Early Coastal Migration Routes in the Pacific Northwest: A Case Study in Predictive Least Cost Surface Analysis

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Abstract

The purpose of this study was to develop methodologies for determining coastal migration routes that may have been used by the first inhabitants of the Americas as they moved into North America from Northeast Asia, approximately 13,000 years ago. This goal was accomplished and coastal migration routes were predicted to destinations on the Dundas Islands located off the coast of British Columbia, Canada using multiple weighting scenarios, the most successful of which emphasized the "cultural costs" of moving across land and seascapes. Routes were predicted which emphasized coastal movement, showing areas with an increased probability of containing prehistoric material culture.

Background and Relevance

Recent discoveries in the field of archaeology have contested the long held belief that the first Paleo-Indian peoples to arrive in North America migrated via the ice-free Bering Straight corridor 12,000 years ago (Bryson 1969, Dixon 1999, Gruhn 1994, Mandryk *et al.* 2001.). These new findings have caused archaeologists to look for alternative methods that these peoples may have used to travel into the New World. Recent scholarship supports the idea of boat-based coastal migrations as a viable alternative to the ice-free corridor model (Erlandson *et al.* 2007).

The melting of glacial ice and the subsequent isostatic rebound during the last 13,000 years has resulted in large-scale changes to the coastline of the Pacific Northwest (Moss 2011). Once dry areas are now inundated by ocean water and formerly submerged locations are now dry (Fedje *et al.* 2011, Hutchinson *et al.* 2004, McLaren 2011). The result of this coastline change is that early sites on the Northwest Coast are rare and hard to identify, causing the majority to go undiscovered. This has created a gap in the archaeological record from this time period, which has led to significant unresolved questions about the cultures of Paleo-Indian peoples (Moss 2011).

Geospatial analysis is a methodology that is playing a fundamental role in helping researchers to answer questions about the migrations and movements of ancient peoples (Wheatley and Gillings 2002, Conolly 2006). A small number of early Northwest coast sites have been identified; prominent among these include early components at sites on the Dundas Island, located off the northern coast of British Columbia (McLaren *et al.* 2011, Fedje *et al.* 2012). Analysis of this location has the potential to allow for the locations of other early sites to be predicted. Research at these sites would help to fill the many gaps in the timeline of the peopling of the New World, which is one of the most important events in the prehistory of the Americas. The primary purpose of this study is to pioneer the use of predictive Least Cost Path (LCP) analysis techniques across seascapes to identify the most probable routes of travel to and from sites on the Dundas Islands. This work has resulted in a new migration analysis methodology that reveals robust and clear migration routes and would allow for the discovery of new sites, which will help answer questions about the Paleo-Indian period on the Northwest coast.

This project's study area is composed of the Dundas Island Archaeological Site on the Dundas Islands located in British Columbia. Extensive archaeological survey and excavation, as well as ethnographic fieldwork, have been conducted at this location between 2005 and 2008. All of the archaeological data used in this project was obtained from The Dundas Island Archaeology Project (DIAP), a Social Science and Humanities Research Council of Canada-funded project run through collaboration between the University of Victoria and the University of British Columbia. This project has brought academics together from across North America to try to better define the chronology and material culture of the Tsimshian occupation of the Dundas Islands area by mapping, coring, and developing a sea-level curve for the islands.

Methods and Data

Feature data was recorded from 2005 to 2008 using GPS and Total Station mapping technology. Sea-level curve data was also collected, resulting in a series of still-stands over the past 12,000 years at elevations of 13 m, 10 m, and 5 m above modern mean sea level. Digital Elevation Model (DEM) data was gathered from the Terrain Resource Information Management Program (TRIM) dataset via the GeoBC website. All data sets are accurate to within 10 metres of their actual elevation and spatial location (McLaren 2009).

The locations of known archaeological sites on the Dundas Islands were used to determine the boundaries of the study area, and a study area centroid was calculated using the known site locations. This point was then buffered by 20,000 metres and eighteen new points were then placed at 20° intervals on the perimeter of this buffer to serve as origin locations for least cost paths. The circular placement of these points around the study area perimeter allows for approaches from any direction to the islands to be modeled.

A model was constructed using the work of Herbert Maschner to predict the location of likely destination points on the islands (Maschner 1995). Contour lines were derived from the TRIM DEM, which allowed for the maximum prehistoric sea rise (+13 metres) to be modeled and ancient shorelines determined (McLaren 2011). Areas on the island were identified which are located within 200 metres of freshwater rivers and lakes, are on an island larger than 3 km^2, have a slope less than 2, occupy an east-facing aspect, and are within 15 meters of the prehistoric shoreline (Maschner 1995). The result of this analysis was the identification of 22 unique locations that show a high probability of serving as stopping points for ancient mariners.

A friction surface was created for the study area with cost values determined by several criteria. The first set of cost input factors used to construct the friction surface was environmental factors: topography, aspect, and proximity to freshwater. Areas with a slope less than 2%, facing east, within 200 metres of fresh water were all given a movement cost value of 1 while all other cells in the study area were given a movement cost value of 2 (Moss 2008). The lower the cost value, the more travel is facilitated by that factor.

The second set of input cost values was determined by cultural costs, specifically Paleo-Indian overnight site preference and near shore travel corridor. The viability of Paleo-Indian coastal migrations is predicated based on access to coastal ecological resources. As such a prehistoric mariner would probably have restricted their travel to areas within eyesight of the island's shoreline (Erlandson *et al.* 2007). A near shore travel corridor was developed from viewsheds, which were calculated at various distances from the shore. It was determined that 3 km from shore was the furthest distance from which the islands could be seen. Using this data the islands were buffered by 3000 meters and this data reclassified so that the area inside this distance received a cost value of 1, the open ocean beyond 3000 metres a value of 3, and the island landmasses a value of 5.

Physiological costs were used to create the last input value. It has been determined from ethnographic research that the maximum distance that could be traveled by a prehistoric mariner in one day is 5,260 m (Ames 2002). A buffer operation was used to identify areas within one day's travel from predicted stopping locations. Areas within the buffer were given a cost value of 1 and areas outside the buffer a value of 2.

These reclassified inputs were then summed and weighted to highlight each of the different types of input cost. This produced very different friction surfaces, which produced markedly different least cost paths. Additionally, another analysis was run which incorporated the location of modern day Bull Kelp (*Nereocystis luetkeana*) beds. While these results are not representative of the prehistoric conditions, they do show how this analysis can be influenced by the presence of resources, which are located in marine portions of the study area. All of the friction surfaces were then used to produce least cost paths from all 18 origin points to the predicted destination site locations on the islands.

Results

Comparisons were done for all the paths from every friction surface for each individual site and for all the paths from a single friction surface for all sites. The latter method proved to be much more useful and revealed that the culturally weighted and the unweighted friction surfaces produced the most promising sets of least cost paths. These paths are composed largely of maritime segments and these paths show high levels of homogeneity, frequently traveling over the same areas. These paths tend to pass through, or in close proximity, to the locations of other predicted stopping points. These are all features which increase the likelihood that these paths predict the location of human activity on the Dundas Islands.

Paths that were derived from the friction surfaces weighted to emphasize physiological and environmental costs resulted in least cost paths that have low suitability for archaeological site prospection on the Pacific Northwest Coast. These paths have large overland portions, which is of little help when trying to identify coastal migration routes. The marine segments of these paths are very linear, which is not reflective of actual human movement over water (Moss 2008).

The paths derived from the friction surface which included the location of kelp beds were extremely similar to the results derived from the unweighted friction surface. It had been thought at the onset of this analysis that the presence of resources located in the ocean would have a significant impact on the routes used. However the weighting of kelp beds used here was too great, which caused a significant distortion to the predicted paths. This weighting scenario needs to be re-examined before it can be effectively applied.

Conclusions

This analysis helped to answer several questions about the use of LCP analysis for modeling the movement of Paleo-Indian peoples through the coastal landscape of the prehistoric Dundas Islands and this methodology shows promise for helping researchers determine where to locate their surveys and excavations so as to find very early sites possibly used by the first migrants to the New World. Additionally, these findings highlight the amount of variation that can be produced in least cost paths depending on how friction surfaces are weighted. Some weighting schemes are much more effective at producing least cost paths that model maritime movement and demonstrate the importance of a carefully constructed analysis. Lastly this project demonstrated how this methodology could be implemented in a GIS model, which will allow for it to be easily applied to other locations on the Northwest Coast.

The use of LCP to predict maritime movement is still in its infancy. Further accuracy assessment and ground truthing of high probability site locations identified in this model are needed. Once this feedback has been integrated into the analysis, researchers will have a new method for finding Paleo-Indian sites, which will help to shed light on the timeline of one of the most important events in the history of the Americas.

References

Ames, K. (2002). *Going by boat: the forager-collector continuum at sea. Beyond Foraging And Collecting : Evolutionary Change In Hunter-Gatherer Settlement Systems / Edited By Ben Fitzhugh And Junko Habu*. New York : Kluwer Academic/Plenum Publishers.

Bryson, R. A., Wendland, W. M., Ives, J. D., & Andrews, J. T. (1969). Radiocarbon isochrones on the disintegration of the Laurentide ice sheet. *Arctic and Alpine Research*, *1*(1), 1-13.

Conolly, J., & Lake, M. (2006). *Geographical information systems in archaeology / James Conolly, Mark Lake*. Cambridge, UK; New York: Cambridge University Press, 2006.

Dixon, E. (1999). *Bones, boats & bison: archeology and the first colonization of western North America / E. James Dixon*. Albuquerque: University of New Mexico Press, 1999.

Erlandson, J. M., Graham, M. H., Bourque, B. J., Corbett, D., Estes, J. A., & Steneck, R. S. (2007). The Kelp Highway Hypothesis: Marine Ecology, the Coastal Migration Theory, and the Peopling of the Americas. *Journal of Island & Coastal Archaeology*, *2*(2), 161-174.

Fedje, D., Mackie, Q., Lacourse, T., & McLaren, D. (2011). Younger Dryas environments and archaeology on the Northwest Coast of North America. (Report). *Quaternary International*, (2), 452.

Gruhn, R. (1994). The Pacific Coast route of initial entry: An overview. *Methods and Theory for Investigating the Peopling of the Americas*, Robson Bonnichsen and D. G. Steele, eds. Pp. 249-256. Corvallis, Oregon: Oregon State University.

Hutchinson, I., James, T. S., Clague, J. J., Barrie, J., & Conway, K. W. (2004). Reconstruction of late Quaternary sea-level change in southwestern British Columbia from sediments in isolation basins. *Boreas*, *33*(3), 183-194.

Mandryk, C., Josenhans, H., Fedje, D., & Mathewes, R. (2001). Late Quaternary paleoenvironments of Northwestern North America: implications for inland versus coastal migration routes. *Quaternary Science Reviews*, *20*(1-3), 301-314.

Maschner, H. G. (1995). The Politics of Settlement Choice on the Northwest Coast: Cognition, GIS, and Coastal Landscapes. In D. Sweeney (Ed.), *Agriculture in the Middle Ages: Technology, Practice, and Representation* (pp. 175-189). Philadelphia, PA: U of Pennsylvania P.

McLaren, D. (2009). Sea Level Change and Archaeology Site Locations on the Dundas Island Archipelago of North Coastal British Columbia. *Dissertation Abstracts International 69*(1): 2762.

McLaren, D., Martindale, A., Fedje, D., & Mackie, Q. (2011). Relict Shorelines and Shell Middens of the Dundas Island Archipelago. *Canadian Journal of Archaeology*, *35*(1), 86-116.

Moss, M. L. (2008). Islands Coming Out of Concealment: Traveling to Haida Gwaii on the Northwest Coast of North America. *Journal of Island & Coastal Archaeology*, *3*(1), 35-53.

Moss, M. (2011). *Northwest coast: archaeology as deep history / by Madonna L. Moss*. Washington D.C.: Society for American Archaeology, c. 2011.

Wheatley, D., & Gillings, M. (2002). *Spatial technology and archaeology [electronic resource]: the archaeological applications of GIS / David Wheatley and Mark Gillings*. New York: Taylor & Francis, 2002.