

RESEARCH REPORT

Paleoindian Settlement Decisions in the Great Basin: A Test of the Pluvial Lake Hypothesis with the Ideal Free Distribution Model

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ABSTRACT

Researchers propose that early Great Basin occupants preferentially settled near pluvial lakes to exploit highly profitable wetland habitats. Here we offer a preliminary systematic evaluation of this Pluvial Lake Hypothesis by testing two predictions from an ideal free distribution (IFD) model using a comprehensive database of radiocarbon-dated archaeological sites relative to reconstructed lake extent. We find that Paleoindian (>8000 calendar years ago) settlements are significantly closer to wetlands than random across the Great Basin. However, when broken out by subregion (western, central, and eastern), the trend only holds for the western basin, likely because wetlands are so abundant in the central and eastern subregions that even random settlements fall within a 10-km foraging radius. The eastern subregion is the most suitable, having the lowest average distance to wetland habitats, and is the earliest occupied, which supports IFD predictions. This general pattern may help explain Paleoindian settlement patterns more broadly.

KEYWORDS

Paleoindian; Prearchaic; behavioral ecology; ideal free distribution; geographic information systems

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1. Introduction

Researchers hypothesize that early occupants of the Great Basin preferentially settled near highly profitable wetland habitats (Adams et al. 2008; Duke and King 2014; Goebel et al. 2011; Elston and Zeanah 2002; Elston et al. 2014; McGuire and Stevens 2017; Sanchez et al. 2017) associated with Pleistocene pluvial lakes that were ubiquitous throughout the region (Martin et al. 1990; Grayson 2011; see Figure 1). This Pluvial Lake Hypothesis is based on the notion that these environments would draw in game, fish, and waterfowl, offering the most profitable resources (following Charnov 1976a) available to terminal Pleistocene Great Basin foragers (Elston et al. 2014; Goebel et al. 2022; McDonough et al. 2022). This may be particularly true as lake levels receded, but before complete desiccation, when models suggest the availability of wetland habitats may have increased (Duke and King 2014). The hypothesis is empirically supported by Adams et al. (2008), who show that pluvial lake levels predict human settlement distribution near Lake Lahontan. It is also supported by Elston and Zeanah (2002; Elston et al. 2014), who show that Paleoindian settlement in Railroad Valley is disproportionately clustered in association with proposed wetland habitats when compared to Archaic sites. Sanchez et al. (2017) also support the argument, showing that Paleoindian tool types (crescents) are found 99% of the time within 10 km of wetland environments. However, while empirically supported within some basins or subregions or with some artifact types, the Pluvial Lake Hypothesis has yet to be tested systematically throughout the Great Basin within a theoretically-informed framework.

Here we offer a preliminary evaluation of the Pluvial Lake Hypothesis using a comprehensive database of radiocarbon-dated archaeological sites (Figure 1; Gajewski et al. 2011; Chaput and Gajewski 2016; Kelly et al. 2022; Martindale et al. 2016; Meyer 2020; Thomas 2013) to evaluate predictions derived from the ideal free distribution model (IFD; Fretwell and Lucas 1969). Supported by simulations (e.g., Tyler and Hargrove 1997) and ethnographic tests (e.g., Moritz et al. 2014), the IFD outlines how individuals with perfect knowledge of their environment and who are "free to move" should preferentially settle in the most suitable (i.e., energetically profitable) habitats, only occupying less suitable locations when competition in the best locations drives down per capita yields (Figure 2; for reviews see Coddling and Bird 2015; Weitzel and Coddling 2022).

In this analysis, we operationalize suitability following the logic Magargal et al. (2017) outlined. The most suitable locations to settle should be near or within habitats where foragers can acquire the highest in-patch returns (Charnov 1976b; Orians and Pearson 1979). Applying this logic to the Pluvial Lake Hypothesis, we suggest that in-patch returns will be highest in wetland habitats associated with pluvial lakes, where a forager can maximize encounters with highly profitable resources. Given that these wetland habitats have the most profitable resources (Zeanah 2004; Elston et al. 2014), settlers seeking to maximize their energetic foraging yields should preferentially settle near these pluvial wetland habitats to minimize travel distance from resource patches to home bases (Zeanah 2004). Thus, settlement suitability should co-vary inversely with the distance to pluvial lakes. The average distance to wetland habitats available for settlement can then characterize the suitability of a region. Using distance to wetland patches as a proxy for habitat suitability and following previous archaeological applications of the IFD (e.g., Coddling and Jones 2013; Jazwa and Jazwa 2017; Winterhalder et al. 2010), we derive two empirically testable predictions:

Prediction 1: The earliest people in the Great Basin should preferentially settle near wetland habitats.

Prediction 2: More suitable regions with shorter average distances to wetland habitats should have earlier occupation dates.

We evaluate these predictions by coupling reconstructions of pluvial lake habitats with the record of well-dated Paleoindian sites in the Great Basin (Chaput and Gajewski 2016; Gajewski et al. 2011; Kelly et al. 2022; Martindale et al. 2016; Meyer 2020; Thomas 2013). While limiting our sample to radiocarbon-dated sites may bias observations toward residential settlements in areas with good preservation and a history of intensive research, it has the advantage of creating a systematic sample that covers the entire breadth of the Great Basin from the eastern slope of the Sierra Nevada to the western slope of the Wasatch Front. More specifically, the focus regions are the western, central, and eastern subregions of the Great Basin delineated as Paleoindian lithic conveyance zones (see Jones et al. (2003), and more detail below). This study does not include the northern and southern peripheries (as defined below).

Because lake levels and associated wetland habitats fluctuated significantly over the Paleoindian occupation period (Anderson and Gillam 2000; Adams et al. 2008; Duke and King 2014; Goebel et al. 2011; Goebel et al. 2022), here we take a coarse-grained approach by calculating the distance to reconstructed Paleolake high-stands, historic lake levels, and modified historic lake levels (described below), creating a complete envelope of possible values. The results offer a broad, comprehensive evaluation of the Pluvial Lake Hypothesis across the western, central, and eastern Great Basin, providing a baseline for future research to develop more fine-grained assessments.

2. Materials and methods

2.1. Radiocarbon data

Chronological data were sourced from the Canadian Archaeological Radiocarbon Database (CARD). CARD was created to allow researchers open access to the vast amount of published radiocarbon data (Martindale et al. 2016). While CARD is available to the public, access to sensitive data requires researchers to be vetted and authorized before open access to CARD is granted. It should be noted that recent updates have masked location information (i.e., coordinates are county centroids, not site-specific), and dates from contexts associated with human remains have been removed from CARD. Thus, obtaining coordinates and information on culturally sensitive materials requires additional research following ethical and legal guidelines. CARD data were also supplemented with additional data provided by Meyer (2020) and Kelly et al. (2022). Site locations for the samples included here are available through the Nevada and Utah State Historic Preservation Offices. The authors have included a supplemental guide with reference information for the data used here (see online supplement GBC14PA Reference Guide).

To gather Paleoindian data from the Great Basin, CARD was queried to identify all available samples for the project study area. All non-cultural materials were removed (e.g., geological and paleontological contexts). Then all ages were normalized to account for isotopic fractionation, as some ages are only reported as measured or normalized but not both. We manually normalized the measured ages, where needed, using the material type or when none was cited, -25 ± 16 ppm for every ppm deviation to find the normalized age (Martindale et al. 2016). Using the R environment, the radiocarbon estimated ages were calibrated with the *Bchron* package (Haslett and Parnell 2008) using the *Intcal20* calibration curve (Reimer et al. 2020; R Core Studio Team 2022). We then subset the remaining calibrated ages to limit median age estimates ranging > 8000 calendar years ago (cal yr BP). We use the median age taken from the calibrated upper

97.5 and lower 2.5 to allow a single calibrated date in this assessment. The lead author then assessed each sample relative to the published literature's reported context and interpretation. If an age or sample was questionable (i.e., cultural context uncertain), it was removed (see online supplement GBC14PA Reference Guide). This resulted in a robust sample size ($n = 190$ across all three regions). For analysis, we further limited the sample to only the oldest date for each site to avoid over-represented distances to wetlands from well-dated sites. Once these duplicates were removed, the sample was reduced to 34 dated sites (Figure 1).

2.2. Study area

The project boundary was delineated into three subregions (western, central, and eastern) following Jones et al. 's (2003) and, more recently, Smith and Harvey's (2018) Paleoindian lithic conveyance zones, as to keep consistent with previous and ongoing research in the region. Conveyance zones are inferred from obsidian sourcing and are argued to represent semi-bounded regions within the Great Basin where sourced tool stone helps show the extent of the area traveled by Paleoindian foragers (Jones et al. 2003). The western subregion provides our analysis with 18 sites, the central offers four sites, and the eastern includes 11 sites. This results in a comparable radiocarbon-dated Paleoindian site density of 0.0007, 0.0002, and 0.0003 across an area of 22,897 km², 18,225 km², and 44,021 km² for the western, central, and eastern regions, respectively. This division is only used to delineate the subregions for these analyses and not to identify cultural affiliations. The northern and southern subregions of the Great Basin (i.e., southeastern Oregon and the Mojave Desert, respectively) were excluded from this assessment for ease of comparison and articulation from west to east. The authors' future direction will include watershed-scale analyses to see if any new forms of control will help interpret this type of data at smaller scales.

2.3. Pluvial lake reconstruction

Modern hydrologic geospatial data came from publicly accessible sites: United States Geological Survey (USGS), University of Nevada, Reno (Keck Library), National Hydrology Dataset, Department of Conservation and Natural Resources (Nevada Natural Heritage Program), and U.S. Fish & Wildlife Service (National Wetland Survey). Pleistocene lake level data were used to identify the maximum extent of pluvial lakes (Reheis 1999). In this assessment, we acknowledge that we cannot determine the recession of lake levels with temporal control (see Duke and King 2014) due to geological variables such as isostatic elasticity, and we only use the lake extent to identify the Late Pleistocene Pluvial Lake (LPPL) levels and modern extent of the wetland landscape to envelope all possible distances. Since settlement occurred after the LPPL, calculating the distance to wetland leads to elevated zeros since most observed dates are under the maximum elevation of LPPL lakes (Figure 1). The modern wetland dataset is also not a reliable substitute, given that it includes all water sources, such as ephemeral pools, which would not support wetland habitats. To remedy this, we apply hydrologic hygiene to manually modify the modern dataset to only include larger modern bodies of water for the analyses that were likely to support wetland habitats in the Late Pleistocene and Early Holocene. Though this approach will still overestimate the distance Paleoindian people had to travel to wetlands, the relative distances among sites should be comparable. It should also be known that the authors acknowledge the stabilization of lake extents during the Younger Dryas (YD) and believe that at the scale of this project area, more work in stitching together YD lake extents in the Great Basin is still needed to test equally across the project area. Duke and King (2014) discussed that future work combining geomorphological and archaeological methodologies is required to identify temporal changes in water elevation as the lakes receded.

2.4. Spatial and statistical analysis

2.4.1. Random points. To compare strategic human settlement decisions within each of the three subregions, we generated 1000 random points across the study area using the data management tool in ArcGIS (ESRI 2022). The random points offer a null settlement model that serves as a statistical comparison with the observed settlement data. The null model assumes the settlement distribution will not follow predictions derived from the IFD model (i.e., no strategic assessment of surroundings or resources when deciding to settle in the project area). Thus, the average random distance to wetland patches also offers a regional estimate of suitability by providing the average suitability available to settlers. We randomly distributed points without restriction to avoid introducing any bias into the null sample; however, because of this, some random points (~140) ended up in locations where humans could not settle (e.g., "underwater" or just out of the subregion boundary); these were dropped from the analyses.

2.4.2. Spatial analysis

We used proximity analysis to estimate the relative travel distance between dated material and wetlands. Specifically, we applied the Near Tool under the Analysis toolbox (ESRI 2022) to identify the closest wetland to each location (dated material and random points) and calculate the distance in meters. Because most of the sites used in this test are lower in elevation than the surrounding restrictive topographic features, the least cost path tool was not used to determine the distance of a site to a wetland. In the past, we conducted this test and found no significant differences in the outcome, and it adds unnecessary complexity to the overall mapping analyses at this large scale. As a note, future assessments on smaller scales could add in cost path analyses when comparable fine-grained data is available to add.

2.4.3. Statistical analysis and plotting

To compare variation in the observed settlement locations and the random points, we ran a series of Kolmogorov-Smirnov tests (KS tests) in the R environment (R Core Team 2022). Two-sample KS tests allow for statistical comparisons to identify the distribution of observed site locations in proximity to wetlands. Because the sample sizes vary across each subregion and are relatively small for the central subregion, we also implemented a method of up-sampling the total samples in each subregion to $n = 25$ and bootstrap the results for 10,000 iterations with replacement to evaluate the maximum settlement age and the median distance from wetlands within each region. The code used to complete the analysis and create the figures is provided as online supplementary information, sans location data, which must be gathered independently given federal restrictions (see online supplement GBC14PA Code Guide).

To ease the visual identification of the subregions for both the analyses and the readers, a package called *viridis*, a colorblind-friendly color pallet, was used in the R environment to create the figures for this project (Garnier 2018; R Core Team 2022).

3. Results

3.1. Prediction 1: The earliest people in the Great Basin should preferentially settle near wetland habitats

Across the entire project area (Figure 3), radiocarbon-dated sites are significantly closer to pluvial habitats than random point locations ($D = 0.35371$, $p < 0.001$), indicating that settlement is biased towards potential wetland habitats when compared to the random points. However, when breaking out the subregions (Figure 4), the trend only holds for the western subregion ($D = 0.66667$, $p <$

0.0001). In contrast, the central ($D = 0.20573$, $p = 0.644$) and eastern ($D = 0.013986$, $p = 0.9825$) subregions are not significantly different ($p < 0.05$) from random (Figure 5). The median distance between sites and wetland habitats is still around modern hunter-gatherers' average daily foraging radius of ~10 km (Lee 1969).

To ascertain if the sample size is biasing this result, we up-sampled ($n = 25$) the distances with replacement from each region 10,000 times to estimate the underlying population for both the random points and observed sites (Table 1; Figures 6 and 7). These bootstrapped results support the initial KS test, indicating that only early forager settlements in the western subregion were preferentially located near wetland habitats compared to random. However, a few sampling iterations identify significant differences from random in the central Great Basin (Figure 6). This finding helps to show that settlements across the central and eastern subregions may not differ from random. The CIs in the central and eastern subregions are farther than the western subregion but still fall within the average daily foraging radii of modern hunter-gatherers (Lee 1969; Figure 7), suggesting that marshland habitats could be accessed even with a random settlement decision.

3.2. Prediction 2: More suitable regions with shorter average distances to wetland habitats should have earlier occupation dates

We used the median distance from random points to wetlands as a proxy for the suitability of each subregion to represent the costs of foragers to access wetland habitats. This examination reveals that the eastern subregion is the most suitable, followed by the western subregion, and lastly, the central subregion. The earliest occupation in each subregion is identified by the oldest calibrated dates (Figure 8) and shows initially that the eastern subregion was occupied by 13,547 cal yr BP (Smith Creek Cave, Goebel et al. 2007), followed by the western at 12,224 cal yr BP (Pyramid Lake, Danise and Jerems 2005), and finally, the central at 12,091 cal yr BP (Sunshine Locality, Huckleberry et al., 2000).

Re-sampling the data to an up-sampled size of $n = 25$ from each subregion with replacement for 10,000 iterations reveals consistent patterning. The resampled earliest median age for the eastern subregion is 12,884 cal yr BP (95% CI, 12,560-13,547 cal yr BP), with the western settled next at 12,173 cal yr BP (95% CI, 10,710-12,224 cal yr BP), and finally the central at 12,091 cal yr BP (95% CI, 11,709-12,091 cal yr BP). Given that the CIs for the eastern subregion do not overlap with the western and central subregions, these results suggest that the eastern subregion was settled significantly earlier. The western subregion was settled second and the central subregion third, though these settlement times may have been identical given the overlapping CIs. Overall, these findings support the second IFD prediction.

4. Discussion

4.1. Prediction 1: The earliest people in the Great Basin should preferentially settle near wetland habitats

Our analyses indicate that the early occupants of the Great Basin did settle closer to wetland habitats than random; however, when looking at settlement by subregion, the trend only holds consistently for the western Great Basin, and for the central Great Basin in some re-sampling iterations. People in the western subregion preferentially settled closer to wetlands than random when compared by subregion. While the initial result supports the Pluvial Lake Hypothesis as tested, the differences between subregions offer some unique variation that requires further interpretations.

Possibly, given the ubiquity of marshland habitats in the central and eastern Great Basin subregions, foragers could have settled no different than random and still have been within a daily foraging radius of highly profitable resource patches. But there may also have been individual differences in subsistence-settlement adaptations in each subregion.

In the east, the large and relatively flat topography contains Lake Bonneville, which covers a substantial surface area of the subregion. Possibly it contained more substantial wetlands that we cannot catch in this scale of analysis. Compared to random, the eastern observed settlement locations are farther from the edge of a wetland polygon. Still, the extent of the wetlands during this time may have been more ubiquitous than in the western subregion, where topography restricts settlement locations. The wetlands react faster to climate change in steeper terrain (Duke and King 2014).

Trends in the central subregion suggest that something other than the distribution of wetlands may be driving settlement patterns. Specifically, dated sites in the central subregion are close to seven times (~ 13.6 km) farther from wetlands than in the western subregion (Figure 5). However, settlements are only ~ 3.6 km outside the average distance of 10 km for a daily foraging radius, which is not outside IFD predictions.

Given that the central subregion has a more dispersed distribution of numerous but smaller lakes, we suggest three possible avenues to help interpret the findings. First, possibly the dispersed wetland resources in the central subregion encouraged increased mobility, an adaptive land-use strategy not seen in the western and eastern subregions, which produces an increasing number of sites at intermediate distances away from wetland habitats. The maintenance of social networks and sharing of information from a non-utilitarian mobility pattern may be what we see in the central Great Basin (Newlander 2012). Second, possibly given that lakes were smaller and presumably hosted less wetland habitat, foragers reached diminishing returns sooner and had to rely on less suitable habitats (Elston et al. 2014). Third, our proxy, a composite of major modern wetlands, does not adequately capture the terminal Pleistocene and Early Holocene distribution of wetland habitats in the central subregion. Regardless of which is true, it is essential to note that the distance between the observed dates and wetland habitats is still around the ethnographically established 10 km foraging radius (Lee 1969), which indicates that Paleoindian foragers in all three basins had wetland habitats in their daily foraging range. It also suggests that there may not have been a bad place to settle in the Paleoindian occupation era until the region's climate shifted during the early Middle Holocene.

Jones et al. (2003) identified a similar pattern of differences in raw material conveyance zones across each subregion, with the central subregion differing from the western and eastern subregions. Their interpretations focus on possible geographical boundaries, which may have limited material movement longitudinally into neighboring subregions. The dispersed nature of the wetland habitats within the central Great Basin may have allowed for more dispersed site distribution. People were less tied to large bodies of water in the central subregion than the surrounding larger subregions.

The distribution of wetlands in the central Great Basin also may have benefited highly mobile groups who could have used the region to move quickly from location to location where the dispersed resources allowed them to resupply along the way instead of moving through a barren landscape as they moved to procure required material (Jones et al. 2003; Smith and Harvey 2018). In the central Great Basin, the dispersed wetland habitats may have allowed mobility to follow a

nonutilitarian pattern as people would need to travel greater distances to meet with other groups (Newlander 2012). The larger subregions along the peripheries of the Great Basin may have remained suitable enough for several thousand years so that individuals did not find it worthwhile to settle in the central Great Basin, as IFD predicts.

4.2. Prediction 2: More suitable regions with shorter average distances to wetland habitats should have earlier occupation dates

We measured suitability as the median distance (from random points) to wetland habitats, indicating less travel time to the most profitable locations. This pattern is identified by Zeanah (2004), where women's foraging goals would lead to locating more closely where abundant and less risky resources are readily available. Wetlands are closest to random settlement locations in the eastern basin, followed by the western and central Great Basin. The analysis shows that the earliest median date comes from the eastern subregion at 12,884 cal yr BP, followed by 12,173 cal yr BP in the western subregion, which has significantly more settlement locations near wetland habitats.

In reassessing this analysis, where the data were rerun for 10,000 iterations and a 95% CI is applied, the results are similar. Both results show that earlier settlement occurred in the eastern subregion (12,560-13,547 cal yr BP), where early settlers would be better supported by wetland habitats, which people preferentially occupied until competition drove down per capita yields and incentivized others to move into the western subregion (10,710-12,224 cal yr BP) and finally the more marginal central subregion (11,709-12,091 cal yr BP). While the earliest date comes from the eastern subregion, where settlement distances are significantly greater than the western subregion, the distance to a wetland is well within the modern hunter-gatherer foraging radius. Earlier dates may be discovered in the central subregion with additional archaeological investigations, which will benefit this scale of approach. These relatively short lags between subregions suggest that it takes only very small declines in suitability to incentivize movement to less suitable habitats, following O'Connell and Allen's (2012) IFD-informed modeling of the colonization of Sahul.

Paleoindian settlers relied on game (large- and small-bodied), fish, waterfowl, and other resources that were concentrated near wetland habitats, which would have offered the most profitable resources available to terminal Pleistocene Great Basin foragers (Elston et al. 2014; Goebel et al. 2022). As this period ended, more reliable but less profitable resources would have been exploited (e.g., Magargal et al. 2017; Zeanah 2004; Rhode and Louderback 2007; Goebel et al. 2022; McDonough et al. 2022), such as plants and seeds no longer tied to wetlands. With the data presented here, we show that denser wetland environments hold significantly higher numbers of occupations and earlier settlement dates.

The east-to-west patterning of the earliest dates in the Great Basin also could be used to infer the routes of early colonization. Here, we show that the eastern subregion, which contained the largest potential wetland area near Lake Bonneville, may have drawn people following a coastal migration route into the Great Basin via the Snake River corridor due to the presence of oldest-dated sites predating the appearance of suitable environmental conditions in the interior Ice-Free Corridor (Davis and Madsen 2020). More fine-grained work in the future may help elucidate this.

4.3. Potential issues and future work

While using radiocarbon-dated material avoids any issues surrounding the potential association of temporally sensitive artifacts, it also reduces the overall sample size because there are fewer radiocarbon-dated sites (e.g., Sanchez et al. 2017). This is partly due to the factors that restrict the deposition and preservation of organic material, which should be limited to specific contexts that are relatively shielded from taphonomic loss (Surovell et al. 2009). Thus, while this study underestimates the total number of Paleoindian sites by limiting them to well-studied contexts with good preservation, we suggest the spatial distribution of these sites relative to wetland habitats should be representative of residential sites overall. We also suggest that the radiocarbon dates used in this paper offer a starting point for gathering more robust data to delve deeper into the behavior of early settlers of the Great Basin, including fine-grained evaluations of settlement relative to more temporally precise lake-level reconstructions as well as including the temporally discrete lithic record of diagnostic bifacial points.

The combination of this type of assessment with robust date associations of projectile point types (e.g., Davis et al. 2022), and their locations around lake margins (e.g., Rosencrance 2019), would help to understand better how the distribution of non-residential sites may differ from what we report here. Suppose the variation in distance to wetlands holds. In that case, future investigations in the central Great Basin may be better informed by adapting survey methodologies to include landforms that would have been available to Paleoindian settlers at greater distances than the average foraging radius.

In recent years, a growing number of archaeological assessments have turned to using radiocarbon dates to inform on population densities where data are available (e.g., Chaput and Gajewski 2016; Contreras and Meadows 2014; Robinson et al. 2019). In short, the 'dates as data' approach uses summed radiocarbon dates as a proxy to inform on population density. The more substantial the population, the more material is left in the archaeological record. In the case of the analysis reported here, we did not have a large enough sample of well-dated sites in the project area to appropriately simulate relative population densities across the period of interest. Therefore, we have not strictly assessed populations using such methods. However, we use the basis of the 'dates as data' approach to infer that where there is more radiocarbon-dated material generally, it means that a more substantial population was needed to create the archaeological footprint.

To the extent that radiocarbon-dated Paleoindian sites are a marker for population density, the eastern and western subregions of the Great Basin have a more significant number of dates. Using the modified 'dates as data' approach, we can provisionally infer that these subregions had greater population sizes than the central subregion. However, future work will require more research into using dated material to assess this finding, as our sample size is meager.

We also have larger samples in the mesic regions compared to the xeric central subregion. As is expected by IFD predictions, the most productive basins hold the most profitable wetland environments. Following Prediction 2 and the shortcoming of sample size, this assessment could benefit from a more robust dataset to evaluate the clustering or dispersion of dated sites through time (Robinson et al. 2019).

5. Conclusion

To test whether early foragers followed theoretical predictions derived from IFD, we gathered Paleoindian radiocarbon-dated site data and statistically compared settlement locations in three

subregions of the Great Basin to randomly created site locations. The available data support both predictions of the Pluvial Lake Hypothesis. While the sample size of radiocarbon-dated Paleoindian sites is relatively small, more work in the project area will offer more robust datasets in the future to reassess our findings. These preliminary results show that early occupants of the Great Basin preferentially settled near wetland habitats. We hope this project provides a starting point to examine theoretically-derived predictions with quantitative data about Paleoindian foragers' settlement decisions.

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Disclosure statement

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FIGURE CAPTIONS

Figure 1 Project area map showing the extent of analyses with subregions identified and both Late Pleistocene Pluvial Lake (LPPL) extent and modern lake levels.

Figure 2 Graphical representation of the ideal free distribution model (IFD) indicating where individuals should settle first (point 1), only switching to the next-best basin when population density drives down suitability in the best basin (point 3). The Pluvial Lake Hypothesis derived from the IFD Model indicates where one should stay in a basin (points 2 and 5) or ideally move to a new, more profitable basin (points 3, 6, and 7).

Figure 3 Cumulative Density Plot showing the distance to wetlands from both observed sites and random points across the Great Basin ($D = 0.35371$, $p\text{-value} < 0.001$). The vertical dashed lines indicate the median distances of the observed ages, and the dot-dash lines show the median distances of the random points.

Figure 4 Cumulative Density Plot showing the distance to wetlands from both observed sites and random points by subregion (Western: $D = 0.66667$, $p < 0.0001$; Central: $D = 0.20573$, $p = 0.664$; Eastern: $D = 0.013986$, $p = 0.9825$). The vertical dashed lines indicate the median distances of the observed ages, and the dot-dash lines show the median distances of the random points.

Figure 5 Boxplot showing the distance (m) from observed sites and random points to wetland habitats in the Great Basin grouped by subregion. The dashed line indicates daily hunter-gatherer foraging radii at 10 km (Lee 1969).

Figure 6 Bar plot showing the frequency of D statistic for each model iteration of the up-sampled median distance (m) from sites and random points in each subregion. The vertical line indicates the cut-off for significance at the 0.05 level; significant model runs are color-coded in red.

Figure 7 Whisker plot showing the up-sampled median distance (m) from sites (color-coded dots) and random points (gray background) in each subregion to wetland habitats with bootstrapped 95% confidence intervals.

Figure 8 Whisker plot showing earliest median radiocarbon dates by subregion with upper and lower CIs based on the resampled ages.

Table 1 Summary table showing median distance of sites and random points with confidence intervals after bootstrapping.

Region	Variable analyzed	Median distance	Lower CI	Upper CI
Western	Sites	1880.08	1214.56	3128.49
	Random points	7561.82	4,673.06	10,961.17
Central	Sites	13,600.64	6472.35	13,600.64
	Random points	10,424.82	7251.06	15,123.92
Eastern	Sites	3027.81	1606.78	5415.01
	Random points	2200.915	1352.39	3130.31