Beyond the Marsh: Settlement Choice, Perception, and Spatial Decision-making on the Georgia Coastal Plain

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Abstract

When we consider the intrinsic value of land units (or cells) in an archaeological analysis of landscape, settlement choice, or site selection, we tend to develop models which use static, unchanging costs or benefits, or which rely on least common denominators for a wide range of human actions or time frames. This is naturally driven by the tendency to find correlative evaluations as the most comforting means of both hypothesis building and hypothesis testing. Correlative approaches used in such applications as "inductive" predictive models are inherently reductionist and typically global-inferential. In actual application, though, cell-based attractors are dynamic and distinctly contextual. Thus, we need to develop models which can provide an egocentric, rather than a global, frame of reference, and which are explanatory rather than merely correlative. The first steps in this direction are provided by agent-based models; however, even agent-based models utilize fixed frames of reference, or tools that rely on universal knowledge and global decision-making. Likewise, the acceptance of large dataset correlation testing, or training sets, as the primary means for assessing model success (even in agent-based models or neural network applications) precludes approaches which deal in sequential actions, local behaviors, or unique site types. Here we develop a model which uses cell-based analysis in several ways. First, attractor values are derivative of perception, the interface of knowledge and confidence in that knowledge. Second, spatial decision-making is temporally sequential; thus proximity tempers attractor values. Third, the scale of decision-making distinctly relies on both immediate and long-range planning and returns. These concepts will be illustrated with data from the Coastal Plain of Georgia (USA) and placed in the context of adaptations to a seemingly homogenous cultural and ecological landscape.

Keywords: *cell-based analysis, GIS modeling, predictive modeling*

1 INTRODUCTION

As our technological limitations continue to decrease, we can incorporate increasingly complex notions of past behaviors into our interpretative models. Our approach to identifying, observing, and explaining these behaviors is dependent upon either abstract conceptual ideas which present cultural hypotheses in a metaphoric but generally non-spatial context, or models which specifically define cultural ideas as spatial phenomena. The goals of such models may be quite diverse, and the approaches may need to be evaluated on an individual basis. However, in general, there have been two primary outcomes, or trajectories, employed in building spatial archaeological models—explanation or prediction. In such models, explanation is usually intended to illustrate systemic interactions or interpretive context, while prediction is meant largely as a classification tool to forecast site locations or guide land management activities. In most past examples, prediction has been superfluous for explanatory models (especially purely conceptual ones), and explanation in turn was largely irrelevant for predictive models. There is no reason why this has to be the case, however, and the potential to develop models that are both explanatory and predictive is better now than ever before.

2 OBJECTIVES

The ultimate goal of our study is to develop a comprehensive yet flexible model that has the ability to explain past human cultural and even cognitive behaviors by illustrating causal processes, but which illustrates the interaction between individuals and their environmental and cultural landscape. It should also be able to spatially represent explanatory hypotheses in such a way that site or activity location predictions can be made and tested against the archaeological, historic, or ethnographic records. In this sense, it is not a single model, but rather a framework within which many models may be outlined and tested. As a tool it would provide an explanatory understanding of past behaviors, as well as a way to manage endangered cultural resources and to prioritize regional research topics. To achieve this there are several attributes to the model which we need to consider.

2.1 THE SPATIAL MANIFOLD

First, an applied spatial model (i.e., a GIS-based real world landscape) has several advantages over purely abstract conceptual models or even ones which fit a conceptual model to a simulated spatial manifold. Conceptual models are typically used to present complex systemic explanations or theoretical frameworks in a flow chart or some other representation. It is often very difficult to grasp how these models relate to actual landscapes, let alone how they may be consciously or subconsciously cognized by past agents (instead of the archaeologists). Abstraction to the level of the archaeological site is even more difficult, and prediction or management of resources "on the ground" is impossible, despite the understanding of complex systems that a non-spatial conceptual model alone might engender.

Simulated spatial manifolds allow us to comprehend how conceptual models of complex systems may represent themselves on a spatial plane, but they too are removed from the actual environment. Projecting how a simulated landscape fits over a real one is extremely difficult, as is especially clear when the costs of travel and the distribution of resources are not clearly understood. Additionally, simulated manifolds are typically greatly simplified versions of a real world environment. However, that simplification may negate, or obviate, the results of the conceptual model to the point at which it is difficult to say whether it applies or not.

The framework we are building has a conceptual basis but is applied to a real world GIS-spatial manifold. The quantitative nature of the GIS manifold makes it possible to standardize the data, derive detailed environmental observations, use proxy representations for cultural variables, and examine and test many different settlement or behavioral hypotheses. The translation of these hypotheses into probability values is also necessary to derive predictive value from the model. This could theoretically be done with a non-spatial conceptual model, or a simulated spatial manifold, but it would be much more difficult, and it would still require an interpretation placed upon real world spatial data.

2.2 AGENCY AND PERCEPTION

Agent-based models come in essentially two varieties; those which incorporate agency as a theoretical concept in how the model operates (individual or group decision-making is integral to its explanatory power[1]), and those which employ programmed cellular automata to run through an iterative process on a spatial manifold according to general rules of behavior, typically in a simulated environment,[2] but sometimes in a GIS.[3] These may perhaps be seen as "passive" or "active" agent-based models respectively.

To be able to theorize about the cognitive landscape, or the variations in how past people made decisions, agency should be incorporated in the model at least on the theoretical level. However, if we are able to simulate the cognitive elements involved in spatial decision-making, then incorporating cellular automata programmed to evaluate the relevant criteria according to behavioral rules becomes possible. This is exactly the approach taken by researchers in the American Southwest.[4]

However, because we are interested in causal processes and examining the spatial basis of decision-making, we are concerned with both intentional and unintentional actions, and the ways in which those actions come about. An agent-based model needs to rely not only on intentional actions (programmed rules for cellular automata) that fit with the spatial conditions at the time (the cell values at each iteration of the model), but they must also be able to illustrate each component of the process, realistically resolve conflicting information, and generate outcomes from the limited and conditional knowledge that an agent would have had.

This implies that an explanation of spatial behavior should incorporate a "perspective" or a representation of the perception held by the agent. An understanding of the causal processes entailed by the model does not come from a global view, but one conditioned by the costs and benefits of an action, along with the knowledge, confidence, and risks involved in taking that action.

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[1]Tony J. Wilkinson et al., "Modeling Settlement Systems in a Dynamic Environment: Case Studies from Mesopotamia," in *Model-Based Archaeology of Socionatural Systems*, ed. Timothy A. Kohler and Sander E. Van Der Leeuw (Santa Fe: Resident Scholar Series, School of Advanced Research Press, 2007) 175–208; Serge Cleuziou, "Evolution Toward Complexity in a Coastal Desert Environment: The Early Bronze Age in the Ja'alan, Sultanate of Oman," in *Model-Based Archaeology of Socionatural Systems*, ed. Timothy A. Kohler and Sander E. Van Der Leeuw (Santa Fe: Resident Scholar Series, School of Advanced Research Press, 2007) 209–228.

[2]Joshua M. Epstein, "Modeling Civil Violence: An Agent-Based Computational Approach," in *Generative Social Science*, ed. Joshua M. Epstein (Princeton: Princeton University Press, 2006), 247–270.

[3]H. Randy Gimblett, ed. *Integrating Geographic Information Systems and Agent-Based Modeling Techniques*. Santa Fe Institute Studies in the Science of Complexity (Oxford: Oxford University Press, 2002).

[4]Timothy A. Kohler et al., "Settlement Ecodynamics in the Prehispanic Central Mesa Verde Region," in *Model-Based Archaeology of Socionatural Systems*, ed. Timothy A. Kohler and Sander E. Van Der Leeuw (Santa Fe: Resident Scholar Series, School of Advanced Research Press, 2007) 61–104; Jeffrey S. Dean et al., "Understanding Anasazi Culture Change through Agent-Based Modeling," in *Generative Social Science*, ed. Joshua M. Epstein (Princeton: Princeton University Press, 2006) 90–116; Robert L. Axtell et al., "Population Growth and Collapse in a Multiagent Model of the Kayenta Anasazi in Long House Valley," in *Generative Social Science*, ed. Joshua M. Epstein (Princeton: Princeton University Press, 2006) 117–129; George J. Gumerman et al., "The Evolution of Social Behavior in the Prehistoric American Southwest," in *Generative Social Science*, ed. Joshua M. Epstein (Princeton: Princeton University Press, 2006) 130–143.

2.3 COSTS AND BENEFITS

But what are the "costs" and "benefits" and how are they envisioned and derived from spatial data? In agent-based models that function within a real-world GIS-spatial framework, the primary emphasis has been on resource availability and the decisions which evolve out of the access to or moderation of those resources. For example, in the model presented by Kohler et al.,[1] the decision to move a household, merge households, or abandon an area is a composite evaluation of the available resources (such as soil nutrients, access to game, water, or fuel sources) and the elements which modify productivity of those resources (such as annual rainfall, changes in population rates, competition, etc.). Beginning with different configurations, cell values are extracted and evaluated according to the rules, and a spatial decision is made. After each iteration, the spatial locations are re-evaluated.

These are essentially key players in the cost-benefit analysis, with the benefits being the value of the resources extracted and the costs being modifications to those resource values. Using cells, or land units, as the basis for evaluating costs and benefits is clearly the easiest way of creating a composite GIS surface as a means to standardize value per spatial unit. The sorts of spatial decisions identified in an automata-based model are usually made on a local level, but with a global and complete understanding of the cell values within specified classifications across the entire landscape.

Although we tend to see benefits intrinsically as directly measureable resources, we also need to think about them more abstractly as the knowledge of and predictability for recovering those resources, the potential to derive secondary benefits (perhaps strictly sociocultural) through controlling them, and the planning of future derivatives. The perception of what those benefits are, where they are, how easily they can be accessed (i.e., the cost of travel, extraction, and competition), and how much they will return are all factored in the agent's decision. Additionally, the agents need to consider the complex changing distribution of costs and benefits as seasons change, when other agents are involved, as populations grow or shrink, and as a result of the shift in political power that may come with warfare or the arrival of others from across the sea.

3 THE GEORGIA COAST MODEL

The Lower Coastal Plain of Georgia is considered to be a very homogenous environment. Our region of study includes the six coastal counties of Georgia, plus the next five, immediately inland (fig. 1). This area is flat, wet, and heavily forested. The elevation ranges from mean sea level to no more than 56 meters (183 ft) at a point 100 km inland. Slope exists almost entirely along very narrow and heavily eroded river bluffs, and always occurs as small breaks in elevation. There are currently nearly 6000 archaeological sites recorded within the terrestrial portion of the study area, and they represent more than 10,000 years of occupation.

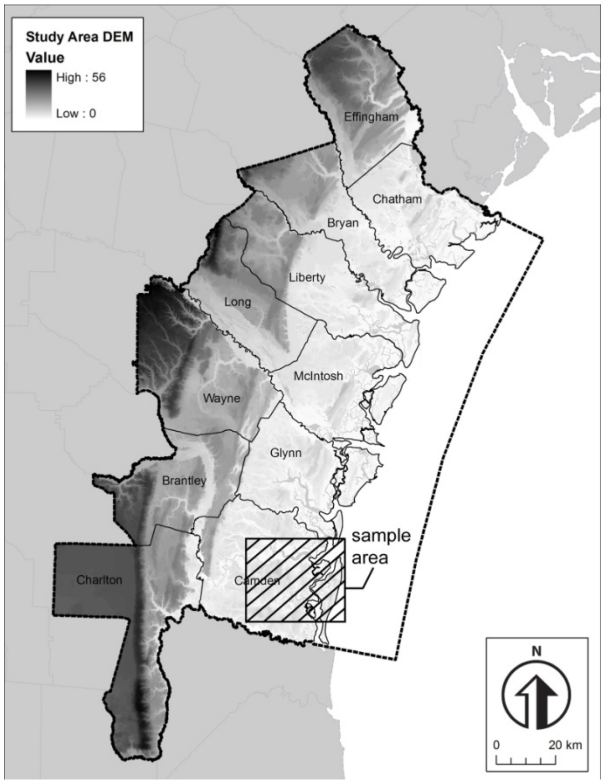

Figure 1. *The coast of Georgia.*

Although the study area covers almost 1.9 million hectares, more than 1 million hectares of it (about 57%) is marsh. The soil types are quite numerous, yet are very similar and tend toward either a very sandy or saturated clay texture. They are generally no better than moderate quality for agriculture, and typically poorly drained in low elevations and excessively or well drained in the slightly higher ones. Historically, old-growth live oak and hickory forests covered the higher, sandy elevations of the ancient and now land-locked interior barrier islands.

Such forests were also found along the coast itself, as well as along dry bluffs overlooking salt marsh or rivers. In the interior of the mainland and larger barrier islands, yellow, slash, and loblolly pine, along with cypress, dominated the wetter marshes and expanses of low inter-riverine ridges. Today, modern logging has changed most of the upland climax growth forest (which would have had a fairly open pinegrass understory) to a denser scrub understory with mixed evergreen and deciduous forest, but the marshlands remain much as they were at the time of European contact.

[1]Kohler et al. 2007 (p. 373n4 above).

Along the coastal estuaries, protected by the barrier islands, lie vast expanses of salt marsh with shallow muddy tidal flats and emergent grasses. These brackish wetlands are often bordered immediately by mixed oak, pine, and hickory forest along with thick palmettos and other scrub. The eastern sides of the barrier islands typically exhibit long stretches of narrow sandy beaches backed by dunes, scrubby deciduous trees, and sea oats. The ends of the islands give way to the fast-moving and variable tides at the mouths of the wide slow rivers that travelled several hundred kilometers from the Piedmont to empty into the Atlantic. Recent historic modifications to these landscapes include expanses of former rice fields in the wetlands, upland farms, roadways, small communities, a few urbanized landscapes, and numerous historic sites and fortifications.

This environment is not conducive in the slightest to building a correlative archaeological predictive model. The absence of steep slopes entirely and the presence of freshwater almost everywhere makes it impossible to use those variables as a means to limit our expected distribution of settlement choice. The use of soil types also does not limit site selection, because archaeological sites from all periods are known from virtually all soils that are not currently underwater. Soil types themselves in this region are fine-grained distinctions between very similar textures and productivity.

Though there is a large sample of known sites, regression analysis does not work for any portion of that population and traditional environmental variables; the only method for defining archaeological probability areas has been to use an intuitive model built upon the physical limitations of not being able to survey areas underwater with terrestrial methods. However, when we consider the key characteristics of moisture, salinity, water depth, cover, vegetation type, soil texture, and soil drainage, we begin to see the actual diversity of habitats that is present and can provide the framework within which an explanatory model operates.

4 AN EXAMPLE

Because this project covers a vast terrain and a wide range of sites and time periods, we will focus here on a smaller portion and a limited temporal range to illustrate some key concepts (see fig. 1). Near the boundary between Georgia and Florida, we have selected an area within Camden County measuring approximately 36 km east to west and 28 km north to south (a total of just over 1000 square km). This sample area includes numerous combinations of wetland and soil types, and incorporates all or portions of the Satilla, Cumberland, and Crooked Rivers and their tidal estuaries.

The intersection of the National Wetlands Inventory (NWI) shapefile and the Soil Survey Geographic Database (SSURGO) were used to extract close to 300 wetland-soil combinations. Some of these were virtually redundant, but when defined by moisture, salinity, depth, cover, vegetation, soil texture, and soil drainage, the combinations were reduced to 174 habitats. Moisture types include dry uplands, intermittent and seasonal wetlands, intertidal zones, and permanent water habitats. Salinity includes freshwater, brackish, and saltwater zones; the tidal currents, depth, and vegetation affecting individual areas. Cover types include open, emergent, scrub, and forested. Vegetation types include minimal, aquatic, grasses, evergreen, deciduous, or mixed. Soil textures range from clay to saturated organic peaty soils to beach sands. Drainage ranges from very poor to very good.

4.1 SIXTEENTH CENTURY TIMUCUA

In the sixteenth century this area was inhabited by the Northern Timucua, a tribal group which is now extinct. The Timucua were very similar in culture and lifestyle to their neighbors, the Guale (another extinct group). The Altamaha River (about 10 km north of this sample area) formed the boundary between the two groups. The Timucua and the Guale lived both on the barrier islands and into the marshy interior. They were sedentary (or at least semi-sedentary) chiefdom-level societies that subsisted on intensive and slash-and-burn horticulture focused on maize, beans, and squash.

The Timucua engaged in a great deal of saltwater and tidal fishing, and hunting of deer, turkey, and a wide range of other species. Lithic sources are almost entirely absent from the region, and all lithic raw materials had to be imported from well into the interior. In contrast, high prestige items such as whelk shells, sea turtle carapaces, and shark's teeth can be found along the coastal strip and would have been exported into the interior, probably along with perishables such as textiles, salt, and fish.

Spanish and French explorers made several contacts with the Timucua and Guale between the 1520s and 1560s. Population rates at that time were fairly high, and continued to be up through a series of devastating epidemics in the late 1500s. By then the Spanish had established missions on the Sea Islands and along the major waterways to convert the natives and to make them dependent upon European goods and ways of life. By the early seventeenth century, the mainland sites were abandoned, in favor of dependent settlement with the Spanish. Eventually, in the middle of the eighteenth century, Timucuan and Guale settlement contracted into Florida with the Spanish (under military pressure from the English), where portions were eventually absorbed into the Apalachee, the Miccosukee, and the Seminole Nations.

4.2 AVAILABLE CALORIC RETURNS

Thomas[1] provides an extremely detailed look at the nature, abundance, productivity, average caloric return rates, and habitat descriptions for nearly all subsistence sources for the Guale on St. Catherines Island (about 65 km to the north of this sample area). Though his data is extremely useful, it is not presented in a spatial format. Rather, it is tabular and focuses on identifying abstract ideas of foraging limits or strategies for investment of time and effort. Nevertheless, it is clearly the most definitive study of Guale behavior to date. His hypotheses are taken from central place theory focused on island resource patches.

To build upon its application in a truly spatial manifold, the St. Catherines data was used here to develop an in-depth GIS analysis of the spatial distribution of preferred, secondary, tertiary, and occasional habitat for faunal resources, as well as the variations in productivity rates under different horticultural and wild collecting regimes for botanical resources. The average caloric return rates that would be associated with each species for each habitat type, or estimate of soil productivity, was based on seasonal abundance, harvesting schedules, and land unit size. Because the coarsest baseline data we used for this project is 30 meter cells, we translated all projected caloric estimates in terms of 30 meter land units (or 900 square meters).

The caloric return of 37 species by individual and by kilogram were calculated and used as the basis for the spatial analysis. This included only usable meat or grain weights, and did not include the cost of acquisition or processing time (because we are still trying to interpret those from the original data). The data relied on the maximum abundance of each species one would expect to encounter per 30m grid cell of preferred habitat, based on estimates of the animals' range size, their typical population, and the maximum harvest rate (by kg) of plant resources, assuming intensive horticulture methods and a five year fallow cycle.

These abundance numbers were translated into caloric returns and multiplied by the habitat types for each species in the GIS. The preferred habitats (or highest productivity soils for horticulture) provide a 100% return on calories as estimated in the table. The secondary, tertiary, and occasional habitats provide 75%, 50%, and 25% respectively. Some further reductions are also taken for maize, beans, and squash as calculations for slash-and-burn, being somewhat less productive than intensive horticulture.

The result is a series of 120 grid surfaces which represent the expected caloric returns for each of the species in the manifold by each of four seasons (spring, summer, autumn, and winter). Several of the species are also dependent upon other food sources or environmental conditions. For example, acorns and hickory nuts are heavily tied to the previous distribution of oak and hickory forests. However, the modern distribution does not correlate well, since logging has changed the upland forests to a great degree. We do know that oak and hickory preferred the higher, well drained elevations, and we can moderate the distribution of drier uplands with the digital elevation model. Thus, the higher the elevation the more likely it would have contained an abundance of oaks and hickories at the time of European contact.

Deer are heavily dependent upon mast harvests, and would be closely tied to oak-hickory forest; therefore their abundance increases with elevation (fig. 2). Maize is also more productive on the higher, better drained elevations. In contrast, saltwater fish are tied to greater salinity; therefore their abundance decreases with decreasing salinity (fig. 3). For each species which is affected by elevation or salinity a proportional decrease in caloric return is calculated by translating the DEM or salinity surfaces into a decimal value range between 0 and 1, and using it as a multiplier.

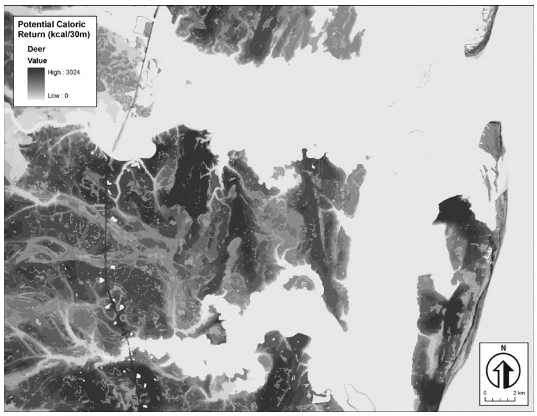

Figure 2. *Potential caloric return: deer.*

In a simple deductive predictive model, we might then look at the composite surface of all resource availability (fig. 4) for each season, which indicates the total caloric potential assuming all species were utilized equally, and that full information was available to the agents throughout the manifold. This surface could be turned into a probability surface, once we have deleted modern disturbed areas and unsurveyable terrain, and transformed marsh resources into cost distances to nearest upland (i.e., habitable) areas (fig. 5).

[1]David Hurst Thomas, ed., *Native American Landscapes of St. Catherines Island, Georgia. Anthropological Papers 88, Volume I: Theoretical Framework* (New York: American Museum of Natural History, 2008).

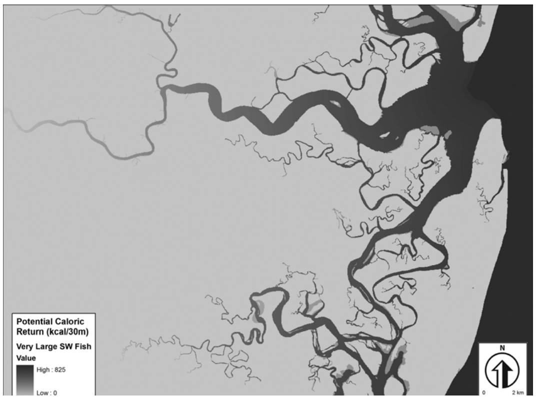

Figure 3. *Potential caloric return: very large saltwater fish.*

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The assumption is that the habitable areas closest to highest caloric return rates would have been selected for settlement. The results can be compared to the known locations of existing sites; in this case 308 sites fall within the manifold. Merely splitting the values equally into three categories (low, moderate, and high) produces a gain statistic in excess of 0.80 (fig. 6). And for that surface, almost all of the sites which occur in low potential areas are actually along the edge of high or moderate probability areas; their location can likely be attributed to lack of resolution in the data, or lack of accuracy in recording, rather than a preference for low probability areas for some other reason.

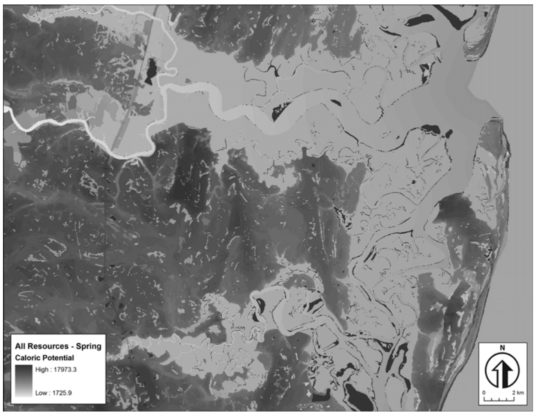

Figure 4. *Potential caloric return: all resources, spring.*

But we are not interested in just producing a predictive model, even if the gain statistic is quite high. We are interested in understanding what kinds of activities occurred in which areas, what the nature of resource competition was like, how foraging differed between genders, and how the perceptions of the agents affected their knowledge of resources and their costs for acquisition. To get at this we need to dig further, and assess additional criteria, such as travel costs.

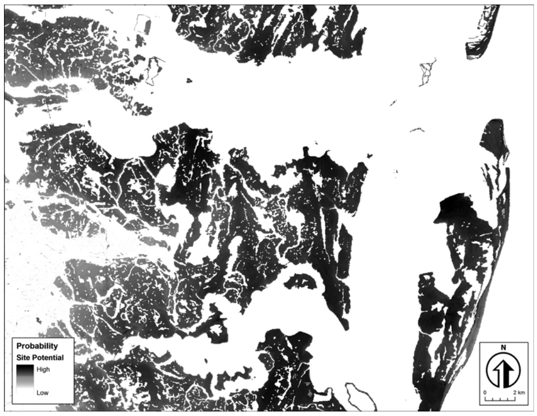

Figure 5. *Probability surface: site potential.*

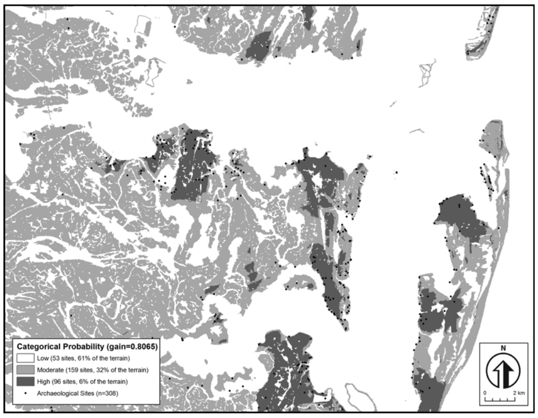

Figure 6. *Categorical probability.*

4.3 TRAVEL COSTS AND FORAGING

To access the resources available from every cell in the manifold, the Timucua had only their own foot power or watercraft to travel by. The costs of traveling are modeled from friction surfaces. The key factors of friction in this landscape are vegetation density, firmness of the ground, depth of water, tidal current strength, and weight of burden. The same habitat polygons created by intersecting the soil and wetland types were used to define the caloric costs to cross 30 meters of each of the grid cells, as either foot travel or by watercraft.

Foot-travel costs per 30 meters (fig. 7) ranged from 2 calories (for walking across dry, firm, uplands unhindered by vegetation and unburdened) to 20 calories (for swimming across deep, fast-moving tidal waters). Values in between included estimates for wading across various depths of wetlands, both obstructed and unobstructed by scrub or other thick vegetation. Caloric values were based on estimates from comparable exertion derived from several different websites.[1] Watercraft travel costs per 30 meters (fig. 8)

[1] http://calorielab.com/burned/ and www.healthstatus.com/calculate/cbc.

ranged from 1 calorie (to paddle across still water) to 20 calories (to portage across dry upland carrying up to 40kg).

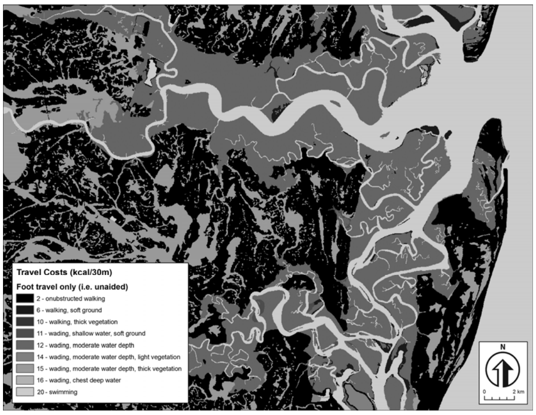

Figure 7. *Travel costs: foot travel only.*

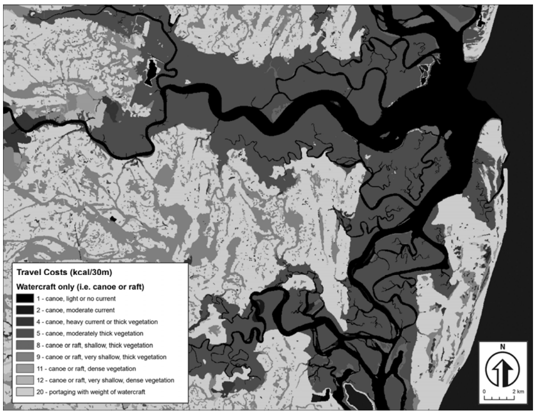

Figure 8. *Travel costs: water travel only.*

Bearing these travel costs in mind, it is simple to calculate the cost distance from any given point. For example, Site 9CM471 is a Timucuan period village known during the Spanish occupation as Yufera, located along the Satilla River. Cost distances from 9CM471 were calculated for both water travel and foot travel in terms of accumulated calories burned. These surfaces allow us to estimate the range of both marine and terrestrial foraging. Although there is much more detail provided by species regarding pursuit times, processing, etc., Thomas[1] estimates the effective single day one-way foraging range for the Guale does not exceed about 10 km (or around 450 calories burned). Using 450 calories as the threshold then, the single-day marine and terrestrial foraging patterns can be observed (fig. 9).

We can overlay the single day foraging threshold with the caloric returns from each (or all) species hunted or fished to get a feel for the areas in which the most productive returns would be found. Figure 10 illustrates the single day marine foraging threshold over the caloric returns for all fish species. A statistical evaluation of the intersection of these two surfaces indicates that a mean available return of 1408 calories per 30m land unit should be expected within a single day's foraging limit.

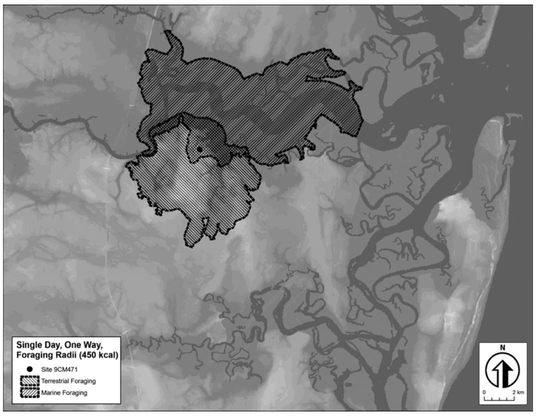

Figure 9. *Single day, one-way, foraging radii.*

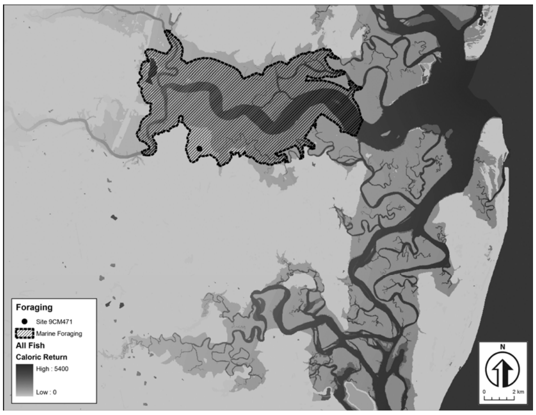

Figure 10. *Marine foraging limits.*

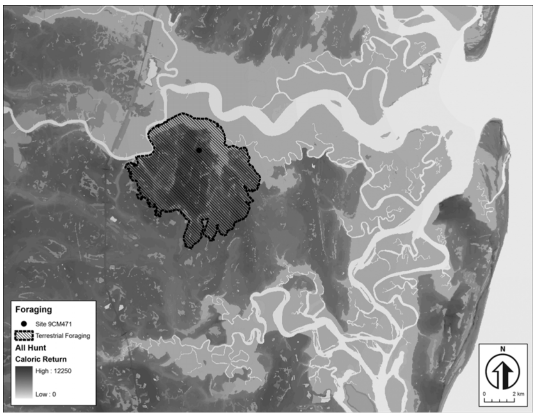

Figure 11. *Terrestrial foraging limits.*

Similarly, the single day terrestrial foraging limits overlaid on the combination of all hunted species (fig. 11) indicates a mean available caloric return of 7638 calories per 30m land unit. This equates to a total potential caloric return of more than 399 million

[1]Thomas (p. 376n1) 282.

calories within a single day's terrestrial foraging. Not many of those calories would be captured, of course, but they are potentially available. This means that travel beyond a single day's foraging boundary does not appear to be necessary, either through marine or terrestrial foraging. The only resources which do not fall within a single day's foraging radius of 9CM471 (or at least not in sufficient quantities to support a sedentary village) are sea turtles, their eggs, and shellfish.

4.4 Perception and Gender Differences

There is a lot more to be said about how we can use travel costs and available calories to represent sociocultural phenomena. If we consider that the available calories are in reality tempered by the predictability of their return (as we have modeled with seasonal abundance by habitat type), and the familiarity agents have with them, their proximity, and repetitive ease of extraction, then a global perspective on resource densities or distributions across the entire manifold must give way to an egocentric perspective of those densities or distributions most likely to have been used.

Assuming that the Timucuans would have been most familiar and knowledgeable about resources and activity areas close to home, we can recalculate a cost distance evaluation to represent that familiarity as a geometric progression from 100% knowledge (at Yufera) to 0% knowledge (at some distance from the town). The distance at which the immediate knowledge of resource density patterns dissolves would be the point at which a daily mental map of high resource density areas becomes replaced by "on-the-fly" observation of environmental characteristics which act as markers for potential target resources.

If we assume that the 450 calorie daily limit marks a point at which the agent retains about 50% predictability, then a simulated perception surface for terrestrial hunting only would look like figure 12. This indicates a decreasing familiarity with, and hence a diminishing potential to exploit, high caloric return areas further from the site. In essence this represents the intrinsic daily exploitable value of all land units from the agent's perspective.

When we additionally consider that there are resource acquisition activity and target differences between genders, we can develop different perception surfaces for men and women, and even children. For example, the Timucuan women spent a much larger proportion of their time tending horticultural plots and harvesting plant products than men.

This entails a greater expenditure of calories in tedious localized tasks such as weeding, hoeing, and planting, which did not require long distances of travel. Even though horticultural plots were, by necessity, dispersed across the moderately poor soils, they were kept close to the residential site. Thus we should expect that women would have to travel, on average, far less distance to acquire a much more predictable set of calories.

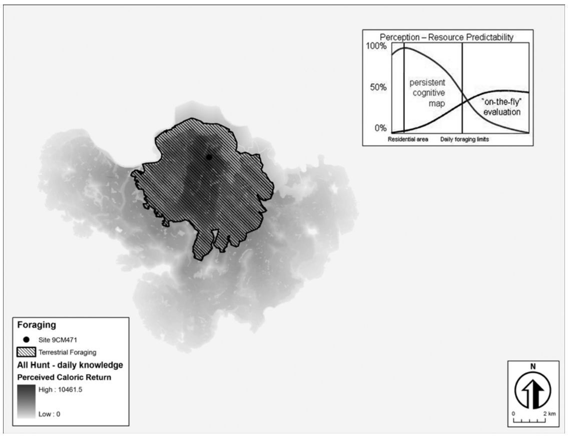

Figure 12. *Terrestrial foraging: perception surface.*

Figure 13. *Horticulture/gathering radius.*

The daily caloric travel threshold for women was not calculated in the St. Catherines data, but in figure 13, it is estimated to be around 2 km (or 90 calories), and uses only foot travel; it is shown over the available caloric returns for all horticultural crops, assuming a five year fallow cycle. Using the same parameters for the egocentric perspective then, the female daily resource exploitation perception surface would be very different (fig. 14). We can also generate a travel threshold and perception surface for male or female children, assuming that they are acquiring a different set of resources as part of their training in the tasks of their parents.

Now, when we recognize that the cost-distance algorithm is in itself purely an accumulation tool, we can think about using friction in different ways. Consider that the potential caloric return value (moderated by perception of what that return is) of a given land unit functions as an attractor to the agent. The cumulative value of that attraction can be used to generate simulated pathways from the residential site to areas most commonly exploited (or at least with the greatest potential return).

Figure 14. *Horticulture/gathering: perception surface.*

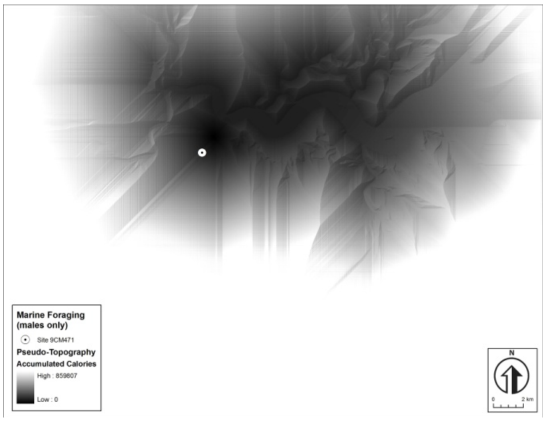

Figure 15. *Marine foraging: pseudo-topography.*

By inverting the perception surface (so that the highest perceived caloric return areas are now the lowest value) a new friction surface results, where it costs more to travel across land units which produce little caloric return. A cost distance evaluation from Yufera using this modified friction surface can be used to generate a pseudo cost topography (fig. 15).

A hydrological analysis of this pseudo topography creates false "stream" values that flow from the edges of the daily effective foraging radius to the residential site location within areas of highest potential caloric return. These are, essentially, pathways by which the resource gathering agents would routinely be able to acquire the greatest predictable returns for their investment of time (fig. 16). These pathways differ by gender as well. We would expect that sites resulting from the loss or discard of artifacts associated with daily activities would occur along these pathways.

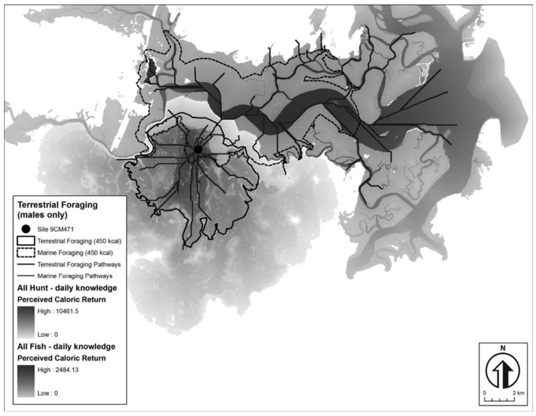

Figure 16. *Optimal marine and terrestrial foraging pathways.*

4.5 COMPETITION AND SOCIAL DOMINANCE

When we look at villages similar to Yufera occupied at the same time in the same region, we can calculate their single-day foraging ranges as well. There are four archaeological sites, including 9CM471, in the sample area that have earthen mounds. There is some evidence that all four sites were occupied during the Timucuan period. If we extract the marine and terrestrial single-day foraging limits from all four sites (fig. 17) we can see that there is actually very little overlap, while most available resource areas are pretty well covered. This suggests that even though each site is situated in high resource density areas, they are spaced in such a way that they do not directly compete with each other.

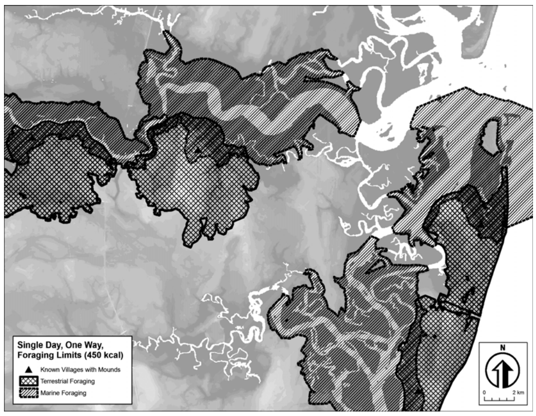

Figure 17. *Terrestrial and marine foraging limits: competition areas.*

However, there are three additional villages, without earthen mounds, located on the Black Point/Cabin Bluff landform (a remnant barrier island), which have Timucuan occupations as well. These villages consist predominantly of shell middens and are located in close travel proximity to potential shellfish resource areas. Spanish records indicate that these villages were occupied at the same time during the late 1500s. The foraging limits from these villages overlap with each other and with those from the mound sites (fig. 18).

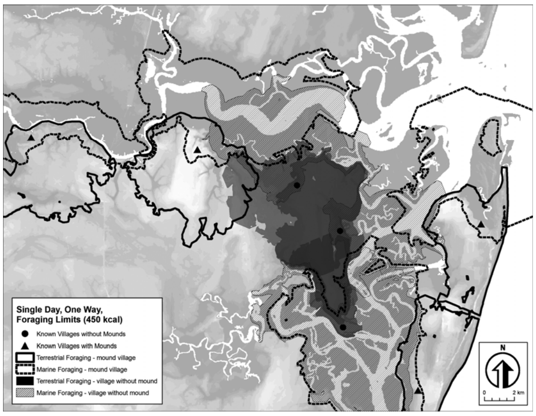

Figure 18. *Minor village competition areas.*

This suggests that their populations were limited in size, and that resource competition would have been mitigated through exchange with the larger sites, perhaps as tribute labor, or exchange of shellfish for maize or other resources. Intensity of competition can be illustrated by modeling the degree of foraging range overlaps. Figure 19 shows the intensity of competition for both terrestrial and marine resources around the three smaller villages; darker shading indicates more competition.

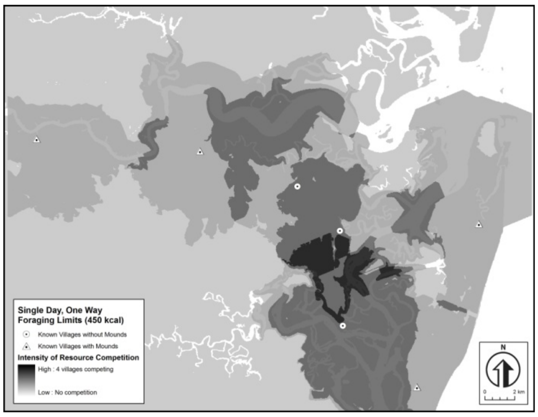

Figure 19. *Intensity of competition.*

During the early 1500s, these villages were allied with, or paid tribute to, the capital of Yufera, at 9CM471. Their ties were based on kinship and linguistics, but the dominance of 9CM471 as the center of power probably arose through the control of the Satilla River trade routes with the interior. High-prestige items such as gold, copper, and red ocher only came from the Piedmont, and even many utilitarian items (such as lithics) were funneled through a narrow travel corridor controlled by the Yufera at 9CM471. This dominance could have been maintained through military might, but it can be simulated with a composite cost-distance depiction representing social control centered on the mound sites (fig. 20). The variability in the intensity of social control is moderated to represent the Black Point villages as being under the influence of Yufera.

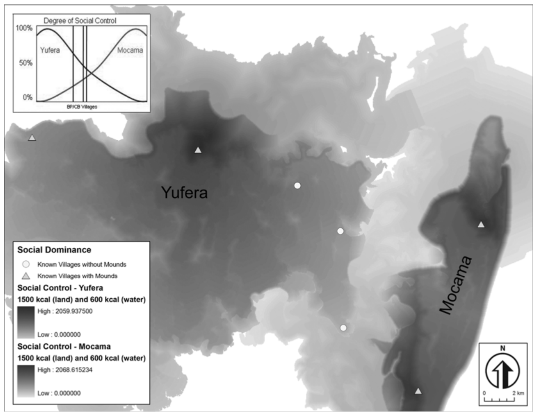

Figure 20. *Social dominance: pre-Spanish period.*

By the mid- to late 1500s however, European contacts drastically shifted the locus of social control. The trade of completely new prestige goods, such as iron tools, metal weapons, glass beads, trinkets, textiles, etc. brought new wealth to the people situated on the Sea Islands. The occupation of Cumberland Island became a much more important attractor as Spanish settlements established new power regimes in the Satilla River area (see fig. 21).

By the early 1600s, the Spanish were constructing mission churches at two of the villages on Black Point, and the power and influence of Yufera was in decline. This shift in power led to the abandonment of the villages on the mainland, and eventually Yufera itself.

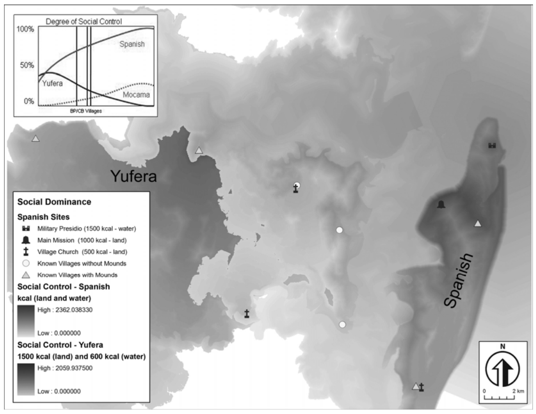

Figure 21. *Social dominance: Spanish period.*

5 CONCLUSIONS

These examples are merely touching on some of the potential avenues of more in-depth research. Likewise, there are a number of areas in which more accurate information regarding species abundance, or return on investment in time and energy expended hunting or processing the resources, will continuously be modifying these results. But the point here is to illustrate that using these tools we can build models of landscape usage, activity areas, and settlement that allow us to explain behaviors, yet predict where these behaviors took place, even when there are no physical remnants of that behavior. Taken one step further, we can use some of these same methods to model processes related to the social control of resources through competition, dominance, and exchange.

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