The Road Not Taken: How Early Landscape Learning and Adoption of a Risk-Averse Strategy Influenced Paleoindian Travel Route Decision Making in the Upper Ohio Valley

Matthew P. Purtill

To evaluate a model of the travel-route selection process for upper Ohio Valley Paleoindian foragers (13,500–11,400 cal BP), this study investigates archaeological data through the theoretical framework of landscape learning and risk-sensitive analysis. Following initial trail placement adjacent to a highly visible escarpment landform, Paleoindians adopted a risk-averse strategy to minimize travel outcome variability when wayfaring between Sandy Springs, a significant Ohio River Paleoindian site, and Upper Mercer–Vanport chert quarries of east-central Ohio. Although a least-cost analysis indicates an optimal route through the lower Scioto Valley, archaeological evidence for this path is lacking. Geomorphic and archaeological data further suggest that site absence in the lower Scioto Valley is not entirely due to sampling bias. Instead, evidence indicates that Paleoindians preferred travel within the Ohio Brush Creek–Baker's Fork valley despite its longer path distance through more rugged, constricted terrain. Potential travel through the lower Scioto Valley hypothesizes high outcome variability due to the stochastic nature of the late Pleistocene hydroregime. In this case, perceived outcome variability appears more influential in determining travel-route decisions among Paleoindians than direct efforts to reduce energy and time allocation.

Keywords: Paleoindian, eastern North America, least-cost analysis, risk-averse strategy, landscape learning theory, upper Ohio Valley

Para evaluar un modelo del proceso de selección de ruta de tránsito para los recolectores paleoindios del valle superior del Ohio (13.500-11.400 cal BP), este estudio investiga datos arqueológicos a través del marco teórico de aprendizaje del paisaje y análisis del riesgo posible. Siguiendo una ubicación inicial de la senda adyacente a una formación escarpada muy visible, los paleo-indios adoptaron una estrategia adversa al riesgo para minimizar la variabilidad del resultado de tránsito en sus expediciones entre Sandy Springs, un importante yacimiento paleoindio en el río Ohio, y las excavaciones de sílex de Mercer-Vanport superior en el centro-este de Ohio. Aunque un análisis del menor coste indica una ruta óptima a través del valle bajo del Scioto, falta evidencia arqueológica de ese recorrido. Los datos geomórficos y arqueológicos sugieren además que la ausencia de yacimientos en el valle bajo del Scioto no se debe completamente al sesgo del muestreo. En su lugar, la evidencia demuestra que los paleoindios preferían desplazarse por el interior del valle Ohio Brush Creek-Baker's Fork a pesar de ser una distancia mayor a través de terreno más escabroso y restringido. Un recorrido potencial a través del valle bajo del Scioto proponía una alta variabilidad de resultados debido a la naturaleza aleatoria del régimen hídrico en el bajo Pleistoceno. En este caso, la percepción de variabilidad de resultado era más influyente en la elección de la ruta de tránsito entre los paleoindios que los esfuerzos directos de reducir la asignación de energía y tiempo.

Palabras clave: Paleoindio, este de América del Norte, análisis del menor coste, análisis del riesgo posible, aprendizaje del paisaje, valle superior del Ohio

During the late Pleistocene, Paleoindian foragers (13,500–11,400 cal BP) of eastern North America traversed dynamic landscapes during early migration pulses and subsequently established annual-seasonal mobility patterns (e.g., Anderson 1990, 1995;

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Anderson and Gillam 2000; Anderson et al. 2014, 2015; Ellis 2011; Ellis et al. 2011; Kelly and Todd 1988; Meltzer 2004, 2009; Steele et al. 1998; Surovell 2000). Embedded within this literature are studies that explore lithic procurement strategies, many through some iteration of least-cost path analysis (LCP) to identify potential toolstone acquisition routes (e.g., Boulanger et al. 2015; Eren et al. 2016, 2019; Lothrop et al. 2018; Miller et al. 2019). Understanding the nature of such movements has significant implications for anthropological and archaeological theory (e.g., Anthony 1990, 1997; Bruno et al. 2014; Burmeister 2000; Cabana and Clark 2011; van Dommelen 2014), particularly as it relates to regional variability in land-use behavior, culture change, subsistence strategies and prey choice, band territory development, demographic trends, technological organization, and cultural learning and transmission.

This article advances an explanatory model that evaluates potential travel corridors connecting a significant upper Ohio Valley Paleoindian site, Sandy Springs (33AD30; Purtill 2017; Seeman et al. 1994), to Upper Mercer–Vanport chert outcrops in central Ohio. To identify diverse components of the decision-making process, this model integrates elements of two theoretical perspectives: landscape learning (Golledge 2003; Kelly 2003; Meltzer 2002, 2003, 2004; Rockman 2003, 2009) and risk-sensitive analysis (e.g., Kahneman and Tversky 1979; Tversky and Kahneman 1992; Winterhalder 2007; Winterhalder et al. 1999). To compensate for limited landscape knowledge early in the Paleoindian occupation of southern Ohio, this model hypothesizes that Clovis foragers established an early route in the constricted, rugged Ohio Brush Creek–Baker's Fork (OBC-BF) drainage immediately adjacent to the high-relief escarpment of the Allegheny Plateaus. Throughout the Paleoindian Period, travel by the OBC-BF route continued despite the presence of the seemingly more energy-efficient alternative, the broader lower Scioto Valley (LSV). This study interprets the persistence of the OBC-BF route as reflecting the adoption of a risk-averse strategy to mitigate outcome variability resulting from the hydrologically stochastic LSV system, a condition that characterized most major eastern North American rivers during the late Pleistocene (e.g., Arbogast et al. 2008; Holliday and Miller 2014:228–233; Knox 1995). This study evaluates the proposed model through cross-temporal archaeological site patterning, assessment of geomorphologic processes for site preservation and visibility, and quantitative cost-benefit comparison of two hypothesized routes using an LCA geographic information systems (GIS) workflow. Finally, this study compares findings to current immigration and settling-in models of eastern North American Paleoindian societies.

Study Area and Geomorphic History

The study area includes the upper Ohio River drainage basin, specifically seven counties in south-central Ohio: Adams, Highlands, Jackson, Pike, Ross, Scioto, and Vinton (Figure 1). The Scioto River and Ohio Brush Creek watersheds, both tributaries of the Ohio River, principally drain the study area. The Scioto River is a substantial north-to-south trending drainage that extends from Auglaize County in central Ohio, 372 km south to its confluence with the Ohio River at Portsmouth. In its entirety, the Scioto Valley drains 16,878 km^2 of land (Sherman 1999) and extends from the deglaciated, low-relief Till Plains of central Ohio to the unglaciated, high-relief Appalachian Plateaus of southern Ohio.

Within the current study area, the Scioto Valley includes 8,762 km^2 of land that extends from just north of the Wisconsinan glacial margin near Chillicothe to its intersection with the Ohio River at Portsmouth. This study further divides the reach into middle and lower watersheds. The middle Scioto Valley (MSV) extends from just north of Chillicothe, 75 km downriver to Waverly. The lower reach, or LSV, flows 161 km between Waverly and the Ohio River at Portsmouth (Figure 1). The modern Scioto River is underfit and flows through a precut ancestral bedrock valley that ranges in width up to approximately 5.4 km (Kempton and Goldthwait 1959). Modern average discharge for the Scioto at Piketon is 198 m^3/s with reaches of the lower Scioto experiencing discharge as high as

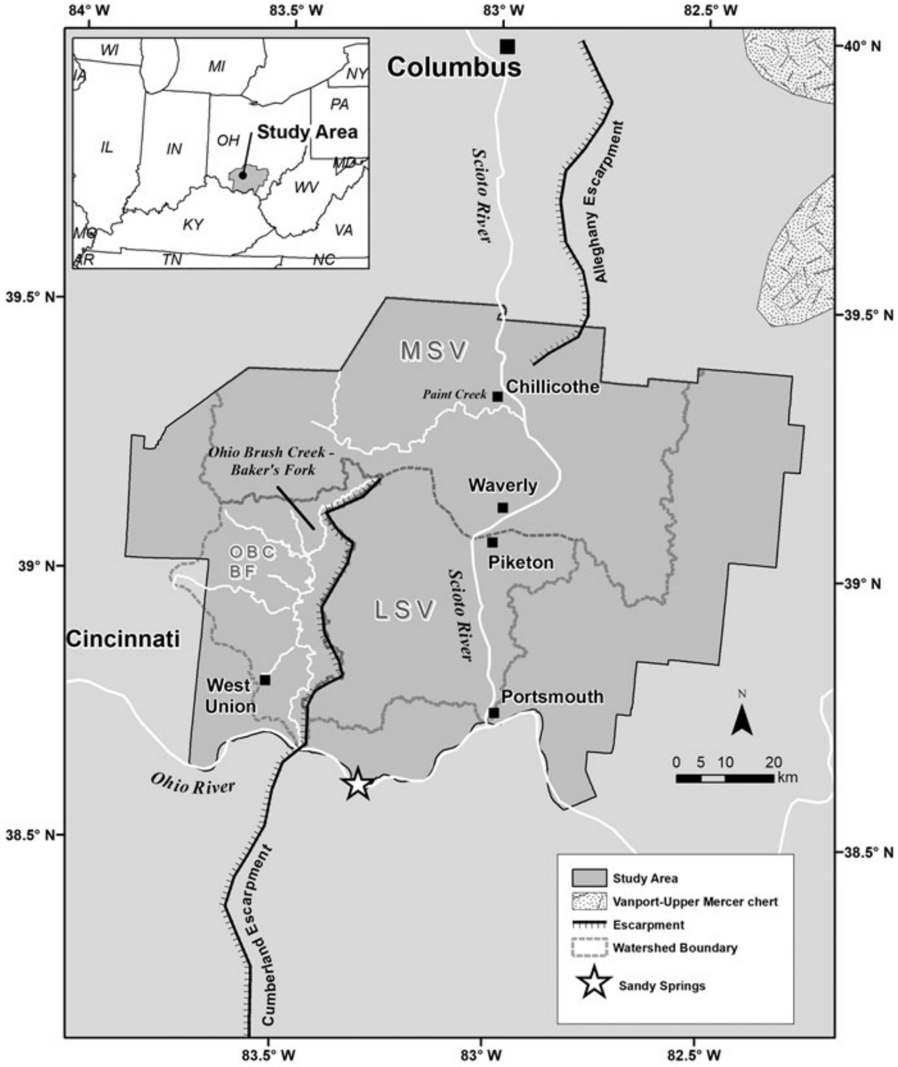

Figure 1. Location of the study area in southern Ohio showing Ohio Brush Creek–Baker's Fork (OBC-BF), middle Scioto Valley (MSV), and lower Scioto Valley (LSV) catchment basins. Location of Sandy Springs and Upper Mercer–Vanport chert outcrops also illustrated.

>15,000 m^3/s during major floods (U.S. Geological Survey 2020; Webber and Bartlett 1976:48; Figure 2).

MSV-LSV valley-bottom geomorphology is complex and consists of glacial outwash and alluvial terraces. During the Wisconsinan glaciation, meltwater pulses delivered significant glaciofluvial sediment loads that resulted in valley-floor aggradation and reworking of earlier Illinoian outwash. Significant outwash delivery to MSV-LSV ceased by roughly 14,000 cal BP, coincident with the northward retreat of the Scioto Sublobe out of the Scioto River's headwaters (Dyke et al. 2003). Post-deposition erosion and lateral river migration resulted in discontinuous preservation of Illinoian (>130,000 cal BP) and Wisconsinan (22,000–14,000 cal BP) outwash terrace remnants that range in height from 13 to 46 m above the modern Scioto River. Importantly, current terrace geochronology is poorly established and largely based on soil weathering properties and topographic correlation to radiocarbon-dated moraines to the north.

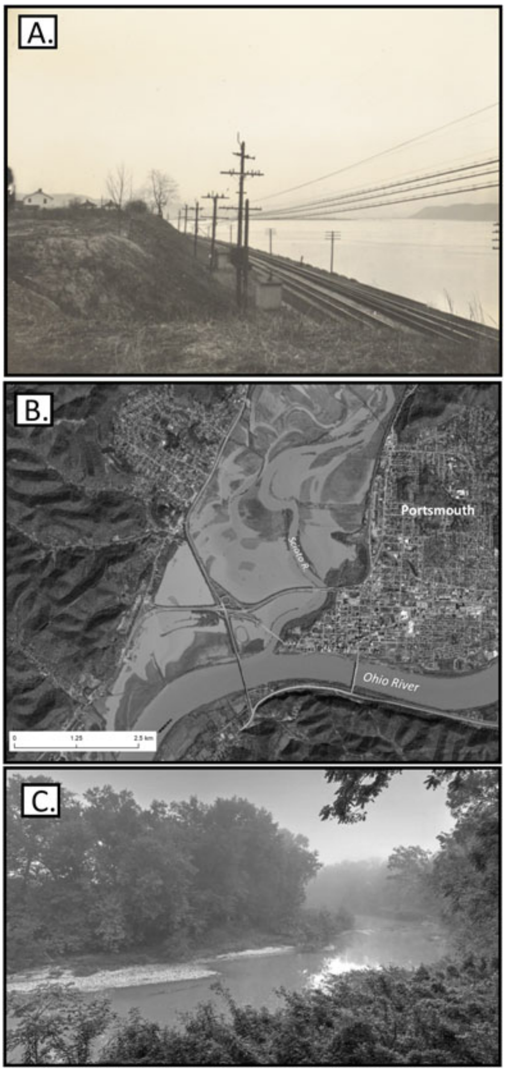

Figure 2. Photographs of the lower Scioto River and Ohio Brush Creek. (a) Scioto River near Portsmouth during 1940 flood with discharge at approximately 10,400 m^3/s (Portsmouth Public Library 2020). Note inundation of significant portions of valley bottom (~2.2 km in width), with railroad situated on the upper alluvial terrace as defined in this study; (b) Google Earth aerial image of lower Scioto River at its confluence with Ohio River showing significant inundation of valley bottom during moderate flooding (discharge at ~3700 m^3/s) on March 4, 2017; (c) Modern view of Ohio Brush Creek approximately 10 km east of West Union, Ohio. Photo courtesy of Jim M. McCormac and used with permission.

Compared to the Scioto River, the OBC-BF is a significantly smaller regime that drains 1,117 km^2 of land primarily in Adams and Highland Counties (Figure 1). With its headwaters just south of Bainbridge, Ohio, the drainage system flows 92 km south along the western edge of the Allegheny Plateaus escarpment in a high-relief section of the Outer Bluegrass Region. This karstic region contains common tallgrass prairie remnants of uncertain age (Braun 1928). As measured near West Union, average modern OBC-BF discharge is 13 m^3/s, more than an order of magnitude less than the Scioto River. This valley was primarily unglaciated except the northernmost headwaters of Baker's Fork system during the Illinoian (Pavey et al. 1999; Rosengreen 1974). Unlike MSV-LSV, OBC-BF has narrow valley bottoms, typically less than 0.8 km in width. Illinoian outwash terrace remnants discontinuously line the valley bottom and rise 9–17 m above the modern river surface (Rosengreen 1974:23). DEM data inspected for this study reveal two undated alluvial surfaces, including an intermediate surface at 6–8 m and a low surface at 3–4 m above the modern river surface. As with the MSV-LSV, OBC-BF terraces remain poorly dated.

Archaeological Data and Distributions

Paleoindian Occupation of the Upper Ohio Valley

The upper Ohio Valley boasts a robust inventory of Paleoindian sites, especially those containing fluted bifaces (e.g., Buchanan 2003; Prasciunas 2011; Prufer and Baby 1963; Seeman and Prufer 1982). High densities led Anderson and colleagues to propose the Ohio Valley as an early staging area for eastern U.S. colonizing populations (e.g., Anderson 1990, 1995, 1996; Anderson and Faught 2000; Eren et al. 2016). One of the largest Paleoindian occupations in the unglaciated upper Ohio Valley is Sandy Springs (33AD30; Cunningham 1973; Purtill 2017; Seeman et al. 1994). Known primarily from amateur collections, the surface site reflects a thin scatter of material over 40+ ha of agricultural fields on middle- to upper-alluvial/outwash terraces of the Ohio River that are characterized by dune and loess deposition (Purtill 2017). Although undated by radiometric means, the recovery of over 100 diagnostic bifaces classified as Clovis or Gainey, Cumberland, Beaver Lake, Agate Basin, and additional lanceolate forms (Seeman et al. 1994) indicates repeated occupation during the entire Paleoinidan Period. Early Paleoindian toolstone procurement at Sandy Springs mirrors regional trends with strong preference for Upper Mercer chert (Miller et al. 2019; Prufer and Baby 1963; Seeman and Prufer 1982; Seeman et al. 1994; Tankersley et al. 1990) from east-central Ohio (Carlson 1991; Stout and Schoenlaub 1945). At Sandy Springs, Upper Mercer accounts for 69% of the Clovis-Gainey assemblage ($n = 9$), although nonlocal materials include Hixton Silicified Sandstone (HSS; $n = 1$), which outcrops approximately 890 km to the northwest in Wisconsin (Carr and Boszhardt 2010) and Paoli chert ($n = 2$), which outcrops about 20 km to the southeast in Kentucky (Vickery 1983). Collectively, toolstone exploitation suggest multiregional interaction at Sandy Springs (Seeman et al. 1994) with increased southern interaction through time as revealed through the recovery of post-Clovis Cumberland bifaces ($n = 15$), many manufactured from Kentucky Paoli chert (Seeman et al. 1994; Tune 2016a, 2016b).

Paleoindian research indicates strong latitudinal, perhaps seasonal, mobility in deglaciated landscapes (e.g., Boulanger et al. 2015; Ellis 2011; Redmond and Tankersley 2005; Simons 1997), although this pattern is ambiguous in unglaciated southern clines where range mobility appears restricted (e.g., Anderson et al. 2015; Broster et al. 2013; Parish 2018). A natural ford of the Ohio River at Sandy Springs may have facilitated river crossing, both by humans and potential prey (Seeman et al. 1994), making the site an attractive waypoint for any north-to-south movement. Latitudinal movements likely included travel along the high-relief escarpment zone of the Cumberland Plateau and Allegheny Plateaus that connects the unglaciated Southeast to deglaciated Midwest (Purtill 2017; Seeman et al. 1994). Given Sandy Springs's dense artifact collection, significant portions of the upper Ohio Valley Paleoindian population commonly moved through Sandy Springs as part of seasonal or annual rounds. Site inhabitants likely traveled north to Upper Mercer–Vanport chert outcrops to retool; strengthen social relations and learning opportunities; and facilitate the exchange of goods, ideas, and mates (Anderson 1990, 1995; Eren et al. 2015, 2019; Lepper 2005; Meltzer 2004; Miller et al. 2019).

Paleoindian and Archaic Site Distributions

To provide a proxy for valley demography and/or intensity of travel, Paleoindian ($n = 50$), Early Archaic ($n = 292$; 11,400–8450 cal BP), and Late Archaic ($n = 468$; 5950–2650 cal BP; Purtill 2009) sites are plotted for the study area (Figure 3). Site locations and cultural affiliations derive from Ohio Archaeological Inventory (OAI) forms maintained by the Ohio Historic Preservation Office. Prior to analysis, the author reviewed artifact inventories from OAI forms with Paleoindian components and relevant publications (e.g., Prufer and Baby 1963; Seeman and Prufer 1982). This study excludes components with dubious Paleoindian affiliation as determined during review. This study does not conduct similar reviews of Early and Late Archaic components given the database's size ($n = 760$) and limited potential that vetting would significantly alter overall trends.

To mitigate potential effects of collector or taphonomic bias widely cited in Paleoindian studies (e.g., Anderson and Faught 2000:509; Buchanan 2003; Loebel 2012; Shott 2002, 2004), this study employs a cross-temporal approach that uses the presence of Early and Late Archaic components to asses potential impacts of collector or taphonomic bias in areas characterized by an absence of Paleoindian material. This approach assumes that at every Early or Late Archaic find spot, there should be a near-equal chance for recovery of Paleoindian material, if present, even considering some bias. Although the assumption of progressive removal of older sites from the archaeological record is reasonable, studies (e.g., Bluhm and Surovell 2019; Surovell et al. 2009; Williams 2012), suggest that the rate of taphonomic site loss is not constant through time. Instead, it decreases through time primarily due to the protective agents of site burial (Surovell et al. 2009:1718).

To control for potential collector and taphonomic bias, this study applies Surovell and colleagues' (2009) nonlinear regression taphonomic correction model to determine *expected*

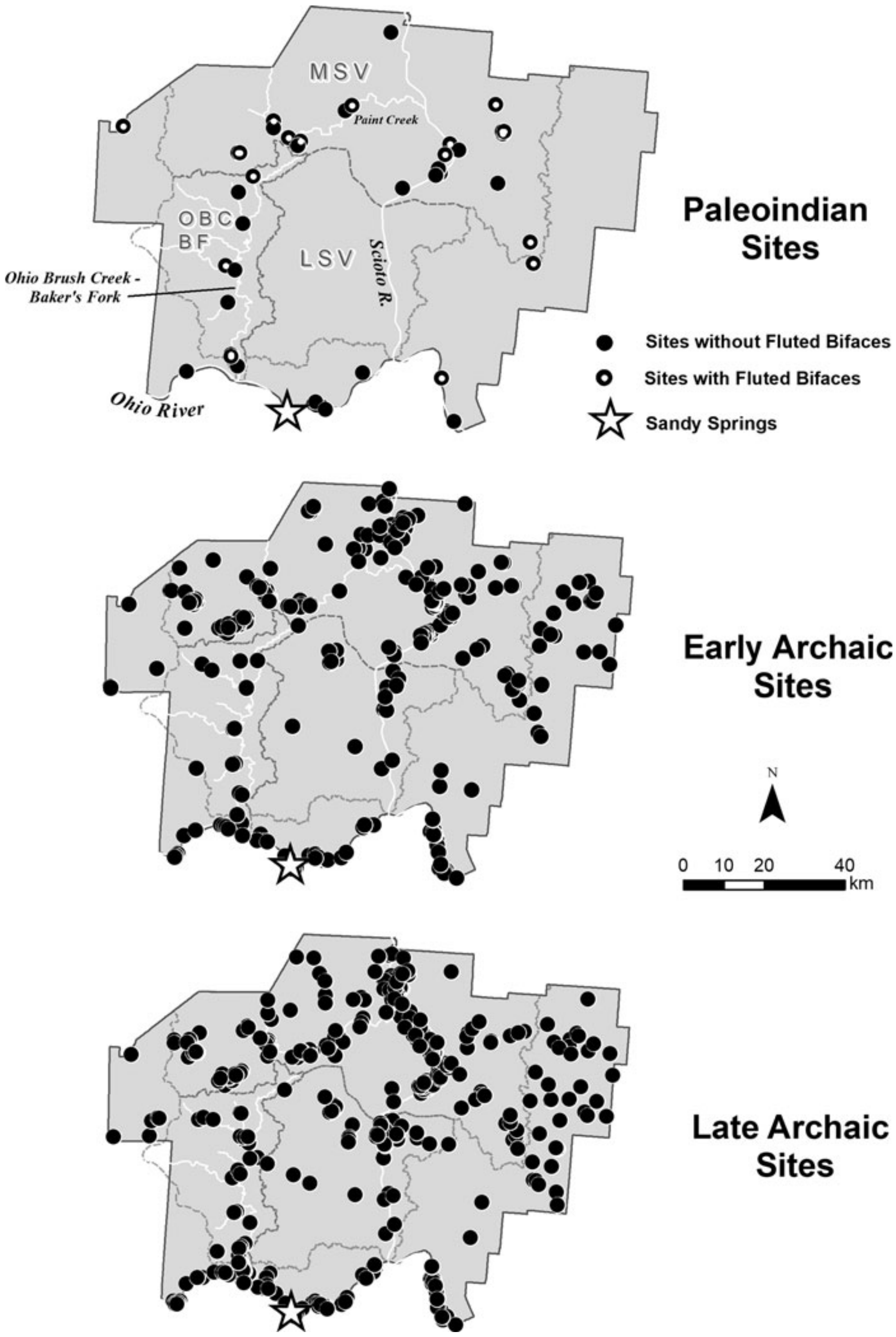

Figure 3. Distribution of Paleoindian (*n* = 50), Early Archaic (*n* = 292), and Late Archaic (*n* = 468) sites recorded on OAI forms maintained by the Ohio Historic Preservation Office.

site survival rates for Paleoindian, Early Archaic, and Late Archaic assemblages based on period age. Although the taphonomic correction model is typically applied to radiocarbon inventories, this study employs it to predict the expected frequency of sites in southern Ohio's archaeological record. To accomplish this, this study mimics Surovell and colleagues'

Table 1. Results of the Taphonomic Correction Model for Predicted Site Survival Rates in the Project Area.

Temporal Period	Temporal Midpoint (cal BP)	Number of Hypothetical Sites Produced at Midpoint	n_t	Predicted Site Survival Frequency ($n_t \times k^a$)	Predicted Site Survival Rate in Archaeological Record
Paleoindian	12,450	10,000	9.07	705	7%
Early Archaic	9925	10,000	11.81	917	9%
Late Archaic	4300	10,000	28.22	2,191	22%

[a] k is a constant (77.682) derived by Surovell et al. (2009:1717) to force the model to intersect the y-axis (time zero) at 10,000 sites.

(2009:1717–1718) example by modeling the survival rate of 10,000 hypothetical sites produced at the midpoint year of each temporal period under consideration (Table 1). The taphonomic correction model regression equation is

$$n_t = 5.726442 \times 10^6 (t + 2176.4)^{-1.3925309}$$

where n_t = predicted number of geologic contexts from time t, and t = temporal period midpoint.

Results from the taphonomic correction model predict that Early Archaic sites should have only a 2% higher survival rate than Paleoindian sites, whereas Late Archaic sites should have a 15% higher survival rate (Table 1). Given the negligible interperiod differences, taphonomic or sampling bias fails to fully explain the absence of Paleoindian material at locations of documented Early Archaic, and to a lesser degree, Late Archaic sites. Instead, this study interprets the absence of Paleoindian material at these locations as the result of deliberate avoidance behavior. Accordingly, relative interperiod site densities illustrate chronological shifts in land-use behavior between Paleoindian and Archaic populations. Similar comparative approaches have proven successful in previous studies (e.g., Jennings 2015; Miller and Carmody 2016; Purtill 2009).

Spatial and temporal variation in site patterning is apparent in the dataset, especially with relative densities between the three major watersheds considered in this study: OBC-BF, MSV, and LSV (Fisher's exact test = 19.851, $p <$ 0.000[1]; Table 2). Results indicate a significant overrepresentation of Paleoindian sites in the OBC-BF valley (standardized residual score +2.8; $p < 0.01$), concomitant with a complete lack of Paleoindian sites in LSV (standardized residual score −2.0; $p < 0.05$). In fact, review of all test standardized residual scores indicates that overall strength of association for the test derives from these two trends alone given that no other cells in Table 2 produce residuals beyond the critical value of 0.05 (standardized residual scores >1.96).

Table 2. Distribution of Sites by Temporal Period and by Catchment Basin.

	OBC-BF	MSV	LSV	Total
Paleoindian	10 *(29%)* *[2.8]*	25 *(71%)* *[−0.3]*	0 *(0%)* *[−2.0]*	35 *(100%)*
Early Archaic	16 *(8%)* *[−1.8]*	167 *(83%)* *[1.1]*	19 *(9%)* *[−1.0]*	202 *(100%)*
Late Archaic	42 *(13%)* *[0.5]*	230 *(72%)* *[−0.8]*	47 *(15%)* *[1.5]*	319 *(100%)*
Total	68 *(12%)*	422 *(76%)*	66 *(12%)*	556 *(100%)*

Note: Fisher's Exact Test = 19.851, $p < 0.000$; residual scores in [ ].

The most striking pattern is the absence of Paleoindian sites in the LSV coupled with higher-than-expected site densities in the OBC-BF valley. A parsimonious explanation for the absence of valley-bottom sites in LSV is that it reflects poor site preservation or limited archaeological visibility, not deliberate underutilization. This possible explanation assumes that Paleoindian travel *did* occur in LSV but that archaeological evidence has subsequently eroded or remains undiscovered in the valley. Although limited geochronological control exists for LSV, evidence provided below suggests that Paleoindian site absence in the LSV reflects deliberate underutilization of the basin and not preservation bias.

To help evaluate this proposal, this study incorporates 30 m resolution DEM data to map valley-bottom landforms in the project area (Figure 4). Review of relevant Quaternary geological and pedological literature and maps supplemented topographic information (e.g., Erber et al. 2016; Kempton and Goldthwait 1959; Pavey et al. 1999) to classify and correlate geomorphic surfaces across the valley. Outwash terrace remnants attributed to the Illinoian (>130,000 cal BP) range from 30 to 46 m above the modern river surface. In contrast, remnants attributed to the Wisconsinan (22,000–14,000 cal BP) rise 13–30 m (Pavey et al. 1999) above the modern river surface. DEM data also reveal a flight of alluvial terraces/floodplains between 0 and 13 m above the modern river surface that should date to <14,000 cal BP. This study defines an upper alluvial terrace, 6–13 m in height, and a lower alluvial terrace, <6 m in height. Despite limited geochronological control, the distribution of Paleoindian and Early Archaic sites on upper alluvial surfaces, and to a lesser degree on some lower alluvial terraces, suggests that these landforms were available for Paleoindian travel/utilization during the late Pleistocene (Table 3). Although substantial erosion in LSV is evident, this study suggests that at least 14% of modern LSV bottomland is sufficiently old to contain Paleoindian material, if it exists (see Figure 4).

Although fluvial erosional processes potentially explain Paleoindian site absence in the LSV valley bottoms, the absence of sites from surrounding tributary valleys and uplands is more difficult to explain using a preservation bias argument. In fact, Paleoindian sites are absent from the *entire* 17,866 km^2 LSV watershed, not just the 122 km^2 (<1% of watershed) Scioto River bottomlands where erosion was prominent (see Figure 4). If Paleoindians explored or utilized the valley to any significant degree, some archaeological evidence should exist in the watershed. In fact, in other studies of deglaciated valleys where lateral erosion rates during the Holocene project to be similar to LSV (e.g., White River, Indiana [Herrmann 2013; Herrmann and Monaghan 2019]), the surfaces of "protected" valley-margin landforms and tributary mouths commonly yield some evidence of Paleoindian occupation. It is noteworthy that, despite the lack of Paleoindian utilization, Early Archaic sites occur along valley-margin landforms and tributary valleys in the LSV watershed. Because documented Paleoindian sites occur in secondary tributary valleys in both the MSV and OBC-BF basins, their absence in LSV fails to suggest deliberate avoidance of secondary drainages in southern Ohio. Finally, the simple fact that archaeological evidence supports rather intensive Paleoindian use of the OBC-BF route provides a plausible alternative for any need for travel through LSV. In fact, the Ohio River drainage proper has no recorded fluted bifaces between Sandy Springs and the mouth of the Scioto River (see Figure 3), suggesting eastward movement toward this drainage only later (post-Clovis) in time.

The lack of evidence for Paleoindian utilization of LSV is curious because, based on topography and route distance, the LSV route appears to be a logical travel corridor connecting Sandy Springs to Upper Mercer–Vanport outcrops. Historically, the Scioto Valley was a well-established route for Native Americans traveling between central Kentucky, where it was part of the "Warrior's Path," and northern Ohio (Mills 1914). Hypothesized travel through LSV also matches expectations of proposed Paleoindian land-use behaviors, including a desire to minimize travel through the rugged terrain of the Appalachian Plateaus (e.g., Anderson and Faught 1998:175; Lane and Anderson 2001; Meltzer 1985; Prufer and Baby 1963:62–63; Seeman and Prufer 1982) and a preference to utilize major river valleys (e.g., Anderson 1995:13–15; Anderson and Faught 2000; Anderson and Gillam 2000; Tune 2016b). In addition to human travel, it is likely that the Scioto Valley was a preferred migration route for herd animals commonly targeted by eastern-U.S. Paleoindians, such as caribou and bison (e.g., Gingerich and Kitchel 2015). For these reasons, the LSV route appears optimal for travel by Paleoindian groups. Archaeological evidence, however, fails to support use of this corridor. Instead, evidence supports travel through the

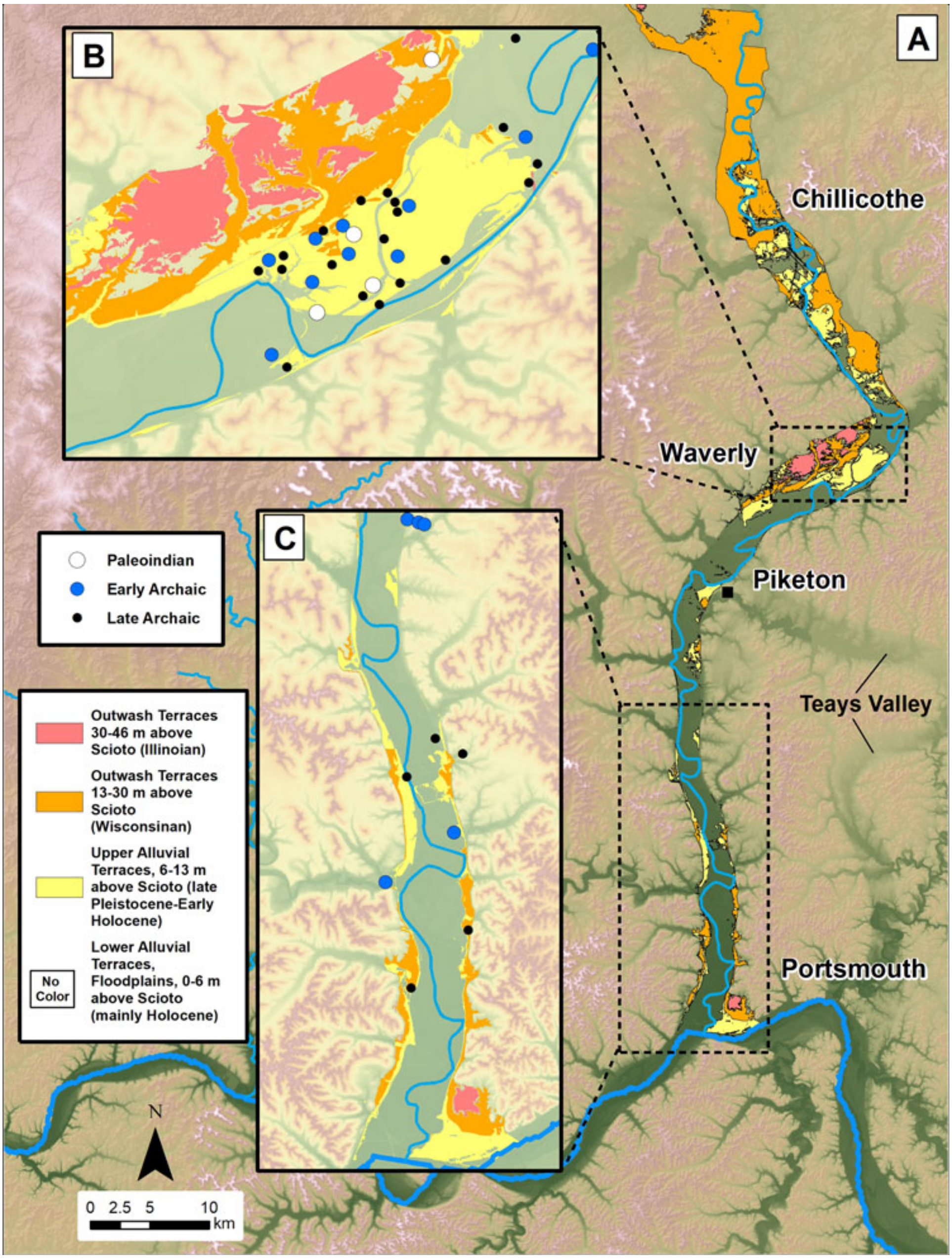

Figure 4. Geomorphic surfaces of the MSV-LSV and distribution of Paleoindian and Archaic archaeological sites: (a) planview of MSV-LSV showing Illinoian (>130,000 cal BP) and Wisconsinan (~22,000–14,000 cal BP) outwash terraces and upper to lower alluvial terraces of late Pleistocene–Early Holocene age (<14,000 cal BP). Insets (b) and (c) provide examples of site distributions.

less-optimal OBC-BF valley, with its comparatively steeper terrain and constricted valleys. To better quantify the cost in travel hours between each route, the following section provides the results of a least-cost analysis (LCA).

Least-Cost Analysis

Least-cost analysis (LCA) is a common method to reveal early forager migration travel and resource-acquisition routes in the Americas

Table 3. Frequency Distribution of Paleoindian and Early Archaic Sites by Landform Type in MSV-LSV.

	Outwash Terrace (Illinoian)	Outwash Terrace (Wisconsinan)	Upper Alluvial Terraces	Lower Alluvial Terraces/ Floodplains	Total in MSV-LSV
Paleoindian	0	1	5	2	8
	(0.0%)	*(12.5%)*	*(62.5%)*	*(25.0%)*	*(100.0%)*
Early Archaic	0	19	13	6	38
	(0.0%)	*(50.0%)*	*(34.0%)*	*(16.0%)*	*(100.0%)*

(e.g., Anderson and Gillam 2000; Boulanger et al. 2015; Eren et al. 2016, 2019; Gustas and Supernant 2019; Krist and Brown 1994; Lothrop et al. 2018; Rademaker et al. 2012). Most traditional LCA studies in archaeology assume that human actors employ consistent decision-making behavior, possess complete environmental knowledge, and search for the most cost-effective—or optimized—route based on environmental factors of distance and topographic relief (Herzog 2013; Surface-Evans and White 2012:2; White 2015:407–408). Although some suggest that eastern-U.S. Paleoindians prioritized time optimization during seasonal trips (e.g., Lothrop et al. 2018:75), ethnographic data on forager decision making does not fully support this proposition (Kelly 2013:33–36). Non-optimal satisficing principles, or bounded rationality, often guide forager decisions, including selection of the first option that surpasses some acceptable threshold (e.g., Golledge 2003; Morgan 2015; Simon 1956). As Golledge notes, "Wayfinders are often satisfied with the act of reaching a destination while paying little heed to how effective or efficient they have been in pursuing the wayfinding task" (2003:25). This observation provides pause for studies that assume, a priori, rational optimality when interpreting LCA travel routes, especially when done in the absence of archaeological support. This study considers the results of the LCA as a null hypothesis tested against archaeological evidence to evaluate potential travel routes.

With this caution in mind, this study employs LCA to quantify the travel effort, measured in hours, to traverse the OBC-BF and LSV routes connecting Sandy Springs to Upper Mercer–Vanport outcrop areas. This represents a straight-line distance of approximately 180 km. LCA workflow for this study replicates White's (2015) workflow and includes the creation of friction and cumulative cost raster surfaces derived from DEM (30 m resolution) and degree-slope raster files. This study uses the Mean Center tool in ArcMap 10.5 to create a single node that reflects the geometric mean of the Upper Mercer and Vanport outcrop areas to facilitate LCA creation. The Mean Center approach is necessary because, aside from the Welling site (Miller et al. 2019; Prufer and Wright 1970), specific Paleoindian quarries are unknown as Upper Mercer and Vanport chert outcrop broadly over 2,700 km^2 of land (Carlson 1991; Stout and Schoenlaub 1945).

Because more sophisticated LCA workflows that model additional environmental and social "costs" of travel (e.g., Güimil-Fariña and Parcero-Oubiña 2015; Gustas and Supernant 2019; Livingood 2012) are not utilized, LSV and OBC-BF routes constructed here are considered the *minimal* effort required to travel on foot between locations. Following White (2015:409), this workflow employs a modified version of Tobler's hiking function (Tobler 1993) that quantifies travel by determining the number of hours required for an individual to traverse the distance of each grid cell (or 30 m in this case). Below is the formula to calculate time:

$$T = \frac{\frac{R}{1000}}{6{*}e^{-3.5{*}\left|\tan\left(D{*}\frac{\pi}{180}\right)+0.05\right|}}$$

T = travel time (hours)
R = DEM spatial resolution (30 m in this case)
D = slope in degrees

LCA Results

The first step in LCA is to determine if the optimal route between Sandy Springs and Upper Mercer–Vanport outcrops involves travel

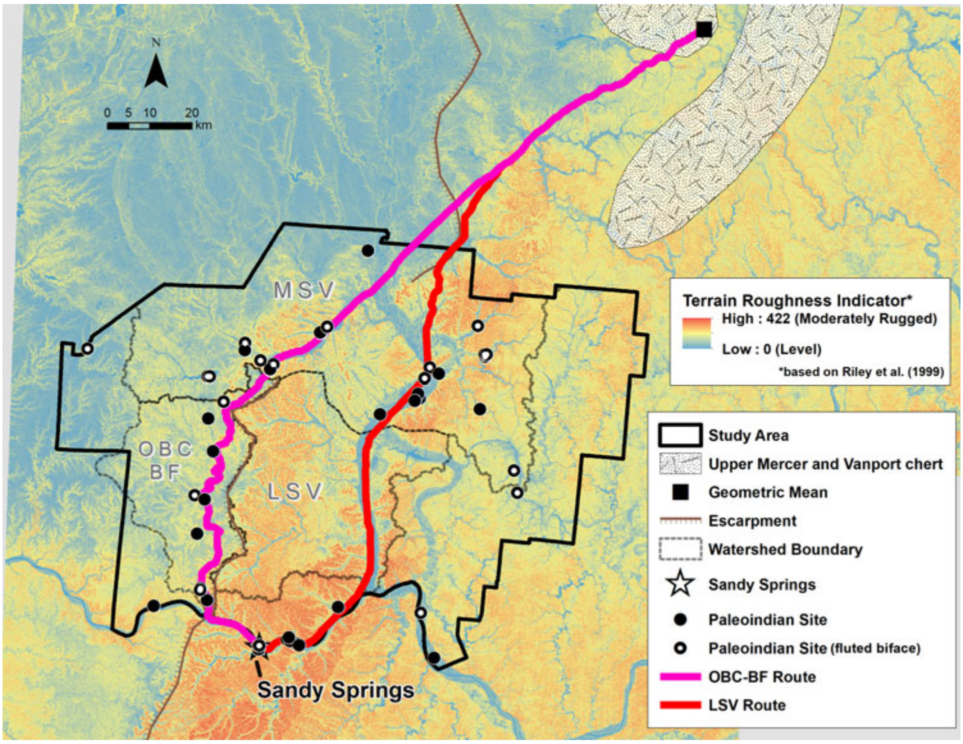

Figure 5. Results of LCA analysis showing the creation of two potential travel routes, LSV and OBC-BF, connecting the Sandy Springs site to Upper Mercer–Vanport chert outcrops. Travel routes set against a terrain roughness map were generated utilizing Riley and colleagues' (1999) Terrain Roughness Indicator formula. Please note that archaeological site distributions are only mapped for study area.

through LSV, as originally hypothesized. Unsurprisingly, LCA results indicate that the LSV route is the optimal route path connecting the two locations (Figure 5). Using Sandy Springs as a starting point, the generated LSV route proceeds east along the Ohio River, enters the LSV at its mouth, and moves north through MSV until just south of Chillicothe, where it enters several smaller tributaries skirting parts of the Wisconsinan glacial boundary. The LSV route is 209 km long with a mean slope of 1.3° and a maximum slope angle of 15°. LCA estimates a total of 46 hours of travel time between Sandy Springs and Upper Mercer–Vanport chert outcrops.

Although LCA indicates an optimal travel corridor, LSV route use is unsupported with current OAI data. Instead, archaeological data suggest travel through the more rugged OBC-BF valley via a longer route path. To quantify the costs associated with this alternative route, this study created a second LCA route through the OBC-BF valley by using the Mask tool in ArcMap 10.5 to block potential travel through LSV (Figure 5). The generated OBC-BF route proceeds from Sandy Springs west up the Ohio River until it enters Ohio Brush Creek at its mouth, moves north to northeast into the Baker's Fork drainage, and then into the Paint Creek valley of the MSV watershed before entering the deglaciated landscape just north of Chillicothe. The final OBC-BF route is 234 km long, with a mean slope of 1.7° and a maximum slope angle of 32°. Through extraction of travel costs from the friction raster, LCA estimates a total of 54 hours of travel time for the OBC-BF route. Given these values, the OBC-BF route reflects a 17% increase in travel time over the LSV route and traverses generally steeper terrain. From an energy and time allocation perspective, the OBC-BF route is not optimal for travel, yet it closely matches the known distribution of Paleoindian sites.

Modeling Distribution Data with Landscape Learning and Risk-Sensitive Analysis

This study now explores Paleoindian site patterning in southern Ohio from two theoretical perspectives: landscape learning and risk-sensitive analysis. This plurality allows for development of an explanatory model that integrates cultural, historical, and evolutionary elements while analyzing decision making for late Pleistocene foragers. Some may question the application of landscape learning theory for a Paleoindian dataset under the premise that there is little chance of observing truly colonizing behavior due to low fertility rates and low archaeological visibility of initial migrants (cf. Surovell 2000). Although this may be true to some degree, it is argued that the warm-cold paleoclimatic oscillations associated with the Bølling-Allerød to Younger Dryas to Holocene created dynamic late Pleistocene environmental/climate patterns with responding hydrological/geomorphological evolutions (e.g., Holliday and Miller 2014; Knox 1995; Meltzer and Holliday 2010; Shane 1994; Yu 2000; Yu and Eicher 2001). This dynamism undoubtedly complicated—and lengthened—attempts at landscape learning by early foragers in southern Ohio beyond the initial colonizing event. This especially is true when obtaining limitational environmental knowledge (Rockman 2003, 2009), defined as long-term cyclical trends such as flood recurrence intervals or seasonal precipitation patterns. As Rockman illustrates (2003:5), it takes generations to acquire limitational knowledge, perhaps longer on recently deglaciated landscapes similar to LSV (e.g., Loyola et al. 2019; Tolan-Smith 2003). Under these conditions, it is expected that landscape learning continued throughout the Paleoindian period.

The presence of sites containing fluted bifaces paralleling the Allegheny Plateaus escarpment in the OBC-BF valley indicates route establishment during the early Paleoindian period, specifically Clovis. Although most acknowledge a pre-Clovis population in the Americas, most also view Clovis as a population that migrated into a largely unoccupied, poorly understood terrain (e.g., Meltzer 2009). Adjacency to the visible escarpment accords well with predictions of landscape learning theory for wayfinding groups possessing incomplete environmental knowledge (Rockman 2003, 2009), notably the use of easily legible geographies for travel such as river valleys, linear mountain ranges, and escarpments (e.g., Golledge 2003; Kelly 2003; Kelly and Todd 1988; Meltzer 2003:226–229, 2004:133; 2009:223). For foragers exploring dynamic and evolving landscapes, decisions to establish early trail systems likely involved settings that increased trail visibility and ease of relocation, rather than ones that simply increased travel efficiency (e.g., Anderson 2012:242; Golledge 2003:25; Rademaker et al. 2012:34). Furthermore, the OBC-BF route may have been part of a previously reported early travel corridor connecting the unglaciated Cumberland, Ohio, and Tennessee drainages (Purtill 2017:171; Seeman and Prufer 1982:157–158) to northern deglaciated landscapes along the combined escarpment system of the Cumberland Plateau and Alleghany Plateaus.

A second potential reason for the initial establishment of the OBC-BF travel route is that it represented "familiar" territory given its location in the karstic, prairie-rich Bluegrass section of the Interior Low Plateau Province (Braun 1928; Brockman 2006; Fenneman 1928). The OBC-BF watershed represents the northernmost extension of the Interior Low Plateau, with the escarpment zone of the Cumberland Plateau and Allegheny Plateaus accounting for the eastern edge of this province. Proximity to physiographic boundaries is a documented pattern for eastern-U.S. Paleoindian sites given that populations likely exploited edge habitats (Miller 2016:710; Tune 2016b:310). To the south, the Interior Low Plateau includes the Tennessee and Cumberland drainages, a region rich in Paleoindian material (e.g., Anderson 1990, 1995, 1996; Anderson et al. 2015; Broster et al. 2013; Miller and Carmody 2016; Tune 2016a). By contrast, limited evidence exists of Paleoindian utilization of the Appalachian Plateaus that contains LSV (e.g., Anderson and Faught 1998:175; Lane and Anderson 2001; Prufer and Baby 1963:62–63; Seeman and Prufer 1982).

It is likely that Paleoindians traveling north into the Ohio Valley initially favored the

Bluegrass section due to its environmental similarities with southern settings. In this sense, Paleoindians may simply have expanded home ranges within homogenous ecological macroenvironments, thereby facilitating the transfer of accumulated environmental knowledge to new landscapes. Other studies of late Pleistocene foragers in the Americas suggest similar exploration and colonization of homogenous landscapes (e.g., Johnson et al. 2006; Loyola et al. 2019; Meltzer 2004; Osorio et al. 2017). Although initial OBC-BF route establishment may be due to the highly legible escarpment landscape, this fails to explain why Paleoindians never adopted the optimal LSV route once they learned of the valley's existence. Foragers assuredly encountered LSV early in their seasonal and annual movements, and it is likely that they actively explored valley margins during scouting or hunting forays (Meltzer 2002, 2004).

Although various reasons could account for a deliberate avoidance of LSV by Paleoindians, many of which are untestable with archaeological evidence, this study proposes that such behavior represents the adoption of risk-averse behavior by early foragers facing a stochastic environment. Risk-averse individuals avoid "behaviors linked to unpredictable outcomes in favor of more certain ones" (Winterhalder et al. 1999:303), which relates to optimal foraging theory, behavioral ecology and economics, and human cognition studies. Risk-averse theory in anthropological studies defines gains or losses from the perspective of fitness (survival and reproduction) and utility (efficient energy expenditure and time allocation; e.g., Winterhalder 1986, 2007). Referred to as the "certainty effect" in prospect theory (e.g., Kahneman and Tversky 1979:262; see also Tversky and Kahneman 1992), behavioral and cognitive studies demonstrate that risk-averse individuals avoid probabilistically ambiguous outcomes even when such outcomes have higher probability of gain compared to more constant ones (e.g., Mukherjee et al. 2017; Rode et al. 1999; Sharp et al. 2012). Finally, cognitive and behavioral studies reveal that humans consistently overestimate the probability of catastrophic, or low-probability, events (e.g., Armantier 2006; Kahneman and Tversky 1979; Taleb 2010). This implies that experience with rare events—for example, catastrophic floods—significantly influences how individuals weigh potential choices in the decision-making process.

Large rivers such as the Scioto had higher, more variable discharges during the late Pleistocene when compared to modern flow regimes (e.g., Arbogast et al. 2008; Holliday and Miller 2014:228–233; Knox 1995). The potential for catastrophic floods increases with higher discharges, notably downstream. Even today, modern floods often inundate significant portions of the valley bottom, especially near LSV's confluence with the Ohio River (see Figure 2a–b). In alignment with risk-aversion behavior, the mere memory of past flood events may have heightened subjective uncertainty among Paleoindians, even if actual probabilities of high-magnitude flooding in LSV remained low annually.

During the late Pleistocene, the Scioto River likely fluctuated between unstable braided and single-thread river planforms. Such fluctuations occur in response to episodic increases in sediment load, including occasional release of stored glaciofluvial sediments during high-magnitude floods or extreme paleoclimate events (e.g., Younger Dryas Chronozone; Knox 1995:94). During braided stages, rivers have variable discharges, and they are transitory, with complete reworking of geomorphic units within a matter of years (e.g., Ashmore 1991; Malard et al. 2006; van der Nat et al. 2003). For example, van der Nat and colleagues (2003) report that approximately 60% of the aquatic area and approximately 30% of vegetated channel bars on the Tagliamento River (Italy) experienced complete restructuring in just 2.5 years. The transitory nature of in-channel geomorphic units in the LSV during braided stages would hamper travel attempts as trail systems became impassable or destroyed. Minimally, constant trail reestablishment would increase travel outcome variability, especially for recently deglaciated landscapes such as LSV (e.g., Loyola et al. 2019; Tolan-Smith 2003). Probability overweighting in such settings may have been exacerbated under instances of high residential mobility (e.g., Goodyear 1989; cf. Meltzer 2004) as vulnerable group members such as the very young and very old were prone to injury or death due the stochastic environment.

In addition to travel outcome uncertainty, the late Pleistocene LSV also may have been generally inhospitable to humans, and perhaps even to migrating animal herds, due to environmental degradation and habitat fragmentation that accompanies sudden increases in sediment load. The presence of sandy loess sediments on adjacent, easterly alluvial surfaces and uplands in the valley (Rutledge et al. 1975) suggests eolian deflation of newly created braid bars and alluvial plains. Although undated in the Scioto Valley, sandy loess deposition on high alluvial surfaces at Sandy Springs date to the late Pleistocene–early Holocene (Purtill et al. 2019). Contemporary eolian deflation and subsequent transport likely occurred in the Scioto Valley, perhaps increasing air dustiness and deposition of fine sediment in rivers. Elevated dustiness increases health issues related to respiratory functions (Karanasiou et al. 2012; Mitsakou et al. 2008). Excessive fine sediment in rivers decreases water quality through increases in salinization due to the dissolution of solids.

In contrast to LSV, the more geomorphically stable OBC-BF valley would facilitate acquisition of landscape knowledge and reduce travel outcome variability, although at the expense of higher energy expenditure due to the longer path route. Given its single-thread planform and low volume of stored glacial outwash, OBC-BF likely possessed fewer in-channel physical obstacles than LSV, such as transitory gravel bars or islands. LCA results indicate that under optimal conditions without significant delays, foragers would expect a 17% decrease in utility—that is, increase in travel time—for travel along the OBC-BF route in lieu of the LSV route. It is interesting to note that in their study of decision-making under risk, Sharp and colleagues found that most participants followed the certainty effect except in situations where "the less likely proposition had an expected value of 38% or more than that of the safer prospect" (2012:6). This suggests that even with risk-averse behavior, individuals may select choices of high outcome uncertainty but only when the expected value—or reward—crosses a specific threshold. For Paleoindians in southern Ohio, this study suggests that any potential gains for travel through LSV failed to offset the more certain travel outcomes associated with the OBC-BF route.

Discussion and Conclusions

This study interprets the avoidance of LSV as an adoption of a risk-averse strategy to limit outcome variability during travel by Paleoindians operating in the upper Ohio River Valley. The preference for travel through the longer OBC-BF route rather than the shorter, more optimal LSV route has several implications concerning Paleoindian land-use behavior in eastern North America. This study suggests that factors embedded in landscape learning and risk-aversion theories motivated decisions concerning trail placement and continued use in the seemingly less efficient OBC-BF valley. Intensive use of a smaller, more constricted valleys such as OBC-BF contrasts with many cited Paleoindian land-use behaviors, including a preference to utilize major river valleys and avoid rugged terrain (e.g., Anderson and Faught 2000; Anderson and Gillam 2000; Lane and Anderson 2001; Seeman and Prufer 1982; Tune 2016b). Although current evidence for Paleoindian exploitation of LSV is absent, this study does not suggest that early foragers entirely avoided, or were unaware of, the "road not taken." It is likely that at least some valley exploration and accumulation of environmental knowledge occurred in LSV during the late Pleistocene. Current evidence, however, clearly indicates intensive utilization of the OBC-BF valley in lieu of the LSV. Future research should document the exact role site preservation or visibility plays in modern site-distribution patterns for the study area.

Recently, Miller and colleagues (2019) and Eren and colleagues (2019) proposed an early Clovis settlement model for northeastern Ohio. They suggest that Clovis immigrants from the Ohio Valley entered northeastern Ohio carrying tools manufactured from nonlocal cherts such as Wyandotte or Dongola. Following a settling-in phase that included discovery of local Upper Mercer–Vanport chert outcrops, Paleoindians migrated into Michigan and western New York, perhaps within the framework of seasonal rounds (Miller et al. 2019:67–68). Similarly at Sandy Springs, long-distance procurement of nonlocal sources by Paleoindian foragers is evident, including material from western Wisconsin (HSS [$n = 1$, 8%]), northeastern Ohio (Upper Mercer chert [$n = 9$, 68%]), and northeastern Kentucky (Paoli chert [$n = 2$, 15%]; Seeman et al. 1994). A reported Clovis-Gainey biface of HSS at Sandy Springs (Seeman et al. 1994; Tankersley 1994) is especially interesting given its linear 890 km distance from known outcrops. The presence of four clustered Clovis-age sites with HSS artifacts approximately 660 km from Sandy Springs on the Ohio River near Evansville, Indiana (Tankersley 1994:110–111), however, may be a more reasonable source of this material if we assume early migration up the Ohio River to Sandy Springs as part of what Miller and colleagues term a "long distance colonizing migration" (2019:67–68) event.

Although Clovis migrants may have arrived at Sandy Springs from the west, as predicted by the model of Miller and colleagues (2019) and Eren and colleagues (2019), Sandy Springs is distinct from northern Ohio sites such as Nobles Pond, Welling, Black Diamond, or Paleo Crossing in its apparent cultural ties to the Southeast. Clovis-Gainey bifaces of Paoli chert ($n = 2$) and 15 Cumberland bifaces of Dover and Paoli cherts suggest interaction with the Cumberland and Tennessee River drainages throughout the early to middle Paleoindian Period (e.g., Purtill 2017; Seeman et al. 1994:88; Tune 2016b). When coupled with evidence for repeated occupation during the entire period, Sandy Springs may be part of a settlement and mobility pattern distinct from contemporary sites in northeastern Ohio. Such landscape avoidance also may signal that early travelers in southern Ohio practiced leapfrogging or stepwise migrations (e.g., Anderson and Faught 1998; Anderson and Gillam 2000; Anthony 1990:902–903; Eren et al. 2019; Miller et al. 2019).

In summary, this study applied the principals of landscape learning and risk-sensitive analysis to model and interpret Paleoindian distributional data between the Sandy Springs site and Upper Mercer–Vanport outcrops. This study proposes that the presence of the Allegheny Plateaus escarpment, which served as a visible marker for wayfarers still learning a novel landscape, influenced the initial decision to establish the OBC-BF trail. Following regional exploration, Paleoindians undoubtedly became aware of the broad LSV, but they perceived travel through the valley as potentially dangerous and uncertain due to its dynamic hydrogeomorphic regime. Accordingly, Paleoindians adopted a risk-averse strategy and avoided LSV despite its potential benefits in reducing travel time between Sandy Springs and chert outcrops. Transition to a more stable, vertically accreting hydroregime in the LSV may not have occurred until the mid-Holocene (e.g., Herrmann and Monaghan 2019), and archaeological data only support significant occupation of the LSV catchment beginning in the Late Archaic (see also Purtill 2009).

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Data Availability Statement. Archaeological site data used here are available through the Ohio Historic Preservation Office, Columbus, Ohio. Geomorphic surface data in Figure 4 and LCA results in Figure 5 are available from the author.

Note

1. The more common χ^2 statistic was not calculated for this dataset due to the fact that 22% ($n = 2$ of 9) of cells in the 3×3 contingency table yielded expected cell frequencies <5, a violation of one of the assumptions of the χ^2 statistic (Field 2009:690–692). In lieu of a χ^2, this study calculated a Fisher's exact test, which computes the exact probability of the χ^2 statistic to account for the small sample size in the data (Field 2009:690).

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