Beyond Hubs and Spokes

Regional and Local Networks in the Caribbean

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INTRODUCTION

In small-scale societies, social resources are perhaps the most important way to deal with the chaotic world. The best adaptation to the variability of seasons and the stochastic forces of demography is not the distance to fresh water or physiographic province, but in the construction and maintenance of social relations with one's neighbors. How these relations are constructed may change, and differences in the scalar properties of social networks provide a glimpse of the structure regional and micro-regional social interactions.

The purpose this poster is to show how the development of a network approach can facilitate interpretation of relational patterns of interaction among social groups at the regional or micro-regional level. The utilization of concepts and analytical methods associated with relational perspectives and the structural properties of social networks have been widely adopted in sociology over the past 25 years. However, conceptual and practical approaches to examining the structure of relational networks in archaeological settlement systems remain underdeveloped (for examples see Brughmans 2009; Campbell 2009; Hage and Harary 1996; Jenkins 2001; Munson and Macri 2009).

A network approach differs from traditional perspectives reliant upon central place theory as it is focuses on the structure of interacting units. There are several synonyms for network nodes (*e.g.*, vertex, point, actor) and links (*e.g.*, edge, tie, line). In this research the term node represents discrete spatial locations on the landscape in terms of residential settlements and links which form the potential relationships between them. Here actors and their actions are viewed as part of a larger whole--interdependent rather than independent. These relational links between settlements are channels for the transfer of information and resources (either material or nonmaterial). Spatially, the distributional properties of social groups within the landscape provide opportunities for or constraints on agency and action that influences organizational structure.

MODELING SOCIO-SPATIAL INTERACTION

One method, frequently employed by habitat ecologists for modeling genetic variability in wildlife populations, utilizes least-cost paths as a realistic measure of spatial isolation (or its inverse, connectivity) rather than linking points using standard Euclidean distances. The development of cost paths utilizes spatial computations that finds the least cost-distance paths *linking* settlement nodes together. From this data, distance matrices (and connectivity graphs) can be generated which allow for further manipulation and analysis.

Examining the structure of the regional network offers insight into several important aspects of the sociopolitical landscape through time. Focusing on the network as a whole it is possible to develop an understanding of the relation between social agents, their position within the network and, how shifts in spatial organization affected interactions within and between communities through time. For instance, differences in how connected settlements are may be a key indicator of the cohesion or fragmentation of social groups that can be examined diachronically and at different scales of analysis. Here we present two examples from the south-central coast of Puerto Rico and the Island of Vieques based on the distribution of residential settlements between AD 600 and AD 900. **(FIG. 1)**

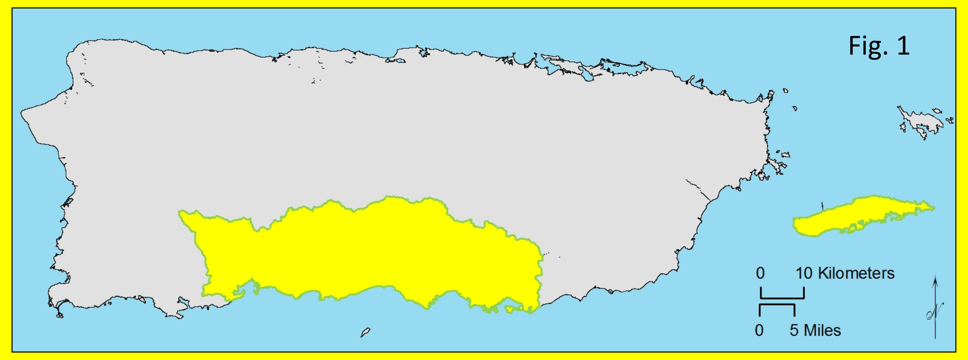

Fig. 1

STEP 1. Friction Surface and Measuring Cost

Cost models measure surface distance based on impedance factors, which take into account characteristics of the natural topography. Differing from other models of travel based on two dimensional modeling techniques, cost models measure resistance units across a topographically non-uniform plane to calculate a least accumulative surface from a given point location. In the present study, the Digital Elevation Model (DEM) of topography was used to generate slope for the two regions, which in turn was used to develop a friction surface for measuring cost-distances. As the slope increases, cost values increase accordingly.

The the friction surface is based on the following formula applied to the slope grid: (((slopegrid/45)*3.168)+1). (based on Van Luesen 1998:3)

In this formula slope is divided by 45 to convert from degrees to vertical proportion per cell width. This value is then multiplied by an ascent cost factor of 3.168 taken from conventional backpacker calculations and increased by a value of 1 to represent the effort required to traverse the horizontal distance of the cell. The resulting raster is an isotropic friction surface of relative energetic cost for moving across the landscape. **(FIGS. 2a-2c)**

Fig 2a DEM

Fig 2b Slope

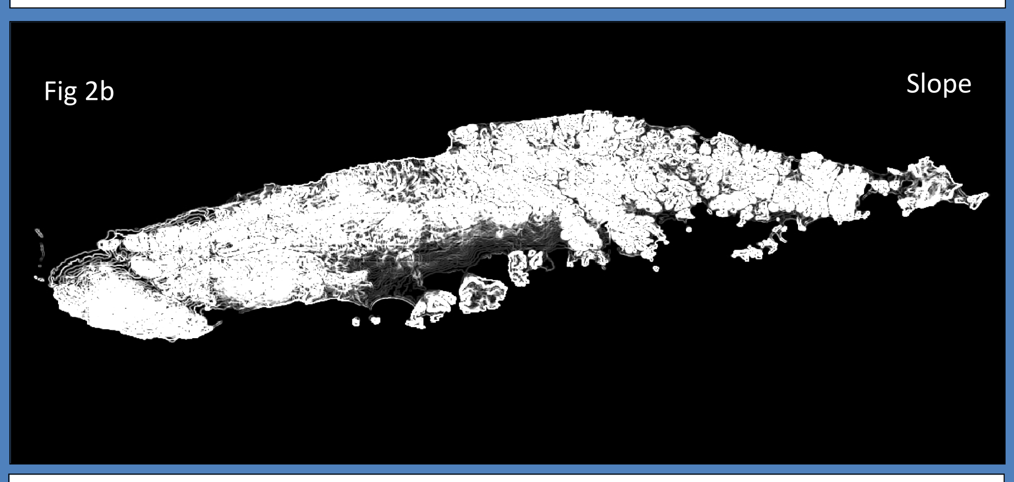

Fig 2c Cost Surface

STEP 2. Cost Paths

To develop the least cost paths and associated distance matrices in this study, a modified version of the Landscape Genetics toolbox was used in ArcGIS 9.3 (Etherington 2011). This tool box possesses a function to compute matrices of effective geographic distances among points (or nodes), based on a least-cost path algorithm (Adriaensen *et al.* 2003). The sample points, in this case residential settlements for each period, were used in conjunction with the friction surface developed with the DEM to represent the cost of movement through the landscape between settlement nodes. Creation of the network develops a polyline shapefile linking each residential settlement resulting in (n*(n-1))/2 links (*i.e.*, nodes are not linked to themselves) and matrices of effective (cost) distances. **(FIG. 3 [Vieques Example])**

Fig. 3

NETWORK TYPES

In developing a least cost path approach for analysis of the regional network through time, we focus on examining the cascading linkages of settlements that were most likely to interact on a consistent basis. Because the calculation of the network mentioned in the previous section takes into account the total linkages between each settlement in the region, the network becomes saturated and meaningful patterns in the morphology of residential social groups become difficult to discern. Further, total linkages create redundancies in the data, as linkages will consist of overlapping segments that pass through multiple nodes. To address this shortcoming, we constructed subsets of the total cost paths to display the utility of three different scales of network connectivity (**FIG. 4a-f**).

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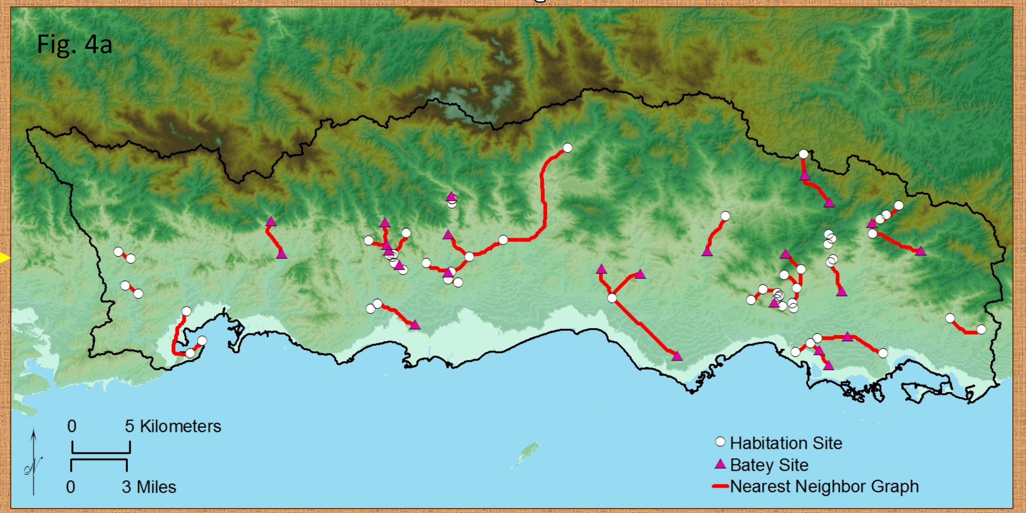
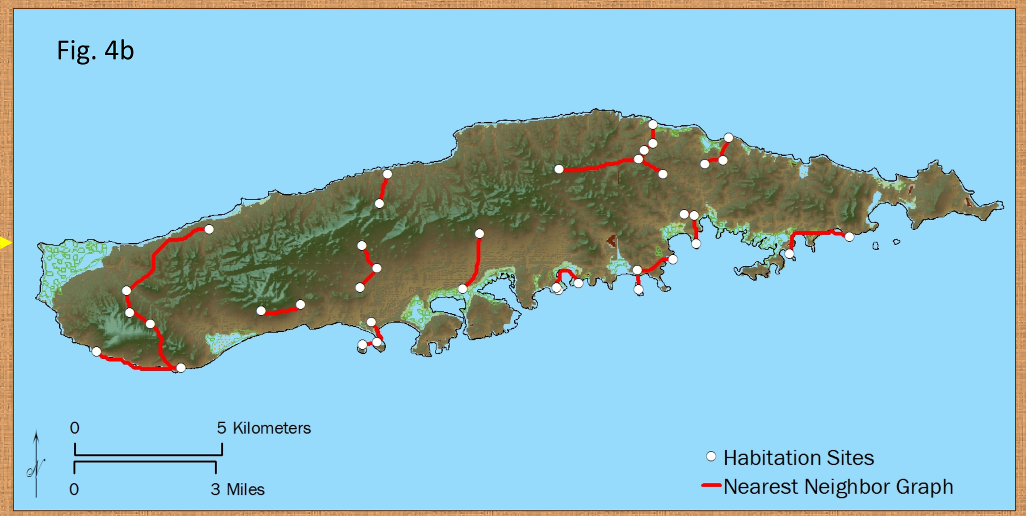
Fig. 4a



A Nearest Neighbor Network (NNN) a the set of nodes with links that are the closest in space, here expressed in Cost Distance. This graph is a series of nearest neighbors. If a nearest neighbor relationship is symmetrical, this graph will be a series of pairs. More complex networks arise when the relationships are asymmetic, forming directed networks.

Fig. 4b

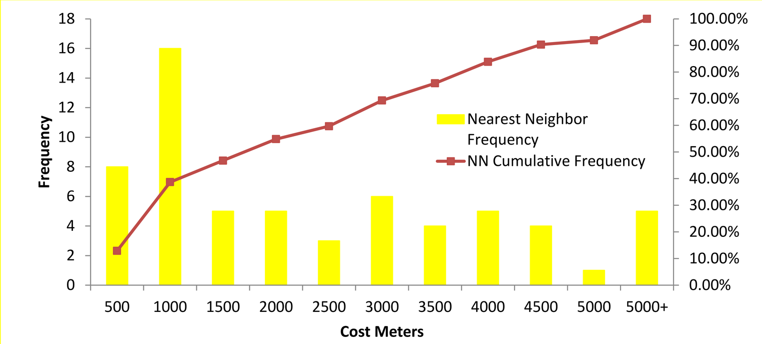


The **Nearest Neighbor Network (NNN)** creates small clusters that generally occur at very short cost distances. These networks can be conceived of residentially cohesive communities in which each single site is only one part of a spatially distinct group.

•Though we may label smaller habitation sites as homesteads, small middens, or hamlets, through each NNN they inhabitants belonged to a larger local community.

•In the data from the **south-central area of Puerto Rico (below, top)** and **Vieques (below, bottom)**, over 50% of all NNN links occur within 2000 cost meters. This is consistent with previous (Torres 2005) analysis using cost boundaries.

•Over 90% of all links within the NNN occur in less than the 4500 cost meter distance band. This consistency indicates a **similar structure of settlement spacing in both regions**.



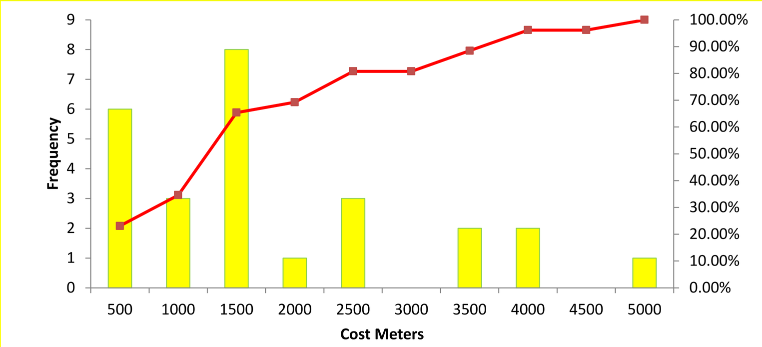
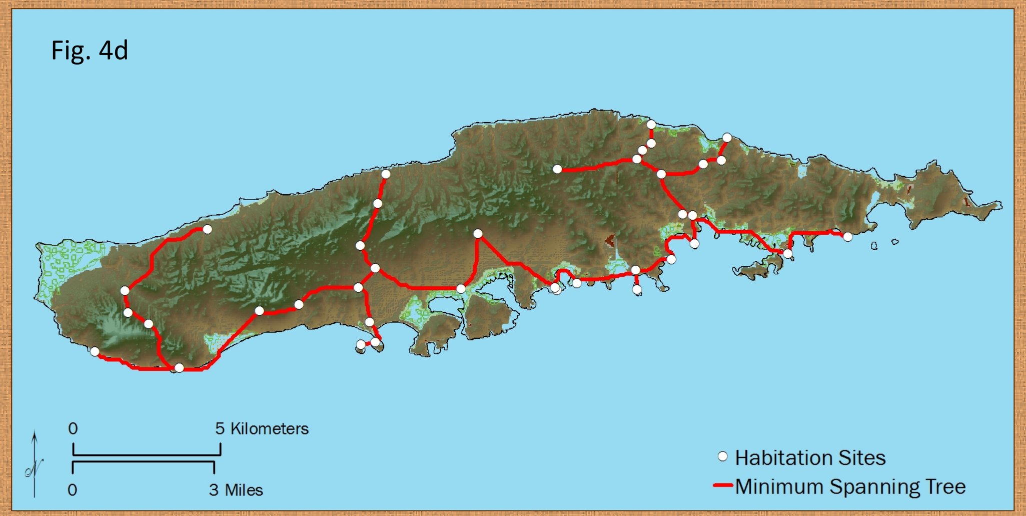


Fig. 4c

A Minimum Spanning Tree (MST) is a concept from electrical engineering and graph theory that is the most efficient way to connect a network with no loops or cycles (King 1985; Supowit 1983; Yao 1982). It includes all NNN edges. The MST is not intended to fully characterize an entire network, but instead provide measures of the minimum complexity and extent of relationships.

Fig. 4d



The **Minimum Spanning Tree (MST)** in south-central Puerto Rico and Vieques the data show a horizontal trunk extending along the coastal plains complimented by links running to the coast and interior.

• The Least Cost Paths suggest certain avenues across the landscape, connecting the NNN.

• Clusters of interconnected settlements separated by small buffer zones become increasingly apparent.

•In the south-central dataset, plaza/ball court site locations can be noted at both the central portion of settlement clusters (centers) as well as at their terminal points (peripheries) potentially representing different functions in the articulation of the regional socio-political network.

•The linearly-arrayed network suggest down-the-line social interaction between the clusters, as travel to and from specific river basins would likely involve passing through the central portions of the network.

CONCLUSIONS

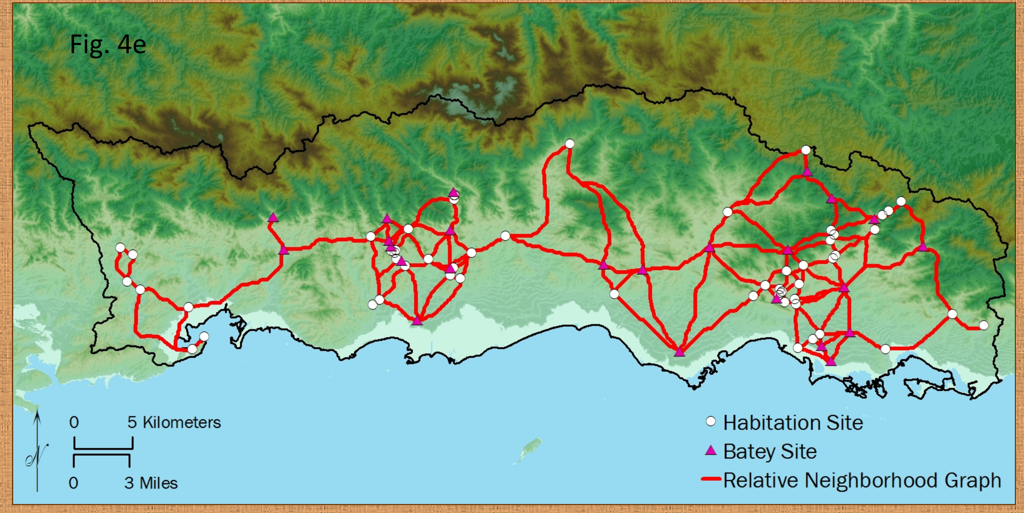
The methods presented here offer a means of exploring the structure of interaction at multiple spatial scales. These methods can be used as a heuristic device for developing research hypotheses to test interaction of locally situated settlement systems. The focus on relationships between sites and the characterization of networks, rather than individual sites or artifact classes, reflects a perspective grounded in active agents moving across a socialized landscape.

The settlement pattern represents the structure of a network of social relationships comprised of the links that connected people across local and regional scales of interaction. This scale is one of hours or days, rather than weeks, months, or years. These distributions reflect lasting patterns of relations among actors and the places in which they lived. **Examining the morphology of these interactions provides key indicators of the organization, cohesion, and complexity of social formations, offering a picture of ancient society unavailable at other scales.**

Graph Theoretic approaches characterize these relational site patterns in meaningful ways. **Employing documented, repeatable, and objective methods of describing and characterizing distributions also provides the opportunity to compare different regions, spatio-temporal scales of interaction, and time periods.**

This approach offers new insights into site locations beyond environmental variables and emphasizes the connectivity of past socialized landscapes. **These studies indicate there is an Early Ostionoid way of structuring the landscape. The data also reflect different uses of ball courts and suggesting their use as an integrative landscape and social feature, rather than a hub of power.**

Fig. 4e



A Relative Neighbor Graph (RNG), first proposed in graph theory by Toussaint (1980), removes all edges between points which pass closer to a third. This can be adopted by using cost allocation boundaries and least cost paths. This method is intended to create a network or series of links consistent with human perceptions of relationships (Jaromczyk and Toussaint 1992).

Fig. 4f

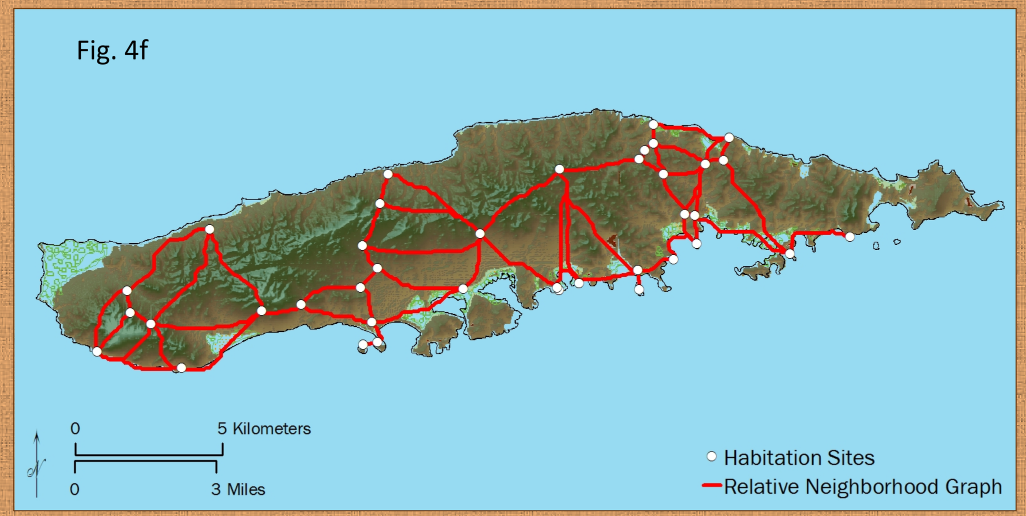
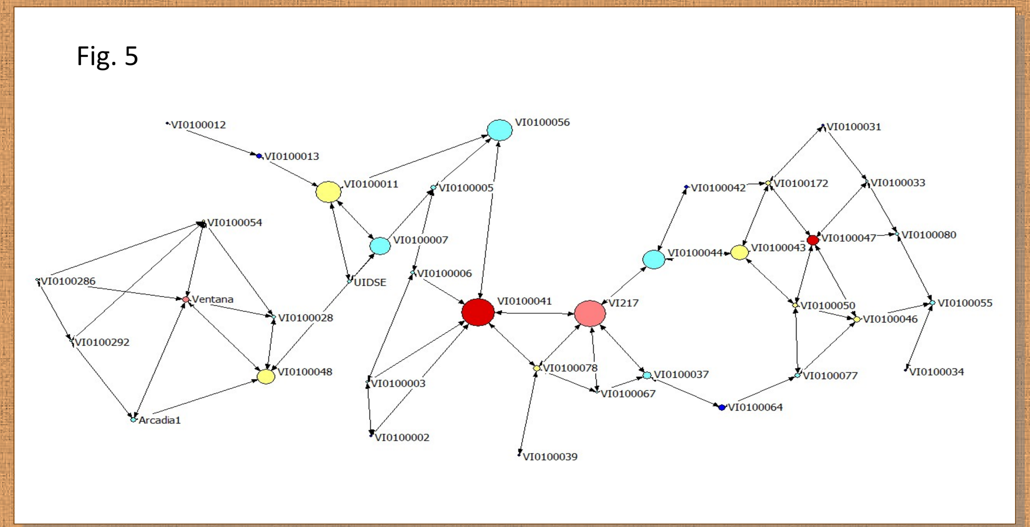


Fig. 5



The **Relative Neighbor Graph (RNG)** in the south-central and Vieques datasets reveal increased clustering of local residential settlements and their articulation at the regional level. **Analysis of network structure helps provide an explanation for settlement nodes: rather than a localization of demonstrated political authority, the location within network suggests integration of otherwise independent networks of settlements.**

The Vieques RNG dataset was visualized and analyzed in UCInet 6.0 (Borgatti et al 2002) (**FIG. 5**). The graph illustrates the betweenness centrality values of each node (settlement) in the network by scaled size and degree centrality by color.

•**Betweenness centrality** measures the number of paths which pass through each node within the network. Betweenness can be conceived of as a measure of relative traffic within a network, and how important an individual node is to the flow of people and information.

•In this instance the highest value corresponds with El Destino, Lujan 2 (VI0100041) on Vieques, the only site within this speculative network with a recorded *batey*.

•The **degree centrality** measures the number of links connecting each individual node. This is the simple measure of how many habitations within the network are only one link away; conversely this measures how many locations have access to any given node. Locations with low degree values are relatively isolated within a network and high degree values are cores or focal points. A low degree value can also be places which are protected.

•Several sites have high degree, including Ventana where there may be a *batey*.

The graph displays three networks with cycles or loops, in the east, center, and west. The approximate center of this graph, where multiple networks integrate, is El Destino. This site also exhibits the highest degree value, 6, found in the graph.

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