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Social Network Analysis of Iroquoian Sites in the St. Lawrence River Valley: AD 1400–1600

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Abstract Relatively little is known from the sixteenth- and seventeenth-century AD ethnohistorical record about Iroquoian societies in the St Lawrence River Valley compared to the Huron-Wendat in southern Ontario and Haudenosaunee in New York. This is because Iroquoian villagers dispersed from the valley over the course of the sixteenth century. Here we use formal social network analysis to build on understandings of St. Lawrence Iroquoians' socio-political interactions within and outside of the valley from AD 1400 to 1600. This analysis is based on pottery vessel decorations as signals of female membership in socio-political networks. Results indicate valley-long coalitional networks that became looser at the end of the sixteenth century as St. Lawrence Iroquoians dispersed from the valley.

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1. Introduction

Draining the Great Lakes, the St. Lawrence River extends some 1000 km from its headwaters at Lake Ontario to the Gulf of St. Lawrence. Analogous to the Mississippi, Amazon, Indus, and Nile rivers in terms of its substantial role in the surrounding hydrological landscapes and cultural networks[1], today it is a major international cargo shipping route as part of the Great Lakes-St. Lawrence Seaway System.[2] Beginning in the 16th century (all dates in this article are AD), the river became a major conduit for European exploration of North America[3] and in later centuries for Euro-American and Euro-Canadian settlement of the continent's interior.[4] In the centuries before this, the valley was home to Iroquoian peoples who spoke closely related dialects of Northern Iroquoian languages and shared cultural traits. Although there is disagreement on the ethnic identification of the Iroquoian populations inhabiting the valley, archaeologists have commonly applied the term St. Lawrence Iroquoian. In the 15th and 16th centuries, St. Lawrence Iroquoian villages were distributed from the headwaters of the river near the east end of Lake Ontario to the location of present-day Québec City some 550 km distant. St. Lawrence Iroquoians made use of the river for water-borne transportation, allowing interactions between far-spread communities within and beyond valley.[5] The river also served as transportation to camps and fishing grounds further east in the estuary and Gulf of St Lawrence.[6] However, its importance as an artery for trade and transport also made the St. Lawrence Valley contested terrain and subject to commercially motivated warfare, diplomacy, and negotiation over rights to access and habitation.[7]

Iroquoian peoples in the St. Lawrence River Valley (SLRV) played prominent roles in the pan-Iroquoian world system and in the development of relations be-

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1 Blackwell 1869.
2 Chamber of Marine Commerce 2022.
3 Loewen and Chapdelaine 2016.
4 Olson and Suzuki 2020.
5 Chapdelaine 1989; Tremblay 2006.
6 Chapdelaine 1993, 1995; Cook 2010; Plourde 2012; Tremblay 1999a.
7 Trigger 1976.

tween Indigenous eastern North America and early European explorers and colonists.[8] Jacques Cartier encountered Iroquoians in the SLRV between 1534 and 1542. However, Samuel de Champlain, who traversed the valley in 1608–9, did not encounter permanent Iroquoian settlements there.[9] This seeming abandonment of the valley for habitation by Iroquoian-speaking people has been a major focus of archaeological investigations for decades – why was the valley abandoned and where did the former inhabitants go?[10] Current archaeological evidence indicates that rather than an "abandonment", external forcing led these people to relocate away from the valley and integrate with Iroquoian communities in southern Ontario and eastern and central New York[11], Anishinabe communities to the north[12], and Abenaki communities to the east.[13] Iroquoians returned to the valley permanently several decades later in the mid-17th-century, arriving both from the Huron-Wendat Confederacy in present-day Ontario[14] and the Mohawk Nation in present-day New York.[15] Their descendants continue to live there today at Wendake (Huron-Wendat) outside Quebec City, at Kahnawake (Mohawk) opposite the river from Montreal, Kanesatake at the mouth of the Ottawa River (Mohawk), and Akwesasne (Mohawk), opposite the river from Cornwall, Ontario.

Because the SLRV was largely depopulated – although never entirely abandoned – prior to sustained European contact and the concomitant proliferation of written accounts of Iroquoian peoples[16], the social and structural dynamics of both St. Lawrence Iroquoians and their roles in the larger Iroquoian world remain less well-known; "[t]here has long been debate regarding the cultural identity, political organization, and internal and external relationships that characterized St. Lawrence Iroquoians".[17] These debates have been based on similarities and differences in material culture including pottery, smoking pipes, and bone and stone tool types and attributes, along with foodways, linguistic reconstructions, and oral histories.[18]

Here we approach these issues through social network analysis (SNA) based on a large dataset of pottery collar decorative motifs from 242 ancestral Iroquoian sites in New York, Ontario, and Québec dating from AD 1350 to 1650 (Figure 1).

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8 Delâge 1991; Loewen and Chapdelaine 2016; Trigger 1976, 1985.
9 Giguère 1973; Trigger 1976: 214–228; Viau 2021.
10 Englebrecht 1995; Tremblay 1999b; Trigger 1962, 1976; Pendergast 1991, 1993.
11 Birch 2015; Micon et al. 2021; Snow 1995; Tremblay 2006.
12 Fox and Pilon; Pendergast 1999; Viau 2006.
13 Tremblay 1996, 2006.
14 Lesage and Williamson 2020.
15 Green 1991; Lozier 2018.
16 See e.g., Biggar 1924; Wrong 1939.
17 Lesage and Williamson 2020: 36; also see Tremblay 1999b, 2006.
18 Chapdelaine 1989, 1991; Engelbrecht and Jamieson 2016; Gates St-Pierre 2016; Hawkins et al. 2022; Lesage and Warrick 2016; Lesage and Williamson 2023; Tremblay 1999a.

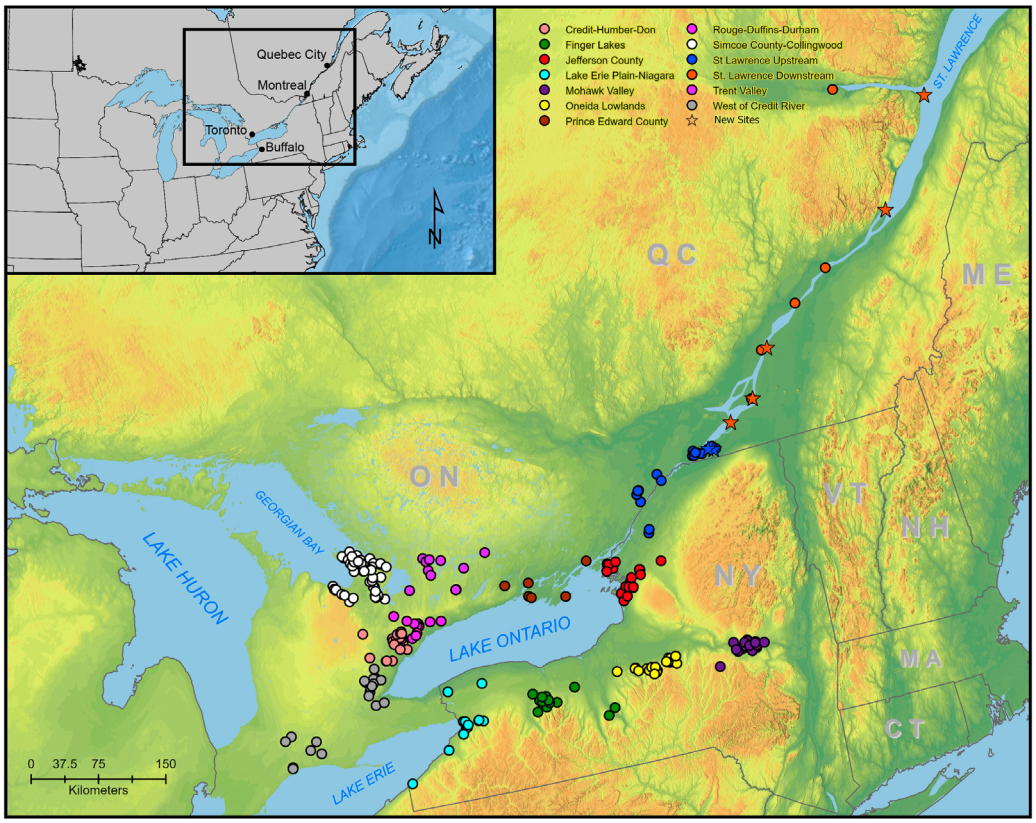

Fig. 1 Map of Iroquoia with sites in this study indicated by geographical groupings. Colors correspond to those used in figures 4, 6, 7, 8, 10, and 11. Star symbols represent the seven sites added in the current analysis.

These decorative motifs were signals produced by women, the primary producers of Iroquoian ceramic vessels, who participated in social and political networks that crosscut historical nation and confederacy territories[19], little constrained by distance.[20] Our previous SNA focused on the SLRV established that Iroquoian villagers occupying the east shore of Lake Ontario at the headwaters of the St. Lawrence River, generally referred to as Jefferson County[21] or Northern New York[22] Iroquoians, during the mid-15th through mid-16th centuries, acted as brokers between villages in southern Ontario and eastern New York.[23] Here we expand that analysis through the addition of seven St. Lawrence Iroquoian sites from down-

19 Birch and Hart 2018; Hart and Engelbrecht 2012.
20 Hart 2012.
21 Engelbrecht 1995.
22 Abel 2021.
23 Hart et al. 2017, 2019; also see Wonderley 2005.

stream, whose collar decorations were coded as part of the Tiohtià:ke Project.[24] This brings the total St. Lawrence Iroquoian sites in the database to 50, 32 of which are downstream from the cluster of sites at the St. Lawrence River headwaters. Our current analysis is also conducted in the context of recent changes in understandings of regional chronologies, interregional conflicts, and geopolitically motivated population movements.[25]

Broadly, we are interested in how historical conditions in northern Iroquoia fostered the development of different sets of relations within and between geographically distinct Iroquoian populations. Specifically, we are interested in understanding relations among St. Lawrence Iroquoians, as well as between these and other Iroquoian peoples living in the territories associated with the historical Haudenosaunee and Huron-Wendat confederacies in present-day New York and southern Ontario, respectively. Our primary aim is to understand how these dynamics articulated at the meso- and macro-regional scales of analysis[26] by asking: (1) What do network topologies tell us about the social and political signaling networks among various groups occupying the St. Lawrence Valley between AD 1350 and 1550? More specifically, do network topologies suggest a valley-long sociopolitical structure of some kind? There are discrete clusters of sites, or "provinces", that archaeologists have described and assigned names;[27] what was the significance of these regional clusters or provinces in intra-valley relationships? Previous SNA in the Mohawk Valley of New York,[28] and among ancestral Huron-Wendat communities on the north shore of Lake Ontario,[29] indicate that traditional interpretations of site clusters representing the removals of single communities over several generations, while logical, are not always supported when critically analyzed with SNA: what can the present analysis indicate in the case of the SLRV? (2) What were the roles of St. Lawrence Iroquoian sites in the pan-Iroquoian networks? Does the broker role of the Jefferson County Iroquoians[30] still hold with the addition of those downstream sites in the dataset? Beyond the headwater sites, how strong were connections between St. Lawrence Iroquoian sites located further downstream and sites in the nascent Haudenosaunee and Huron-Wendat confederacy regions? And finally, (3) how does this analysis shed new light on the debated identity of the St. Lawrence Iroquoians? Does it allow us to confirm or to reject the hypothesis of a distinct cultural identity for the inhabitants of the SLRV during the two centuries prior to the arrival of the first Europeans on this territory?

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24 Cross-Delisle and Marquis 2023; Hart 2023; van Gijsegehm et al. 2022.
25 e.g., Abel et al. 2019; Birch et al. 2021.
26 Following Birch and Hart 2021; Mills et al. 2015.
27 Chapdelaine 1989, 2015.
28 Hart 2021.
29 Birch and Hart 2021.
30 Hart et al. 2017, 2019.

2. Iroquoians in the St. Lawrence River Valley

St. Lawrence Iroquoian-associated material culture and settlement patterns were fully developed in the region by ca. AD 1000–1300[31], although not throughout the valley.[32] Possessing distinctive ceramic traditions, a well-developed bone tool industry, and a riverine-oriented economy, groups labelled St. Lawrence Iroquoians by archaeologists appear to have possessed a cultural identity separate from their Iroquoian-speaking neighbors[33], including a distinct language.[34] At the same time, the question of whether St. Lawrence Iroquoian is an emic ethnic identification remains a matter of debate.[35]

Groups occupying the upper SLRV and northern New York from the mid-fourteenth century onwards lived in palisaded villages and practiced intensive agriculture, resembling cultural patterns shared by other Iroquoian peoples in present-day Ontario and New York. The easternmost of the St. Lawrence Iroquoians, on the other hand, occupied smaller villages and engaged in intensive fishing activities and spring seal-hunting at camps in the St. Lawrence estuary.[36]

Through an attribute analysis of ceramic vessels, Chapdelaine[37] studied the cultural variability of the St. Lawrence Iroquoians, initially defining three provinces: the Province of Canada in the Quebec City area; the Province of Maisouna around Trois-Rivières; and the Province of Hochelaga around Montreal. Later, he added the Province of Jefferson[38] to better take into consideration sites in Jefferson County in northern New York, at the headwaters of the St. Lawrence River.[39] Shortly after, Chapdelaine further subdivided these last two provinces and identified a total of 9 concentrations or "clusters" along the SLRV.[40]

The question remains as to whether St. Lawrence Iroquoian villages or clusters represent separate, distinct communities or whether they at some point formed one or more emically defined nation(s) that formed a temporary alliance, or perhaps a more perennial confederation such as those of the Huron-Wendat and Haudenosaunee. Sixteenth-century accounts remarked upon the different political systems and cultural characteristics of Stadaconans (located near mod-

31 Chapdelaine 1989; Gates St-Pierre 2004, 2016; Tremblay 2006.
32 Abel 2021; Abel et al. 2019.
33 Chapdelaine 1989, 1991; Pendergast and Trigger 1972; Tremblay 1999b, 2006; Trigger 1966, 1968.
34 Julian 2010; Lounsbury 1978; Mithun 1981; Steckley 2016.
35 Hawkins et al. 2022; Lesage and Warrick 2016; Lesage and Williamson 2023.
36 Chapdelaine 1993, 1995; Clermont 1984; Plourde 2012; Tremblay 1993.
37 Chapdelaine 1989, 1990.
38 Chapdelaine 2004.
39 Abel 2001, 2002; Engelbrecht 1995; Engelbrecht et al. 1990.
40 Chapdelaine 2015, 2019b; Tremblay 2006.

ern Quebec City) and Hochelagans (located near modern Montreal).[41] Jacques Cartier mentioned the distrust between Stadaconans and Hochelagans in the lower valley[42], possibly resulting from competition over access to Europeans and their trade goods. The preservation of autonomy while maintaining the ability to act in concert to secure collective benefits were defining features of political relations among Iroquoian societies.[43]

3. Women, Pottery, Signaling and Networks

Our SNA is based on pottery collar decoration motifs. Collars are several mm thick bands of clay that encircle the exterior of the rims of pots and may extend several cm down from the lips. Collars are generally decorated with combinations of straight incised and/or stamped lines that form horizontal bands of distinctive patterns or motifs, sometimes elaborated with annular punctations and/or effigy figures (Figure 2). Iroquoian women were the primary producers of pottery and usually worked in matrifamily groups.[44] Designs were chosen from a corpus of socially mediated motifs that conveyed information about the potter(s) but also exhibited individual skill.[45] Pottery vessels were primarily used or displayed in domestic or public contexts involving the storage, preparation, or consumption of food.[46] Collars were not necessary for pots to function well for cooking or storing. Indeed, pottery without collars was used for thousands of years in the northeastern woodlands before collars became high-visibility features of Iroquoian ceramic practice around AD 1350.[47] Adding collars to pots used additional resources (clay, temper), planning and time (constructing and decorating the collar), and added to the complexity of drying and firing. That heavy collars were often applied to vessels with necks only a few mm thick illustrates the skill needed to successfully manufacture these vessels. Collars drew the observer's eye, acting as platforms for decorative elaborations with high absolute and contextual visibility.[48] The decorative motifs on Iroquoian pottery vessel collars were readily decoded by visitors to longhouses, conveying information about the members of the matrifamily.[49] They were highly visible to visitors receiving hospitality and occupied a visible position when employed at feasts and ceremonial events. As such, collar decorations were active, intentionally deployed signals. The designs mirrored and complemented signals visible in wider contexts such as tattoos, hair

41 Cook 2010.
42 Biggar 1924.
43 Birch 2022.
44 Perrelli 2009.
45 Braun 2015; Hart and Engelbrecht 2012.
46 Chilton 1996.
47 Brumbach 2011; Taché and Craig 2015; Taché and Hart 2013.
48 Carr 1995.
49 e.g., Bowser 2000; Bowser and Patton 2004.

Fig. 2 Collared rim sherds from the Mandeville site (first row), the Bourassa site (second row), the Isings site (third row), and the Droulers-Tsiionhiakwatha site (fourth row), all located within the St. Lawrence River Valley. Primary decorations occur on the collars. Photo credits: Jean-Christophe Ouellet (upper three rows) and Claude Chapdelaine (lower row).

styles, pendants, and clothing beadwork and quilling, among others.[50] We therefore interpret pottery collar decorations as an archaeologically visible medium in which women signaled their membership in social and political networks.[51]

Iroquoian women were and are still actively engaged in local, regional, and inter-regional politics.[52] The seventeenth-century ethnohistorical record indicates they arranged marriages, held councils, and controlled which men served

50 Krutak 2013; Steere 2013.
51 Bliege Bird and Smith 2005; Wobst 1977.
52 Beauchamp 1900; Labelle 2021.

in leadership positions.[53] The strength of women's political positions was derived from the matrilineal and matrilocal nature of Iroquoian societies, whereby most women spent their entire lives within a single matrilocal extended family household, while the loyalty of adult males was divided between their natal and marital households, clans, and communities.[54] Although women's political influence was primarily executed in the domestic sphere, their political roles and influence extended to negotiations that determined and strengthened the nature of relations within and between communities, including decision-making related to waging war, alliance-building, structuring confederacies, and foreign affairs with both Indigenous and colonial societies.[55]

The design elements produced by St. Lawrence Iroquoian women were distinctive and often more technically sophisticated than pottery wares produced by other Iroquoian potters. They included the execution of thin, even-width, closely spaced incised designs that have been described as "neat, precise, symmetrical, and esthetically pleasing"[56]. St. Lawrence Iroquoian pottery also included distinctive design elements such as deep basal collar notching, "corn-ear" motifs, "ladder" motifs, punctations arranged in vertical rows or in arrangements interpreted as evoking a "human face," and sometimes three-dimensional effigy figures.[57] The "finesse"[58] employed in the decoration of St. Lawrence Iroquoian pottery suggests a distinctive community of practice around teaching and learning among St. Lawrence potters. A recent multi-method study of ceramic manufacturing techniques suggests that the technological practices involved were homogeneous across eastern Ontario and the St. Lawrence Valley.[59] These data highlight the distinctiveness of St. Lawrence Iroquoian pottery decoration as a set of intentionally deployed social signals.

4. Social Capital, Network Structure, and Confederacy Dynamics

At the time of European contact, multiple Iroquoian societies were organized into confederacies of allied nations.[60] The largest of these were the Huron-Wendat located just south of Lake Huron's Georgian Bay, and the Haudenosaunee in the Finger Lakes region and Mohawk River basin. Confederation was a negotiated political arrangement that allowed multiple, autonomous nations and

53 Tooker 1991; Viau 2000.
54 Trigger 1990: 141–142.
55 Labelle 2013: 159–175; Macgee 2008; Shannon 2008: 92–93.
56 Ramsden 1990: 90.
57 Chapdelaine 1989; Pendergast 1980; Tremblay 2006: 80–86.
58 Ramsden 1990: 90.
59 Hawkins et al. 2021.
60 Morgan 1851; Trigger 1976.

communities to achieve collective action.[61] The existence of formal political structures, including confederacy councils, mutual non-aggression pacts, and cooperation in external military and economic strategies is well-documented in historical accounts and oral tradition.[62] However, social and political dynamics differed markedly among and between Iroquoian confederacies.[63] SNA has contributed to our understanding of those differences through analyses of network topologies and cohesion.[64]

The concept of social capital bears on our consideration of network structure and confederacy dynamics. Social capital is a functional property in the structure of relations between actors. These relations confer social and economic benefits on members of a network because of shared social ties and the norms of trust and reciprocity that arise between them.[65] The distribution of social capital can include both individual and collective benefits. Individuals may form connections that benefit them directly, but benefits can also accrue at the community, national, or regional levels within larger networked social structures.[66] Given the inherently collective nature of Iroquoian societies, networks based on ceramic decoration practices likely reflect distributions of social capital at the household and community level rather than among individual potters.

Discussions of social capital in SNA often differentiate "bonding" and "bridging" ties[67], which are reflected in network topologies (Figure 3). Bonding networks are characterized by the strength and density of relations among members. Each member is strongly tied to many other members of the network, whereby the density of network ties is facilitated by face-to-face interaction and specific reciprocity. They are typically inward-facing and effective at mobilizing solidarity. Bridging social networks are characterized by weaker ties[68] and promote information diffusion and links to external assets across diverse social groups. Benefits accrue among actors, whether individuals or groups, as opposed to within the network. Coalitional networks are a third network category that is intermediate between the dense- to loose-network continuum and consist of weak network structures that link together more tightly clustered members.[69] These network topologies are most productively understood as a continuum rather than a set of distinct network categories. Understanding network topologies as part

61 Birch 2022.
62 Fenton 1998; Bureau du Nionwentsïo 2022.
63 Birch 2020, 2022.
64 Birch and Hart 2018.
65 Bourdieu 1986; Coleman 1988; Kwon and Adler 2014; Lin 1999; Putnam 2000.
66 Bourdieu 1986; Putnam 2000.
67 Bodin and Crona 2009; Crowe 2007; Putnam 2000; Ramirez-Sanchez and Pinkerton 2009; Woolcock and Narayan 2000.
68 Granovetter 1986.
69 Crowe 2007; Ramirez-Sanchez and Pinkerton 2009.

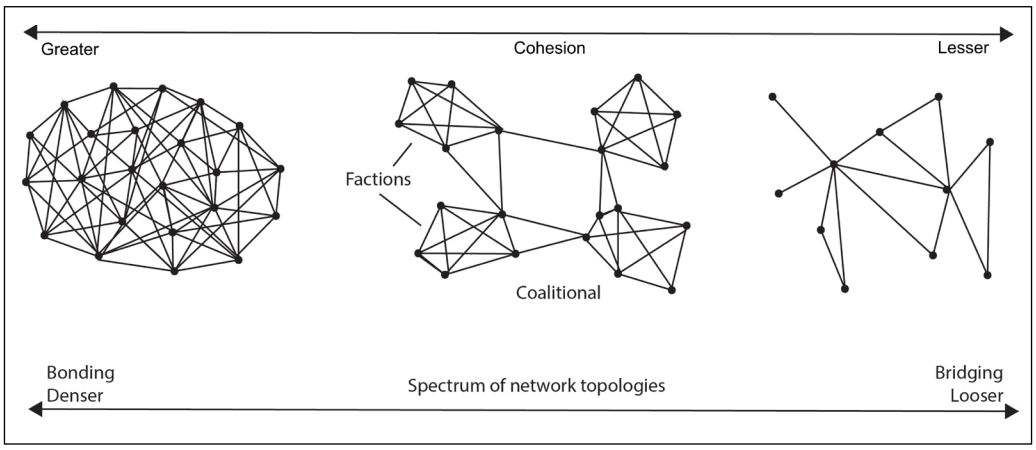

Fig. 3 Schematic of network structure topology. Following Crowe 2007: fig. 1; Ramirez-Sanchez and Pinkerton 2009: fig. 2.

of this continuum allows us to productively interrogate both pan-Iroquoian and sub-regional community networks to define and situate network structures along a bonding-coalitional-bridging continuum. It should be noted that these topologies do not necessarily track with their social configurational counterparts. Depending on the size and configuration of the networks, some groupings of villages may represent regional communities, nations, or confederations along this continuum, but such identifications are rarely conclusive. Previous analyses indicate that the Huron-Wendat and Haudenosaunee confederacies possessed very different topologies in their respective 1550–1650 AD networks.[70] The Huron-Wendat network (which includes their allies the Tionontaté) consisted of one dense and highly cohesive bonding cluster. This was interpreted as being derived from regular intra-group communication and the accumulation of social capital and trust engendered by costly reciprocity among the Huron-Wendat.[71] By contrast, the Haudenosaunee network formed distinct sub-groups of nodes that were linked together by only a few ties. This network configuration can best be described as located in the coalitional section of the spectrum. Such ties permitted increased cohesiveness between sub-groups and facilitated effective communication between diverse stakeholders – an example of the "strength of weak ties".[72] What is less clear is how and where the St. Lawrence Iroquoians fit into this spectrum of network topologies and the corresponding implications for understanding social relations within the SLI network as well as between the SLI and the historically documented confederations. As such, we consider the SLI network in

70 Birch and Hart 2018.
71 Borgatti et al. 1998; Granovetter 1973.
72 Granovetter 1986; see also Bodin and Crona 2009.

isolation, akin to the approach used to evaluate the network topologies of the Huron-Wendat and Haudenosaunee as well as the topology of the entire pan-Iroquoian network.

5. Methods and Materials

Following our previous social network analyses, pottery collar decorative attributes from seven additional St. Lawrence Iroquoian sites were coded using Engelbrecht's[73] scheme, to compensate for the under-representation of St. Lawrence Iroquoian sites in our database and previous analyses. Coding documented 98 decorative attributes, which were then combined into 30 analytical motif categories as previously modified.[74] Counts of each analytical category for each site were entered into the collar decoration database, which now consists of collars from 77,610 distinct pottery vessels representing 242 Iroquoian sites dating between AD 1350 and 1650 (Table S1).[75] This database was then used to calculate a Morisita Overlap Index[76] similarity matrix in PAST 4.1.1 (Table S2)[77], for use in the social network analyses. The Morisita Index is recommended in instances where sample size and diversity vary between cases.[78] Morisita[79] demonstrated that the index is effectively independent of sample size and Wolda[80] found that it is also effectively independent of sample diversity.

For the present analyses, three regions were identified: Haudenosaunee in New York, Huron-Wendat in southern Ontario, based on historical territories, and St. Lawrence Iroquoian along the St. Lawrence River Valley (Figure 1). Networks were created for three 100-year time spans during which sites in the St. Lawrence River Valley were present in the pottery collar decoration database. Following our previous analyses, these were AD 1400–1500, 1450–1550, and 1500–1600, with the 50-year overlaps taking into account chronological uncertainty, population circulation among extant villages, and the periodic movement of village communities to newly constructed villages.[81] In the present analysis, we updated the associated site attributes file (Table S3) to account for recent chronological adjustments based on Bayesian analyses of radiocarbon dates from Iroquoian sites.[82]

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73 Engelbrecht 1971, 1996.
74 Hart et al. 2017.
75 Tables S1–S7 are available on Zenodo at https://doi.org/10.5281/zenodo.7992153.
76 Morisita 1959.
77 Hammer et al. 2001.
78 Brughmans and Peeples 2023.
79 Morisita 1959.
80 Wolda 1981.
81 Birch and Hart 2018; Hart et al. 2016, 2017.
82 Abel et al. 2019; Birch et al. 2021; Manning and Hart 2019; Manning et al. 2018, 2019, 2021.

All network visualizations were produced in visone version 2.24.1.[83] Two forms of network visualization are used. The first, backbone visualization, uses Nocaj and associates'[84] algorithm in which structural embeddedness is identified through the accumulation of weighted triangles within quadrangles. This untangles networks and identifies ties that have the greatest influence on network structure. Within the visualizations, these ties are identified by heavier lines. The other form of visualization places each site in its geographical position on a regional map. Within these visualizations, heavier ties reflect higher Morisita Index values. This enables a visual assessment of the strengths of ties across physical space.

We provided a schematic of a spectrum of network topologies from loose to dense, with the ends characterized by bridging and bonding ties, respectively (Figure 3). To quantitatively assess the place of regional networks on this spectrum we calculated several network cohesion measurements[85]. Cohesion is the connectiveness of a network, or how strongly it is tied together on the spectrum of network topologies (Figure 3), with greater cohesiveness reflecting denser networks with bonding ties. Network cohesion measurements were calculated in UCINET 6.764[86] for each of the three regions and time spans, resulting in average measures at varying similarity index thresholds when measurements required matrix binarization. Three thresholds were used for the Morisita Index: (1) ≥ 0.500, (2) mini-max – the highest value for each time span that did not fragment a given network[87], (3) and ≥ 0.750 (Table 1). The first threshold deleted the weakest ties, the second allowed comparisons between networks in their most complete unfragmented forms, and the third eliminated all but the strongest ties. Weighted graphs were used in network visualizations, with ties below the respective thresholds eliminated.

There is no single measure of network cohesion. Rather, there is a group of measures that provide different characterizations of cohesion. Following our previous comparison of Haudenosaunee and Huron-Wendat confederacy networks, we make use of several of these measures[88]:

- **Density:** the number of ties in a network divided by the total number of possible ties. Because it is based on the number of possible ties in a network, the measurement can be compared across networks of different sizes.
- **Average degree:** the average number of ties of each node to other nodes in the network.

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83 Brandes and Wagner 2004.
84 Nocaj et al. 2015.
85 Borgatti et al. 2018.
86 Borgtti et al. 2002.
87 Cochrane and Lipo 2010; Golitko and Feinman 2015.
88 Borgatti et al. 2018.

- **Compactness:** the mean of node reciprocal distances.
- **Weighted clustering coefficient:** the average density of each node in a network weighted by the number of node pairs in each node's ego network.
- **Average distance:** the mean number of steps from one node to every other node in a network.
- **Diameter:** the length of the longest path between two nodes.
- **Distance weighted fragmentation:** the average reciprocal distance between all node pairs subtracted from one.

Higher values for density, average degree, compactness, and weighted clustering coefficient, and lower values for average distance, diameter, and distance weighted fragmentation indicate denser networks and thus reflect greater bonding ties, while the reverse suggests more bridging ties and looser networks.

We also calculated K-cores, cutpoints, and blocks in UCINET.[89]

- **K-cores:** the maximum sized subgraph (k) with a maximum degree greater or equal to k. Higher values reflect larger numbers of bonding ties.
- **Cutpoints:** nodes whose removal results in network fragmentation, resulting in two or more blocks.
- **Blocks:** subgraphs connected to the network by a cutpoint. Bridging ties are reflected in larger numbers of cutpoints and blocks.

Taken together, these various network measurements allowed assessments of the extent to which networks reflected a spectrum ranging from bonding to coalitional to bridging ties across network topologies.

In addition, we calculated measurements of potential brokerage and the external-internal (E-I) index for graphs using all sites from each time span. The potential brokerage index was calculated with Peeples and Haas's[90] code in R (version 4.2.2) within RStudio (version 2023.03.0+386) using 5,000 permutations and normalized for sample size. This index provides a measure of the potential of nodes to mediate relationships within a network.[91] The E-I index was calculated with Borck et al.'s[92] code in R with 5,000 permutations on weighted graphs and normalized for sample size. The index, ranging from –1 to +1, indicates whether a given unit (node, group) was more strongly focused on interactions within (homophily) or outside (heterophily) of the network group, with homophily represented by negative and heterophily by positive values. We performed Louvain

89 Crowe 2007: 478.
90 Peeples and Hass 2013.
91 Peeples and Haas (2003: 238).
92 Borck et al. 2015.

community detection analysis, which maximized modularity in the networks[93], in visone with initial clustering set at uniform and edge weight to Morista Index values.

All of these network measurements are relative when comparing two or more graphs. However, it is possible to determine if vectors of node-level (as opposed to graph-level) values differ significantly between graphs. To that end, vectors of measures for which the software outputs individual node values (average degree, weighted clustering coefficient, density, distance, and distance weighted fragmentation) were used for permutation t-tests in UCINET to test for significant differences between pairs of regions at each Morisita Index threshold. These tests are independent of underlying assumptions about data distribution.[94] Significant differences ($p < 0.05$) indicate that the mean of one vector is greater than the mean of the second vector, suggesting more or less cohesion as appropriate to the measurement.

6. Results

6.1 Intra-regional Network Topologies

Figure 4 consists of 100-year time-span network mini-max visualizations of St. Lawrence Iroquoian sites using a Morisita Index. Colors reflect different geographical divisions within the St. Lawrence River Valley (see Figure 1). Figure 5 consists of network visualizations with sites plotted in their geographical locations and their colors representing Louvain community detection clusters. It is clear from these sets of visualizations that signaling networks in each 100-year time span extended across the length of the valley; some sites within geographical clusters were more strongly tied to sites in other geographical clusters, often at great distances.

Network cohesion measure values for all three independent sub-regional networks (Haudenosaunee, St. Lawrence Iroquoian, and Huron-Wendat) are presented in Table 1. The St. Lawrence Iroquoian networks exhibit greater cohesion in the 1400–1500 and 1450–1550 networks than in the 1500–1600 network. When the measurements are compared across the three regions, the pattern for each set of 100-year time spans is Huron-Wendat > St. Lawrence Iroquoian > Haudenosaunee; the St. Lawrence Iroquoian networks exhibit greater cohesion than the Haudenosaunee networks, but less than the Huron-Wendat networks (Figures 6–8). The K-core index indicates that the St. Lawrence Iroquoian 1400–1500 and 1450–1550 networks have more bonding ties than the Haudenosaunee net-

93 Blondel et al. 2008.
94 Borgatti et al. 2018.

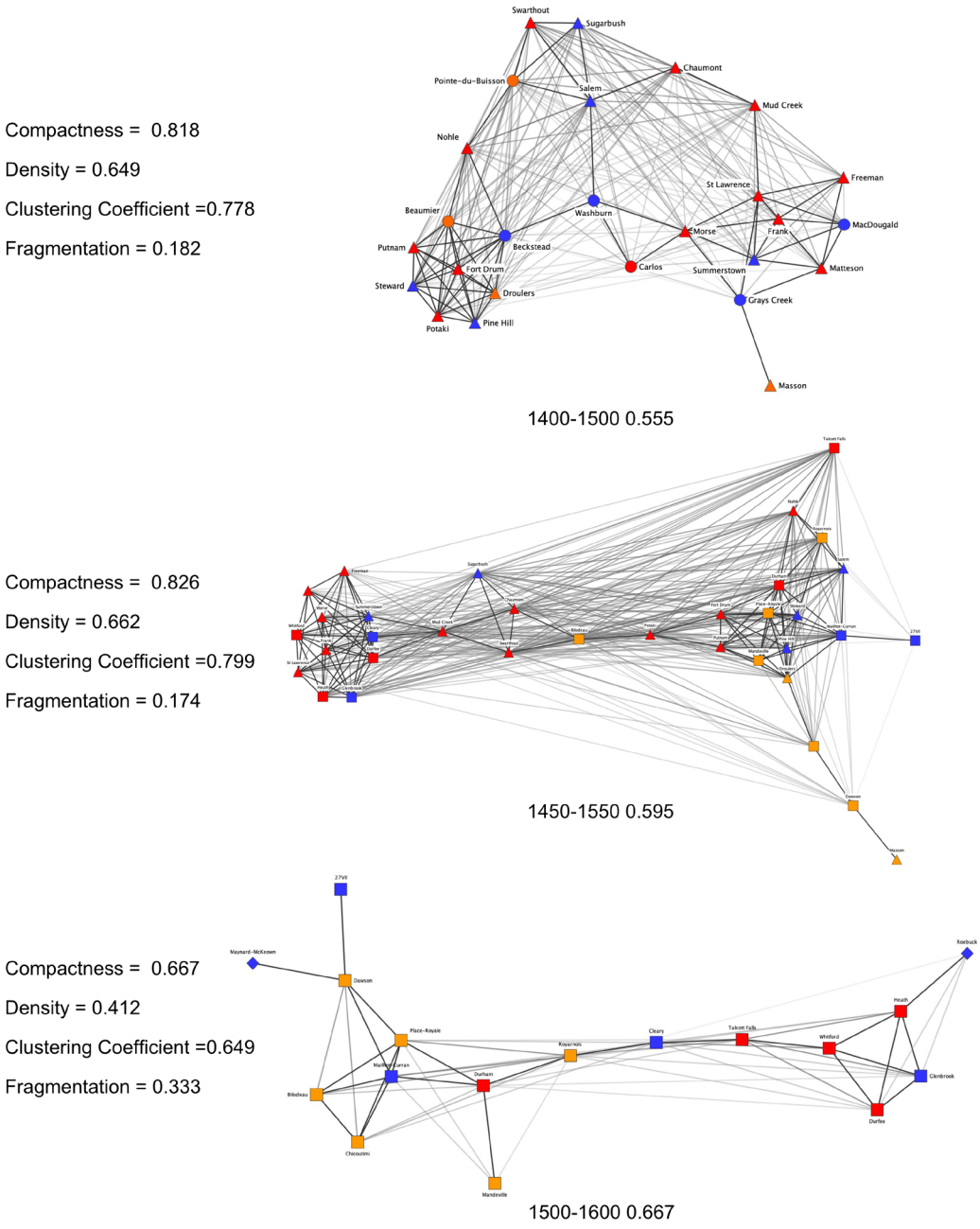

Fig. 4 Mini-max backbone network visualizations of St. Lawrence Iroquoian sites in 100-year time spans. Darker ties represent higher backbone strength. Numbers after time span are the mini-max threshold. Colors reflect different geographical divisions within the St. Lawrence River Valley; red = Jefferson County/Northern New York; blue = upstream; orange = downstream (see Figure 1 for geographic locations of each division). Circles = 1400–1450; triangles = 1450–1500; square = 1500–1550; diamond = 1550–1600.

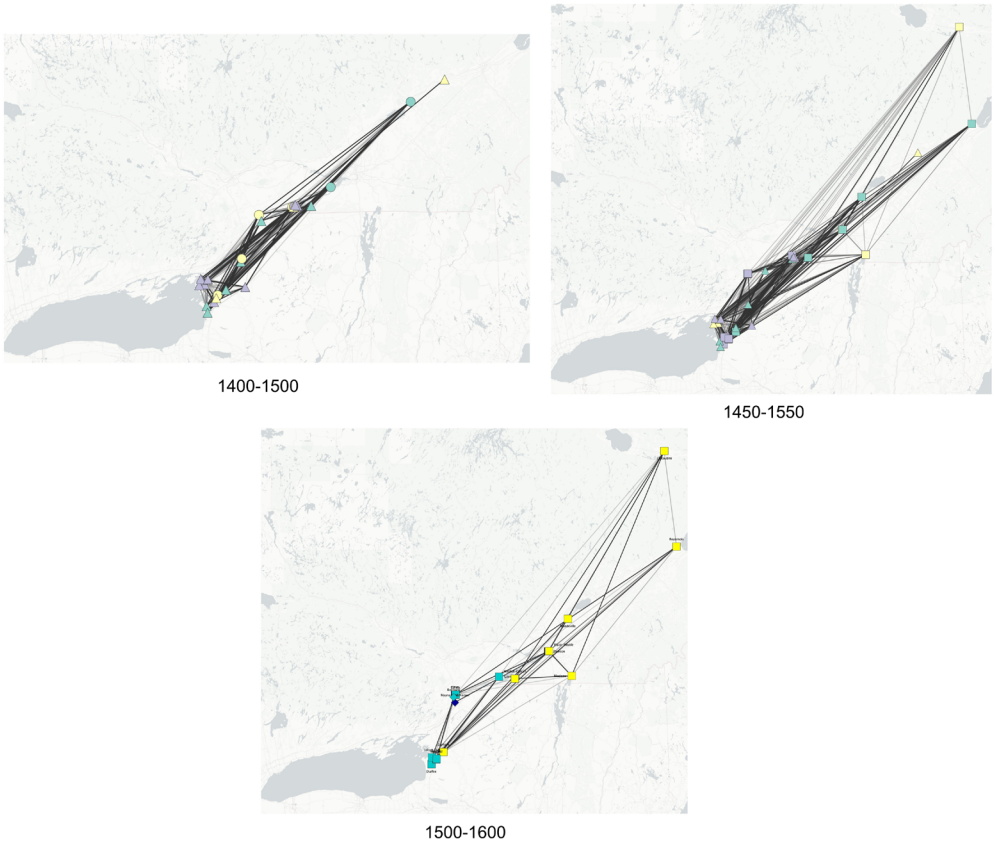

Fig. 5 St. Lawrence Valley River Valley network visualizations with sites plotted in their geographical locations and their colors representing Louvain community detection clusters. Darker lines indicate higher Morisita Index values. Circles = 1400–1450; triangles = 1450–1500; square = 1500–1550; diamond = 1550–1600.

works, but fewer than the Huron-Wendat networks; however, the St. Lawrence Iroquoian and Huron-Wendat networks more strongly resemble each other. The Haudenosaunee networks with Morisita Index thresholds other than 0.500, on the other hand, have higher percentages of cutpoints than the St. Lawrence Iroquoian and Huron-Wendat networks, indicating more bridging ties.

The significance of these differences was tested with a series of permutation single-tail t-tests when the measurement provided vectors of individual node values; the p-values for each test are presented in Table 2. Here too, the general pattern is Huron-Wendat > St. Lawrence Iroquoian > Haudenosaunee in which the majority of measures are significantly different between two regions. However, in the mini-max graphs for 1400–1500 and 1450–1550 neither Huron-Wendat or St. Lawrence have greater cohesion in a majority of measures.

Region	n	MI	Compactness	Average Degree	Average Distance	Diameter	Density	k-core index (% of n)	Weighted Clustering Coefficient	Distance Weighted Fragmentation	Blocks	Cutpoints (% of n)
1400–1500												
Haudenosaunee	14	0.500	0.604	5.000	1.182	4	0.385	5 (35.71)	0.792	0.396	1	2 (14.29)
St Lawrence	26	0.500	0.866	18.538	1.289	3	0.742	15 (57.69)	0.842	0.134	1	2 (7.69)
Huron-Wendat	38	0.500	0.990	36.263	1.020	2	0.980	34 (89.47)	0.983	0.010	1	0 (0.00)
1450–1550												
Haudenosaunee	17	0.500	0.697	7.059	1.706	4	0.441	5 (29.41)	0.653	0.303	1	0 (0.00)
St Lawrence	35	0.500	0.910	28.114	1.193	3	0.827	23 (65.71)	0.901	0.090	2	1 (2.86)
Huron-Wendat	34	0.500	0.985	23.059	1.029	2	0.971	31 (91.18)	0.978	0.014	1	0 (0.00)
1500–1600												
Haudenosaunee	23	0.500	0.714	10.000	1.625	3	0.455	9 (39.13)	0.692	0.286	1	0 (0.00)
St Lawrence	17	0.500	0.907	13.059	1.919	3	0.816	11 (64.71)	0.904	0.093	1	0 (0.00)
Huron-Wendat	30	0.500	0.974	25.552	1.052	2	0.948	27 (90.00)	0.985	0.026	1	0 (0.00)
1400–1500												
Haudenosaunee	14	0.641	0.478	3.143	1.669	6	0.242	4 (28.57)	0.692	0.353	7	4 (28.57)
St Lawrence	26	0.555	0.818	16.231	1.388	3	0.649	12 (46.15)	0.778	0.182	2	1 (3.85)
Huron-Wendat	38	0.796	0.806	23.211	1.420	3	0.627	22 (57.89)	0.834	0.194	2	1 (2.63)
1450–1550												
Haudenosaunee	17	0.613	0.578	6.059	2.331	6	0.316	5 (29.41)	0.592	0.422	3	2 (11.76)
St Lawrence	35	0.595	0.826	22.514	1.370	3	0.662	17 (48.57)	0.799	0.174	2	1 (2.85)
Huron-Wendat	34	0.796	0.881	25.529	1.258	3	0.774	26 (76.47)	0.920	0.119	3	2 (5.88)

Region	n	MI	Compactness	Average Degree	Average Distance	Diameter	Density	k-core index (% of n)	Weighted Clustering Coefficient	Distance Weighted Fragmentation	Blocks	Cutpoints (% of n)
1500–1600												
Haudenosaunee	23	0.562	0.647	8.261	1,881	4	0.375	8 (34.78)	0.692	0.353	3	2 (8.69)
St Lawrence	17	0.667	0.667	6.588	1.860	4	0.412	5 (29.41)	0.649	0.333	3	1 (5.88)
Huron-Wendat	30	0.638	0.966	26.069	1.069	2	0.931	26 (86.67)	0.995	0.034	2	1 (3.33)
1400–1500												
Haudenosaunee	14	0.750	0.174	1.857	1.368	3	0.143	3 (21.43)	0.750	0.826	2	5 (35.71)
St Lawrence	26	0.750	0.565	7.000	1.937	4	0.280	6 (23.08)	0.587	0.435	3	2 (12.50)
Huron-Wendat	38	0.750	0.865	27.158	1.280	3	0.734	23 (60.53)	0.861	0.135	1	0 (0.00)
1450–1550												
Haudenosaunee	17	0.750	0.263	2.353	2.068	4	0147	2 (11.76)	0.477	0.737	6	2 (11.76)
St Lawrence	35	0.750	0.587	11.714	1.670	3	0.345	11 (31.43)	0.664	0.422	2	0 (0.00)
Huron-Wendat	34	0.750	0.912	27.235	1.176	3	0.825	26 (76.47)	0.937	0.088	1	0 (0.00)
1500–1600												
Haudenosaunee	23	0.750	0.306	3.826	1.347	6	0.174	5 (21.74)	0.711	0.694	7	3 (13.04)
St Lawrence	17	0.750	0.445	4.235	1.837	4	0.265	4 (23.53)	0.631	0.555	3	1 (5.88)
Huron-Wendat	38	0.750	0.911	24.966	1.042	2	0.892	24 (80.00)	0.969	0.089	1	0 (0.00)

Tab. 1 Cohesion measurements for regional 100-year binarized graphs at different Morisita Index (MI) thresholds.

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Regions	Morisita Index Threshold	Average Degree	Weighted Clustering Coefficient	Density	Average Distance	Distance Weighted Fragmentation	Region with greater cohesion
1400–1500							
St Lawrence > Haudenosaunee	0.500	0.000	0.219	0.216	1.000	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.500	0.000	0.000	0.000	1.000	1.000	Huron-Wendat
1450–1550							
St Lawrence > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.500	0.000	0.000	0.000	1.000	1.000	Huron-Wendat
1500–1600							
St Lawrence > Haudenosaunee	0.500	0.001	0.000	0.000	1.000	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.500	0.000	0.000	0.000	0.996	1.000	Huron-Wendat
1400–1500 (mini-max)							
St Lawrence > Haudenosaunee	0.555–0.641	0.000	0.008	0.009	1.000	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.796–0.641	0.000	0.001	0.001	1.000	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.796–0.555	0.000	0.149	0.148	0.348	0.000	Neither
1450–1550 (mini-max)							
St Lawrence > Haudenosaunee	0.595–0.613	0.000	0.003	0.032	1.000	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.796–0.613	0.000	0.010	0.011	1.000	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.796–0.595	0.000	0.099	0.100	0.960	1.000	Neither

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Regions	Morisita Index Threshold	Average Degree	Weighted Clustering Coefficient	Density	Average Distance	Distance Weighted Fragmentation	Region with greater cohesion
1500–1600 (mini-max)							
St Lawrence > Haudenosaunee	0.667–0.562	0.959	0.545	0.705	0.927	0.995	Neither
Huron-Wendat > Haudenosaunee	0.638–0.562	0.000	0.000	0.000	0.990	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.638–0.667	0.000	0.000	0.000	0.002	1.000	Huron-Wendat
1400–1500							
St Lawrence > Haudenosaunee	0.750	0.000	–	0.008	0.000	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.750	0.000	–	0.000	0.298	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.750	0.000	0.000	0.000	1.000	1.000	Huron-Wendat
1450–1550							
St Lawrence > Haudenosaunee	0.750	0.000	0.030	0.029	0.697	1.000	St. Lawrence
Huron-Wendat > Haudenosaunee	0.750	0.000	0.000	0.000	0.451	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.750	0.000	0.000	0.000	0.991	1.000	Huron-Wendat
1500–1600							
St Lawrence > Haudenosaunee	0.750	0.436	0.319	0.321	0.743	1.000	Neither
Huron-Wendat > Haudenosaunee	0.750	0.000	0.000	0.000	0.866	1.000	Huron-Wendat
Huron-Wendat > St Lawrence	0.750	0.000	0.000	0.000	0.043	1.000	Huron-Wendat

Tab. 2 Single tail permutation p-values for t-tests of binarized vectors of network measures between 100-year time span regional graphs at different Morisita Index thresholds. The p-values indicate whether the mean of the first group is significantly greater ($p \leq 0.05$) than the second group.

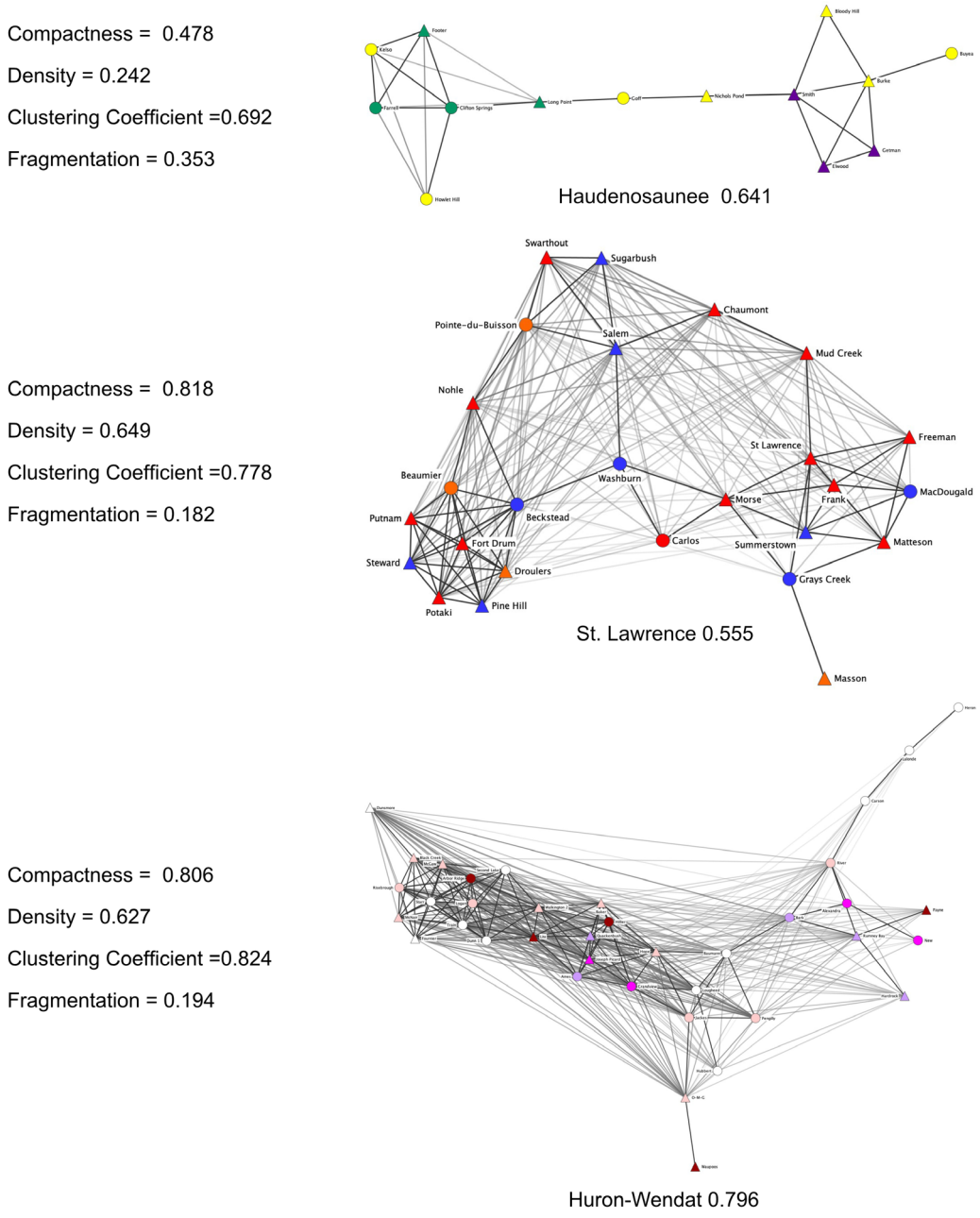


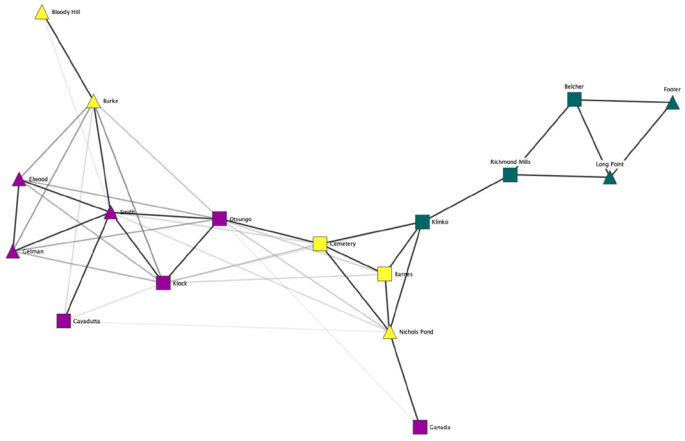
Fig. 6 Regional 1400–1500 mini-max backbone networks. Darker ties represent higher backbone strength. Numbers after time span are the mini-max threshold. See Figure 10 for color key; circles = 1400–1450; triangles = 1450–1500.

Compactness = 0.578

Density = 0.316

Clustering Coefficient =0.592

Fragmentation = 0.422



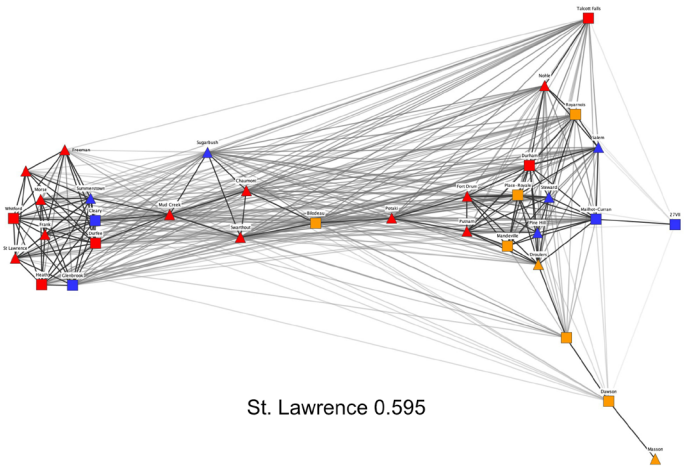
Haudenosaunee 0.613

Compactness = 0.826

Density = 0.662

Clustering Coefficient =0.799

Fragmentation = 0.174



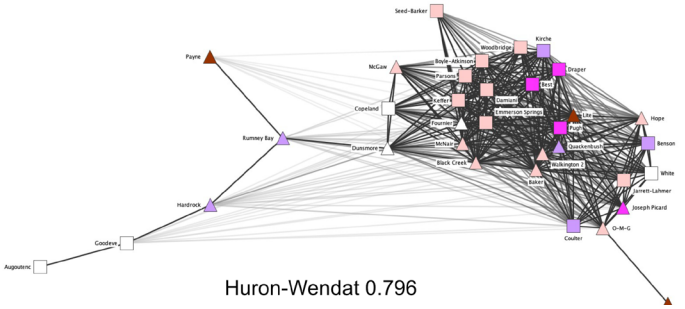
St. Lawrence 0.595

Compactness = 0.881

Density = 0.774

Clustering Coefficient =0.920

Fragmentation = 0.119



Huron-Wendat 0.796

Fig. 7 Regional 1450–1550 mini-max backbone networks. Darker ties represent higher backbone strength. Numbers after time span are the mini-max threshold. See Figure 10 for color key; triangles = 1450–1500; squares = 1500–1550.

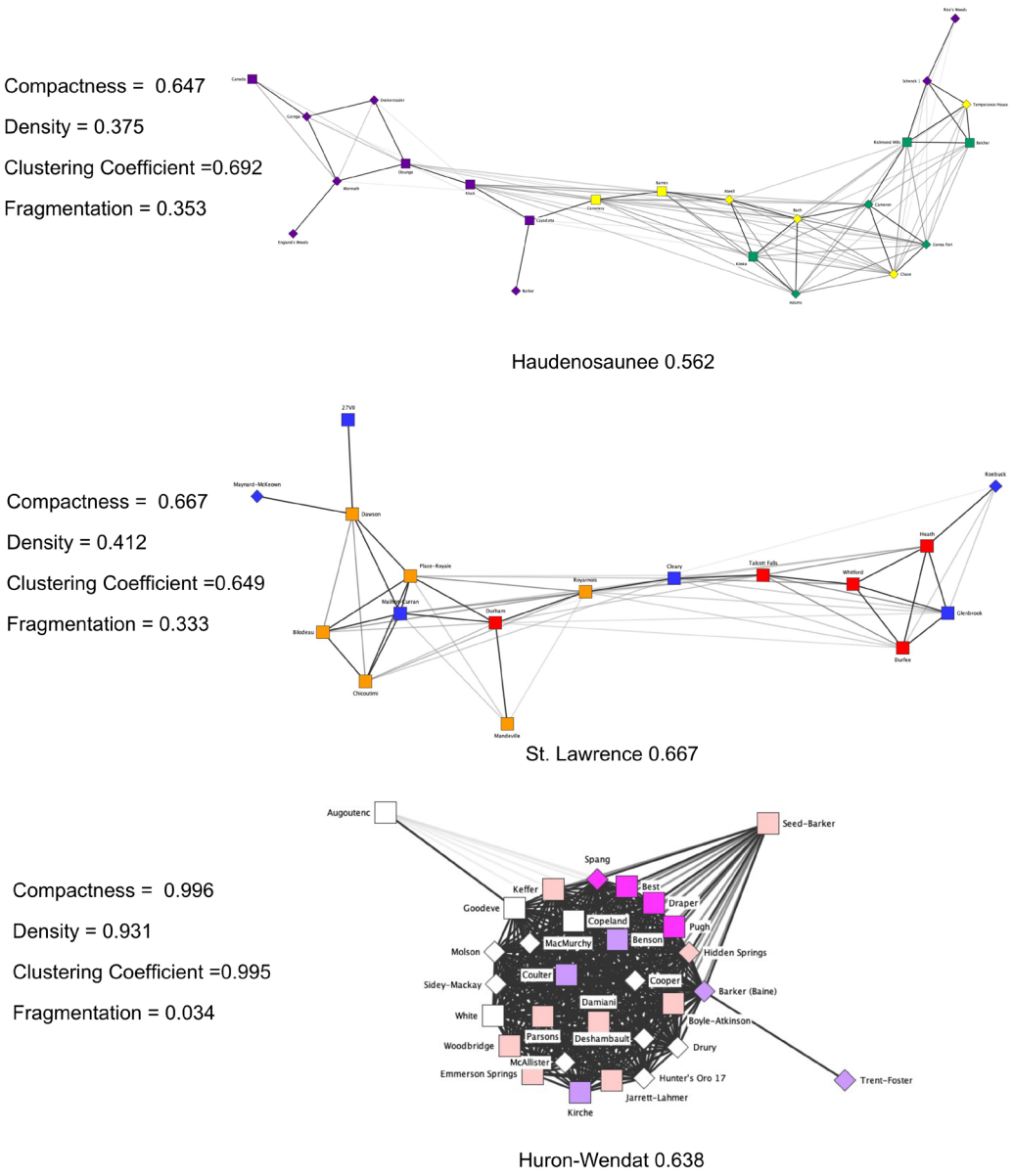


Fig. 8 Regional 1500–1600 mini-max backbone networks. Darker ties represent higher backbone strength. Numbers after time span are the mini-max threshold. See Figure 10 for color key; squares = 1500–1550; diamonds = 1550–1600.

6.2 Pan-Iroquoian Network Measures

Pan-Iroquoian mini-max network visualizations on regional map backgrounds are presented in Figure 9 with colors representing Louvain community detection clusters. In the 1400–1500 visualization, the Louvain clusters mostly comprise sites within one of the three regions. However, there are sites in the St. Lawrence valley that are within the cluster comprised of sites primarily from the Haudenosaunee territory. The cluster comprised of primarily St. Lawrence sites includes sites from the Huron-Wendat territory. It is also the case that some Huron-Wendat sites located in the historic Wendat heartland south of Georgian Bay cluster with St. Lawrence sites. In the 1450–1550 visualization, the Louvain clusters are consistent with the three regions, except for a group of sites in historical Seneca territory that are in the St. Lawrence cluster, and one site in Prince Edwards County that is in the St. Lawrence cluster. In the 1500–1600 network there are a few sites in the Haudenosaunee region that are assigned to the St. Lawrence cluster, and a few sites in the Huron-Wendat region that are assigned to the Haudenosaunee cluster.

Regional E-I index values for weighted graphs are presented in Table 3. Values are negative for each of the regions, indicating that each region is more inter-

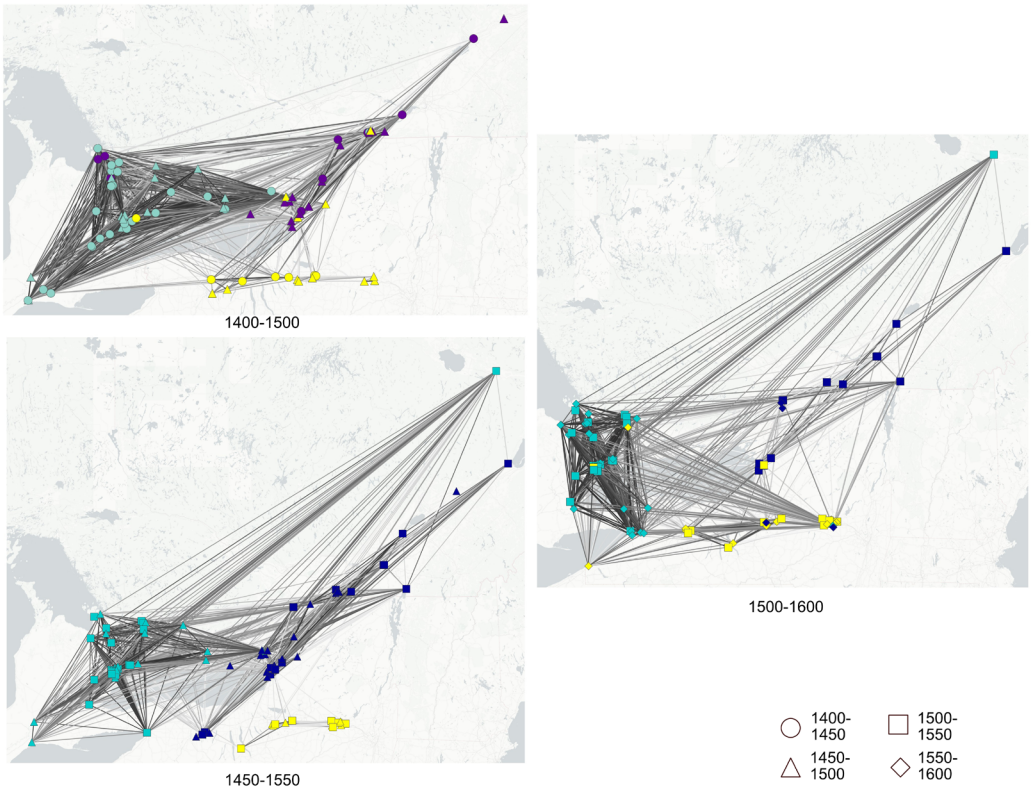


Fig. 9 Louvain clusters maps. Darker ties indicate higher Morisita Index values.

Region	1400–1500		1450–1550		1500–1600	
	n	E-I	n	E-I	n	E-I
Haudenosaunee	14	–0.332	17	–0.484	23	–0.459
St Lawrence	26	–0.344	35	–0.454	17	–0.484
Huron-Wendat	38	–0.432	34	–0.550	30	–0.552

Tab. 3 Morisita Index normalized E-I group index by 100-year time span.

nally than externally focused (homophily). This is further demonstrated with the results of t-tests on vectors of Morisita Index values for each St. Lawrence site (Supplemental data file tables S4–S6). The results indicate in general that the St. Lawrence Iroquoian sites' strongest ties are to other St. Lawrence Iroquoian sites in each 100-year graph. St. Lawrence Iroquoian sites generally have stronger ties to Huron-Wendat sites than to Haudenosaunee sites. In the 1400–1500 graphs, when there is no significant difference between means of the Haudenosaunee and Huron-Wendat vectors it is most often sites at the headwaters of the St Lawrence River. In the 1450–1550 graph, when there are stronger ties to Haudenosaunee than to Huron-Wendat sites, they are also ties to sites located in this area. In the 1500–1600 graph, there are more vectors with no significant differences in means between the Haudenosaunee and Huron-Wendat vectors.

P-values for single-tail, permutation t-tests of regional cohesion measurement vectors for each 100-year time span at each Morisita Index threshold for pan-Iroquoian graphs are presented in Table 4. The results are generally consistent with those comparing the regional graphs. The majority of measurements for the St. Lawrence Iroquoian vectors in the 1400–1500 and 1450–1550 graphs are significantly different from means of the Haudenosaunee vectors, while the Huron-Wendat vectors have significantly different means than both the other regions, except St. Lawrence for the 1450–1550 0.500 threshold network. The measurements for the 1500–1600 graphs indicate no significant differences between the means of the Haudenosaunee and St. Lawrence Iroquoian vectors.

This pattern does not extend to the potential brokerage and E-I indices (Tables 4 and 5). In the 1400–1500 and 1450–1550 graphs, the St. Lawrence Iroquoian potential broker vector means are significantly greater than the Haudenosaunee and Huron-Wendat vector means. The 1500–1600 graphs show no difference between the St. Lawrence Iroquoian and the other regions at the 0.500 and minimax thresholds and with the Huron-Wendat at the 0.750 threshold. In the E-I case (Table 5), there is no significant difference between any of the vectors except the St. Lawrence Iroquoian mean, which is significantly greater (less negative) than the Haudenosaunee mean for the 1500–1600 weighted graph. Figure 10 shows sites in each region as nodes scaled to reflect their potential brokerage values.

Regions	Morisita Index Threshold	Average Degree	Weighted Clustering Coefficient	Density	Distance	Region with greater cohesion	Brokerage
1400–1500							
St Lawrence > Haudenosaunee	0.500	0.000	0.501	0.498	1.000	St. Lawrence	0.000
Huron-Wendat > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	Huron-Wendat	0.000
Huron-Wendat > St Lawrence	0.500	0.000	0.000	0.000	1.000	Huron-Wendat	0.961
1450–1550							
St Lawrence > Haudenosaunee	0.500	0.000	0.002	0.001	1.000	St. Lawrence	0.000
Huron-Wendat > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	Huron-Wendat	0.042
Huron-Wendat > St Lawrence	0.500	0.069	0.000	0.000	0.792	Neither	1.000
1500–1600							
St Lawrence > Haudenosaunee	0.500	0.188	0.311	0.308	0.868	Neither	0.244
Huron-Wendat > Haudenosaunee	0.500	0.000	0.000	0.000	1.000	Huron-Wendat	0.632
Huron-Wendat > St Lawrence	0.500	0.000	0.000	0.000	0.999	Huron-Wendat	0.904
1400–1500 (mini-max)							
St Lawrence > Haudenosaunee	0.555	0.000	0.368	0.370	1.000	St. Lawrence	0.001
Huron-Wendat > Haudenosaunee	0.555	0.000	0.000	0.000	1.000	Huron-Wendat	0.003
Huron-Wendat > St Lawrence	0.555	0.000	0.000	0.000	0.348	Huron-Wendat	0.943
1450–1550 (mini-max)							
St Lawrence > Haudenosaunee	0.595	0.000	0.299	0.298	1.000	St. Lawrence	0.000
Huron-Wendat > Haudenosaunee	0.595	0.000	0.000	0.000	1.000	Huron-Wendat	0.431
Huron-Wendat > St Lawrence	0.595	0.000	0.000	0.000	0.960	Huron-Wendat	1.000

Regions	Morisita Index Threshold	Average Degree	Weighted Clustering Coefficient	Density	Distance	Region with greater cohesion	Brokerage
1500–1600 (mini-max)							
St Lawrence > Haudenosaunee	0.562	0.214	0.254	0.247	0.898	Neither	0.243
Huron-Wendat > Haudenosaunee	0.562	0.000	0.000	0.000	1.000	Huron-Wendat	0.786
Huron-Wendat > St Lawrence	0.562	0.000	0.000	0.000	0.002	Huron-Wendat	0.919
1400–1500							
St Lawrence > Haudenosaunee	0.750	0.000	–	0.015	0.092	St. Lawrence	0.000
Huron-Wendat > Haudenosaunee	0.750	0.000	–	0.000	0.634	Huron-Wendat	0.000
Huron-Wendat > St Lawrence	0.750	0.000	0.000	0.000	1.000	Huron-Wendat	0.000
1450–1550							
St Lawrence > Haudenosaunee	0.750	0.000	0.027	0.027	0.288	St. Lawrence	0.000
Huron-Wendat > Haudenosaunee	0.750	0.000	0.000	0.000	0.526	Huron-Wendat	0.000
Huron-Wendat > St Lawrence	0.750	0.000	0.000	0.000	0.956	Huron-Wendat	0.095
1500–1600							
St Lawrence > Haudenosaunee	0.750	0.388	0.642	0.642	0.725	Neither	0.097
Huron-Wendat > Haudenosaunee	0.750	0.000	0.000	0.000	0.989	Huron-Wendat	0.000
Huron-Wendat > St Lawrence	0.750	0.000	0.000	0.000	0.995	Huron-Wendat	0.000

Tab. 4 Single tail permutation p-values for t-tests of vectors of measures between regions for binarized 100-year time span graphs at different Morisita Index thresholds for pan-Iroquoian networks. The p-values indicate if the mean of the first group is significantly greater ($p \leq 0.05$) than the second group.

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Regions	Brokerage	nE-I
1400–1500		
St Lawrence > Haudenosaunee	0.001	1.000
Huron-Wendat > Haudenosaunee	0.002	1.000
Huron-Wendat > St Lawrence	0.942	1.000
1450–1550		
St Lawrence > Haudenosaunee	0.000	1.000
Huron-Wendat > Haudenosaunee	0.421	1.000
Huron-Wendat > St Lawrence	1.000	0.997
1500–1600		
St Lawrence > Haudenosaunee	0.241	0.003
Huron-Wendat > Haudenosaunee	0.969	1.000
Huron-Wendat > St Lawrence	0.998	1.000

Tab. 5 Single tail permutation p-values for t-tests of vectors of measures between regions for weighted 100-year time span graphs for pan-Iroquoian networks. The p-values indicate if the mean of the first group is significantly greater (p = 0.05) than the second group.

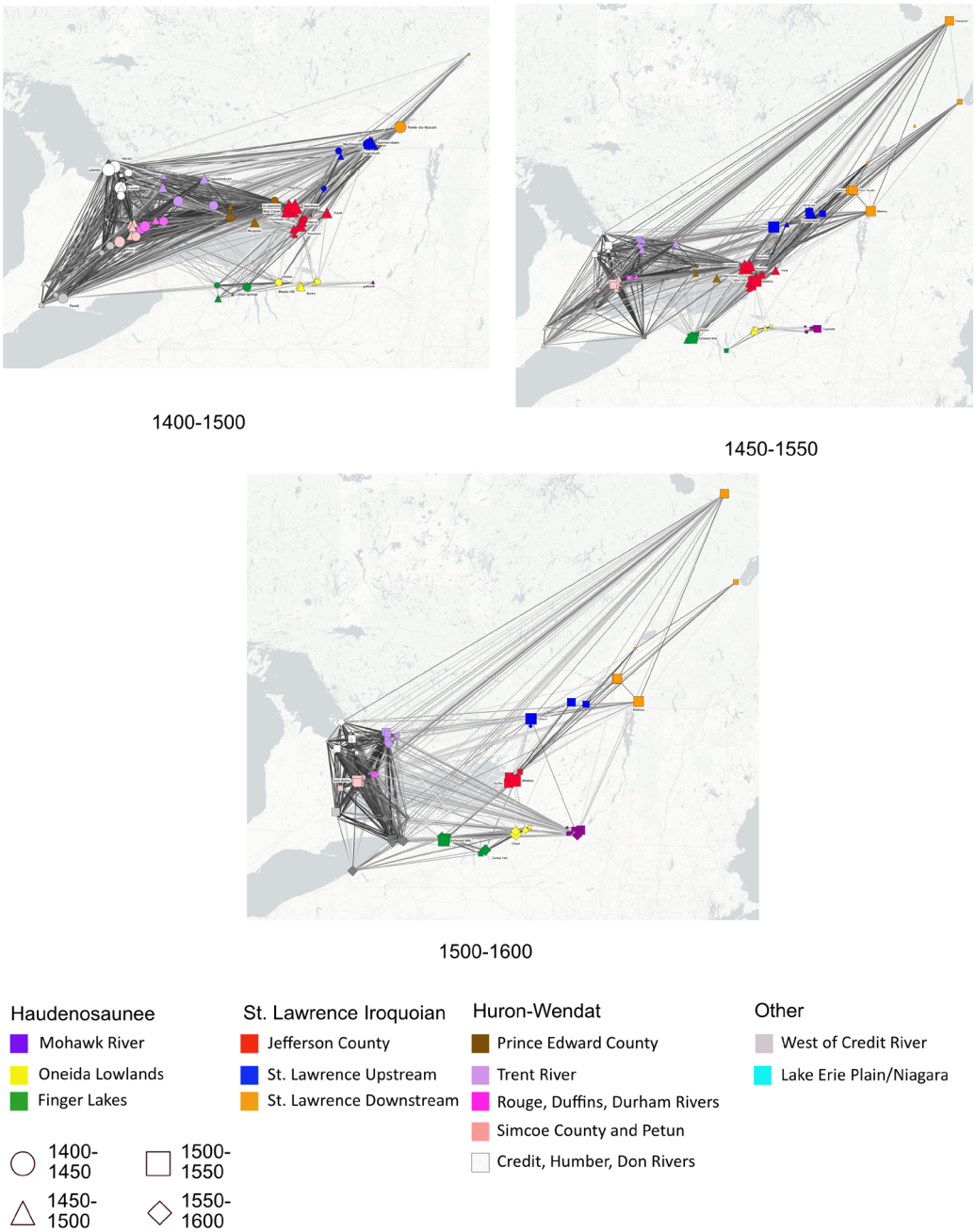

Fig. 10 Pan-Iroquoian networks. Higher potential brokerage scores are represented by larger node size, darker ties indicate higher Morisita Index values.

7. Discussion

Women played a very important role among Iroquoian societies. They were in charge of the cultivated fields and, as such, they became food providers who were as important, if not more so, than men. This high economic status also conferred significant political influence, with women choosing leaders in villages and nations.[95] Women were also responsible for pottery production.[96] While we do not wish to assert that ceramic styles reflect cultural identities, it remains true that ceramic productions allowed for the expression of shared stylistic preferences within communities of practice. Thus, women played a central role in social signaling strategies through the making and using of pottery, hence the focus on them in this study.

Our first goal for the present analyses was to determine how SNA can inform us about relationships within the St. Lawrence River Valley. It is evident based on the network visualizations that geographic location was not the primary determinant of network tie strength. Community detection clusters extend across the valley. Although some sites within geographic clusters belong to the same network clusters, others do not. It is not possible at current chronological resolution to determine if these latter sites were occupied contemporaneously with the former sites, although in many cases they are assigned to the same 50-year time span. This result suggests that the geographic proximity of sites within the valley did not determine network topologies. Rather, the distinct clusters in the 1400–1500 and 1450–1550 networks comprised sites from different geographical clusters. This indicates that St. Lawrence Iroquoian women moved throughout the valley and often maintained relationships at great distances, resulting in a social signaling repertoire that crosscut archaeologically inferred St. Lawrence provinces. These geographical clusters or provinces do not reflect actual networks of interaction 'on the ground', which were in fact distributed widely throughout the valley. The E-I index analysis indicates that each region's networks were more inwardly than outwardly focused. Permutation t-tests of Morisita Index vectors indicate that St. Lawrence Iroquoian sites were on average more strongly tied to other St. Lawrence Iroquoian sites than to sites in the Huron-Wendat or Haudenosaunee regions.

St. Lawrence Iroquoian women participated in social signaling networks within the valley that identified them as separate from signaling networks within the Haudenosaunee and Huron-Wendat regions. This is supported by the Louvain community detection analysis, which indicates that most sites in the St. Lawrence River Valley are identified in the same cluster within each network. These

95 Beauchamp 1900; Tooker 1991; Tremblay 2006; Viau 2000
96 Wrong 1939

results, coupled with a distinctive material culture and evidently separate language dialect, support the suggestion that the St. Lawrence Iroquoians did form a distinct, socio-political group and emic-ethnic identity with shared communities of practice and symbolic repertoires. We cannot reject the hypothesis that St. Lawrence Iroquoians formed a distinct socio-political group and emic-ethnic identity prior to the arrival of the first Europeans to the valley.

What does the structure of each regional network indicate about flows of social capital and intra-regional variability? Our prior analysis of the Haudenosaunee and Huron-Wendat regional networks based on the Brainerd-Robinson similarity coefficient and two of the three-time spans used here (1450–1550, 1500–1600) established that the Haudenosaunee networks represented coalitional networks while the Huron-Wendat represented a complete or bonding network.[97] Our current analysis using the Morisita Overlap Index duplicates those results. This indicates that confederacies can occupy different places on the loose/bridging to dense/bonding continuum. As such, we cannot infer the existence of a St. Lawrence Iroquoian confederacy or not based on network structure. However, the variability in network structures suggests that Iroquoian women possessed a diverse repertoire of social signaling strategies for articulating and maintaining socio-political ties.

The St. Lawrence Iroquoian networks are different from those of the other regional Iroquoian networks. Each of the St. Lawrence Iroquoian networks can be categorized as coalitional in that there are distinct clusters of sites with strong ties and these clusters are tied together into a single larger network. However, the 1400–1500 and 1450–1550 St. Lawrence networks have many more ties between clusters than the contemporaneous Haudenosaunee networks. The clusters within these St. Lawrence network visualizations more closely resemble the Huron-Wendat than the Haudenosaunee networks in as much as they are composed of sites from different geographic locations. This suggests that patterns of social interaction among St. Lawrence Iroquoian women more closely resembled those of Huron-Wendat women. If the dense, bonding nature of Huron-Wendat networks are interpreted as representing a cohesive, widespread social signaling repertoire based on intergroup cooperation and in-group loyalty, we are seeing a similar pattern among St. Lawrence Iroquoian women in the pre-1550 networks, prior to the dispersal of population away from the valley. The 1400–1500-time span is when ancestral Huron-Wendat communities began gradually moving away from the north shore of Lake Ontario to historical Wendake south of Georgian Bay, as reflected in the Louvain clusters.[98] The dense, bonding structure of the Huron-Wendat network was fully formed in the 1500–1600 network,

97 Birch and Hart 2018.
98 Williamson 2014.

likely reflecting the formation of the Huron-Wendat Confederacy and its concentration in historic Wendake,[99] although it should be noted that this bonding network also includes communities remaining on the north shore of Lake Ontario prior to the depopulation of that region shortly after 1600.[100]

Network measurements indicate that the St. Lawrence Iroquoian networks had greater cohesion than the Haudenosaunee networks, but less than the Huron-Wendat networks. The differences between the St. Lawrence and Huron-Wendat networks, however, were considerably less than those between the St. Lawrence and Haudenosaunee in the 1400–1450 and 1450–1550 networks. In the 1500–1600 networks, the St. Lawrence Iroquoian network visualization more closely resembles the Haudenosaunee than the Huron-Wendat network. These results indicate that while the Huron-Wendat continued a trend toward a dense network of bonding ties, the St. Lawrence Iroquoian network did not. Rather, its topology became looser, possibly reflecting the movement of its members away from the valley and a corresponding loss of network cohesion within the valley, with fewer 'weak' ties among those communities that remained. It is also possible that the previously identified brokerage role that St. Lawrence Iroquoians women played in pan-Iroquoian geopolitics gave them access to a wide range of signaling repertoires that they selectively deployed over time.

Our second goal for the SNA was to determine the roles the St. Lawrence Iroquoians played in the pan-Iroquoian networks. Specifically, we were interested in verifying if sites on the east shore of Lake Ontario at the headwaters of the St. Lawrence continued to hold important brokerage roles within the pan-Iroquoian networks with the addition of more sites from downstream. The potential brokerage index indicates that some of the sites in this segment of the valley had the potential to mediate relationships within the network. Our previous analysis indicated it was the geographical location of these sites that resulted in, or facilitated, that potential role.[101] The current analysis shows strong ties between sites in northern New York and "upstream" sites located west of Montreal as well as sites downstream. It is possible that the brokerage function included mediations between downstream St. Lawrence Iroquoians and Iroquoians in the Huron-Wendat and Haudenosaunee regions. Regardless, it is apparent that specific St. Lawrence Iroquoian women from all three sub-regional groups were important in the functioning of the pan-Iroquoian networks (Figure 10), potentially mediating between members of the different regions.

We must consider what is known about the wider societal contexts in which these network structures were embedded. In the later 1400s, there is evidence for

99 Birch and Hart 2018; Hart et al. 2016.
100 See Birch and Hart 2021.
101 Hart et al. 2019.

the escalation of conflict throughout the Lower Great Lakes region.[102] Internal conflict among the Haudenosaunee ceased with the development of mutual non-aggression pacts and formal diplomatic protocols, perhaps in association with the formation of their confederacy or a precursor of it around this time.[103] Hostilities between the Haudenosaunee and their neighbors intensified in the early-to-mid 1500s.[104] The St. Lawrence Iroquoians who formerly occupied northern New York had dispersed by 1510–1550.[105] Evidence for conflict on the north shore of Lake Ontario peaks in the mid-1500s; the St. Lawrence Iroquoians in the lower river valley were dispersed around 1580, and the north shore region was abandoned by the Huron-Wendat shortly after AD 1600.[106] Documentary and archaeological evidence suggests that the Haudenosaunee shifted their military strategy to depopulating the St. Lawrence River Valley between ~1550 and 1580 in an effort to control access to European trading partners and to prevent neighbors from engaging in military alliances with the same.[107] After 1580, the valley appears to have been mostly depopulated, although it was certainly not devoid of human presence. In the first decade of the 1600s, both Iroquoian and Algonquian nations "stood in mortal terror of the Iroquois [Haudenosaunee] who dominated the region [and]... were unable to travel along the St. Lawrence for fear of the Iroquois war parties that were infesting the banks of the river"[108]. How is the relocation of St. Lawrence Iroquoian peoples away from the valley and their incorporation into adjacent societies reflected in our analysis?

The dispersed St. Lawrence Iroquoians have long been thought to have found themselves living among adjacent societies as a result of holding social positions as either refugees or captives.[109] However, more recent analyses argue that St. Lawrence Iroquoian peoples were strategic actors who made decisions to relocate away from the valley on their own terms, often following sets of long-established relations.[110] St. Lawrence Iroquoian women's roles as brokers within the pan-Iroquoian network may have afforded St. Lawrence Iroquoian individuals and groups multiple options when forced out of the valley. The stronger ties between St. Lawrence Iroquoian women and the Huron-Wendat women in the 1400–1500 and 1450–1550 networks may reflect early connections between these groups that formed pathways for later population movement (Figure 11). Thus, women's signaling networks may have provided movement pathways along which

102 Birch et al. 2021.
103 Birch and Hart 2018; Wonderley and Sempowski 2019.
104 Birch et al. 2021.
105 Abel et al. 2019.
106 Birch et al. 2021; Williamson 2023.
107 Williamson 2023; Trigger 1976.
108 Trigger 1976: 276.
109 Engelbrecht 2003; Kuhn 2004; Pendergast 1999; Tremblay 1996, 2006; Ramsden 1990; Wonderley 2005.
110 Lesage and Warrick 2016; Lesage and Williamson 2021; Micon 2022; Micon et al. 2021.

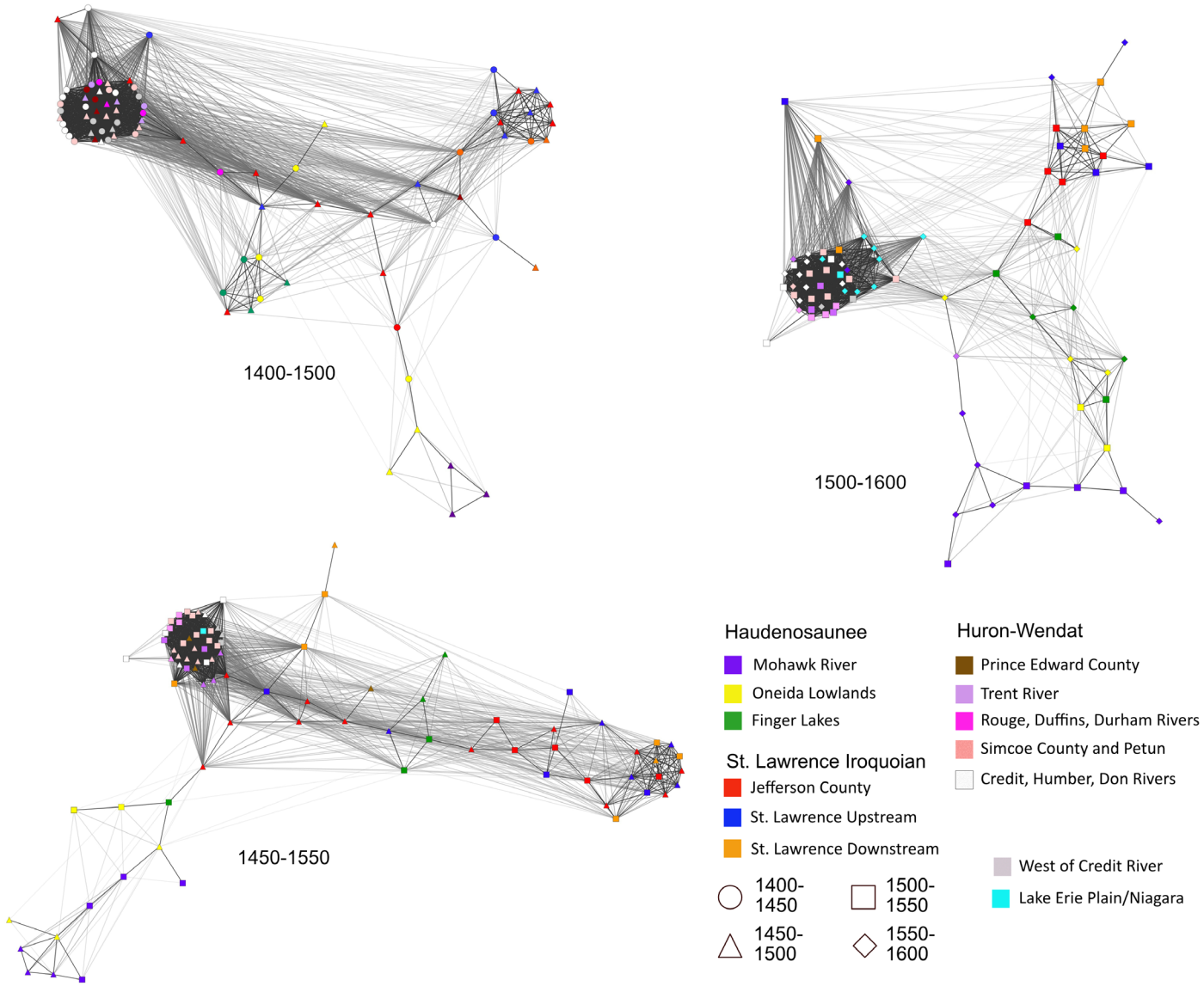

Fig. 11 Mini-max backbone compiled pan-Iroquoian network visualizations. Dark ties are backbone connections.

flows of St. Lawrence Iroquoian populations took place during the 1510–1600 interval. It is notable that the Louvain community detection analysis places sites south of Georgian Bay in the same cluster as most St Lawrence sites in the 1400–1500 network, indicating early ties between these regions (Figure 9). Although there are ties between St. Lawrence sites and groups in the Finger Lakes region in the 1400–1500 and 1450–1550 networks, there is also a general increase in the percentage of St. Lawrence sites with stronger ties to Haudenosaunee sites in the 1500–1600 network. We know that the Mohawk were the primary Haudenosaunee engaging in military and trading activities in the valley in the late 1500s to early 1600s. The strong ties between the St. Lawrence Iroquoian network and sites in Seneca territory may reflect connections and potential population movement between the St Lawrence Iroquoian and Seneca groups, despite hostilities with other nations of the Haudenosaunee confederacy. As confederation maximized the autonomy of its constituent parts, Haudenosaunee nations could have acted both independently and in concert to achieve strategic and collective aims.[111] The larger number of ties between Haudenosaunee and Huron-Wendat sites in the 1500–1600 network may also be related to the relocation of St. Lawrence women among these groups, potentially continuing to serve in brokerage roles within these new community settings.

8. Conclusions

As Lesage and Williamson[112] recently noted, there is ongoing debate among archaeologists and First Nations on several key sociopolitical aspects of Iroquoian people occupying the St. Lawrence River Valley in the 15th and 16th centuries, especially with respect to "cultural identity, political organization, and internal and external relationships." Here we have addressed some of those issues through formal social network analyses of pottery collar decoration motifs.

The SNA has shown that the St. Lawrence Iroquoian women's 1400–1500 and 1450–1550 signaling networks were characterized by homophily; the strongest ties of St. Lawrence Iroquoian sites were to other St. Lawrence Iroquoian sites. Community detection analysis of pan-Iroquoian networks placed St. Lawrence Iroquoian sites in distinct clusters, with a few exceptions. These results, coupled with the distinctiveness of the material culture categories and language, strongly suggest that the St. Lawrence Iroquoians were a distinct cultural group, with communities possessing ties to both near and distant communities within the valley persisting over at least a century and a half prior to their dispersal from the valley. In particular, the results suggest that St. Lawrence Iroquoian women participated

111 Birch 2022.
112 Lesage and Williamson 2020: 36.

in social signaling and communities of practice within that valley that were distinct from, but still tied to, communities of practice outside of the valley.

Our SNA is predicated on Iroquoian women signaling personal and matrifamily traits through pottery collar decorations, reflecting networks of sociopolitical interactions. Our previous analyses demonstrated how these networks conformed to what is known about Huron-Wendat and Haudenosaunee confederacy structures.[113] If we accept that pottery collar motifs in part signaled Iroquoian women's political networks, then given the topologies of the St. Lawrence Iroquoian networks we can infer that there were valley-long political affiliations. The 1400–1500 and 1450–1550 networks included at least two distinct clusters with bonding ties that included sites from different geographical site clusters, which were in turn repetitively tied together (Figure 4). These clusters possessed stronger cohesion than the contemporaneous Haudenosaunee networks, a cohesion that, while somewhat weaker than the contemporaneous Huron-Wendat networks, nevertheless suggests a strongly interconnected sociopolitical structure; an emerging coalition whose development halted when conflict with neighboring groups forced movement of communities to other regions and nations. The current SNA is consistent with previous network analyses that demonstrated the importance of St. Lawrence Iroquoians in pan-Iroquoian networks through the high potential brokerage scores of specific sites, suggesting a role for women as mediators between Huron-Wendat and central and eastern Haudenosaunee villagers.[114] The 1500–1600 network indicated a looser topology most similar to the Haudenosaunee network, reflecting the process of dispersal from the valley.

Whether or not the St. Lawrence Iroquoians had developed a confederacy or were gradually building toward one, the dynamics of Northern Iroquoia, including interregional warfare, caused their dispersal. The presence of St. Lawrence Iroquoian individuals and groups in Iroquoia continued to structure network relations following the cessation of permanent settlement in the St. Lawrence River Valley in the later 1500s and early 1600s,[115] and may have laid the foundation for some of these groups to return to settle in the valley in the later 1600s.

113 Birch and Hart 2018, 2021; Hart et al. 2016.
114 Hart et al. 2017, 2019.
115 Hart and Engelbrecht 2017.

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