which the transmission of housing traits has been constrained by the region's numerous linguistic boundaries. The results indicate relatively strong branching patterns of cultural inheritance and also close associations between regional language history and housing styles, pointing to the potentially crucial role played by language boundaries in structuring large-scale patterns of cultural diversification, especially in relation to 'collective' cultural traditions like housing that require substantial inputs of coordinated labour.

Keywords: ethnogenesis; phylogenesis; architecture; cultural transmission; hunter–gatherers; Pacific northwest coast

1. INTRODUCTION

A growing body of empirical research is focusing on the inheritance and diversification of technological traditions. Many studies of material culture diversity now adopt an explicitly Darwinian perspective on 'cultural transmission', employing models, analytical methods and theory from evolutionary biology to study analogous processes in the cultural domain. At the core of these 'descent with modification' approaches is the observation that overall, for a variety of reasons, people tend to imitate others when acquiring cultural traditions rather than invent new skills and practices entirely by themselves, generating a tendency for historical continuity in cultural traditions, rather than radical change (Boyd & Richerson 1985).

While there are a series of well-understood 'micro-scale' processes by which individuals acquire practices within social groups, the large-scale outcomes of these processes are less well-understood, especially at population levels (e.g. Collard *et al.* 2008 with references). In particular, vigorous debates about the most likely patterns of macro-scale cultural diversification are still focusing on two mutually exclusive and competing theoretical models, the first termed the 'branching' (*phylogenesis*) hypothesis and the second the 'blending' (*ethnogenesis*) hypothesis.

The branching model predicts that macro-scale cultural diversification takes place when initial populations demographically expand and then split into successive generations of daughter populations, each new population carrying a modified set of cultural traditions with it. In other settings, similar outcomes may be generated as interacting communities reduce the degree to which they borrow and blend their traditions with other groups, perhaps as a result of emerging hostilities, ideologies of exclusion, perceived cultural or ethnic identities and other factors. In these settings, local cultural traditions may eventually become 'insulated' from outside influences, ensuring strong patterns of vertical transmission within each community. Through time, the dominance of vertical transmission within populations ensures that cultural diversification proceeds in a branching manner akin to biological speciation, enabling patterns of historical relatedness among cultural traditions to be mapped as branching tree diagrams (for recent reviews see Mace *et al.* 2005; Lipo *et al.* 2006; Gray *et al.* 2007; Collard *et al.* 2008 with references; O'Brien 2008; but see also Borgerhoff Mulder *et al.* 2006; Tëmkin & Eldridge 2007).

According to the alternative blending or 'ethnogenesis' model, populations have rarely, if ever, been completely isolated from one another and have always engaged in a ready horizontal exchange of

* Author for correspondence (r01spo7@abdn.ac.uk).

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traditions, ideas and practices. This tendency encourages a rapid and ceaseless blending of cultural traditions across time and space, creating a blur of hybrid forms whose patterns of descent are simply too chaotic for any kind of coherent historical signal to be maintained (Terrell 1987, 1988; Moore 1994, 2001).

More recent investigations employing a quantitative analytical approach have added new dimensions to these debates by demonstrating empirically that macro-scale cultural evolution varies enormously according to the culture–historical context, with branching predominating in some settings (e.g. Gray & Jordan 2000; Tehrani & Collard 2002, 2009*a*), and blending in others (Jordan & Shennan 2003; Jordan 2007). Further case studies have added new levels of complexity by exploring the degree to which a broad suite of material culture traditions and languages have been transmitted in tandem. For example, a number of individual cultural traditions may be characterized by similar patterns of branching descent, while other traditions practised by the same communities may deviate from this pattern, following a more hybridized pattern of inheritance (Jordan & Mace 2006, 2008; Jordan 2009; Jordan & Shennan 2009; for a useful range of summary models, see Boyd *et al.* 1997). Finally, more studies are now starting to address the major gap in our current understanding of the relationship between micro-level (inter-individual) transmission and population-level cultural diversity (Tehrani & Collard 2009*b*).

As the range of published quantitative analyses of cultural transmission expands and diversifies in terms of subject matter and culture–historical setting, we are now moving away from theoretical models towards a fuller empirical sense of both the complexity and local variability that characterizes macro-scale cultural inheritance. Understanding the specific processes that generate these patterns of variability will demand a renewed focus on local social settings in order to understand how and why individuals and populations interact, exchange, re-combine or withhold cultural traits in the myriad ways that they do. For example, most research on the transmission of material culture traditions has tended to focus on the dynamics of 'small-scale' portable crafts that are made by *individual* practitioners, for example, textiles, baskets, clothing and other items in ethno-historic studies, and projectile points and pottery in archaeological analyses (Tehrani & Collard 2002; Jordan & Shennan 2003; chapters in Mace *et al.* 2005; Eerkens & Lipo 2005; Lipo *et al.* 2006; Buchanan & Collard 2007; Stark *et al.* 2008; O'Brien 2008; Jordan 2009).

In contrast, much less research has been directed at understanding the dynamics of *large-scale undertakings* like communal architecture (but see Jordan 2007; Jordan & Mace 2008; Jordan & Shennan 2009). These larger cultural projects cannot be executed by one person working in isolation, and are often undertaken less frequently than the day-to-day production of small craft items, and also tend to require closely coordinated labour inputs from the wider social group. Given these different characteristics, the transmission and diversification of 'collective' material culture traditions, like housing, are likely to possess their own set of dynamics, although these remain poorly understood.

In this paper, we aim to make two contributions to the cultural transmission literature: first, we test basic models about probable patterns of macro-scale cultural diversification in vernacular 'long-house' architecture on the Pacific northwest coast; second, we test whether diversity in long-house styles has been constrained by language boundaries. Two central questions are addressed:

Q1: Have northwest coast long-house traditions been characterized by branching or blending patterns of community-scale transmission?

Q2: Have housing styles been transmitted in tandem with languages, with linguistic boundaries serving to 'canalize' the vertical inheritance of architectural styles within local communities?

In line with similar case studies, the present analysis introduces the ethno-history of the study area, explores local long-house traditions and then employs multiple quantitative methods, each based on different assumptions, to cross-check insights into macro-scale cultural diversification (see Jordan & Shennan 2009).

2. COMPLEX HUNTER–GATHERERS OF THE PACIFIC NORTHWEST COAST

The rich ethno-historic record of the Pacific northwest coast has fascinated anthropologists for many generations (Suttles 1990): stretching from Yakutat Bay in Alaska down to northern California this narrow but tremendously rich and varied ecozone was occupied at the time of European contact by a string of distinctive hunter–fisher–gatherer cultures who spoke a multitude of different languages, practised salmon-based storage economies, occupied permanent winter villages and were organized into highly stratified kin-groups who owned resource sites, houses and other properties (Jorgensen 1980; Carlson 1983; Suttles 1990; Matson & Coupland 1995; Ames & Maschner 1999).

One striking feature of these unique coastal hunter–gatherer societies was their elaborate decorative art based mainly on woodworking (Boas 1955; Drucker 1955; Inverarity 1971; Hawthorn 1979; Jonaitas 1981; Stewart 1984; Emmons 1991). This included the construction of immense wooden long-houses, which were built according to strikingly different styles on different reaches of the coast (Drucker 1955; Vastokas 1966; Nobokov & Easton 1989; Suttles 1990).

Long-houses were generally located at the main winter villages, and served as storage points, ritual settings, as well as primary dwellings for multiple families organized into different lines of descent and usually led by a house chief. Construction and decoration of new houses was an immense logistical operation involving sustained work by a coordinated pool of labour which was supervised and directed by chiefs and specialist builders as they endeavoured to follow process-based 'recipes' of house construction (see O'Brien *et al.* 2010).

Table 1. Central and northern Pacific northwest coast: ethno-linguistic communities (names, codes and linguistic affinities; after Drucker 1950).

number	ethno-linguistic community[a]	code (current paper)	CED code[a]	language (local)[b]	language (branch)[b]	language (family)[b]
1	Chilkat	Tlingit 1	LC	Tlingit	Tlingit	Tlingit
2	Sanyakwan	Tlingit 2	LS	Tlingit	Tlingit	Tlingit
3	Skidegate	Haida 1	HS	Haida	Haida	Haida
4	Massett	Haida 2	HM	Haida	Haida	Haida
5	Gitskan (Kispiyox division)	Nass-Gitskan	GK	Nass-Gitskan	Tsimshian	Tsimshian
6	Tsimshian Proper (Gilutsa division)	Tsimshian 1	TG	Coast Tsimshian	Tsimshian	Tsimshian
7	Southern Tsimshian (Kitqata division)	Tsimshian 2	TH	Coast Tsimshian	Tsimshian	Tsimshian
8	Xaisla (Kitimat)	Xaisla	KX	Xaisla	Kwakiutlan	Wakashan
9	Xaihais (China Hat)	Heiltsuk-Oowekyala 1	KC	Heiltsuk-Oowekyala	Kwakiutlan	Wakashan
10	Bella Bella (Oyalit division)	Heiltsuk-Oowekyala 2	KO	Heiltsuk-Oowekyala	Kwakiutlan	Wakashan
11	Bella Coola	Bella Coola	BC	Bella Coola	Bella Coola	Salishan
12	Wikeno	Heiltsuk-Oowekyala 3	KW	Heiltsuk-Oowekyala	Kwakiutlan	Wakashan
13	Koskimo	Kwakwaka'wakw 1	KK	Kwakwaka'wakw	Kwakiutlan	Wakashan
14	Kwexa	Kwakwaka'wakw 2	KR	Kwakwaka'wakw	Kwakiutlan	Wakashan
15	Clayoquot	Nuu-chah-nulth 1	NC	Nuu-chah-nulth	Nuu-chah-nulth	Wakashan
16	Tsishaat	Nuu-chah-nulth 2	NT	Nuu-chah-nulth	Nuu-chah-nulth	Wakashan
17	Hupachisat	Nuu-chah-nulth 3	NH	Nuu-chah-nulth	Nuu-chah-nulth	Wakashan

[a]After Drucker (1950).
[b]After Thompson & Kincade (1990).

Mobilizing this social effort would have required a high level of power and wealth. Generally, the planning and the building of a new residential house was initiated by the pre-arrangement of an elite marriage, and construction usually took many years of preparation, starting with the procurement of raw materials from forest stands owned by a consenting chief, and their subsequent preparation by large groups of skilled craftsmen working over several seasons.

Construction was supervised by men (Stewart 1984, p. 61) and it is now believed that often as many as 200 people would have worked simultaneously under the direction of a chief during the more intensive construction phases, for example, while raising the massive timber frames, which consisted of logs some 2 m in diameter, some of which had to be perfect-joined with each other while hanging in mid-air (Stewart 1984, pp. 61–63). Consisting of massive timbers, these houses could survive decades with only minor repairs (MacDonald 1983*a*,*b*; Stewart 1984; Nobokov & Easton 1989; Samuels 1991). Once built, they saw collective use by multiple families, each occupying a designated section of the vast interiors. Building a new structure would therefore represent a tremendously important social statement, providing a focus for new household identities, and reflecting and accommodating the needs, expectations and aspirations of extended kinship structures.

3. MATERIALS: NORTHWEST COAST HOUSING TRAITS

There is a well-established typology of Pacific northwest coast housing styles dating to the later nineteenth century ethno-historic 'present' (Drucker 1955; Vastokas 1966; Nobokov & Easton 1989; Suttles 1990), and growing archaeological understanding of developments in long-house architecture prior to this (Samuels 1991; Matson & Coupland 1995; Coupland 1996; Ames & Maschner 1999; Matson 2003).

In general, northern houses (e.g. found among the Tlingit, Haida and Tsimshian) were built to a precise rectangular ground plan, with mortice and tenon joints supporting a high gabled roof. Once erected, these buildings could not be extended further without being completely dismantled and rebuilt. They housed substantial communities, consisting of nobles, commoners and slaves (but see Matson & Coupland 1995). Hereditary titles, wealth and status were inherited down the matrilineal line.

In contrast, shed-roof houses were built further to the south, and involved simpler construction consisting of support posts and rafter beams. This fixed framework was clad with removable planks, which enabled the building to be adapted or extended according to the size of the community it sheltered during any one season. These mutable structures could be seen to reflect a flexible and egalitarian system of the reward of title and inheritance from one generation to the next, based on relatively meritocratic and inclusive social traditions, and clearly manifested in numerous aspirational potlatching events (Rosman & Rubel 1971, pp. 176–200).

Drucker (1950) systematically recorded these variations in housing styles among 17 communities (table 1) inhabiting the central and northerly sections of the classic 'Northwest Coast Culture Area' (e.g. Jorgensen 1980, p. 19). These data form the basis of the present case study, and we also follow Drucker (1950) in focusing only on housing from Chilkat in the north down to Vancouver Island; at this stage, we do not include housing from the Gulf of Georgia

Table 2. Trait-based documentation of house-building traditions of the Pacific northwest coast (edited from Drucker 1950).

housing traditions trait number	general category	trait description
description of house traits		
1	house pits	excavated central pit
2		series of steps into the pit
3		pit walls plank-lined
4	pilings	house built on pilings
5	wall planks	wall planks detachable for move to summer houses
6		framework and wall planks inseparable
7	posts	round posts
8		squared posts
9		zoomorphic relief carvings on posts
10	roof construction	two-pitch roof
11		one-pitch roof ('shed roof')
12		single ridgepole
13		ridgepole as lintel directly on posts
14		ridgepole on cross-lintel
15		double ridgepole
16		intermediate beams
17		roof plates and sills
18	wall support	slots for wall sheathing
19		wall sheathing horizontal
20		supported between vertical stakes
21		overlapping clapboard
22		wall sheathing vertical
23	roof boards	roof of boards
24		roof of bark
25		overlapping peak
26		ridge cover: dugout pole
27		ridge cover: horizontal boards
28	floors	earth floor
29		board floor
30	fireplaces	corner fireplaces
31		central fireplace—for rituals only
32		central fireplace—for everyday use
33		fire on floor level
34		fire in pit
35		roof boards moved to allow smoke escape
36		central smokehole
37		adjustable smokehole shield
38	sleeping platforms	sleeping platform around walls
39		sleeping platform made of boards
40		sleeping platform segmented
41	storage shelves	high shelves for storage
42	partitions	private sleeping cubicles
43		partitions between spaces
44	doorways	doorway in gable end
45		doorway rectangular
46		door oval or round
47		entry directly through portal pole
48		door wooden
49		door propped against opening
50		door suspended at top
51	house facades	façade of house painted
52	furniture	individual backrests or settees
53		above items painted
54		wood stools
55	wall lining	walls at sleeping places lined with mats
documentation of housing traditions		
Tlingit 1		1110010101000010111001100100100101011000110110010100000
Tlingit 2		1110010111000010110001111000100101011110111111110110000
Haida 1		1110011101000010110001010000100101011111110101110111101
Haida 2		1110011111000011110001110000100101011111111111110111101
Nass-Gitskan		0000011011000011110001010001000110011000100110110011111

(*Continued.*)

Table 2. (*Continued.*)

Tsimshian 1	1111011011000011110001110011000110011110010111010111111
Tsimshian 2	0001011011000010110001101001000110011110010111110011101
Xaisla	1111011011000010110001101001000110011111001110111011101
Heiltsuk-Oowekyala 1	1110011011000010110001101001000110011111010111110111101
Heiltsuk-Oowekyala 2	1110011011000010110001101001000110011110110111010011101
Bella Coola	1111011011100010111110101001000110011110111110111011101
Heiltsuk-Oowekyala 3	1111011011000010111111100011011010011110111110111011101
Kwakwaka'wakw 1	1111101011011110001110101001011010100100110110010111100
Kwakwaka'wakw 2	1110101011011110001110101001011010100110111111011011100
Nuu-chah-nulth 1	0000101011011100001110100011011001100110101110000010000
Nuu-chah-nulth 2	0000101011100000001110101001011010100111100010011010000
Nuu-chah-nulth 3	0000101010100000001110100001011010100111100010010010000

Salish (Barnett 1939; Jordan & Mace 2008) or other areas further to the south (i.e. down to California).

Moreover, in contrast to Jordan and Mace's earlier case study (2006), our current focus is strictly on understanding diversification in the style of 'dwelling houses' (i.e. 'rectangular plank houses'; Drucker 1950, pp. 178–180, and not on diversity in Drucker's broader general category of 'structures', which includes bark-houses, earth lodges, storehouses, caches, stockades and sweathouses as well as dwelling houses; Drucker 1950, pp. 180–181). Each of these forms of vernacular architecture could potentially have been affected by a wide range of different transmission processes; a sharper focus on long-houses enables us, in the current paper, to concentrate on understanding the inheritance of a *single* coherent cultural tradition at the heart of daily community life.

Drucker (1950) records variations in long-house architecture in terms of distinct traits that are systematically recorded as being 'present' or 'absent' across the 17 ethno-linguistic communities (table 2). For example, the survey captures the major distinctions between ridgepole/gable-roofed structures found in the north, through to the shed-roof structures found further to the south, as well as the more subtle gradations between these idealized types in the intervening communities (e.g. Vastokas 1966). Several rows of Drucker's original dataset contained missing information; we retained only rows with full sets of data—this exercise generated a binary data matrix of 55 cultural traits for the 17 communities (table 2).

4. MODELS AND METHODS

With imitation, innovation and imperfect replication, central mechanisms in cultural inheritance, we draw heuristic parallels between these cultural processes and a range of analogous processes operating in biological evolution (Cavalli-Sforza & Feldman 1981; Boyd & Richerson 1985; Durham 1992; Shennan 1997, 2002, 2004; Collard & Shennan 2008; Collard *et al.* 2008). While there are many fundamental differences in cultural and biological evolution (e.g. humans have only two biological parents while their cultural traditions may be acquired from multiple sources in both older and contemporary generations), both can usefully be understood as systems of information transmission that operate along principles of 'descent with modification'. Recognizing and exploring both the positive and negative analogies between cultural and biological systems of inheritance also opens the way for application of quantitative analytical tools developed by evolutionary biologists in more rigorous analyses of cultural transmission and cumulative diversification.

(a) *Tree-based methods*

Phylogenetic analysis is employed by biologists to reconstruct the genealogies of organisms, and rests on the axiom that evolutionary relationships can be represented by a branching tree diagram (Hennig 1966; Forey *et al.* 1992; Kitching *et al.* 1998). The key principle involves defining traits and then identifying the presence or absence of these traits across a range of taxa; descent relationships can be reconstructed by determining which similarities are derived from shared common ancestry (homologies), and which are a result of other processes, including lateral borrowing and hybridization (homoplasies; Hennig 1966; Forey *et al.* 1992). Given these goals, biologists have tended to regard homologies as the most important signal for discovering branching evolutionary relationships, whereas signals for homoplastic convergences between lineages tend to be regarded as background noise, which obscures attempts to reconstruct deeper evolutionary relationships (Forey *et al.* 1992, p. 3).

As a range of studies has shown, cultural differences between communities can also be recorded in terms of the presence and absence of particular traits, but in contrast to biologists, anthropologists are equally interested in identifying signals for lateral hybridization, as well as common ancestry—either process may have predominated in a given culture–historical setting (see Holden & Shennan 2005; Gray *et al.* 2007; Collard *et al.* 2008 for recent reviews).

In applying phylogenetic analyses to cultural data, the relative proportions of homology and homoplasy in any given dataset can be measured statistically, quantifying the closeness of fit between the patterns in a data matrix, and a tree model derived from that data. If the statistical measures indicate that the data fit the tree model closely, it can be argued that branching transmission has predominated. If the fit is poor, then it can be argued that processes other than branching have dominated.

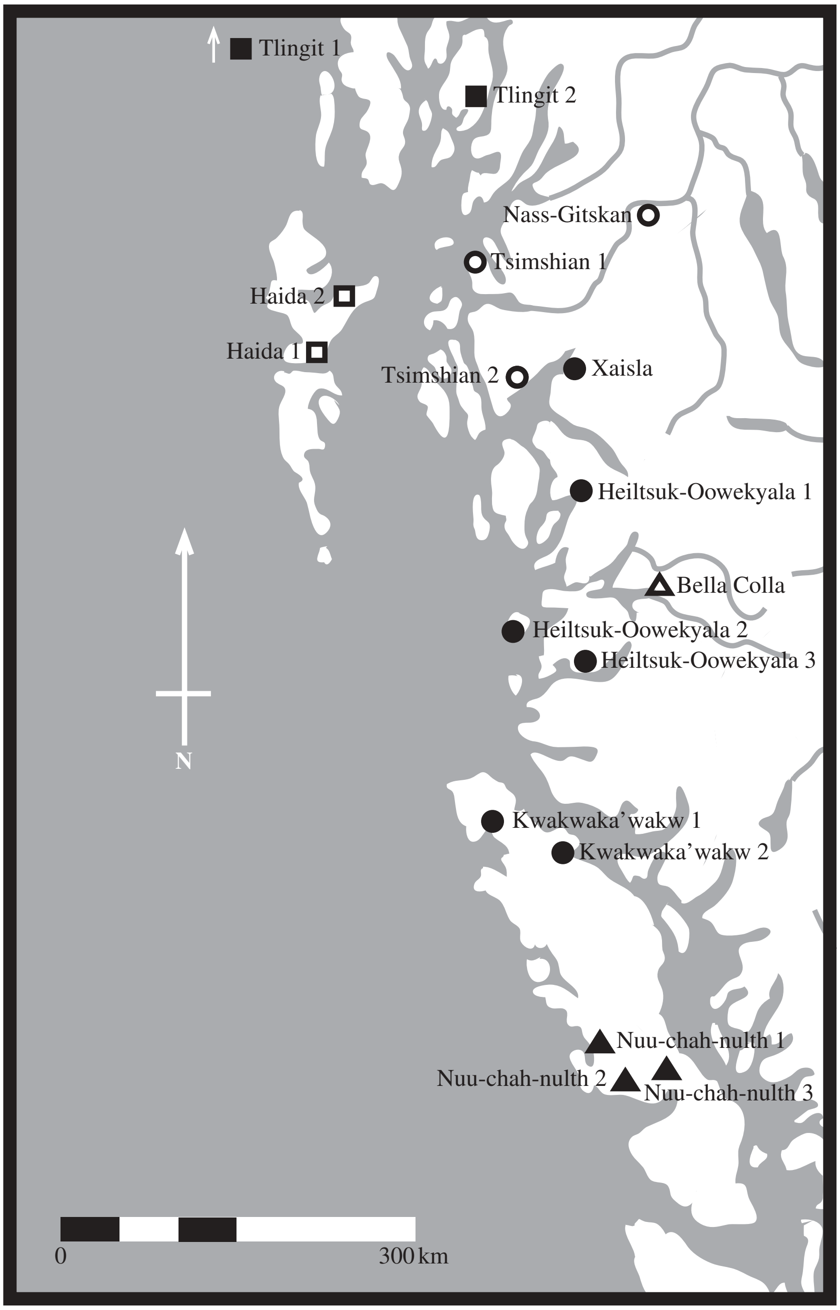

Figure 1. Location map of various ethno-linguistic communities on the Pacific northwest coast (after Drucker 1950). Filled squares, Tlingit; open squares, Haida; filled circles, Kwakiutlan; open circles, Tsimshian; filled triangles, Nuu-chah-nulth; open triangles, Salishan.

In the present analysis, a general heuristic search was performed using the PAUP* 4.0b10 phylogenetic software (Swofford 1998) with the following settings: optimality criterion as parsimony; starting trees obtained via stepwise addition and the branch swapping algorithm set as tree-bisection-reconnection. The results were interpreted using the outgroup method (Watrous & Wheeler 1981; Farris 1982; Clark & Curran 1986), which is commonly used to root the tree (Smith 1994, pp. 55–58; Kitching *et al.* 1998). We selected the Salish-speaking Bella Coola as the outgroup, on the basis that they are a linguistic isolate in the region, whereas all other communities are aligned with the coast's larger language families (Tlingit, Haida, Tsimshian and Wakashan; see Thompson & Kinkade 1990; table 1, figures 1 and 2).

A further descriptive statistic was calculated to test for relative degrees of branching and blending in the housing dataset. Computer algorithms will construct tree diagrams from random data, making it important to directly measure the strength of the phylogenetic signal in any given dataset. In the present study, we employ the 'Retention Index' (RI; Farris 1989*a*,*b*), which calculates the amount of homoplasy as a fraction of the maximum possible homoplasy (Forey *et al.* 1992, p. 75). The RI ranges in principal from 0 to 1.0, with a high RI taken as being consistent with vertical transmission, and hence a branching pattern of phylogenesis.

In addition, the RI is a useful goodness-of-fit measure because it is not affected by either the number of taxa or the number of characters, enabling

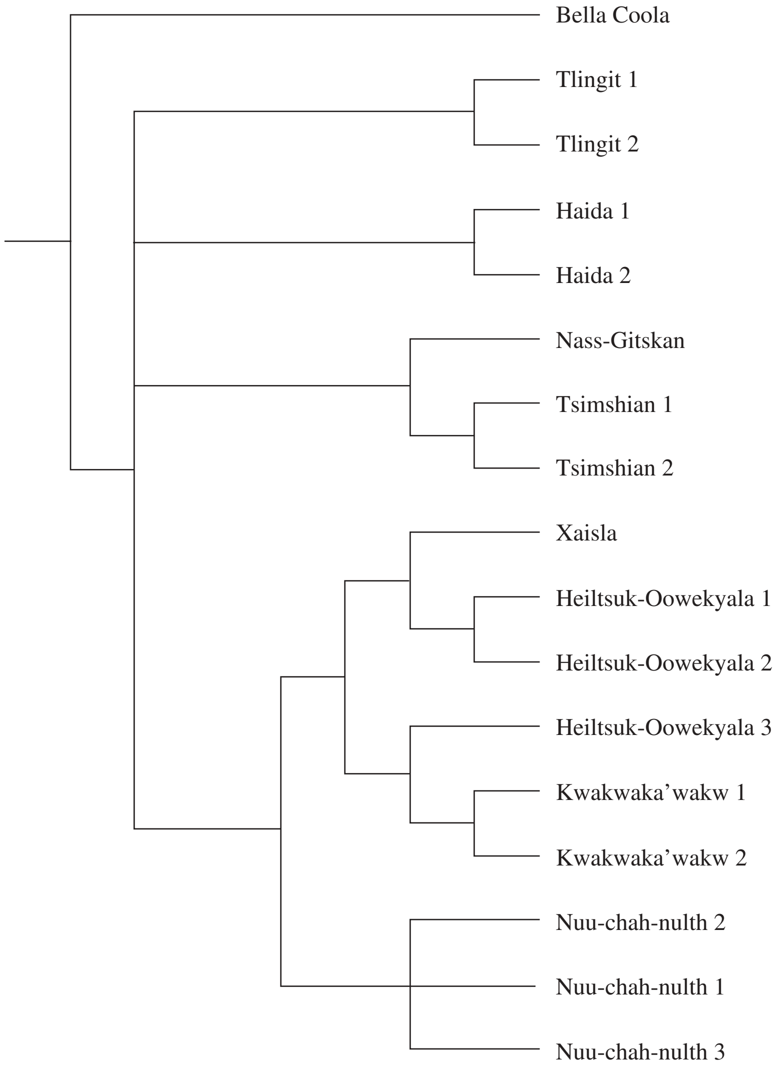

Figure 2. Pacific northwest coast language tree (after Thompson & Kincade 1990 and based on qualitative assessment of linguistic diversity; for further explanation, see text).

results to be compared across a range of case studies. For example, Collard *et al.* (2006*a*,*b*) employed RIs to examine the relative strength of branching signals across a broad range of biological and cultural datasets (Collard *et al.* 2006*a*, p. 57). Recent simulation work by Nunn *et al.* (2010) has also tested the robustness of RI measures, and has concluded that RI values greater than 0.6 do indicate low levels of horizontal transmission, high degrees of vertical transmission and hence the predominance of 'phylogenesis' over ethnogenesis.

Finally, it is important to specifically identify which sections of the tree diagram are well supported by the existence of hierarchical structures in the data matrix (Smith 1994, p. 48). Bootstrap analysis (Smith 1994, p. 50) is a random sampling program that calculates percentage levels of support for each branch in the tree (e.g. Forey *et al.* 1992, p. 76), and a level of support over 50 per cent should be interpreted as a highly conservative measure of the accuracy of tree structure (Smith 1994, p. 51). Bootstrap supports were calculated with 1000 replications in PAUP* 4.0b10 (Swofford 1998), and only tree branches with over 70 per cent bootstrap support were retained.

(b) *Network-based methods*

In addition to using tree-based models, biologists have begun to develop network-based methods to explore more complex evolutionary relationships characterized by potentially higher levels of lateral transfer (Bryant *et al.* 2005, p. 80). The NeighborNet technique (Bryant & Moulton 2004; and see Bryant *et al.* 2005 for a recent application to the analysis of linguistic history; see also Gray *et al.* 2007 for further discussion) starts by calculating a distance matrix from the dataset; these distances are then used to generate a series of 'splits' in the data, using an agglomerative clustering algorithm, which progressively combines clusters into larger and larger overlapping clusters. Weights are then calculated for these splits, which are represented in the form of a network diagram known as a 'split graph' (see Bryant *et al.* 2005, pp. 68–69, 74–79).

Each split graph (or plot) contains two kinds of information: the splits, which represent the groupings in the data; and the branch lengths, which indicate the degree of separation for each split (Bryant *et al.* 2005, p. 77). For example, where phylogenesis has been the dominant process of cultural diversification, the split graph will closely resemble a tree diagram, as cultural descent with modification will have proceeded in a strict branching manner. Conversely, if borrowing and hybridization have been widespread, then the diagram will be much more complex, with conflicting signals represented as 'box-like' sections in the graph. These conflicting signals may, in extreme cases, be so strong that the split graph includes multiple boxes that reflect frequent instances of lateral borrowing and recombination. In the current study, NeighborNet (Bryant & Moulton 2004) incorporated into Splits Tree v. 4beta10 (Huson & Bryant 2006) was employed.

(c) *Testing for co-transmission of housing and language*

Tree- and networked-based analytical methods are based on different assumptions and their combined application to a single cultural dataset enables the results to be cross-checked. Where branching processes do appear to have generated distinct cultural lineages, a further series of hypotheses can be tested, for example, the degree to which cultural traditions and language history have tracked each other with varying degrees of fidelity through time, or the extent to which several cultural traditions have been co-transmitted (see Jordan & Mace 2006; Jordan & Shennan 2009).

Analogous processes of co-transmission are recorded in biological evolution, and a range of methods is now available for identifying the patterns of 'co-speciation' that arise from closely shared evolutionary histories (Page 2003; Page & Charleston 1998; and see Tehrani *et al.* 2010). An analogous culture–historical scenario would involve close association between independent material culture lineage(s) and/or language history (e.g. Boyd *et al.* 1997; Jordan & Mace 2006; Jordan & Shennan 2009).

Were northwest coast long-house traditions transmitted in tandem with language, with language frontiers serving to 'constrain' the exchange of housing traits between adjacent communities? This hypotheses can be tested as follows: first, do the network- and tree-based methods indicate that housing styles had been subjected to branching processes of diversification? If yes, does the branching tree of housing styles share statistically significant structural similarities to the tree of northwest coast languages?

For this second hypothesis, we employed a language tree (figure 2) based on the qualitative classification of local languages into phylum/family, branch and language presented by Thompson & Kincade (1990, pp. 30, 34–35); these groupings and ancestral relationships reflect current consensus among linguists working in the region. The descriptive classifications were used to manually construct a language tree in MacClade 4.05 (Maddison & Maddison 2000), which formed the basis for the tests described below.

The strength of historical associations between language history and the housing tree were tested in Component 2.0 (Page 2003). Unlike PAUP (Swofford 1998), the software does not infer trees from the data but rather requires that pre-existing trees be entered into the program, after which comparison methods can be applied. In these analyses, a single strict consensus tree was generated for northwest coast housing in PAUP* 4.0b10. This was imported into Component 2.0, along with the language tree described above, in order to calculate an overall measure of similarity between the housing and language trees; this can be estimated by breaking down each tree into sets of simpler structures.

We employed the 'triplet' measure, which is the smallest possible informative sub-tree on a rooted tree. If the two trees are very similar, then only a few of these sub-trees will be resolved differently, giving a low overall score. In contrast, if the structure of the two trees is very different, then a large number of triplets will be resolved differently, generating a higher score. As any tree can easily be reduced to its triplets scores, comparison of the overall similarities and differences between large numbers of trees becomes quite straightforward (see Jordan & Mace 2006).

However, Component 2.0 generates only an overall measure of similarity between trees; it is therefore important to identify the point at which apparent similarity between trees actually becomes statistically significant. Component 2.0 generates sets of random trees as the basis for these statistical tests: if the triplet measure of difference between the language and housing trees falls *below* the range of measures for a randomly generated set of trees, then it can be assumed that association between the language and housing trees is greater than would be the result of chance alone, and that a substantial degree of co-transmission has taken place.

Where substantial co-transmission is demonstrated on the basis of the triplets results, a further set of tests can assess whether the housing and language trees are, in fact, identical owing to perfect co-transmission. The Kishino–Hasegawa test, modified to fit PAUP* 4.0b10 (Kishino & Hasegawa 1989; see Jordan & Shennan 2003, 2009 for applications to cultural datasets), measures the difference between the initial best-fit tree for housing, and a second tree, using parsimony as the optimality criterion. The second tree is generated by a heuristic search in PAUP* 4.0b10, which has been *artificially constrained* by the structure of the language tree in order to test the hypothesis that vertical transmission of housing traditions had been closely 'canalized' by a tree mapping language history. If there is no statistically significant difference between the original best-fit tree for housing, and the tree constrained by language history, then a hypothesis of perfect co-transmission can be accepted; in contrast, if the two trees are significantly different then the hypothesis of *perfect* co-transmission can be rejected.

5. RESULTS: MAPPING DIVERSITY IN NORTHWEST COAST LONG-HOUSES

(a) *Branching versus blending?*

The northwest coast housing dataset was initially examined in the NeighborNet program to generate some general insights into the strength of branching

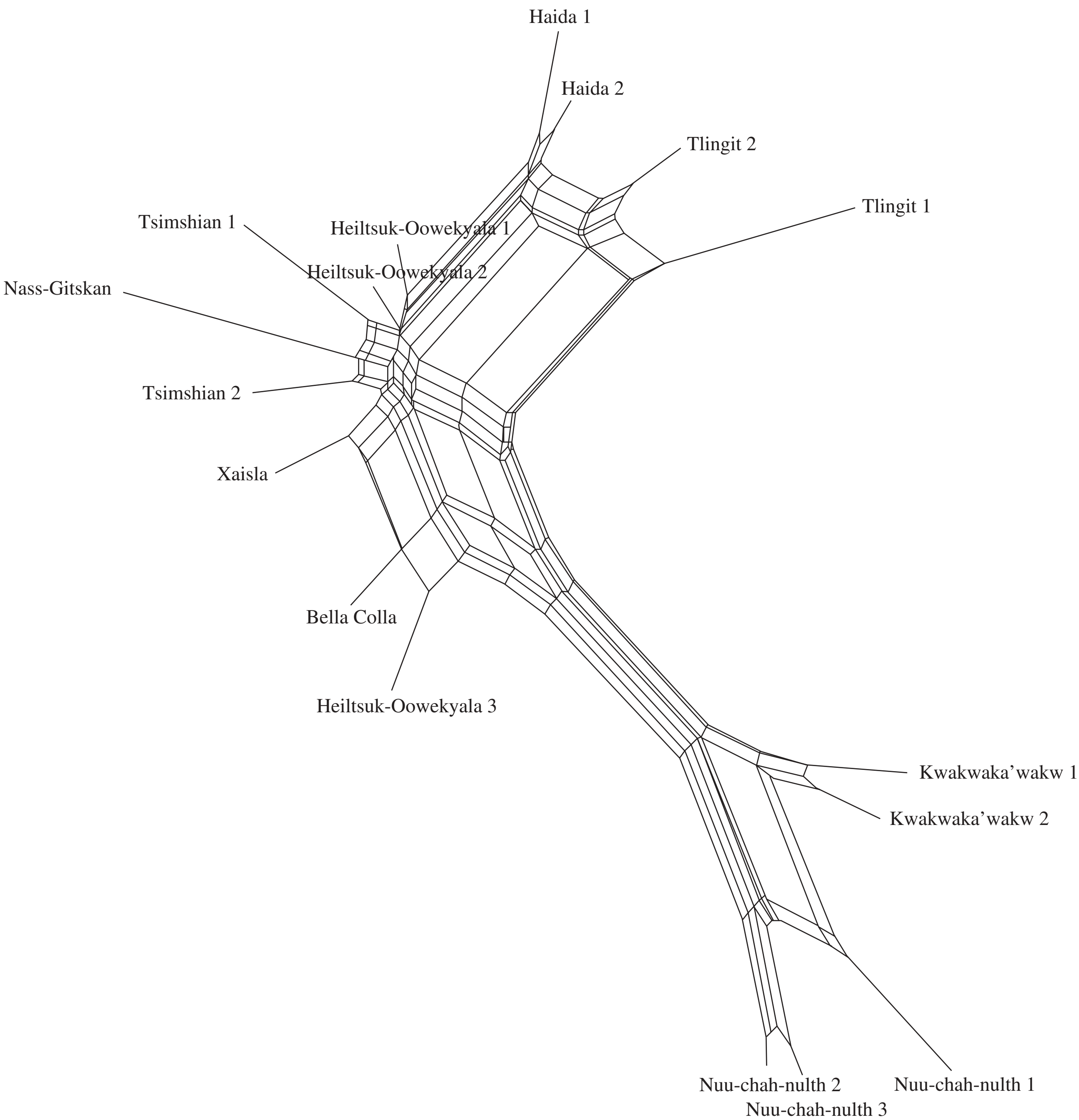

Figure 3. Diversity in northwest coast housing traditions: NeighborNet split graphs.

versus blending signals. As the NeighborNet plot illustrates (figure 3), the length of the individual branches appears to indicate considerable underlying differences in housing styles along the coast, with the most southerly groups pulled out to the bottom right and more northerly groups to the left and upper right; the degree to which the individual housing styles are pulled apart suggests some hierarchical structuring in the dataset, which is consistent with an underlying pattern of branching descent. At the same time, the 'boxed' sections indicate a degree of conflict in the data owing to hybridization between styles.

As noted above, the NeighborNet plots provide only a basic visual exploration of the degree of vertical structure in a dataset; tree-based methods, on the other hand, generate more robust quantitative measures of the degree of branching versus blending in a dataset. The housing data were analysed in PAUP*4.01b10 (Swofford 1998), employing Bella Coola as the outgroup (see above). A heuristic search generated four trees with a length of 112; these trees were converted into a strict consensus tree, which was then bootstrapped at 1000 replicates. Only clades with over 70 per cent support were retained, resulting in a clearly branching tree diagram (figure 4).

The RI for the tree was 0.64, indicating a strong signal for vertical transmission, and hence phylogenesis—this enabled the hypothesis of branching descent to be accepted. Using RI to measure the strength of this signal also enabled the results to be contextualized against other works assessing the relative degrees of branching and blending in both biological and cultural datasets. For example, in a

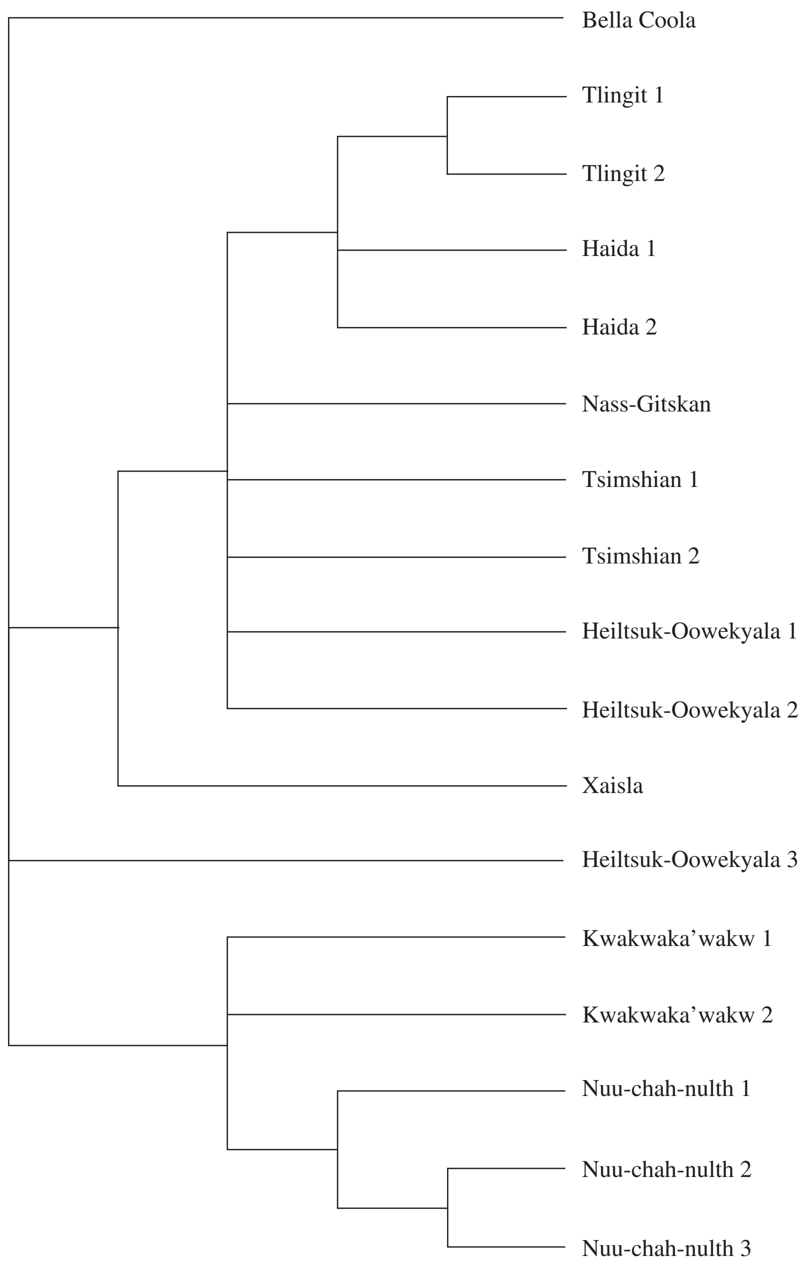

Figure 4. Diversity in northwest coast housing traditions: most parsimonious cladogram (all clades with over 70% bootstrap support).

recent comparative analysis, Collard *et al.* (2006*a*) assembled 21 biological datasets and nine cultural datasets. These biological datasets—ranging from DNA data for lizards, lagomorphs and carnivores, to morphological data for fossil hominids, seals and ungulates—had all been used to reconstruct relationships among species and high-level taxa. Datasets pertaining to simple organisms (e.g. viruses, bacteria) or subspecies of complex organisms were not included in the study on the grounds that they had possibly been affected by blending processes. Cultural datasets included basketry, prehistoric pottery, projectile points, textiles and other forms of material culture (Collard *et al.* 2006*a*, p. 58).

RIs were calculated for trees derived from all individual datasets in order to compare whether biological datasets tended to fit a branching tree better than the cultural datasets. The results indicated that, overall, there was little difference between the fit of tree models to either biological or cultural data (Collard *et al.* 2006*a*, pp. 57–58). In addition, not only were the average RIs similar across biological and cultural datasets, but the ranges were also comparable: for example, mean, minimum and maximum RIs for biological data were 0.60, 0.35 and 0.94, respectively; and for cultural data, they were 0.60, 0.35 and 0.93.

Results of Collard and co-workers provide a useful comparative framework against which the current RI value for northwest coast housing can be evaluated further. This RI of 0.64 falls *above* the mean for both the biological and cultural datasets included in the above study, and falls around the same RI values as ungulate morphology (0.69), Phalacrocoracidae bird mtDNA (0.65) and phocid seal morphology (0.60) (Collard *et al.* 2006*a*, p. 58). These broader comparisons strengthen the conclusion that housing styles on the northwest coast had been influenced by strongly branching processes of descent with modification.

(b) *Co-transmission of long-house styles and language?*

Having accepted the first hypothesis that northwest coast housing diversity was largely the outcome of phylogenesis, we can now move onto testing whether housing styles and languages had, in fact, been co-transmitted, or whether they had separate descent histories.

In order to test the degree of *general* association between the descent histories of language and housing, the northwest coast language tree (figure 2) and bootstrapped consensus tree for housing styles (figure 4) were imported into COMPONENT 2.0 so that triplet measures of difference between the two trees could be calculated. The analysis indicated that 164 triplets had been resolved differently in the language and housing trees. As noted above, however, all trees can be reduced to triplet scores, enabling distances between extremely different trees to be reduced to a single measure. As a result, it was important to identify whether the degree of similarity between the housing and language trees was greater than would be expected by chance alone.

A further 1000 trees were randomly generated in COMPONENT 2.0. The triplet measures of difference between these randomly generated trees ranged between 186 and 504, with a mean of 372.673 (s.d. = 42.726). Clearly, the triplet measure of difference between the housing and language trees (164) was less than the range of triplet distances between the 1000 randomly generated trees (186–504). These results indicated that the trees for housing and language were therefore more similar than would be expected by chance alone, and that they shared a broadly similar pattern of branching descent.

Building on these results, a Kishino–Hasegawa test in PAUP* 2.0b10 was also performed, using the language tree to constrain the search for a new best-fit housing tree. The test generated a new tree that had been constrained by the hypothesis that there had been perfect co-transmission between housing and language. However, this new tree was significantly different from the original housing tree ($p < 0.05$), indicating that *perfect* co-transmission of housing and languages had not taken place.

On balance, these overall results indicate that housing styles had been subjected to branching patterns of descent; second, that the trees for housing and language share more similarity than would be expected by chance alone, indicating some association by descent and suggesting that language boundaries had, in part, constrained the horizontal diffusion and hybridization of housing traits between communities. At the same time, this co-transmission of housing and language had not been perfect, and that while their descent histories had been similar, they had not been identical.

6. DISCUSSION: LONG-HOUSES, LANGUAGE AND SOCIAL INSTITUTIONS

This study has examined patterns of cultural inheritance on the Pacific northwest coast, focusing on variability in long-house architecture, and testing for possible associations between the transmission of language and long-house styles. The results indicate a substantial branching signal in the long-house dataset, which largely supports the phylogenetic model of cultural diversification (see Q1, §1). In addition, there appears to be significant association between regional language history and the community-based transmission of long-house styles (see Q2, §1). With generations of ethnographers highlighting the role of long-houses as the most important focus of local community's social and cultural reproduction, it is perhaps predictable that there should be clear evidence of a branching signal in housing styles, and also that housing diversity should, in part, be associated with regional language history.

Beyond these general patterns of cultural and linguistic diversification, some interesting small-scale patterns also emerge. For example, figures 3 and 4 indicate that the overall branching signal is much stronger among 'southern' groups located south of the Bella Coola (figure 1)—in the NeighborNet plot this is shown by the longer branch lengths and the limited degree of boxing to the bottom right of the plot; in the tree diagram, it is revealed by the progressive splitting of the 'southern' branches, all of which were well-supported by bootstrapping.

In contrast, there appears to have been a more substantial degree of hybridization among groups north of the Bella Coola—this is demonstrated by the increased boxing in the upper half of the NeighborNet plot, indicating transmission signals that conflict with strictly branching processes of descent. In the tree diagram, a greater degree of local hybridization in this part of the coast is indicated by the fact that the bootstrapping returned low levels of support (<70%) for the 'northern' splits—as a result, these branches have been collapsed into a more 'bush-like' structure.

Together, these patterns suggest that there has been a greater degree of 'spillage' in long-house traditions between northern communities, while southern communities retain the strongest signal for strictly vertical transmission of housing styles. With each long-house, the outcome of a carefully choreographed process of collective and coordinated effort, what social factors might have generated these contrasting patterns of diversification? Were there significant local differences in the structure of inter- and intra-community interactions and social networks along these different stretches of the coast?

Drucker reports that along these reaches of the northwest coast, autonomous kin groups were organized by contrasting matrilineal and patrilineal descent reckoning; moreover, each system had a mutually exclusive geographical distribution (Drucker 1955, p. 46). For example, the more northerly groups were matrilineal and avunculocal, and the more southerly groups were organized according to patrilineal and patrilocal descent. Interestingly, these distributions appear to correlate spatially with the stronger branching signals in southern housing and the greater degree of hybridization in the north.

On the northwest coast, these descent rules were crucially important because they structured the transfer of property, status and privilege, and were also linked to postmarital residence rules for both adult men and women. For example, Kwakwaka'wakw, Nuu-chah-nulth and Salish communities had a patrilineal system of inheritance, with a virilocal rule: a new wife would take up residence with her husband's family, either within the same settlement or by moving to another settlement. In this way, 'southern' husbands continued to live and work in the same long-houses and villages as their fathers and grandfathers, eventually inheriting their titles, properties and privileges (Rosman & Rubel 1971, pp. 176–200).

In contrast, the Tlingit, Haida and Tsimshian practised a matrilineal system, whereby status and privileges were inherited through the female line. Marriage residence rules were based on an avunculocal rule, so that at around 10 years of age, a boy would take up residence with their mother's uncle for apprenticeship and preparation for marriage. Generally, there was a cross-cousin preference, for instance a man would marry his maternal uncle's daughter, and eventually rise to take over his maternal uncle's status and privileges when he died. In this way, the relationship with one's maternal uncle was more important in northerly communities than with one's own father (Rosman & Rubel 1971, pp. 10–25).

Given the striking geographical correlation between these contrasting matrilineal and patrilineal kinship systems and the spatial distributions of the 'northern blending' versus 'southern branching' signals in long-house architecture (figures 3 and 4), it is tempting to link the two phenomena together. For example, it is clear from ethnographic accounts that houses were built by men on all stretches of the coastline. However, the greater tendency for men to stay *within* their own households and villages in the south may be generating the stronger branching signal for vertical transmission of long-house styles within each ethnolinguistic community. In contrast, the greater movement of men *between* households and villages in northerly areas may be associated with the greater tendency for the borrowing and exchange of housing styles between communities, especially if the men carried ideas about construction style with them. This may have led to a cumulative horizontal flow of long-house styles between communities, eroding any sharp stylistic differences. At present, these interpretations remain descriptive—fuller investigation of the potential links between kinship and diversification in long-house styles remain beyond the scope of this paper, but certainly point to intriguing directions for future work, both on the Pacific northwest coast and beyond.

7. CONCLUSION

This paper has attempted to address a number of key debates in the current cultural transmission literature by undertaking a quantitative analysis of diversity in long-house styles on the Pacific northwest coast employing models and methods from the biological sciences.

Focusing on the cultural transmission of the 'collective' tradition of communal architecture, rather than 'small-scale' crafts practised by single individuals, we have attempted to identify whether stylistic diversity has been a result of 'branching' or 'blending' processes and the degree to which material culture traditions can be linked with regional language diversity. The results indicate that, overall, branching processes of inheritance have dominated, and that vertical transmission of housing styles has at least partially been constrained by the region's numerous linguistic boundaries.

Looking more closely at the results (figures 3 and 4), it is also clear that the strength of the branching signal varies along different stretches of the northwest coast, with the strongest signals in the south, and a greater degree of blending in the north. Returning to the wider ethnographic literature to interpret these results, it appears that these differences correlate with important geographical variations in primary descent- and postmarital residence rules. Additional research could investigate how diversification of housing styles might be affected by variability in key social institutions.

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