A SPATIAL ANALYSIS OF PLEISTOCENE-HOLOCENE TRANSITION SITES IN THE SOUTHERN COLUMBIA PLATEAU AND NORTHERN GREAT BASIN OF NORTH AMERICA

by

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Abstract

The Western Pluvial Lakes Tradition was proposed by Stephen Bedwell in 1973 to account for an early Holocene lake-marsh-grassland environment adaptation for hunter-gatherers living in the southern Columbia Plateau and western Great Basin of North America. Since then, archaeological site research and regional syntheses have supported this hypothesis with information on concentrations of early archaeological sites found on ancient wetland margins. However, Plateau-Basin archaeology tends to focus on site- and basin-specific analyses to support early subsistence-settlement hypotheses. To explore whether pluvial lakes were central to regional resource use and mobility patterns at the Pleistocene-Holocene transition, it is necessary to broaden the scale of analysis from typical basin-focused studies. Paleoenvironmental and archaeological spatial data from the Burns and Vale Oregon Bureau of Land Management districts are used in this thesis to explore the centrality of pluvial lakes for early peoples across the dynamic landscape of the Plateau-Basin region at the Pleistocene-Holocene transition. This research utilizes data collected in a cultural resource management environment to study spatial bias in data collection and analysis, as well as explore the potential benefits of using under-utilized isolate data collected in a cultural resource management research environment. The statistical analyses in this study confirm a regional association between early Holocene archaeological sites and pluvial lakes, but also indicate that the early Holocene economy was more diverse than is typically suggested in Western Pluvial Lakes Tradition research.

Keywords: Paleoindians; Great Basin; Pleistocene-Holocene transition; pluvial lakes; spatial analysis; Western Pluvial Lakes Tradition.

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Chapter 1: Evaluating the Concept of Early Holocene Resource Specialization in the Southern Columbia Plateau and Northern Great Basin

Water is life. Whether implied or expressly stated, anthropologists have acknowledged that watered places are important to human cultures. The perceived significance of waterbodies and wetlands is so fundamental to the study of the human past that the spatial and cultural centrality of these places is routine. As such, archaeological predictive models often define contemporary or ancient waterbodies as predictors of archaeological sites, thereby assuming watered places are primary attractors in subsistence-settlement practices (Church and Burgett 2000:143; Ebert 2000:130). Generations of archaeologists have collected data that can be used to fine-tune our knowledge of such spatial aspects of ancient cultures. In the interest of understanding the role of watered places in ancient lifeways, settlement models should be refined as archaeological site location databases expand. My study aggregates cultural resource management (CRM) site location data in the southern Columbia Plateau and northern Great Basin of North America, and utilizes exploratory spatial data analysis (ESDA) to discover statistical patterns in this data.

Due to the concentration of early Holocene archaeological sites and the long history of environmental archaeology in the southern Columbia Plateau and northern Great Basin region of North America, this region provides an opportunity to analyze the concept of wetlands having a prominent role in hunter-gatherer subsistence-settlement strategies. Over the past 40 years, Great Basin archaeological research consistently supports the Western Pluvial Lakes Tradition, which is the concept that large pluvial lakes were the center of early Holocene hunter-gatherer life (Bedwell 1973:170). These enormous lakes and fringing wetland ecosystems are believed to have offered hunter-gatherers irresistibly diverse and abundant resources. While Great Basin archaeological research confirms that wetlands and lakes were important places, basin-specific studies fail to situate lakeshores within the broader early Holocene landscape. Large portions of the landscape are not routinely considered in subsistence-settlement pattern discussions, and archaeological studies continue to be focused on sites near pluvial lakes. Statistical research is necessary to determine if the intuited lake-centered spatial patterns are truly representative of early Holocene lifeways.

History of the Western Pluvial Lakes Tradition Debate

Our understanding of ancient Great Basin culture developed rapidly in the mid-1900s following the first scientific studies of the region's prehistory. The earliest academic archaeological research in the northern Great Basin was fueled by Luther S. Cressman's desire to demonstrate that the region was occupied as early as the early Holocene. In the 1930s, Cressman began leading survey and excavation projects in the Guano and Catlow Valleys of southeastern Oregon (Cressman et al. 1940:1). These studies enabled Cressman to develop hypotheses about ancient northern Great Basin culture (e.g., Cressman 1942, 1947). Prior to the federally-sponsored River Basin Survey projects of 1947–1952, few anthropological research questions were associated with archaeological excavations in the Great Basin or Columbia Plateau. The intensive river surveys and excavations, as well as other inundation projects, allowed for the development of the culture history of the Great Basin and Columbia Plateau (Shiner 1961:157). By the 1960s archaeologists had new data with which to develop culture historical sequences and propose subsistence-settlement theories across the Northwest (e.g., Butler 1961; Daugherty 1962; Sanger 1967). After the introduction of the National Historic Preservation Act of 1966, which required federal agencies to study impacts on historic resources, federal agencies began to amass large archaeological datasets.

By the 1950s, archaeologists noted two characteristics about Great Basin Paleoindian peoples that have withstood decades of research: 1) early cultures in this region did not specialize in hunting megafauna, and 2) these cultures seemed to prefer living near lakesides. Due to a lack of evidence of megafauna and big game hunting, archaeologists concluded that the early Holocene inhabitants of the Great Basin subsisted on smaller animals and plant resources (e.g., Jennings and Norbeck 1955:2–3). At that time, the population was thought to have been highly mobile, moving between valleys and uplands during seasonal rounds (Jennings and Norbeck 1955:3). Northern Great Basin ancient cultures were apparently semi-sedentary, focusing their subsistence on lacustrine resources and rarely venturing into nearby deserts and uplands (Cressman et al. 1940:14; Jennings and Norbeck 1955:3). After thirty years of research, the association between relict lakes and early sites was formally defined as the Western Pluvial Lakes Tradition by Stephen Bedwell (1973:170–171). Like Jesse Jennings and Edward Norbeck (1955:3), and Luther S. Cressman et al. (1940) before them, Bedwell concluded that early Holocene peoples had focused their economies on the lake-marsh-grassland environment of the western Great Basin, with little or no reason to leave this zone.

Following Bedwell's definition of the Western Pluvial Lakes Tradition, Great Basin archaeological studies have largely supported the concept that pluvial lakes and fringing wetlands were central to the Great Basin economy (e.g., Aikens 1983; Bense 1972; Dansie and Jerrems 2005; Duke and King 2014; Livingston 2002; Pettigrew 1984; Pinson 2011; Thomas et al. 2008; Willig and Aikens 1988; Willig 1991). Many of these settlement pattern assumptions are based on artifact densities observed near wetlands. For example, Huckleberry et al. (2001:310) concluded that the size, stability, and productivity of wetlands led to concentrated activity in these areas. Oviatt et al. (2003:208) proposed that the size and stability of large wetlands in the early Holocene made it unnecessary for Great Basin cultures to migrate long distances to acquire resources. And Elston et al. (2014:201) argued that archaeological evidence for occupation outside the lowland wetlands is still very limited in the Great Basin.

Despite the support for a lake-centered early Holocene settlement pattern in this region, researchers have questioned the extent to which these early economies were in fact focused on lakes. Arguments against the lake-focused pattern include both a lack of observed patterns (Beck and Jones 1990:231) and what appears to be a more diverse settlement pattern (Aikens et al. 2011:71–72; Hoffman1996:101; Pinson 2004:75; Price and Johnston 1988:242–246). Clinton Hoffman (1996) tested the Western Pluvial Lakes Tradition (WPLT) hypothesis with archaeological data from northwestern Nevada, and concluded that site patterning was much more evenly dispersed on the landscape than expected based on previous studies of early Holocene pluvial lake use. Hoffman used the locations of 46 Great Basin Stemmed Series artifact sites in northwestern Nevada to study whether temporary camps and residential sites were found more frequently in low valleys or high valleys, with the assumption that pluvial lakes were situated in the lowlands (Hoffman 1996:73). Hoffman categorized archaeological sites as residential camps if they (a) contained more than four artifacts, (b) included projectile points and preforms, and (c) were either larger than 10,000 m^2 or contained other cultural features (Hoffman 1996:64). Sites that did not meet these criteria were classified as temporary camps. Each site was categorized as temporary or residential, and lowland or upland, and then site frequencies between uplands and lowlands were compared (Hoffman 1996:75). Hoffman's statistics and associated significance tests led him to conclude that both temporary and residential camps were more often located in uplands than lowlands, and that Western Stemmed Tradition peoples therefor had a much more generalized settlement patterns than what was proposed in the Western Pluvial Lakes Tradition hypothesis (Hoffman 1996:82-84). He concluded that the history of archaeological research in the Great Basin had resulted in an "interpretive inertia" that supported the central role of pluvial lakes because researchers were focusing on lake basins rather than sampling from underrepresented environments (Hoffman 1996:45).

Paleoindian Wetland Environment Exploitation

Paleoindians appear to have repetitively used wetland systems across North America (e.g., Custer and Mellin 1991; Nicholas 1990:127; Yansa et al. 2006). The proximity of many early sites to wetlands has often been used as evidence for wetlands having a central or at least significant role in early subsistence-settlement patterns in western North America (e.g., Aikens 1978; Boyd 2007:198; Dunbar 1991; Janetski and Hughes 2010; LeTourneau 2010). If wetlands were economically important and spatially central in subsistence-settlement strategies, then what aspects of these places made them so attractive to hunter-gatherers? Wetlands are areas of landscape that are at least periodically inundated by water, making them interfaces between terrestrial and aquatic land (Lyon 2011:9). Large freshwater wetlands are often classified as a type of marsh (i.e., playas, wet meadows, freshwater marshes, vernal pools), but the saturated land on the edges of freshwater streams, lakes, and other waterbodies are also wetlands (Environmental Protection Agency 2004:1; Lyon 2011:9). These transitional environments can be highly productive, reliable, and support biodiversity greater than that of surrounding environs (Gopal 2009:67–70; Nicholas 1988:269). Wetlands are considered important habitat for a broad range of life, including vegetation, waterfowl, fish, mammals, and reptiles (Environmental Protection Agency 2004:1). Rich and highly productive wetlands with abundant opportunities for hunting and gathering are logically very attractive places for foragers. As environments and resources fluctuated at the Pleistocene-Holocene transition, the abundance and reliability of certain wetlands or wetland resources may have made them considerably more attractive than resources in nearby environments undergoing more rapid change (Nicholas 2012:770).

Wetlands have high primary productivity generally, but their productivity and composition is highly variable (Clément and Proctor 2009:288). There tends to be an inverse relationship between primary productivity and biodiversity in wetlands, with highly productive wetlands dominated by a small number of species (Gopal 2009:80). In wetlands that are moderately disturbed by physical or climatic processes, less common species can compete with dominant species resulting in species richness (Clément and Proctor 2009:292–293). In these more disturbed settings, wetland biodiversity is largely composed of rare or endemic species (Gopal 2009:70). If early cultures sought select abundant species, then highly productive but less diverse wetlands would have made ideal resource collection places. In this case, species that are common throughout the region might have encouraged a relatively dispersed subsistence-settlement pattern. However, unless these common yet abundant resources fulfilled most subsistence needs, wetlands with abundant yet common species may have o only make up a portion of the overall settlement pattern. If rare wetland species made some wetlands more desirable resource collection places than other places on the landscape, then these wetlands may have been visited more frequently than others in addition to abundant but species-poor wetlands.

Given that Paleoindians in other parts of North America frequented wetlands as part of a subsistence-settlement strategy (Nicholas 1990), it seems unlikely that their counterparts in the Plateau-Basin region would focus their economy on pluvial lakes to the exclusion of other habitats. Site patterns in this region appear to be more consistent with tethered foraging, wherein foragers situate themselves near high-ranked resources, and are willing to expend energy seeking low-ranked resources near their important resource base (Binford 1907:7; Kelly 1995:91–93). Perhaps valued resources near pluvial lakes encouraged a tethered foraging pattern in this region throughout the early Holocene. Given that pluvial lakes and fringing wetlands covered large tracts of land, a tethered land-use pattern in the northern Great Basin might produce redundancy in land-use practices around pluvial lake basins rather than at specific limited extraction sites, as proposed by Binford (1980:7) and Kelly (1995:91–93).

Research Objectives and Methods

Were early cultures focused on pluvial lakes in the Plateau-Basin region, or is a pluvial lake-centered pattern the product of the region's archaeological research history? The objective of this thesis is to explore the Western Pluvial Lakes Tradition hypothesis via spatial analysis of archaeological site and environment associations in eastern Oregon.

The study area for this thesis encompasses the Burns and Vale Oregon Bureau of Land Management (BLM) districts, which contains portions of the Basin and Range (Great Basin) and Columbia Plateau physiographic provinces (Figure 1). Within the study area, the geography of portions of the Columbia Plateau is similar to the Great Basin, featuring internal drainage hydrography and basin and range topography. In this thesis, the area where the southern Columbia Plateau blends into the northern Great Basin is referred to as the Plateau-Basin Interface. A Western Pluvial Lakes Tradition region was defined for the present study to analyze the portion of the study area that once contained pluvial lakes (see Figure 1).

Three research questions were used to investigate early Holocene site patterning:

1. Did early Plateau-Basin cultures focus their subsistence-settlement practices in the Great Basin portion of the study area?;
2. Were early Plateau-Basin hunter-gatherer foraging patterns tethered to wetland dense regions rather than locally concentrated around particular wetlands?;

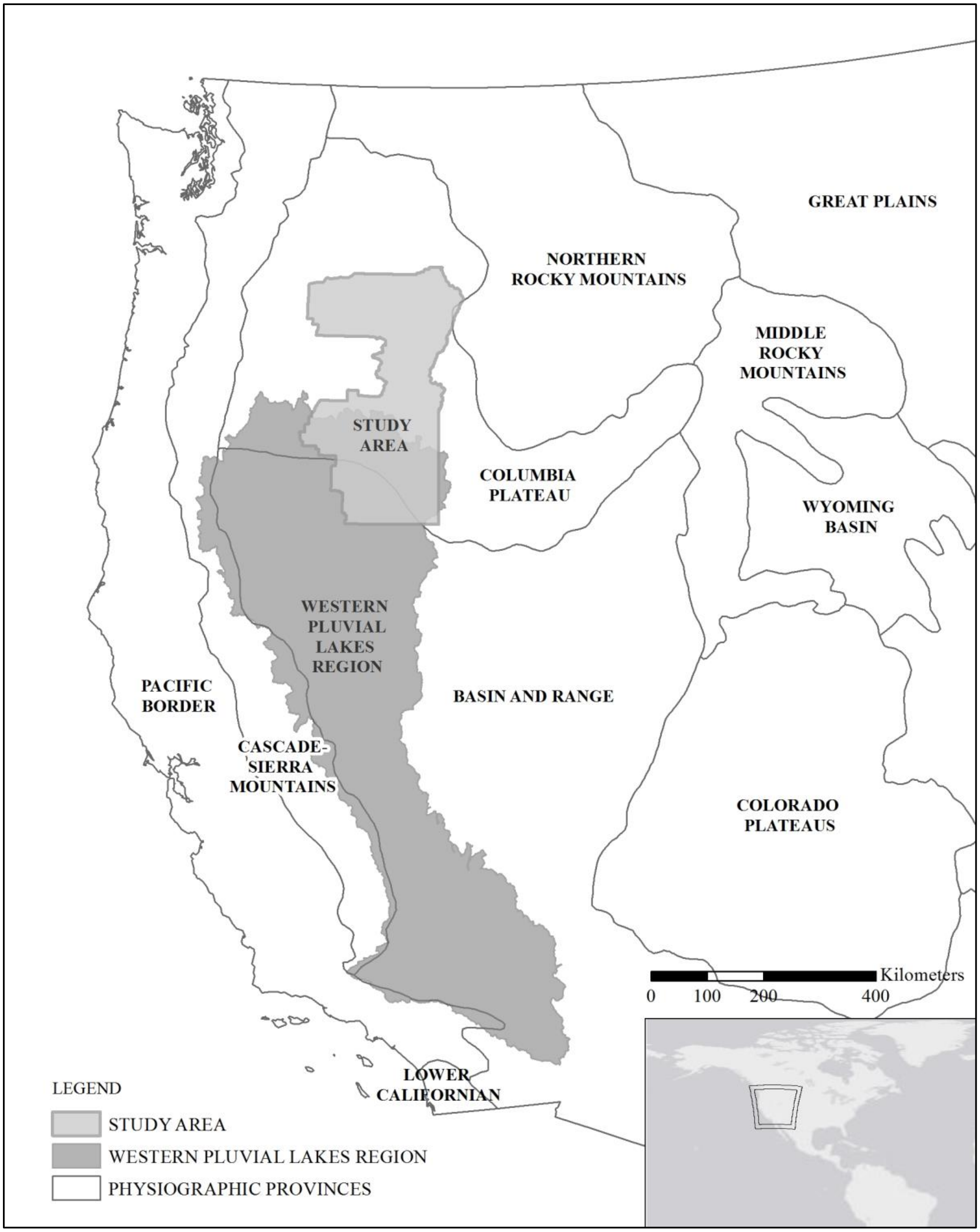


Figure 1. Physiographic provinces, Western Pluvial Lakes region, and study area. Basemap source: ESRI 2012; Physiographic data: USGS 2012.

3. Did early Plateau-Basin peoples focus their foraging activities on areas that were particularly dense with wetland concentrations?

These three research questions are aimed at discovering aspects of early Holocene site patterning within the study area, rather than simply rejecting or confirming the complex WPLT hypothesis. This deductive approach to analyzing an important subsistence-settlement theory has the potential to fine tune knowledge of settlement motivators in the region, as well as inform archaeological predictive modeling in the study area.

In the course of cultural resource management (CRM) studies conducted by the BLM, archaeological site and isolate data had previously been collected in the field and entered into district databases. For this thesis, I reviewed district site files in order to create a Geographic Information System (GIS) containing the location and type of 744 isolate lithic artifacts. The Early Holocene artifacts included Western Fluted, Black Rock Concave Base, Western Stemmed, Great Basin Transverse, and Cascade bifaces. Later Holocene artifacts were also incorporated into the study so that possible differences between early and later site patterns could be studied. Diagnostic lithic bifaces only reveal a small portion of ancient hunter-gatherer activities, but the recorded isolate artifact locations in this database are considered representative of Paleoindian subsistence-settlement patterns.

In addition to the archaeological spatial data, environmental data were also incorporated into the GIS to identify possible differences in how several major landscape types were used in the early Holocene. Environmental features included modeled pluvial lake shorelines, and extant playas, marshes, lakes, streams, and springs. The study area was subdivided in several ways so that environmental and archaeological differences between portions of the study area could be compared. Watersheds, the geographic area where water drains into a waterbody, have become the preferred geographic area for studying wetland impacts by the land and resource management industry (Ji 2007:xvii – xviii). One assumption I use in this thesis is that studying physiographic provinces and basin subdivisions like hydrologic units provide a means for discovering clustering within the study area. Subdivisions included the Columbia Plateau and Great Basin physiographic provinces, and the hydrologic units of basins, subbasins, watersheds, and subwatersheds in these provinces. This study also compared the distribution of sites and environment features both within and outside of an area that is defined here as the Western Pluvial Lakes Tradition Region. This region was defined by Stephen Bedwell (1973:170) as the area “from Fort Rock Basin (the northernmost point), south along the Cascade-Sierra-Nevada Uplift in western Nevada and part of northeastern California (in the region of Lake Lahontan) and finally south into the desert areas of southeastern California and pluvial Lake Mohave.” As Bedwell believed that the density of pluvial lakes in this area was a draw for early Holocene cultures, this region was bounded by his description and limited to watersheds that once contained pluvial lakes.

The GIS was also used to analyze potential site discovery biases in the study area. CRM project areas have been mapped by the BLM in the course of land management activities, and were incorporated into the GIS so that survey patterning could be analyzed and compared to environmental and archaeological site concentration differences across the study area. This research serves as an example of broader spatial and theoretical research questions that might be addressed with CRM geospatial data, and provides an opportunity to study potential data collection and analysis bias in the CRM industry.

Exploratory spatial data analysis was identified as the best means to assess the research questions identified in this thesis. Spatial analyses are formal techniques used to study the geographic positions of data, and can be used to show how observations are related across space (Lloyd and Atkinson 2004:151). The process of exploratory spatial data analysis (ESDA) involves visually exploring a spatial dataset, and may result in identifying errors in the data, forming hypotheses, and observing patterns or other interesting features of a dataset (Haining et al. 1998:457). In this study, ArcMap 10.1 (ESRI 2012) and SPSS Statistics 21 (IBM 2012) software were used to perform statistical analyses, including summary statistics, correlation analyses, cluster analyses, and autocorrelation analyses.

Organization of Thesis

This thesis is organized in five chapters. In this introductory chapter I have summarized the archaeological research history that has resulted in the continued support of the

Western Pluvial Lakes Tradition in the Great Basin region. There is some speculation among northern Great Basin archaeologists that Great Basin Paleoindian cultures did not conform to this relatively simple model of lake-marsh-grassland subsistence. I also identified three research questions for studying site-environment associations within the Western Pluvial Lakes Tradition hypothesis, and then outlined the dataset and spatial analyses that were used to study early Plateau-Basin subsistence-settlement patterns.

Chapter 2 provides detailed background on the environment and archaeology of the Pleistocene-Holocene transition in the Plateau-Basin region. The climate, topography, paleoenvironment, and biota of the southern Columbia Plateau and northern Great Basin are described, noting features that might have been attractive places for resource collection. The early diagnostic tools associated with the Western Pluvial Lakes Tradition are described. Environmental and archaeological information is then used in the chapter to model the locations of wetlands and archaeological sites, in order to identify and test correlations between paleoenvironmental features and early Holocene subsistence-settlement patterns.

The history of archaeological subsistence-settlement pattern studies is presented in Chapter 3. Based on this overview, I developed research questions and methods for testing site-environment associations. The value and status of GIS in archaeology is discussed before specific geostatistical methods relevant to the research object are identified. The chapter concludes with a discussion of how traditional and spatial statistics have been used to address spatial concepts within the Western Pluvial Lakes Tradition hypothesis.

In Chapter 4 I describe my data collection process, analytical methods, and results. Data collection for this study consisted of identifying early Holocene artifact locations in the Burns and Vale BLM district databases, and creating a new database that integrated the spatial and cultural data. This chapter includes a discussion of the spatial models produced for this study, including the construction of the boundaries of the study area, environmental and cultural subdivisions within the study area, pluvial lake models, and the extents of waterbody and wetland environments. After the cultural and environmental models are defined, each statistical method is summarized, and the analysis findings are presented.

The final chapter presents a discussion of what the results indicate about northern Great Basin Paleoindian subsistence-settlement strategies. The findings are discussed as they relate to each early Holocene technological tradition. Challenges and biases in the archaeological dataset and environmental models are also considered. The thesis concludes with recommendations for additional spatial analyses that might clarify environmental predictors of early Holocene archaeological sites.

Chapter Summary

Wetland environments were apparently part of the North American Paleoindian subsistence-settlement strategy, and are considered by many archaeologists to be an important aspect of Paleoindian subsistence-settlement patterns in the northern Great Basin. Wetland environments offer diverse, reliable, and abundant resources, which may have made them particularly attractive places for foragers during periods of climate change. Much of the early Holocene research in the northern Great Basin supports the Western Pluvial Lakes Tradition hypothesis, which holds that early Holocene Great Basin cultures were drawn to pluvial lakes and rarely utilized resources outside the lake basin lowlands. Some researchers suggest that early northern Great Basin cultures did practice a more generalized forager strategy. The intent of this thesis is to statistically analyze Plateau-Basin early Holocene site patterns to discover the relative importance of pluvial lakes and other wetland environments in the study area.

Chapter 2: Early Holocene Environment and Archaeology on the Plateau-Basin Interface

Early North American cultures inhabited an environment significantly different from the present, complicating our understanding of ancient resource use and settlement patterns. In the Intermontane West of North America, short-term climate fluctuations and the general drying trend of the Pleistocene-Holocene transition would have impacted people's use of wetland resources over the course of thousands of years (Duke and King 2014). Extensive pluvial lakes on the Plateau-Basin Interface may have been favored resource collection locations over the span of thousands of years as surrounding environments provided less reliable or less abundant resources during the Pleistocene-Holocene transition.

The objective of this chapter is to describe the environmental and cultural landscape of the Pleistocene-Holocene transition to study associations between the paleoenvironment and Paleoindian subsistence-settlement patterns in the northern Great Basin. To explore the notion that large pluvial lakes were a central feature in early mobility patterns, I first summarize the biophysical environment and history of local pluvial lakes and other environments within the study area. After studying the climate and geomorphology of the study area, I discovered that previous models of Pleistocene Great Basin pluvial lakes do not accurately depict pluvial lake boundaries in the early Holocene, so the fluctuations and high stands of lakes Alvord, Catlow, Coyote, and Malheur are calculated and modeled in this chapter. Following this, the early Holocene biota of the study area are then discussed to gain an understanding of the local trends in resource abundance and diversity during the study period. The final section of this chapter is focused on describing the early Holocene diagnostic lithic artifact types of the Columbia Plateau and Great Basin.

Early Holocene Plateau-Basin Environment

Hunter-gatherer subsistence-settlement strategies are affected by the distribution of natural resources. The climate warming trend and resulting shifts in biophysical environments of the Pleistocene-Holocene transition influenced human adaptation strategies by affecting the availability of natural resources used for food, technology, and shelter, ultimately impacting cultural traditions (Straus 1996:4–6). Worldwide, this warming trend caused glacial retreat, sea-level rise, and changes in weather and vegetation patterns roughly 15,000 to 10,000 calibrated years before present (cal yrs BP) (Anderson et al. 2007:4; Fagan 2009:14). Archaeological research suggests that responses to global climate change varied but included human migration, diversification of resource collection strategies, and resource specialization (Straus et al. 1996). As the first major climate change event to occur when all large land masses were inhabited by humans, the Pleistocene-Holocene transition provides researchers with an opportunity to compare cultural responses to resource fluctuation across a wide variety of biophysical zones. With relatively dense concentrations of Pleistocene-Holocene transition archaeological sites, the Plateau-Basin Interface is thus an ideal study area for examining early adaptive strategies in western North America.

Plateau-Basin Physiographic Provinces and Sections

The study area includes portions of the Columbia Plateau and Basin and Range physiographic provinces (see Figure 1). The region is further divided into five physiographic sections: Walla Walla Plateau, Blue Mountains, Payette Plateau, Harney Lake and Great Basin (Figure 2). The late Holocene landscape of this region can be described as a transition from broad plateaus, level valley floors, prairies and mountains on the Columbia River Plateau to steep canyons and mountain slopes in the Blue Mountains, to dry salt flats and shallow playa lakes in the northern Great Basin (NRCS 1980:3, 1981:1, 1983:4, 1985:3, 1988:4, 2012A:2, 2012B:4). Today, the Harney Lake and Great Basin sections are notable for their concentrations of playas, lakes and marshlands (Hunt 1976:495, 546–547), while the Walla Walla Plateau, Blue Mountains, and Payette Plateau afford access to the Columbia and Snake Rivers and their tributaries. The physiographic provinces and sections are used in this study to highlight differences between the Columbia Plateau and Great Basin portions of the study area.

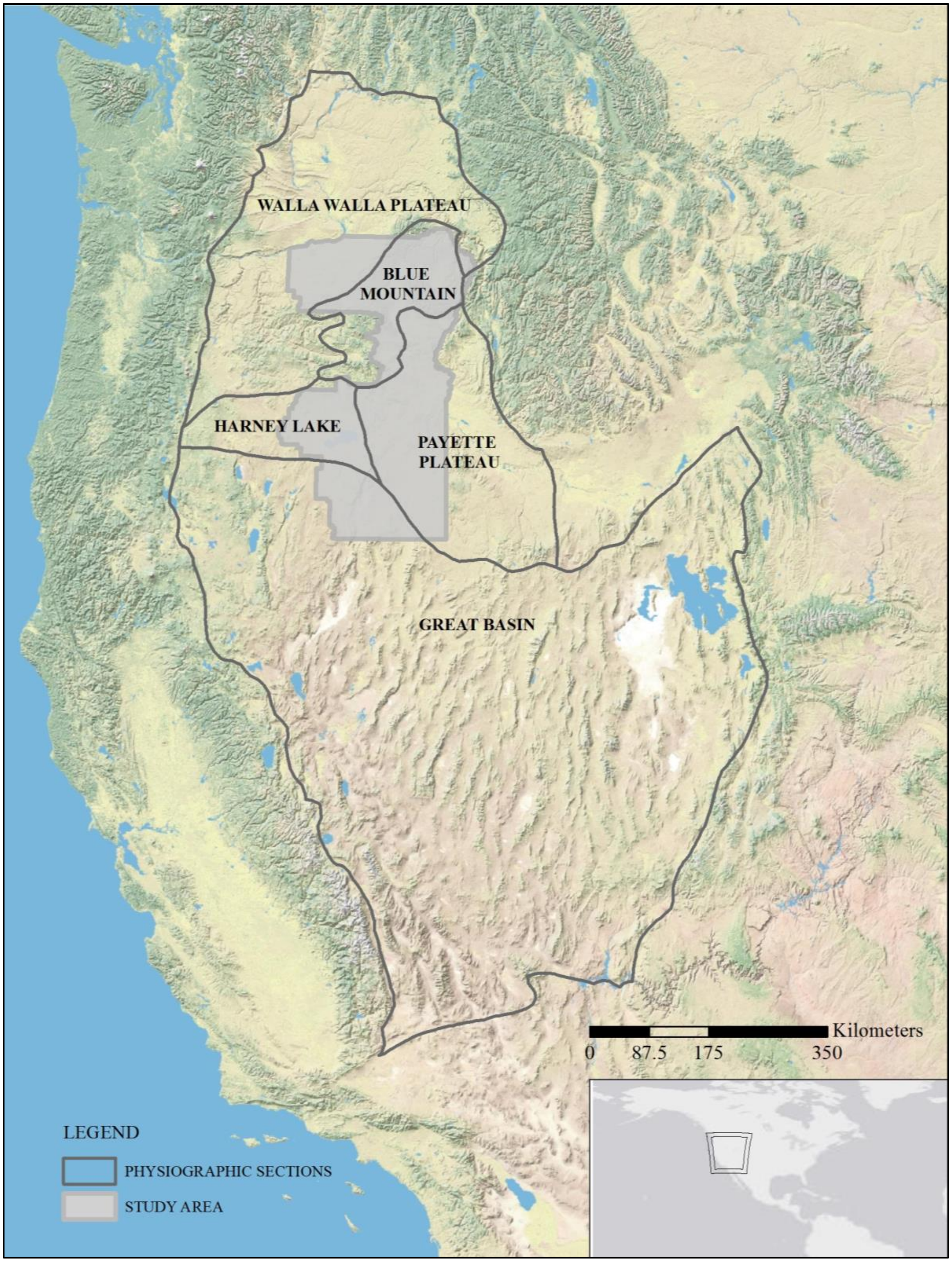


Figure 2. Physiographic sections in study area. Basemap source:ESRI 2012; Physiograhic data source: USGS 2012; Study area source: BLM 2011.

Early Holocene Climate of the Plateau-Basin Region

Lasting several thousand years, the Pleistocene-Holocene transition (16,400–9,000 cal yrs BP) was a shift from the Last Glacial Maximum at the end of the Pleistocene to modern climate conditions (Table 1; Bryson et al. 2009). This transition was gradual on the scale of millennia but included fluctuations that had a significant impact on the Plateau-Basin environment in the short-term. Rapid increases in temperature could occur in the span of a decade, meaning people may have needed to adjust to climate change within their lifetimes as well as over generations (Madsen et al. 2002:7). Two major environmental events were likely to have had a large impact on the inhabitants of the Plateau-Basin region: 1) diminishing extent of lakes and woodlands at the close of the Pleistocene, and 2) the emergence of a drier climate in the Holocene (Aikens 1983:239). I outline the climate trends of the Pleistocene-Holocene transition in the Plateau-Basin region to understand the availability of water and biota in this region.

At the peak of the Last Glacial Maximum (16,400 cal yrs BP), the Cordilleran Ice Sheet covered 2.5 million km^2 of western North America (Booth et al. 2004:17; Fagan 2009:69; Porter and Swanson 1998). As the Cordilleran Ice Sheet receded in the warming climate of the late Pleistocene, its meltwater fed a series of catastrophic floods that scoured the Columbia River drainage prior to 15,000 cal yrs BP (Bjornstad et al. 2007). Glaciers still covered peaks in the Blue and Steens Mountains within the study area, as well as parts of the nearby Cascade and Rocky Mountains (Grayson 2011:129; Porter et al. 1983). At this time, these and other late Pleistocene glaciers forced the North American winter jet stream to pass through the Great Basin, bringing cloud cover and precipitation that led to the formation of extensive pluvial ("rainy") lakes in this region (Grayson 2011:128).

After about 14,000 cal yrs BP, Plateau-Basin temperatures and evaporation levels fluctuated within a warming/drying trend that continued into the Holocene (Bryson et al. 2009:176–203; 273–304). This trend was interrupted by the Younger Dryas, a 1,000-year plunge into nearly glacial conditions, beginning about 13,000 cal yrs BP (Madsen 1999:77). The period is characterized by colder conditions, climatic volatility, and greater seasonal equability (Madsen 1999:79). During this period, glaciers advanced in the

Table 1. Major Pleistocene-Holocene transition events in the Plateau-Basin region.

Climatic Event	Cal Yrs BP	Climate	Source
Last Glacial Maximum	16,950	Cool and moist	Porter and Swanson 1998:212
Pleistocene-Holocene Transition	16,400–9,000	Increasing warmth and dryness	Bryson et al. 2009
Younger Dryas	12,900–11,600	Cool and moist	Goebel et al. 2011
Neoglacial	9,500	Rapid cooling	Grayson 2011:120
Holocene Climate Optimum	8,000–5,000	Increasing warmth and dryness	Grayson 2011: 251

Rocky Mountains to the east of the study area (Pierce 2004:70–71). A dip in evaporation and temperatures followed between 11,000 and 10,000 cal yrs BP, in the Great Basin and Columbia Plateau (Bryson et al. 2009:176–203, 273–304). The early Holocene drying trend was interrupted again at 9,500 cal yrs BP during the Neoglacial period, when glaciers advanced in the highest/wettest ranges of the Great Basin (Grayson 2011:120; Kaufman et al. 2004; Osborn 2004:66; Rosenbaum and Reynolds 2004). A clear division between Pleistocene and Holocene conditions was finally established by 8,000 years ago (Bryson et al. 2009; Mehringer 1986:49). The early Holocene climate of this region was warm and arid, which led to greater seasonality and less volatile fluctuations (Wriston 2003:13).

Hydrology of the Pleistocene-Holocene Transition in the Plateau-Basin

Long- and short-term climate fluctuations throughout the Pleistocene-Holocene transition contributed to changes in the extent and location of Plateau-Basin springs, streams, marshes, and lakes. The general warming/drying trend of the Pleistocene-Holocene transition resulted in surface water disappearing across the region, but climate differences between the two physiographic provinces suggest there were significant differences in resource availability across the Plateau-Basin region. Rainfall averages in the Columbia Plateau decreased by 15% from the late Pleistocene to the present, with most of this change occurring before 8,900 cal yrs BP (Bryson et al. 2009:12), while precipitation is estimated to have been between 17–37% higher in parts of the Great Basin (Smith and Street-Perrott 1983:204–205).

At the Last Glacial Maximum, the cooler environment and greater effective moisture caused large pluvial lakes to form in over 100 closed basins of the Great Basin region (Smith and Street-Perrott 1983:190). Most of these basins supported lakes at least seasonally if not perennially during the Pleistocene-Holocene transition (Madsen et al. 2002:5). During peak pluvial periods, some of these lakes overflowed to neighboring basins, causing series of lakes to join (Madsen et al. 2002:4). Pluvial lakes reached their high and intermediate stands between 24,000 to 14,000 cal yrs BP (Smith 1985:118). About half of the lake basins were freshwater lakes with potable water favorable to plants, animals, and people (Smith 1985:119). Archaeological information suggests people entered this region at the end of the Pleistocene, during what was likely a peak period in regional resource productivity.

Effective precipitation decreased in the early Holocene, causing larger lakes to reduce to between one-fifth and one-tenth their size at the Last Glacial Maximum (Negrini 2002). Isolated basins dried rapidly while others continued to retain small lakes (Mehringer 1986:34). In the Plateau, evaporation rates were also high while ground water recharge rates were low (Chatters 1998:44). Pluvial lakes rebounded during the cool/moist Younger Dryas period, but Great Basin lakes and wetlands shrank again as the climate continued to warm into the mid-Holocene (Benson et al. 1990; Huckleberry et al. 2001).

Though often simply portrayed as a drying trend, the Pleistocene-Holocene transition was much more complex locally in the short-term, with detailed Great Basin lake chronologies only beginning to emerge after decades of research. Changes in pluvial lake levels are clearly linked to climate change events, but fluctuations were not synchronous (Fenner 2011). Storm tracks, water storage rates, evaporation, and drainage morphology vary in time and space, complicating any generalizations of pluvial lake fluctuations (Orme 2008:51). Small changes occurred frequently in relatively short intervals that can be obscured by geomorphic rearrangement (Benson 2004; Sack 2009:746).

Changes in rainfall and evaporation impacted pluvial lake levels, but also impacted the availability of other surface watered places. Late Pleistocene Great Basin runoff volumes may have been as much as three times higher than that of the present (Smith and Street-Perrott 1983:204). During periods of high runoff and higher water tables, springs and streams were also more common (Smith 1985:121). Regional water tables were elevated between 13,800 to 7,500 years ago, resulting in increased spring discharge (Quade et al. 1998:146–147). Studies of southern Great Basin springs suggest spring discharge was at its highest toward the end of the Younger Dryas (Quade et al. 1998:146–147). Given the shifting nature of water resources throughout the Pleistocene-Holocene transition it is likely that moist periods occurred sporadically throughout the general drying trend. Despite their inevitable drying, pluvial lakes may have been more reliably watered than other shallower wetland types in the region. Contemporary lake levels were reached between 9,500 to 7,000 RCYBP (Jenkins et al. 2000:6; Wriston 2003:115-116).

Northern Great Basin Pluvial Lakes

As the largest lakes of the Great Basin have been foci for paleoenvironmental and archaeological research to date, the configurations of northern Great Basin pluvial lakes are discussed here to explore how dominant these features might have been on the Pleistocene-Holocene transition landscape. Four large pluvial lakes existed in the study area: Alvord, Catlow, Coyote, and Malheur (Table 2).

Lake Malheur, located in Harney Basin, is the best researched pluvial lake in the study area. Researchers have collected charcoal, shell, and organic samples to radiocarbon date lacustrine deposits at Lake Malheur, building a chronology of lake levels (Table 3; also see Dugas 1998; Gehr 1980; McDowell 1992; Wriston 2003). The surface elevation record of pluvial Lake Malheur challenges what one might expect of the Holocene drying trend, and highlights how volatile these large lake systems were. Lake levels rose from 1,251 meters (m) in the Pleistocene to 1,254 m in the Younger Dryas,

Table 2. Late Pleistocene pluvial lake areas in the study area.

Pluvial Lake	Approximate Area (km)[1]	Approximate Depth (m)[2]
Malheur	2,380	20
Alvord	1,270	60
Catlow	900	20
Coyote	450	Unknown

[1] Grayson 2011:96; [2] Orme 2008:65

dropping as low as 1,246 m in the early Holocene (Gehr 1980:146; Wriston 2003:85). Minor changes in the lake elevation within the flat topography of Harney Basin cause significant changes in the size of this lake, as it contains three adjoining lakes (Malheur, Harney, and Mud) that connect when water elevation rises above 1,248.9 m (McDowell 1992:31). For example, flooding in the early 1980s caused Malheur and Harney Lakes to join, expanding their usual combined 300 km^2 to 657 km^2 (McDowell 1992:29). As dynamic as this balance is, Harney Basin is considered unusually stable compared to other lakes in the region, owing to perennial streams that support lake level stability (Raven 1992:10).

Little research has been done on the chronology of lakes Alvord, Coyote, and Catlow. To date, no lake level chronology exists for Lake Catlow, although a highstand elevation is recorded (Orme 2008:65). Highstands for lakes Alvord and Coyote are known, and lake level chronologies are very limited (Table 4). When Lake Alvord overflowed the Alvord Basin at 1,292 m, spillover would have flowed into adjoining Coyote Lake meaning the level of Lake Alvord may have been consistent during peak pluvial periods (Carter et al. 2006:352–354). Lake Alvord fluctuated 30 meters in the late Pleistocene, ultimately losing 83 meters in elevation by the late Holocene (Carter et al. 2006:349–350). Catastrophic flooding events in the late Pleistocene would have drastically lowered the level of Lake Alvord (Personius et al. 2007:1675).

Table 3. Lake Malheur Pleistocene-Holocene fluctuations.

Lake	RCYBP	Cal yrs BP[1]	Elevation (meters)	Elevation (feet)	Source
Pluvial Lake Malheur	32,040	36,800	1,251	4,104	Gehr 1980:146
Pluvial Lake Malheur	9,860	11,400	1,254	4,114	Wriston 2003:85
Pluvial Lake Malheur	9,620	11,200	1,252	4,108	Gehr 1980:146
Pluvial Lake Malheur	9,540	10,900	1,252	4,107	Wriston 2003:86
Pluvial Lake Malheur	9,500	10,750	1,246	4,088	Wriston 2003:137
Pluvial Lake Malheur	9,300	10,500	1,247	4,092	Wriston 2003:137
Pluvial Lake Malheur	8,900	10,000	1,255	4,118	McDowell 1992:32
Pluvial Lake Malheur	8,680	9,700	1,255	4,118	Gehr 1980:146
Malheur/Harney	8,600	9,550	1,250	4,102	Wriston 2003:137
Malheur	8,440	9,400	1,249.5	4,099	Dugas 1998:279
Pluvial Lake Malheur	8,070	8,900	1,252	4,110	Dugas 1998:279
Malheur/Harney	7,760	8,600	1,250	4,101	Dugas 1998:279
Malheur/Harney	7,370	8,200	1,250	4,101	Dugas 1998:279
Malheur	4,400	4,981	1,248[2]	4,095[2]	McDowell 1992:32
Malheur	1,000	950	1,254	4,114	Dugas 1998:280
Malheur/Mud/Harney	–	30	1,250.5	4,102.6	McDowell 1992:29
Malheur	modern	0	1,248	4,095	McDowell 1992:29

[1] Calibrated years before present approximation calculated via Stuiver et al. 2013.

[2] Approximations based on pollen study at nearby Diamond Swamp.

Table 4. Lake Alvord and Coyote Pleistocene-Holocene fluctuations.

Lake	RCYBP	Cal yrs BP[1]	Elevation (meters)	Elevation (feet)	Source
Pluvial Lake Alvord	Last Glacial Maximum	16,950	1,310	4,298	Carter et al. 2006: 347
Pluvial Lake Alvord	14,000–13,000	16,950–15,600	1,280	4,199	Carter et al. 2006: 350–351
Pluvial Lake Alvord	Before 13,000	15,600	1,292	4,239	Carter et al. 2006: 355
Alvord	Present	50	1,227	4,025	NGS 2011
Pluvial Lake Coyote	Last Glacial Maximum	16,950	1,292	4,239	Carter et al. 2006: 347
Pluvial Lake Coyote	14,000–13,000	16,950–15,600	1,278	4,193	Carter et al. 2006: 347

[1] Calibrated years before present approximation calculated via Stuiver et al. 2013.

Pleistocene-Holocene Transition Biota

As the climate fluctuated and gradually shifted into Holocene conditions, the nature of biotic communities changed with it (Hunt 1976:159). The Holocene drying trend influenced a shifting mosaic of plant communities, with plant species reacting differently to climate change, and vegetation communities adjusting to microclimates at different paces (Davis et al. 2002; Madsen 199:80). In the northern Great Basin, late Pleistocene vegetation communities were dominated by sagebrush, juniper, and several species of pine (Goebel et al. 2011:494; Hansen 1947a; Hansen 1947b; Madsen 1999:80). By 12,000 years ago, forests were shifting to uplands and being replaced with sagebrush steppe in the lowlands (Bryson et al. 2009:231; Mehringer 1986:46). Species diversity was greatly reduced at the end of the Pleistocene, but vegetation became more diverse in the northern Great Basin around 10,000 cal yrs BP (Madsen 1999:80). Marshes associated with streams may have been at their most abundant immediately before and after the Younger Dryas (Madsen 2007:12). As the pluvial lakes dried and separated, marshes and wet meadows developed in the previously flooded areas (Wriston 2003:4). Although much archaeological attention has been given to pluvial lake high stands, marshes associated with some pluvial lakes may have been most productive in periods between the lake high stand maximums (Duke and King 2014).

Sagebrush and grass dominate regional pollen profiles by 8,800 cal yrs BP in the Great Basin and eastern Snake River plain (Knox 1983:37; Mehringer 1986:47). In the southern Plateau, biodiversity increased as the region recovered from catastrophic flooding in the late Pleistocene (Chatters 1998). The Columbia Plateau was covered in grasslands by the late Pleistocene, with vegetation communities subsequently changing very little in the Holocene (Blinnikov et al. 2002; Nowak et al. 1994B).

Long-term changes in flora communities were naturally followed by changes in fauna communities, with the abundance and distribution of wildlife tied the shifting mosaic of vegetation communities (Madsen 1999:81). By 13,000 cal yrs BP, the variety of regional fauna species in the Great Basin was approaching that of the present, though the distribution was much less homogenous than present (Madsen 1999). Mammals confined to upland environments in the Holocene actually inhabited lowlands from the Pleistocene into the early Holocene (Grayson 2002:382). The richness of small mammalian communities decreased around 8,000 cal yrs BP with the increasingly arid climate (Grayson 2000:184).

Plateau-Basin Early Holocene Cultural Traditions

The Plateau-Basin Interface region was occupied at the end of the Pleistocene, with radiocarbon dates placing humans in the region by 14,500 cal yrs BP (Aikens et al. 2011:49). North American cultural chronologies typically begin with the Clovis culture, but the northern Great Basin’s Paisley Period (15,700–12,900 cal yrs BP) is thought to include both a pre-Clovis culture and a Clovis culture (Aikens et al. 2011:49). The Paisley Period ends at the Younger Dryas, when the Fort Rock Period (12,900–9,000 cal yrs BP) assemblages indicate that Great Basin groups began focusing on wetland resources (Aikens et al. 2011:60). The Lunette Lake Period (9,000–6,000 cal yrs BP) is marked by temporary occupations on lake margins, and is followed by the Bergen Period (6,000–3,000 cal yrs BP), which marks the beginning of Archaic cultural patterns in the northern Great Basin (Aikens et al. 2011:74). In the Columbia Plateau portion of the study area, early Holocene cultures are not subdivided into cultural periods and so are simply referred to as Pioneer Populations (14,500–7,600 cal yrs BP) by Aikens et al. (2011:154).

Chronologically diagnostic tool types can be used to study archaeological site patterning within a region. For this study, I needed to identify the early Holocene lithic tool typologies in the study area to assign approximate dates to archaeological sites. Early Holocene Plateau-Basin cultures are represented by eight diagnostic lithic artifact types, which serve as cultural markers: Western fluted points, Black Rock Concave Base Points, Great Basin Stemmed points, Parman stemmed points, Windust stemmed points, Great Basin Transverse points (crescents), Haskett stemmed points, and Cascade points (Figures 3–4; Table 5). Below I describe these early tool forms, and discuss the known distribution of these tool types.

Western Fluted Points

Clovis technology was present in North America by 13,250 cal yrs BP and spread throughout subarctic North America and northern South America in less than 500 years (Bradley 2010:1; Meltzer 2009:201; Waters and Stafford 2007:1123). The Clovis toolkit consists of several distinctive tool types, but is most often recognized by concave-based lanceolate bifaces with fluted channels removed along one-third to one-half the length of the biface (Figure 3a; Bradley et al. 2010:1; Justice 2002:67; Meltzer 2004:548). Clovis projectile points are often basally and/or laterally ground on the hafting element and thinned by removing “overshot” flakes that extend beyond the midline of the point (Bradley et al. 2010:65; Justice 2002:67). As Clovis people settled throughout the North American landscape, regional variations of the Clovis toolkit emerged (Beck and Jones 2012:24; Meltzer 2004:548). Western fluted points share the major identifying

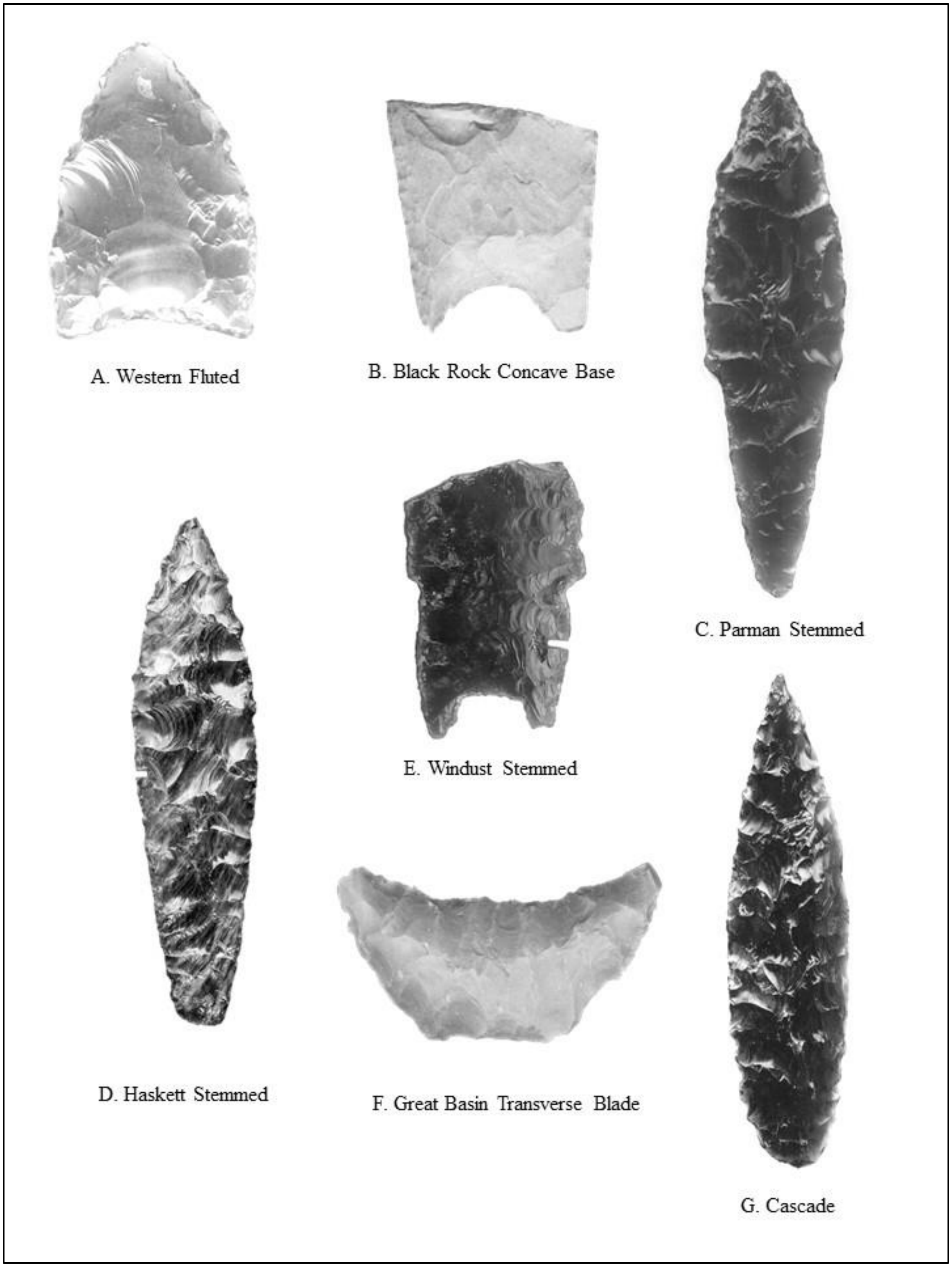


Figure 3. Columbia Plateau/Great Basin Pleistocene-Holocene diagnostic artifact types. Photos courtesy Burns District BLM. Obsidian hydration samples removed from artifacts d and e. Artifacts not to scale.

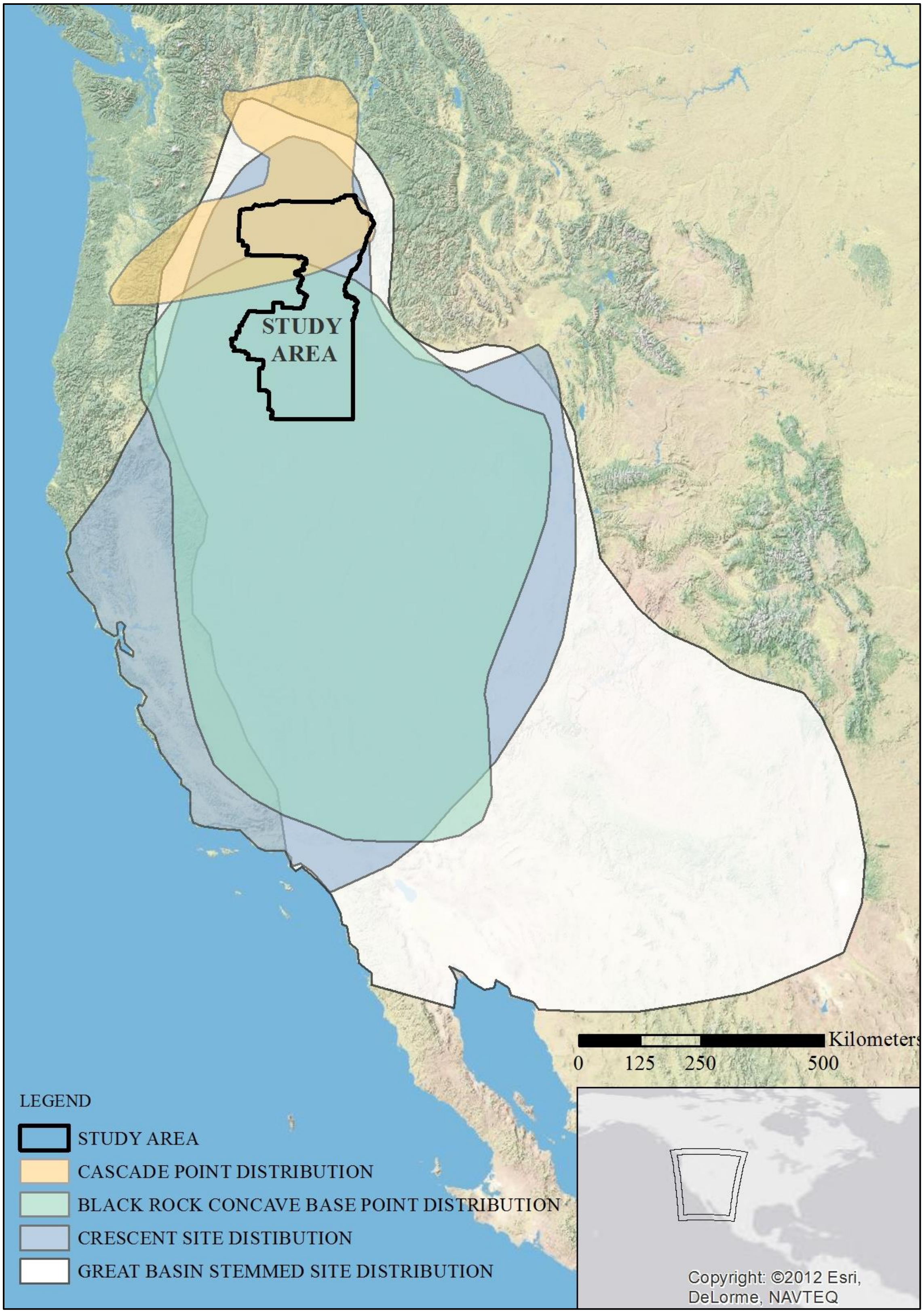


Figure 4. Distribution of diagnostic artifact types. After Justice 2002.

Table 5. Columbia Plateau/Great Basin Pleistocene-Holocene lithic cultures.

Tradition	Biface Type	Cal yrs BP	Source
Western Fluted	Fluted	13,250–12,800	Waters and Stafford 2007:1123
Unknown	Black Rock Concave Base	13,000–7,000	Justice 2002:81
Western Stemmed	Great Basin Stemmed	14,500–8,200	Lyman 2013:227
	Parman	14,500–6,000	Jenkins et al. 2012; Jones and Beck 2012
	Windust	12,800–8,200	Lyman 2013:227
	Great Basin Transverse	11,000–7,800	Smith 2008:94
	Haskett	10,200–9,000	Galm et al. 2011
Old Cordilleran	Cascade	10,600–5,000	Chatters 2012:44

characteristics of Clovis points, but are often smaller and may have multiple relatively narrow parallel fluting scars, a notch in the concave base and scratches on the fluting scars (Rondeau 2009:270). The temporal and cultural relationship between makers of the Clovis toolkit, Western fluted points, and the other early tool traditions in the study area are still being debated (e.g., Andrefsky 2004:27; Beck and Jones 2010; Davis et al. 2012; Fiedel and Morrow 2012; Goebel and Keene 2013; Rondeau 2009:270). Several Western fluted point sites have been found in the Columbia Plateau and Great Basin regions, but they are poorly dated and thus do not offer any definitive insights into temporal and cultural relationships (Andrefsky 2004:26). Much as the Clovis culture is thought to have coexisted with other Paleoindian complexes (Huckell 2013:19), the Western Fluted Tradition likely coexisted with other early traditions in the Great Basin, and represents a separate tool kit from that of other early Holocene Plateau-Basin cultures (Davis et al. 2012:60).

Clovis people are generally considered to have been highly mobile hunter-gatherers who practiced a generalized subsistence economy that could be adapted to unfamiliar environments (Meltzer 2004:549). The rapid spread of this tradition through North America was likely facilitated by ease of travel through places like river valleys, pluvial lake shorelines, and coast margins (Meltzer 2004:549). A generalized subsistence economy and highly mobile settlement pattern may have been either necessary or advantageous given the rapidly changing climate at the end of the Pleistocene (Stanford 1991:5–6). Isolated fluted points are relatively sparsely distributed in Western North America and little is known about associated subsistence-settlement practices in this region (Anderson et al. 2009; Rondeau 2009:271).

Black Rock Concave Base Points

Dating to 13,000 to 7,000 cal yrs BP, the Black Rock Concave Base points (Figure 3b) may mark the demise of fluted technology in this region (Justice 2002:81; Heizer and Hester 1978:14). Similarities between Black Rock Concave Base points, Western Fluted points, and younger concave-based lanceolate points have likely created confusion in the interpretation of cultural chronology for this tool type (Justice 2002:81). Found throughout the Great Basin, these large lanceolate bifaces have excurvate lateral margins that contract toward a pronounced concave base (Clewlow 1968:15; Justice 2002:80). These points are typically created from side-struck flakes and shaped by random or collateral-parallel pressure flaking that terminates at the point midline (Pendleton 1979:134,141). Bases are thinned for hafting by multiple short pressure flakes on one or both sides (Pendleton 1979:141). Haft preparation can also include thinning through the removal of fluted flakes and light grinding at the base and lateral edges (Pendleton 1979:141). Judith Willig and C. Melvin Aikens (1988:20–21) have suggested that the Black Rock Concave type, as well as other fluted and stemmed bifaces found throughout the region, mark a transition from the Western Fluted technology to the Western Stemmed technology. As this point type is rarely discussed in regional literature, more research is needed to determine which cultural tradition these artifacts are associated with.

Western Stemmed Series

The Western Stemmed Tradition coexisted in the region with the Western Fluted and Black Rock Concave technologies across a large portion of western North America (Beck and Jones 2012:28; Jenkins et al. 2012:227). Eight types of large, stemmed, bipointed and leaf-shaped bifaces are assigned to the Western Stemmed Series (Aikens et al. 2011:43). Stemmed points are typically collaterally flaked, with wide flake scars overlapping to form a sinuous midline (Pendleton 1979:246–247). Not all stemmed types have a clear demarcation between the stem and blade, and range from unshouldered willowleaf styles with lateral basal grinding to defined shoulders with heavy lateral grinding (Bryan 1980:82; Pendleton 1979:246–247). In the northern Great Basin these include Parman, Haskett, and Windust types, with Great Basin Stemmed Tradition dates ranging from 14,500 to 8,200 cal yrs BP (Lyman 2013:227).

Initial discussions on the use of stemmed bifaces linked these tools to large herbivore hunting, but researchers have since concluded that stemmed bifaces appear to have been used by people who consumed a broad range of resources, including plants, fish, birds, insects, and mammals (e.g., Aikens et al. 2011:57; Bryan 1980:102). Unlike dart points found in this region, these bifaces are often asymmetrical, are very thick with dull tips and edges, and have extensive haft wear (Beck and Jones 1993:52). The morphology and patterns of usewear suggest stemmed bifaces were often knives or spear points rather than projectiles (Amick 1993:50; Beck and Jones 1997:204). Mark Basgall and M.C. Hall (1991) speculated that stemmed points were contemporaneous with fluted points, and suggested that fluted points were either used by different cultures, or that fluted points were used for long-distance hunting while stemmed points served more general on-site functions at camps. Evidence supporting the contemporaneity of the Western Fluted and Great Basin Stemmed tools continues to grow (e.g., Jenkins et al. 2012), but most research indicates these tools were a part of separate traditions (e.g., Haynes 2002:67; Willig and Aikens 1988:20).

The earliest of the stemmed point styles is the Parman or Lind Coulee type, which spans the entire Pleistocene-Holocene transition from 14,500 to 6,000 cal yrs BP in the Great Basin (Beck and Jones 2012; Goebel 2007:167; Hester 1973:39; Jenkins et al.

2012; Justice 2002:100). The term “Parman” is generally assigned to those stemmed points that are indented at the shoulder-haft junction with an ovate base (Justice 2002:100). Parman type II points, also known as Parman square-stemmed points, have square, straight-stemmed bases with slightly sloping or prominent shoulders (Figure 3c; Layton 1972:4).

Haskett-type stemmed bifaces are found in the northern Great Basin and Pacific Northwest (Justice 2002:100; Layton 1972:4). Haskett bifaces are thick lanceolate-shaped with long tapering stems, weak or no shoulders, slightly concave or convex bases, broad collateral flake scars, and are ground on lateral margins to the point of maximum width which is about two-thirds of the distance from the base to tip (Figure 3d; Holmer 1995:4; Layton 1972:4; Pendleton 1979:182). The Haskett stemmed point appears around 10,200 cal yrs BP, several thousand years after the Western Stemmed Tradition was established in the Great Basin, and falls out of use around 9,000 cal yrs BP (Galm et al. 2011).

The Windust Phase is typically regarded as the earliest of Columbia Plateau cultures, spanning the period from about 11,000 to 9,000 cal yrs BP (Hicks 2004:65; Sappington and Schuknecht-McDaniel 2001:355). Windust stemmed bifaces are typically lanceolate with shoulders of varying prominence, straight or contracting stems, ground edges, and straight or slightly concave bases that are rarely ground (Figure 3e; Leonhardy and Rice 1970:4; Rice 1972:130). Possibly representing the beginning of a riverine-oriented subsistence pattern in the Plateau, Windust points are thought to have been used to hunt large terrestrial mammals, including elk, deer, pronghorn antelope, and occasionally buffalo (Bryan 1980:89; Leonhardy and Rice 1970:6; Rice 1972:157–160; Hicks 2004).

Great Basin Transverse Bifaces

Found throughout much of the Great Basin and California, Great Basin Transverse blades, or crescents, are bifacially flaked tools with a convex edge (Figure 3f, 6; Justice 2002:116). Like many of the early tools discussed represented in the study area, there are few dates associated with crescents, meaning their cultural affiliation is uncertain. Crescents are commonly associated with Western Fluted, Great Basin Concave Base, Great Basin Stemmed, and Cascade assemblages in the Great Basin and Plateau (Justice 2002:67; Smith 2008:13; Tadlock 1966:672). The use of parallel flaking, overshot flaking and basal grinding are all common features in early western North American lithic assemblages (Justice 2002:67). Crescent biface dates range from 11,000 to 7,800 cal yrs BP, meaning this tool type appears after the Younger Dryas (Smith 2008:94). Despite their connection with earlier technologies, this tool is most likely part of the Western Stemmed Tradition toolkit.

Posited uses for these tools include functioning as a general "Swiss Army" tool, scraper, blade, waterfowl hunting tool, fish/duck gorger, fish scaler, skull surgery tool, scarification or tattooing implement, gorget, amulet, or ceremonial object (Clewlow 1968:45; Pendleton 1979:72; Smith 2008:103). Frequently found near playas, lakes, rivers, and coastal settings, crescents are believed to be associated with aquatic resources (Tadlock 1966:664). An analysis of the variation in crescent forms indicated that the intended use of crescents restricted their form, indicating these tools were designed for specific tasks and were not ornamental (Smith 2008:90–92). The presence of crescents at a small percentage (i.e., 1%) of Nevada sites, and their strong association with lacustrine environments, suggests these tools were used for specific tasks at seasonal sites (Smith 2008:96).

Cascade Points

The Old Cordilleran Tradition appeared about 10,600 cal yrs BP in British Columbia, and spread south to Washington and Oregon where it persisted until 5,000 cal yrs BP (Figure 7; Chatters et al 2012:44, Ozbun and Fagan 2010:4). In the Columbia Plateau, this tradition appeared at the end of the Windust Phase, and is believed to mark a cultural influx in this region around 9,500 to 9,000 cal yrs BP (Bryan 1980:88; Chatters et al. 2012:47). This culture is called by several complex and phase names, but in the study area it is most often known as the Cascade Phase (Chatters et al. 2012:44; Ozbun and Fagan 2010:1). The Cascade Phase is marked by slender lanceolate points that commonly have basal facets and are sometimes serrated or possess a concave base (Figure 3g; Bryan 1980:88; Ozbun and Fagan 2010). The Cascade culture was highly residentially mobile with repeated short stays in mountains and river corridors (Chatters et al 2012:46; Smith et al. 2012:29).

Western Pluvial Lakes Tradition

Based on his research in the Fort Rock Basin of central Oregon, Stephen Bedwell (1973:170) proposed the Western Pluvial Lakes tradition is “typified by the presence of tools having well-controlled percussion flaking, non-stemmed and non-notched lanceolate projectile points (with round or indented bases), large lanceolate and ovate knives, and substantial numbers of large and moderate-sized scrapers, gravers, and use-worked flakes.” He notes that a point that would now be described as a Haskett stemmed point is considered typical of these early Holocene assemblages (Bedwell 1973:171). Researchers now include fluted points, concave base points, stemmed points, and crescents in discussions of the Western Pluvial Lakes Tradition (e.g., Aikens et al. 2011:61; Hester 1973:65). Western Fluted, Black Rock Concave Base, Western Stemmed, and Great Basin Transverse bifaces are used in this study to investigate the Western Pluvial Lakes Tradition.

Chapter Summary

In this chapter I summarized the paleoenvironmental and archaeological traditions of the study area. The Western Pluvial Lakes Tradition, which has conventionally been confined to the pluvial lake-dense area of the western Great Basin, is recognized archaeologically through fluted, concave-base, stemmed, and crescentic bifaces. This culture appears to span the period between 14,500 to 6,000 cal yrs BP, which coincides with the Pleistocene-Holocene climate transition. It appears that Paleoindian people began inhabiting the study area at a time when regional precipitation was at a peak and large freshwater pluvial lakes supported diverse biota across the region. Published data on the location and patterning of early Holocene sites in the northern Great Basin are limited, as is data on the chronology of pluvial lakes and other wetlands across the region. In the course of synthesizing the diagnostic tool typologies and environments of the study area, I discovered that new models of early Holocene pluvial lakes were needed, that wetland locations would have to be modeled after modern environmental features, and that archaeological sites would need to include isolate artifact data in order to study site-environment correlations across the study area.

Chapter 3: Subsistence-Settlement Pattern Spatial Analysis

Although an association between early Great Basin cultures and pluvial lakes has been supported by decades of archaeological research, the hypothesis that early peoples in this region favored pluvial lake environments over other resource locations lacks thorough analysis. The wealth of information collected through CRM projects provides an opportunity to empirically test settlement models for this region. The increasing accessibility of geographic information systems (GIS) enables new and more efficient ways to organize and analyze this data, and move beyond intuitive observations of local site-environment associations. My study aggregates CRM data and utilizes geospatial analysis tools to explore Western Pluvial Lakes Tradition site patterns. While the data and analyses in this thesis are specific to the study area, the research methodology more generally serves to illustrate the potential for archaeological spatial analysis at a time when CRM is moving toward providing greater data accessibility for archaeologists.

In this chapter I present the methodology I use for examining Western Pluvial Lakes Tradition site patterns on the Plateau-Basin Interface, and describe my data collection and analysis process. After identifying possible early Holocene site types through the literature review presented in Chapter 2, archaeological site data were gathered from the cultural resource offices of the Burns and Vale Districts of the BLM. Environmental features, including pluvial lakes, playas, freshwater lakes, marshes, springs, and streams, were modeled after modern and paleoenvironmental data. A brief history of archaeological spatial analysis is discussed here to appreciate the development and limitations of subsistence-settlement hypotheses testing in the study area. Specific geostatistical methods relevant to the research objective of this thesis are then identified, and spatial and traditional statistical analyses are outlined for each of my research questions.

A History of Spatial Analysis in Archaeology

The field of archaeology has come to rely on GIS to store and display spatial data. There is growing recognition of the potential to use archaeological databases to test and refine spatial hypotheses. Geostatistical methods have proved useful in archaeological analyses, and should be considered among methods for identifying and testing Paleoindian subsistence and settlement theories. The history of archaeological settlement pattern and geostatistical analyses are explored here before identifying geostatistical methods for analyzing the Western Pluvial Lakes Tradition.

Archaeological Settlement Pattern Research

Objects in natural systems are rarely randomly distributed, meaning the patterns they create indicate the processes they represent (Fotheringham and Rogerson 2009:89). The use of geostatistics originated in the study of crop yield and weather patterns from the 1910s to 1930s, when analyses of the variance of observed data were used to predict spatial variation (Webster and Oliver 2007:6). The method was rediscovered in the 1950s when it was recognized as a valuable predictive tool for the mining industry (e.g., Krige 1951). Mathematicians explored and published on geostatistical methods like spatial central tendency and autocorrelation through the 1950s and 1960s (e.g., Hart 1954; Matheron 1965). Today, geostatistics have a growing number of practical applications in numerous fields, including public health, agronomics, geology, meteorology, environmental sciences, and anthropology.

As mathematicians and geographers were building geostatistical methods and theories of spatial dependence, archaeologists were busy collecting culture region history data, which would subsequently be used in geostatistical analyses. By the 1960s, archaeologists recognized the potential of site patterning to yield information on the spatial distribution of archaeological features and sites. Lewis Binford (1964) suggested that archaeologists should begin to use systematically collected archaeological data to theorize about human culture. Trigger (1967) proposed the term “settlement archaeology” to define a new branch of prehistoric archaeology focused on the spatial aspects of settlements, and by the 1970s archaeologists were beginning to analyze spatial data rather than draw inferences from site distribution maps (e.g., Hodder and Orton 1976; Tobler 1974).

Geographical Information Systems in Archaeological Spatial Analysis

Spatial analysis methods have become increasingly accessible due to the rise in availability of GIS software. GIS typically employ (1) spatial data, (2) software that frequently contains tools to enter, manipulate, analyze and output spatial data, (3) a computer system to operate the software, and (4) a set of data management and analysis procedures (Heywood et al. 2006:18). Introduced in the 1970s, GIS have become essential for implementing spatial analysis methods (Goodchild and Longley 1999:567). Widespread adoption of the technology in the 1990s led to a boom in digital spatial database production, though relatively few users recognized the spatial analysis capabilities within the software (Heywood et al. 2006:377-378). Today, this technology enables analysts to store and access large volumes of spatial data, which promotes powerful spatial analyses from research objectives that can be easily refined based on study findings (Heywood et al. 2006).

Some archaeologists quickly saw the potential in GIS, but it was primarily used for storing and visualizing data (Westcott 2000:1). In the 1980s it was recognized as a means to more efficiently organize and analyze archaeological and CRM data (Kvamme and Kohler 1988:493), although the high costs involved in developing GIS with legacy data have, until recently, prevented many archaeologists from integrating the technology into the research process. The introduction of GIS appears to have encouraged a renewed focus on landscape archaeology in the 1990s. The use of GIS in archaeology was still limited to the visualization of data or creation of basic maps, but archaeologists were also developing a strong interest in creating predictive correlative models (Church et al. 2000:135). The ability to store and process large datasets allowed archaeological studies to expand from site analyses to consider regional settlement patterns (Gaffney and Stančič 1996:30). By the 2000s, settlement pattern analyses had access to enough data to enable archaeologists to develop multi-regional scale studies to answer archaeological research questions (Kowalewski 2008:246). Nearly thirty years after archaeological spatial analysts recognized the potential of GIS, CRM agencies, which arguably have the most to gain from developing GIS, are still working toward establishing systems that promote the sharing of data between managers.

Spatial Analysis Methods

Using GIS, it is possible to utilize a variety of statistical methods to explore site pattern factors in a large data set. I thus employed a variety of spatial and traditional statistical analyses in this thesis to study geographic aspects of the Western Pluvial Lakes Tradition hypothesis. I selected six common statistical methods to address the three research questions identified in the previous section: 1) frequency distribution; 2) spatial mean center; 3) nearest neighbor analysis; 4) Ripley's K-function analysis; 5) Moran's I spatial autocorrelation analysis; and 6) Pearson's r correlation analysis

Frequency Distributions

Before considering the spatial statistics of a dataset, traditional statistics can be used to summarize data, form hypotheses, and select applicable analyses. Frequency is a common statistic used for displaying the cumulative or relative number of times an event occurs within a study. Frequency distributions summarize the distribution of data frequencies and can be used to study whether these frequencies are normally distributed around a mean value (Wong and Lee 2005:72). Often displayed in tables, histograms or bar graphs, frequencies have been used in innumerable archaeological and other scientific studies. For this study, frequency tables and charts were used to summarize and visualize site and environment features in the study area.

Spatial Mean Center

Spatial statistics are used to measure the degree of similarity between objects based on the distance between observations (Fotheringham and Rogerson 2009:92). As with traditional statistics, there are several basic descriptive statistics used to summarize spatial datasets. One of these methods, spatial mean centers are calculated by finding the average location (x,y) for a set of points (Wong and Lee 2005:189). The mean center of a spatial dataset finds the center of a set of observations, providing a simple method for studying how the distribution of observations changes through time (McGrew and Monroe 2000:53). Central place theory posits that interacting central places act as the foci of a behavioral region (Getis and Getis 1966:220; Kowalewski 2008:226). Although this theory was designed to study the economics of urban systems, spatial means can also explain economic foci for ancient hunter-gatherers. In this study I used spatial mean centers to identify bias within the study area, and summarize the distribution of early site types.

Nearest Neighbor Analysis

Point pattern analysis was one of the first spatial analysis techniques to receive attention from archaeologists (Orton 2004:301). The method includes statistical measures of spatial arrangements that discriminate among random, clustered, or dispersed point patterns. The method has included a variety of statistical tests that measure the spatial arrangement of points, often describing point distributions as random, clustered, or dispersed. In archaeology, point pattern analyses have been used for inter- and intra-site studies, including settlement pattern factor studies, analyses of artifact distributions across occupation floors, and studies of archaeological site damage (e.g., Hodder and Orton 1976; Stark and Young 1981; Whallon 1974).

Nearest neighbor analysis is a common point pattern analysis in which the distance between observations and their nearest neighbors is measured, averaged, and compared to an expected random value (McGrew and Monroe 2000:172–173). This average value is considered dispersed, random, or clustered when compared to the expected random value. In ArcGIS, the Average Nearest Neighbor analysis produces: 1) observed mean distance; 2) expected mean distance; 3) nearest neighbor index which measures the ratio of mean distance to expected distance; 4) a z-score; and 5) p-value signifying whether the pattern was created by a random process (ESRI 2012). A nearest neighbor index of 1 is considered perfectly random, an index of less than 1 is clustered, and an index greater than 1 is dispersed. Nearest neighbor analyses were used in this thesis to measure the dispersion of archaeological sites and environmental features across the study area.

Ripley's K-Function Analysis

While point pattern analyses are effective at measuring the general spatial pattern of data across a defined study area, several spatial analysis tools have been developed to measure the variability of local clustering. One of these methods, Ripley's K-Function analysis measures whether a phenomenon is clustered, dispersed, or random at multiple scales within a study area (Fotheringham and Rogerson 2009:308). Whereas a nearest neighbor analysis might detect clustering across a region, Ripley's K-Function analysis can detect the scale at which clustering begins and ends (Dixon 2001:2). In ArcGIS, Ripley's K-Function analysis determines if features are clustered at various distances by comparing expected random and observed values (ESRI 2012). When observed values are larger or smaller than the expected random values, the pattern is considered clustered or dispersed, respectively.

Archaeologists have used Ripley's K-Function analysis in GIS to study the spatial aspects of burial practices and settlement clustering in ecozones (e.g., Bevan and Conolly 2006; Johnston 2010; Sayer and Weinhold 2013). Ripley's K-Function analysis was used in this study to further test spatial distributions discovered in the Nearest Neighbor Analysis, and to determine the distances at which sites clustered.

Moran's I Spatial Autocorrelation Analysis

The First Law of Geography explains that all things are related in space, but those that are closer are more related (Tobler 1970). Many statistical analyses assume data samples are independent, overlooking the fact that data with a spatial component inherently have dependency (Dale and Fortin 2009:188). Spatial autocorrelation statistics utilize this dependency and measure the degree to which spatial features with similar data values cluster in space (Fortin and Dale 2009:89). Moran's I analysis measures the level of spatial autocorrelation in a set of observations, thus measuring the similarity of features across space (Wong and Lee 2005:12). A Moran's I value measures the deviation of observed values from the data set mean, and Moran's I values are then compared to expected random values to test the value's statistical significance (Fotheringham and Rogerson 2009:89). In ArcGIS 10, the Global Moran's I tool calculates a Moran's I index, compares this to expected random values in the data set, and provides a z-score and p-value to measure the significance of that index (ESRI 2012).

Archaeologists have used Moran's I spatial autocorrelation analyses to establish dependency between variables like site locations and environmental variables (Conolly and Lake 2006:46). Archaeological studies involving Moran’s I analyses have included research topics like lithic tool source and manufacture patterning, and household artifact and feature distributions (e.g., Aagesen 2010; Casto 2015; Chiang and Liu 2011). Moran’s I spatial autocorrelation analyses were performed in this study to observe the spatial autocorrelation of site types and environment features within the hydrographic units of the study area.

Pearson’s R Correlation Analysis

Pearson product-moment correlation coefficient (Pearson’s r) measures the strength of the linear correlation between two variables in a sample dataset (Puth et al. 2014:183–184). Pearson’s r correlation coefficient ranges between a perfect negative correlation and a perfect positive correlation between the two variables. Correlation statistics are used to study a wide range of relationships between cultural factors in archaeological research. Archaeological studies have made use of Pearson’s r correlations to study topics like preservation conditions, artifact densities in site features, and settlement factors (e.g., Muckelroy 1978:212; Nord et al. 2005). In this study, I used Pearson’s r correlation analyses to observe associations between environmental and archaeological variables at several levels of spatial division.

Testing the Western Pluvial Lakes Tradition

Is there really a settlement pattern centered on pluvial lakes in the Great Basin, and if so what does it look like? Three research questions were studied in order to explore the type and strength of connections between early sites and relict pluvial lakes within the study area. After reviewing possible statistical analysis methods identified in the previous section, six methods were used to test the three research questions as follows:

Question 1: Did early Plateau-Basin cultures focus their subsistence-settlement practices in the Great Basin portion of the study area?

Archaeologists have argued that the Great Basin was more heavily populated than surrounding regions during the early Holocene because of the rich wetland environments concentrated in this region. Were early peoples using the Great Basin portion of the study area more than the Columbia Plateau? Do sites cluster in either of these regions? Is observed clustering caused by a bias in site discovery? To address this question, I used nearest neighbor analyses to detect general clustering within the study area. Frequencies and mean centers were calculated to summarize site patterns and survey bias. Summary statistics describing the densities of wetland areas and archaeological sites were used to explore the idea that the availability of pluvial lake and other wetland resources could have influenced early subsistence-settlement strategies between physiographic regions. Archaeological site and wetland clusters, as well as the densities of sites and wetlands in the study area, could be indicative of early Holocene land-use patterns on a regional scale.

Question 2: Were early Plateau-Basin hunter-gatherer foraging patterns tethered to wetland dense regions rather than locally concentrated around particular wetlands?

Are archaeological sites clustered around specific resource environments? Does this clustering happen locally at specific sites, indicating a preference for locales? Or does clustering happen at greater distances, indicating a preference for particular basins? In order to discover regional foci, Ripley's K-Function analysis was used in this study to discover the distances at which sites cluster around each other. The average distance between archaeological sites and several categories of environmental features were also calculated to study the distances at which early hunter-gatherers might have been traveling to reach resources. Histograms were produced to indicate how often sites are within a day's travel from particular environment types. Collectively, these analyses were designed to investigate early Holocene land-use patterns on a local scale.

Question 3: Did early Plateau-Basin peoples focus their foraging activities on areas that were particularly dense with wetland concentrations?

If early sites are not directly linked to particular wetland locations, then perhaps they are clustered in watersheds or other hydrographic units with dense concentrations of resources. Moran's I autocorrelation analysis was used here to study whether hydrographic units contain high concentrations of sites. Pearson's R correlation analyses were performed to discover whether these site concentrations are related to environmental feature concentrations. These two correlation studies were utilized to explore connections between densities of archaeological sites and wetlands, with the assumption that there may be differences between correlations at different scales of analysis.

Study Area Definition

To explore the notion that early Columbia Plateau and Great Basin cultures centered their economies on pluvial lakes, I selected a portion of land in the Western Pluvial Lakes Tradition (WPLT) region for analysis (Figure 5). The study was limited to the Burns and Vale Districts of the Bureau of Land Management (BLM), which administer a combined 3.42 million hectares in eastern Oregon (BLM 2011a, 2011b). These BLM districts have completed archaeological projects across 2,945 km^2, creating a 3.5% (2,236 km^2) sample of the WPLT region. I created my study area boundary by selecting the Burns and Vale District boundaries available for download from the BLM Oregon/Washington Data Library (BLM 2010F).

These districts were chosen as the study area for four reasons. First, although my original research design included a much larger study area, the availability of archaeological and environmental data made it necessary to narrow the study boundaries. After contacting the Oregon State Historic Preservation Office and several federal agency CRM offices about the accessibility of archaeological data, the study area was limited to the Burns and Vale districts of the BLM, as they were able to provide sufficient research data. Second, data in the study area were produced by two CRM programs in the same agency, so it was expected that similar standards for recordation would produce a cohesive database. Third, the study area has a long history of research into Pleistocene-Holocene transition archaeology (e.g., Jenkins et al. 2012; O’Grady et al. 2008; Thomas 2008; Thomas et al. 2008; Thomas 2012), which has contributed to a large database of early Holocene archaeological sites. Finally, the area includes portions of both the Great Basin and Columbia Plateau regions, providing both the opportunity to test associations within pluvial lake dense basins, and to compare these associations with site-environment patterns outside the WPLT area.

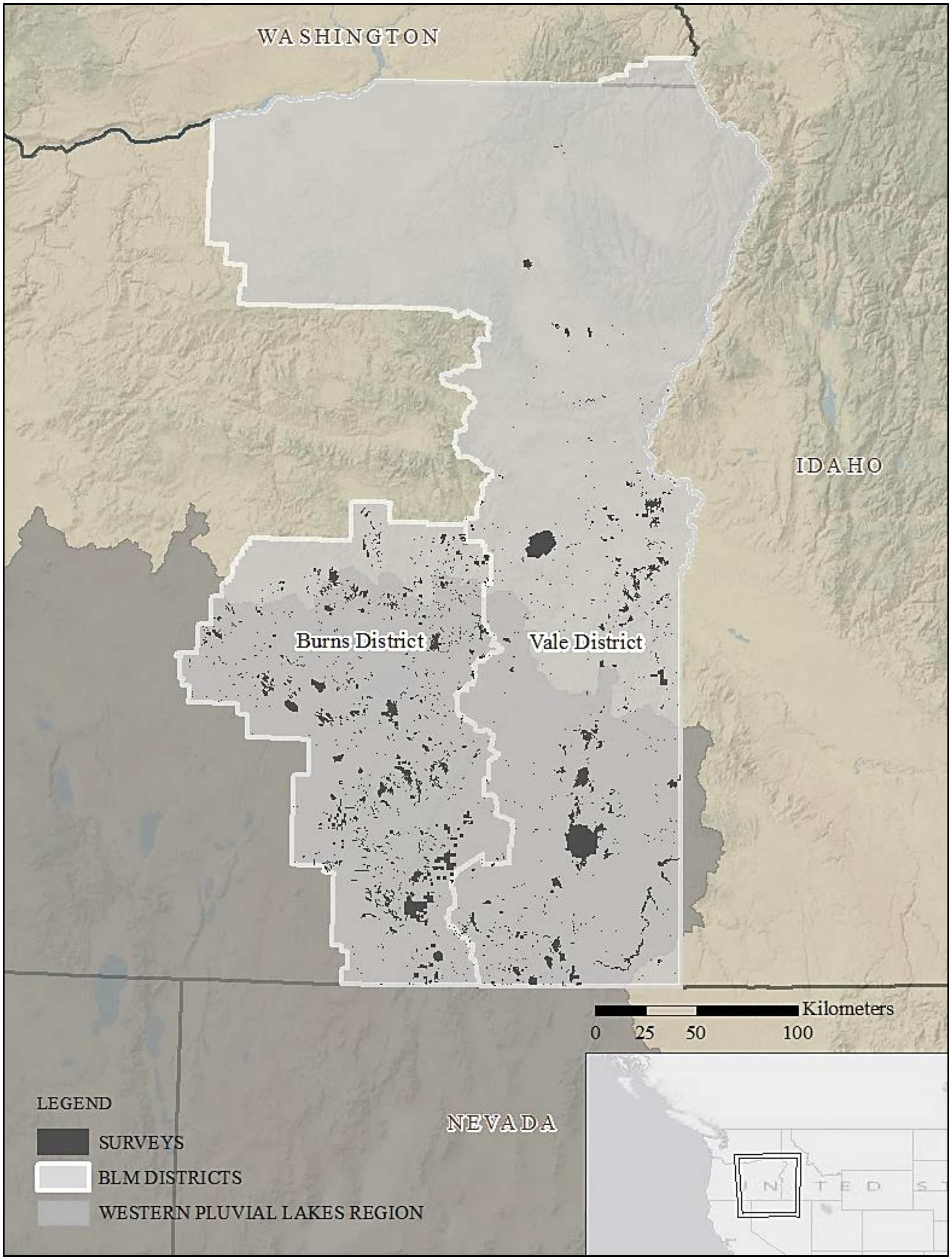


Figure 5. Distribution of CRM projects in study area.

Archaeological Data Collection and Processing

Archaeological site data were provided by the Burns and Vale BLM districts in October 2010 (BLM 2010A, 2010B, 2010C). The BLM conducts pedestrian surveys and records the locations of historic properties on BLM-administered lands in the course of complying with the National Historic Preservation Act as well as for other BLM-initiated studies. At the time of data collection, Burns and Vale utilized several databases to manage cultural resources under their jurisdiction. Burns District archaeological site information was stored in an Access database that contains spatial and descriptive data on sites and artifacts. Burns District archaeologist Scott Thomas provided a digital spreadsheet containing early site information and a catalog of artifact photographs. Most of the Vale District information was also stored in an Access database.

I reviewed this database and selected sites that were identified as early Holocene sites. The following terms were also employed as search queries to locate early sites in the database: black rock [concave], cascade, Clovis, Cody, [black rock] concave, cordilleran, cougar [mountain], [Lind] coulee, crescent, Eden, flute, fluted, Folsom, [lake] Mohave, [lind] coulee, Mazama, outré [passé], palaeo, paleo, parallel [flaking], Parman, [outré] passé, plano, Pleistocene, pluvial, silver [lake], stem, stemmed, and Windust. As the Vale district was in the process of migrating site files to this Access database, I reviewed hard copy files at the Vale and Baker offices of the Vale District. Detailed artifact descriptions in the Burns and Vale databases allowed for identification of Pleistocene-Holocene transition diagnostic artifact types. In instances where a diagnostic type was not clearly described in the original database, I classified artifacts per the typology defined in Chapter 2, based on artifact photos, drawings, and descriptions provided in the site files.

I integrated the archaeological site data from Burns and Vale into one database that contains precise artifact definitions and spatial information. Files were reviewed for indicators of early Holocene sites, and the location and description of each early Holocene artifact was entered into the study GIS. Spatial data were considered

Table 6. GIS data used to test Western Pluvial Lakes Tradition.

Data Category	Feature Type	Format	Source
Western Pluvial Lakes Tradition Area	Polygon	Text	Bedwell 1973:170
Burns Archaeological Site Locations	Point	Access database	BLM 2010A
Vale Archaeological Site Locations	Point	Access database	BLM 2010B
	Point	Hardcopy site forms	BLM 2010C
Burns Survey Areas	Polygon	ESRI shapefile	BLM 2010D
Vale Survey Areas	Polygon	ESRI shapefile	BLM 2010E
Pluvial Lakes	Polygon	Topographic map	NGS 2011
		Text	Carter et al. 2006; Gehr 1980; McDowell 1992; Wriston 2003
Playas	Polygon	ESRI shapefile	NRCS 2012C
Extant Lakes	Polygon	ESRI shapefile	NRCS 2012C
Extant Marshes	Polygon	ESRI shapefile	NRCS 2012 C
Extant Springs	Point	ESRI shapefile	NRCS 2012C
Extant Streams	Line	ESRI shapefile	NRCS 2012C
BLM Boundaries	Polygon	ESRI shapefile	BLM2010F
Hydrologic Units	Polygon	ESRI shapefile	NRCS 2012C
Physiographic Units	Polygon	ESRI shapefile	USGS 2012

precise if entries were assigned to an area no larger than 4 km^2. All spatial data were entered in Universal Transverse Mercator coordinates referenced within zone 11 of the North American Datum 83. Given the sensitive nature of these data, site locations are not displayed in this thesis. The final database contained 744 artifact locations representing early subsistence-settlement patterns in the study area (Table 7).

The Burns and Vale Districts also maintain information on BLM project and archaeological site boundaries, which were used to analyze patterns in site-discovery bias. This information was provided by BLM GIS specialists in the form of ArcGIS polygon and point shapefiles from both districts (BLM 2010D, BLM 2010E). These files were merged in ArcGIS and any overlapping boundaries were dissolved to create one file containing the locations of all 2,945 km^2 of BLM project lands in eastern Oregon.

Paleoenvironment Modeling

Environmental features and catchment basins were modeled with data obtained from the Natural Resource Conservation Service Geospatial Data Gateway (NRCS 2012A, 2012B, 2012C) and the United States Geological Survey (USGS 2012). The study area was divided into the physiographic provinces and sections described in Chapter 2 in order to test differences in site patterning within and between the Plateau and Great Basin regions. Definitions of physiographic provinces and sections were obtained from the United States Geological Survey (USGS 2012).

Hydrologic units were also used in this study to detect variations in local spatial distributions. Four hydrologic levels were selected to explore how settlement patterns might be summarized within watersheds (Table 8). According to studies of toolstone sources in the Great Basin, early foragers used territories that may have ranged from 20,000 km^2 to 40,000 km^2 (Jones et al. 2012: 365; Smith 2010:878). The basin hydrologic unit is representative of these ranges, providing general regional summaries consistent with what we know about hunter-gatherer mobility in this region. Subbasins, watersheds, and subwatersheds, as defined by the USGS (2012) were used to explore fine-grained spatial patterns.

Table 7. Early Holocene artifact counts in integrated Burns and Vale database.

Diagnostic Artifact Type	Vale Count	Burns Count	Study Area Count
Fluted	2	25	27
Black Rock Concave	0	14	14
Haskett	0	6	6
Parman	4	49	52
Parman Square Stemmed	8	19	27
Parman (All)	11	68	79
Windust	0	2	2
Stemmed (unclassified)	8	434	442
Stemmed (All)	20	510	530
Crescent	0	118	118
Cascade	3	3	6
Foliate	5	44	49
Total	30	714	744

Table 8. Hydrologic units of analysis.

Hydrologic Level	Unit Type	# Units	Minimum Area (km^2)	Maximum Area (km^2)	Mean Area (km^2)
3	Basin	8	10,641	45,150	25,444
4	Subbasin	39	751	10,707	4,181
5	Watershed	226	143	1,120	489
6	Subwatershed	1,117	21	428	87

The boundary of the Western Pluvial Lakes Tradition region was created by delineating the pluvial lake dense region of Oregon, Nevada, California, and Idaho (Figure 6). As defined by Bedwell (1973:170), the WPLT extended “from Fort Rock Basin (the northernmost point), south along the Cascade-Sierra-Nevada Uplift in western Nevada and part of northeastern California (in the region of Lake Lahontan) and finally south into the desert areas of southeastern California and pluvial Lake Mohave.” For this study, watersheds with dense concentrations of lakes or playas were identified within the region and then merged into a single polygon covering 306,190 km.^{2}

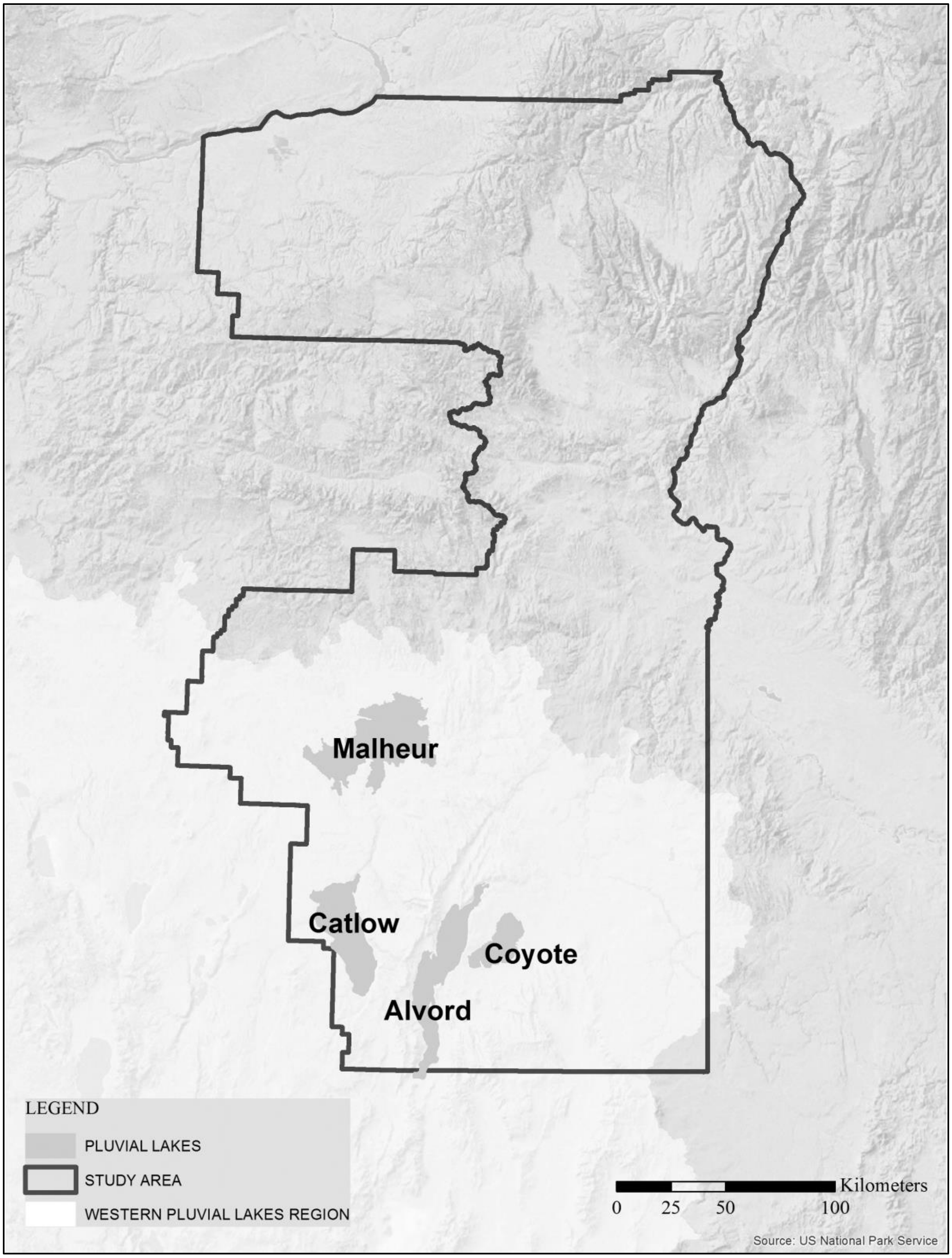
Several methods of pluvial lake modeling were attempted before a satisfactory model of northern Great Basin Pleistocene-Holocene transition lakes was achieved. Discussions of the spatial connections between early sites and pluvial lakes often reference models of pluvial lakes at their maximum extent (e.g., Cannon et al. 1990:175; Freidel 1994:23; Janetski 1990:238; Madsen 2007:6; Mehringer 1986:32; Smith 1985:117; Tuohy 1985:149). Polygons for these Pleistocene lakes were downloaded through USGS (Reheis 1999) and compared to Pleistocene-Holocene transition lake elevations (Table 9). Marith Reheis’s (1999) model of the late Pleistocene pluvial lakes has often been used as a representation for the extent of pluvial lakes in the early Holocene. However, after comparing the lake shorelines with archaeological site locations, I determined that the Reheis (1999) model overestimates the size of pluvial lakes at the time humans were living in the area. Likewise, while hydric soils can be used to identify past and present wetland areas (Lyon 2011:29), the distribution of hydric soils in the study area was also indicative of pluvial lakes at their maximum Pleistocene extent. These maximum extents were reached by the end of the Pleistocene, but do not represent the extent of pluvial lakes when humans inhabited the Great Basin in the early Holocene and further do not represent the complexity of associated smaller water bodies. I created early Holocene models of Lakes Alvord, Catlow, Coyote, and Malheur (Figure 7) by drawing lake high-stand elevations on USGS topographic maps in the project GIS (National Geographic Society 2011). The pluvial lake models used in this study represent the maximum extent of these lakes in the early Holocene; they simplify the complexity of the pluvial lake shorelines over several thousand years.

Figure 6. Western Pluvial Lakes Region as described by Bedwell (1973).

Table 9. Early Holocene pluvial lake elevations.

Pluvial Lake	RCYBP	Cal yrs BP[1]	Elevation (meters)	Elevation (feet)	Source
Alvord	13,000–14,000	17,000–16,000	1,280	4,199	Carter et al. 2006
Catlow	n/a	Late Pleistocene	1,400	4,590	Waring 1909
Coyote	13,000–14,000	17,000–16,000	1,278	4,193	Carter et al. 2006
Malheur	9,880–7,300	11,300–9,700	1,255	4,118	Dugas 1998:279

[1] Calibrated years before present estimate calculated via Stuiver et al. 2013



Source: US National Park Service

Figure 7. Pluvial lakes in the study area at the Pleistocene-Holocene transition.

Although the objective of this study was to analyze the relationship between early archaeological sites and pluvial lakes, several other types of landscape features were also modeled for comparison. The locations of extant watered places within the study area basins were mapped to examine the connections between early sites and watered places in general. Extant or seasonal lake, marsh, spring, and stream locations were used to approximate the distribution of Pleistocene-Holocene transition landscape features, as these features offer a minimum representation of early Holocene watered places prior to the mid-Holocene drying trend. The higher effective precipitation that would have produced the large pluvial lakes in the Pleistocene could have also fed more springs, permanent streams, lakes, and marshes than could be modeled in this study.

Chapter Summary

In this chapter I identified the methods and data used for analyzing Western Pluvial Lakes Tradition site patterns. Hypothesis testing by Hoffman (1996) was limited to site-environment frequency studies, but in the course of this thesis research it was determined that exploratory spatial analysis using six statistical methods would provide opportunity for observing site-environment associations. Archaeology has a long history of studying settlement patterns, and with the advent of GIS, spatial statistical methods are proving to be effective methods for defining archaeological site patterns and correlations. Given the abundance of early Holocene spatial data collected by the Burns and Vale Oregon Districts of the BLM, spatial analysis of site patterning was used as a means to explore the Western Pluvial Lakes Tradition hypothesis. I also identified and described three research questions, my primary research hypothesis, and spatial and traditional statistical methods were proposed for testing these questions. The results of statistical analyses are discussed in detail in Chapter 4.

Chapter 4: Paleoindian Site Patterns in the Southern Columbia Plateau and Northwestern Great Basin

Over the course of several decades, North American archaeologists have produced substantial databases that collectively have great potential to inform archaeological theories. Paleoindian archaeological sites are materially and spatially sparse, complicating identification of early subsistence-settlement practices. Isolated artifact finds have the potential to contribute to discussions of ancient resource use and mobility, but they are under-reported outside of the CRM grey literature and overlooked in regional studies of landscape use. This thesis is both a test of regional subsistence-settlement hypotheses, and a case study in how archaeologists might utilize the archaeological site databases we have been amassing.

In this study, I used the locations of 744 archaeological isolates to research early Holocene site patterns in the southern Columbia Plateau and northern Great Basin. Six statistical methods were used here to explore the research questions discussed in the previous chapters. Detailed figures and tables of these analyses are presented in this chapter. The implications of these findings are discussed in Chapter 5.

Results of Statistical Analyses

Spatial and traditional statistical analyses were employed in this thesis to evaluate the association between Pleistocene-Holocene transition archaeological sites and environmental features. The statistical analyses used were frequency, nearest neighbor, Ripley’s K-Function cluster, Moran’s I spatial autocorrelation, mean center, and correlation analyses. Summary statistics were used to measure (1) regional differences in site and environmental feature abundance, (2) central tendencies of archaeological sites and environmental features, (3) average distance between archaeological sites and environmental features, and (4) frequencies of artifact-environment associations. Cluster analyses were used to detect site and environmental feature clustering among individual features and catchment areas.

Regional Frequencies

Site-environment associations in the study area were summarized in 14 frequency charts and 2 tables (Tables 10–11; Figures 8–21). General differences in the distribution of archaeological sites were first studied by summarizing archaeological site counts within the Columbia Plateau, Great Basin, and Western Pluvial Lakes Tradition (WPLT) regions (Table 10). As the number of site counts varied substantially between the site categories, frequencies were transformed to percentages to easily compare distributions between portions of the study area (see Table 11). The majority of early Holocene sites are located in the Great Basin (92%) and WPLT (94%) portions of the study area. The only exception to this pattern is with Parman square-stemmed points, which are slightly more evenly distributed, with 30% of sites located in the Plateau and outside the WPLT region. The later period sites are also more evenly distributed across the regions. Foliate points are found in the Plateau 24% of the time and outside the WPLT region 20% of the time, while Cascade points are located in the Plateau and non-WPLT region 50% of the time. Despite these higher percentages, it is apparent that all site types are concentrated in both the WPLT and Great Basin portions of the study area.

Frequency charts were used to further study differences between the Great Basin, Columbia Plateau, and WPLT portions of the study area. These study area divisions summarize the frequency of wetland types, archaeological sites, and coverage of CRM surveys in the study area, and were used to compare differences between portions of the study area. Although the study area contains more Columbia Plateau land (73%) than Great Basin land (27%) (see Figure 8), BLM surveys are slightly biased toward the Great Basin (57%) (see Figure 10). While only 41% of the study area is in the WPLT region (see Figure 14), 77% of surveys in the study region were conducted in the WPLT region (see Figure 16). Thus, it appears that BLM survey coverage has been skewed to the Great Basin and WPLT portions of the study area. The survey history may be the cause of the higher number of archaeological sites recorded in the Great Basin and WPLT regions, and it is possible that many archaeological sites remain unrecorded in the Columbia Plateau area.

Table 10. Site frequencies by culture region area.

Site Type	Columbia Plateau	Great Basin	Non-Western Pluvial Lakes Tradition	Western Pluvial Lakes Tradition	Total
Fluted	1	26	1	26	27
Black Rock Concave	1	13	1	13	14
Haskett	0	6	0	6	6
Parman	5	47	7	45	52
Parman Square	8	19	8	19	27
Parman, all	13	66	15	64	79
Windust	0	2	0	2	2
Stemmed, unclassified	25	408	15	419	433
Stemmed, all	38	482	30	491	520
Crescent	1	117	0	118	118
Cascade	3	3	3	3	6
Foliate	12	37	10	39	49
Humboldt	25	233	15	243	258
Northern Side Notched	38	231	26	243	269
All Early Holocene	56	678	45	690	734
All Later Holocene	63	464	41	486	527
All Points	119	1142	86	1176	1261

Table 11. Site type percentages by culture region area.

Site Type	Columbia Plateau	Great Basin	Non-Western Pluvial Lakes Tradition	Western Pluvial Lakes Tradition
Fluted	4%	96%	4%	96%
Black Rock Concave	7%	93%	7%	93%
Haskett	0%	100%	0%	100%
Parman	10%	90%	13%	87%
Parman Square	30%	70%	30%	70%
Parman, all	16%	84%	19%	81%
Windust	0%	100%	0%	100%
Stemmed, unclassified	6%	94%	3%	97%
Stemmed, all	7%	93%	6%	94%
Crescent	1%	99%	0%	100%
Cascade	50%	50%	50%	50%
Foliate	24%	76%	20%	80%
Humboldt	10%	90%	6%	94%
Northern Side Notched	14%	86%	10%	90%
All Early Holocene	8%	92%	6%	94%
All Later Holocene	12%	88%	8%	92%
All Points	9%	91%	7%	93%

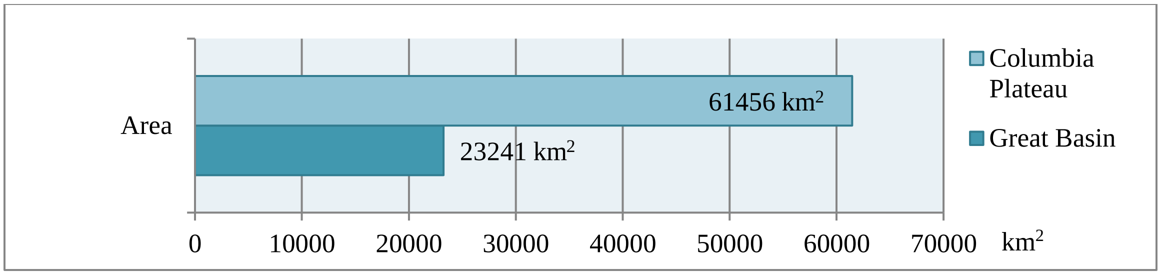


Figure 8. Portion of study area in the Columbia Plateau and Great Basin.

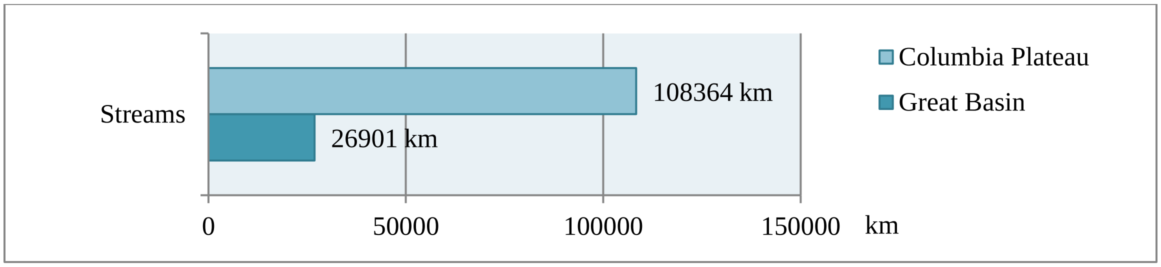


Figure 9. Stream length in the Columbia Plateau and Great Basin.

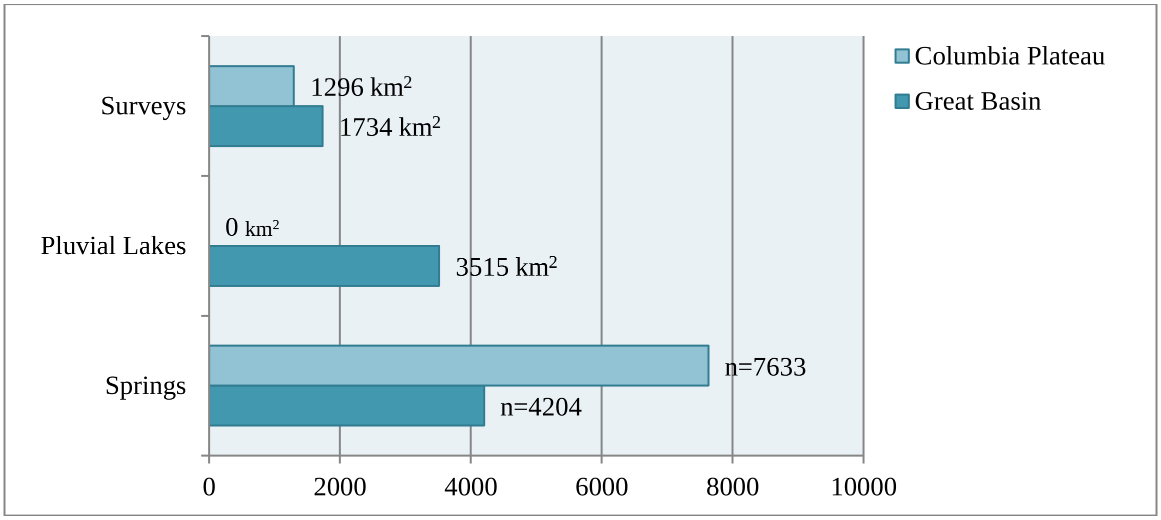


Figure 10. Total area of surveys, and pluvial lakes, and number of springs in the Columbia Plateau and Great Basin.

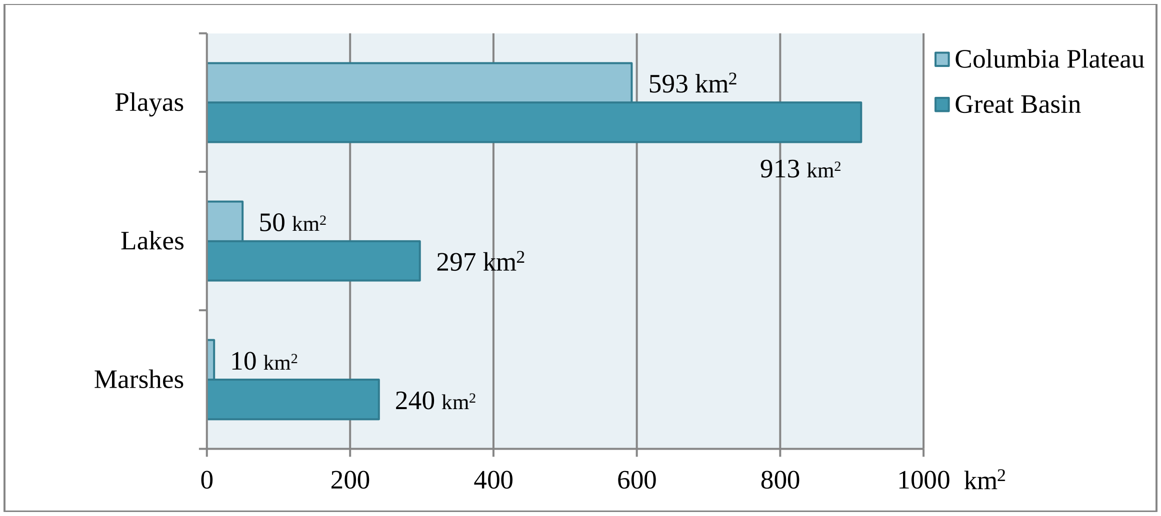


Figure 11. Total area of playas, lakes, and marshes in the Columbia Plateau and Great Basin.

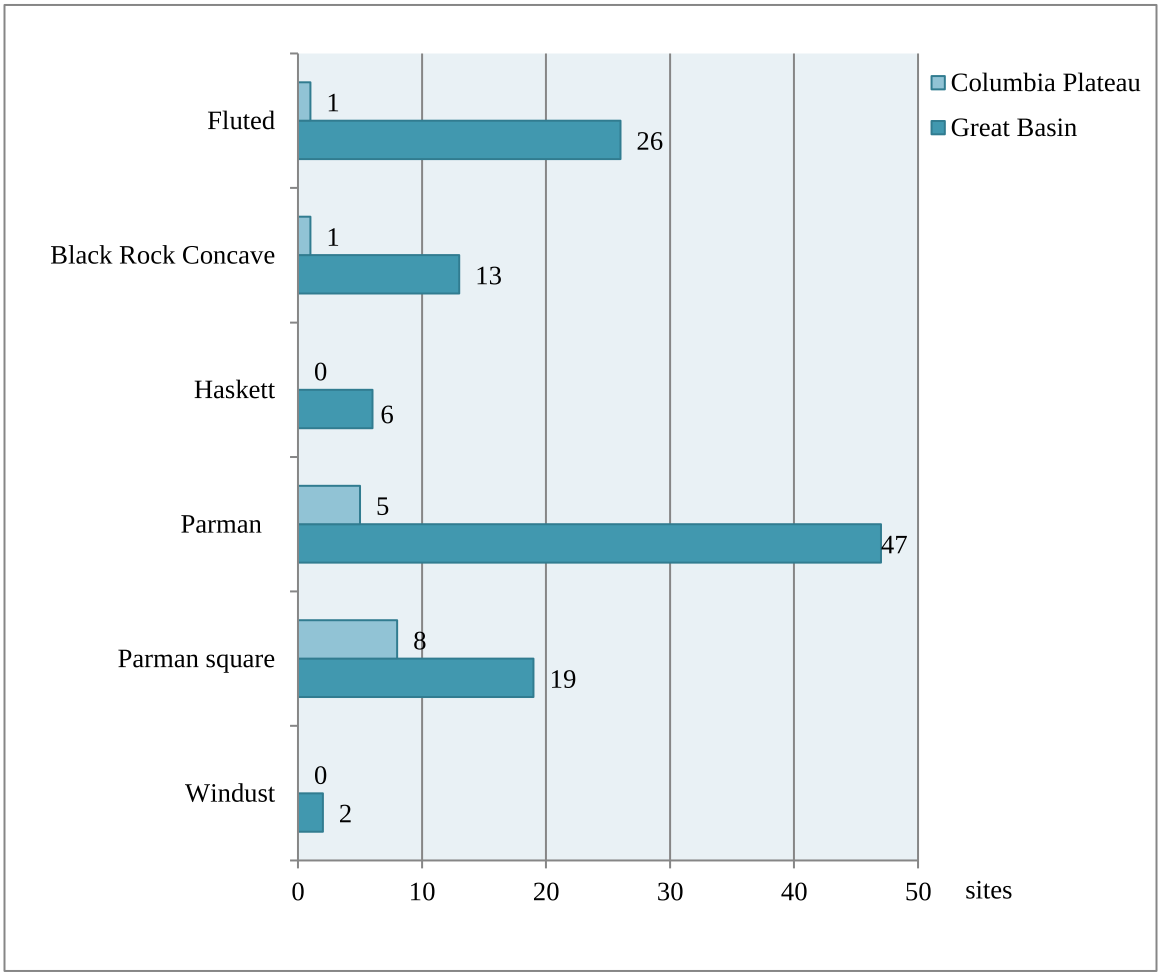


Figure 12. Frequency of Early Holocene sites in the Columbia Plateau and Great Basin.

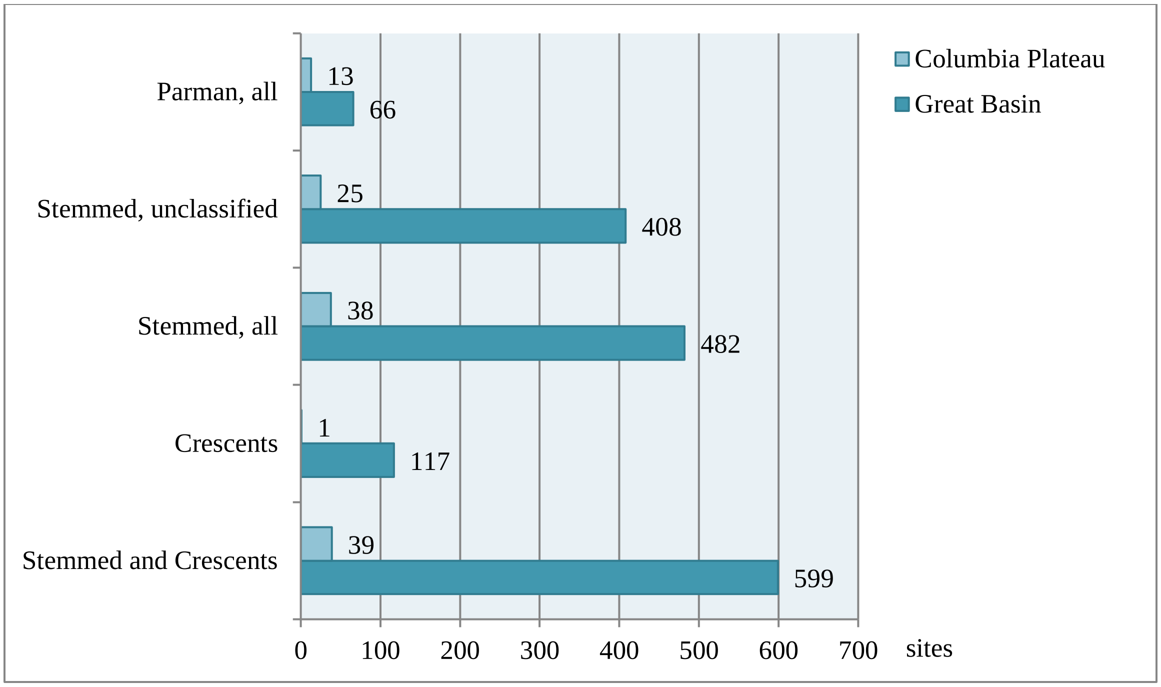


Figure 13. Frequency of Western Stemmed sites in the Columbia Plateau and Great Basin.

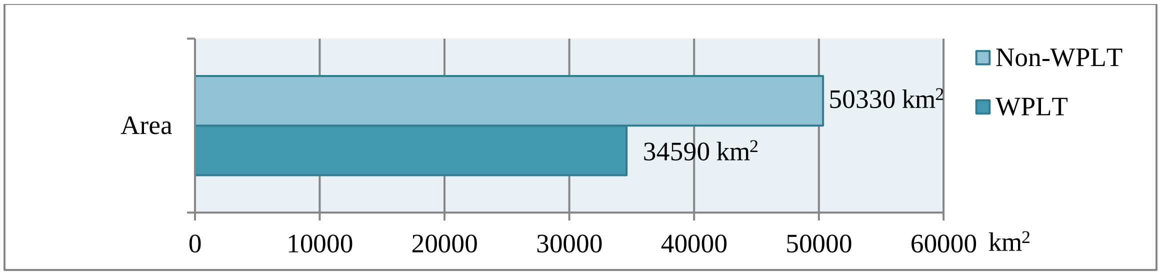


Figure 14. Portion of study area in the Western Pluvial Lakes Tradition region.

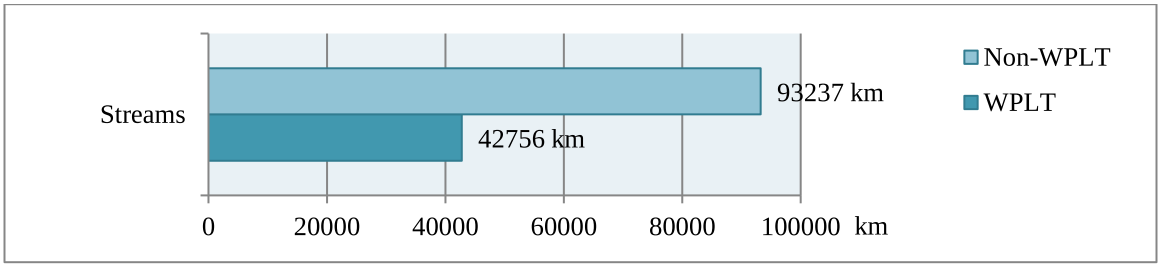


Figure 15. Stream length in the Western Pluvial Lakes Tradition region.

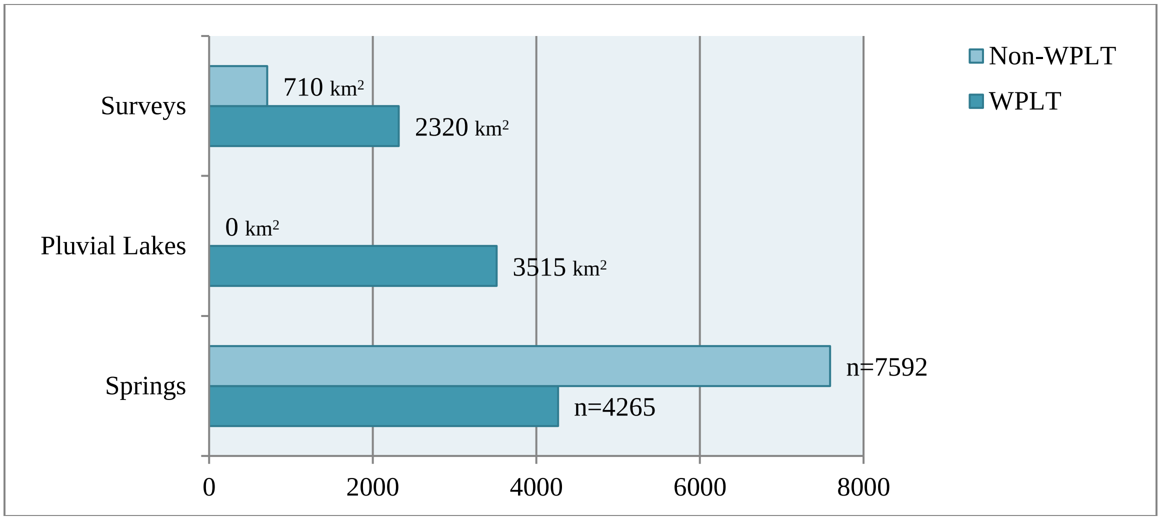


Figure 16. Total area of surveys, pluvial lakes, and number of springs in the Western Pluvial Lakes Tradition region.

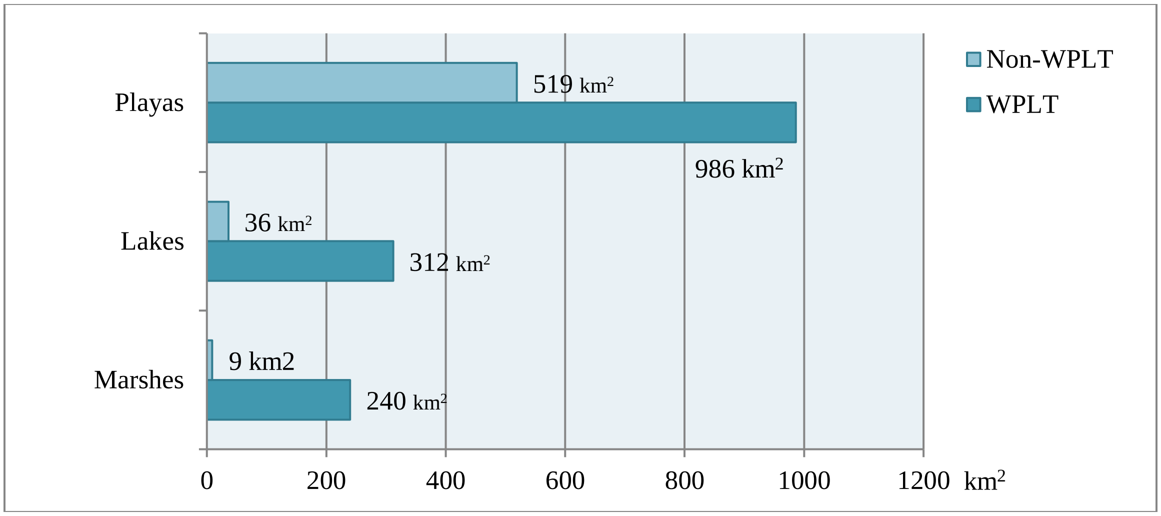


Figure 17. Total area of playas, lakes, and marshes in the Western Pluvial Lakes Tradition region.

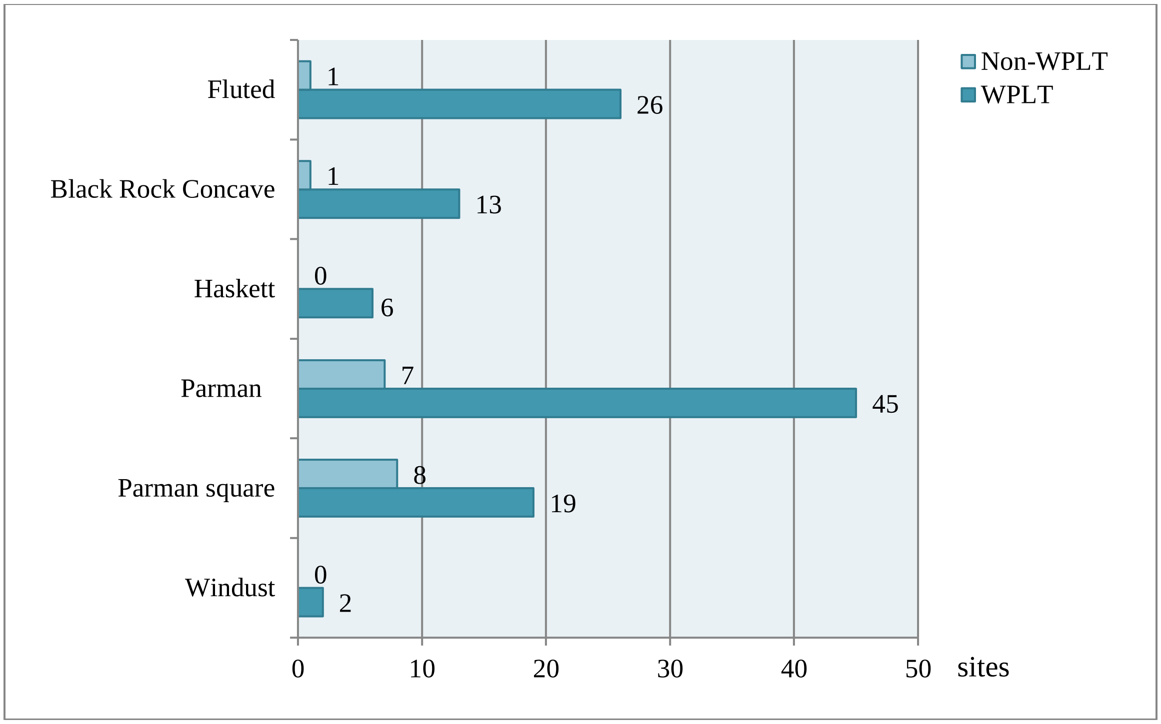


Figure 18. Frequency of Early Holocene sites in the Columbia Plateau and Great Basin.

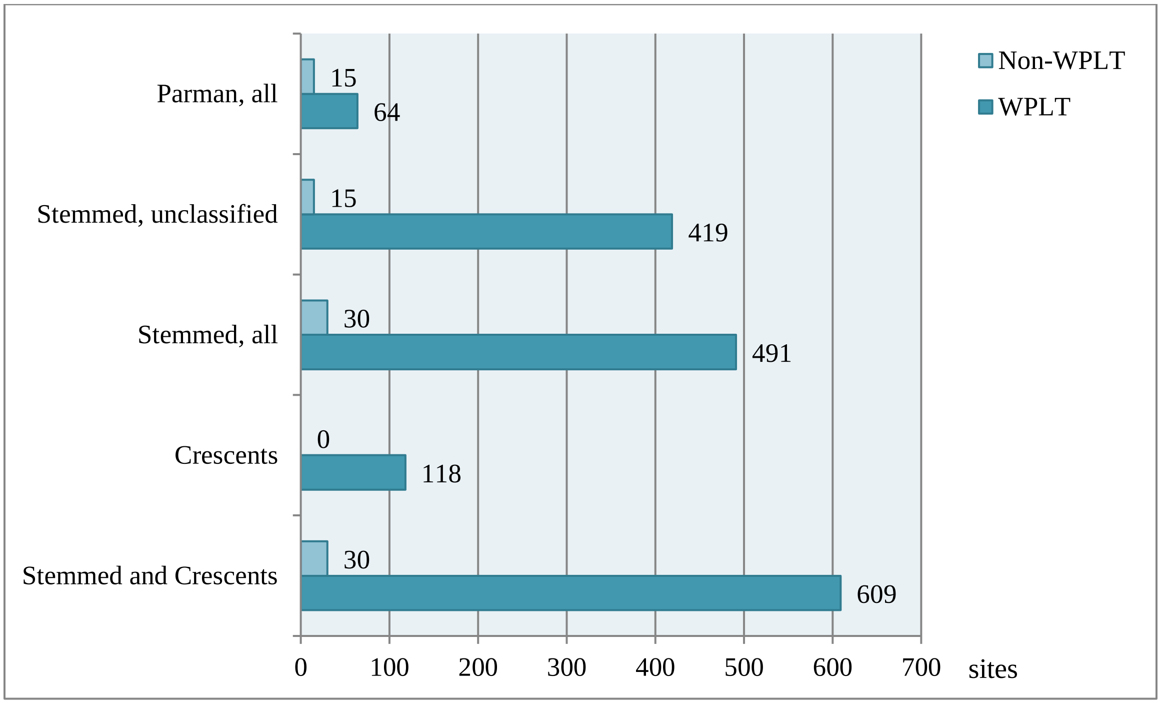


Figure 19. Frequency of Western Stemmed sites in the Western Pluvial Lakes Tradition region.

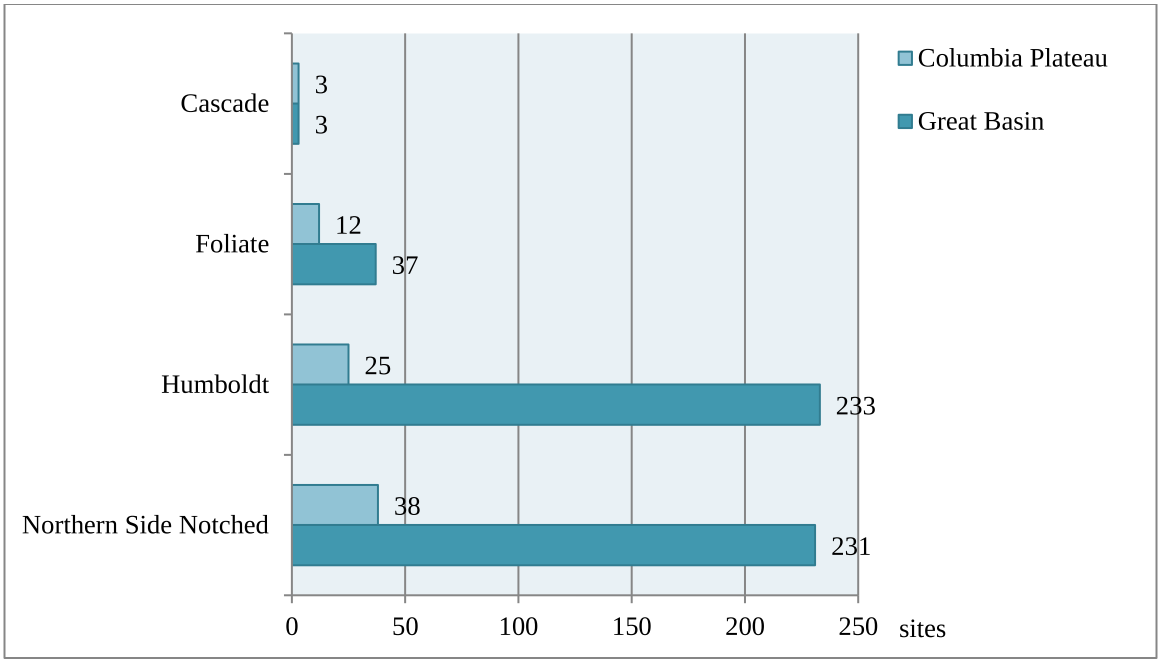


Figure 20. Frequency of later Holocene sites in the Columbia Plateau and Great Basin.

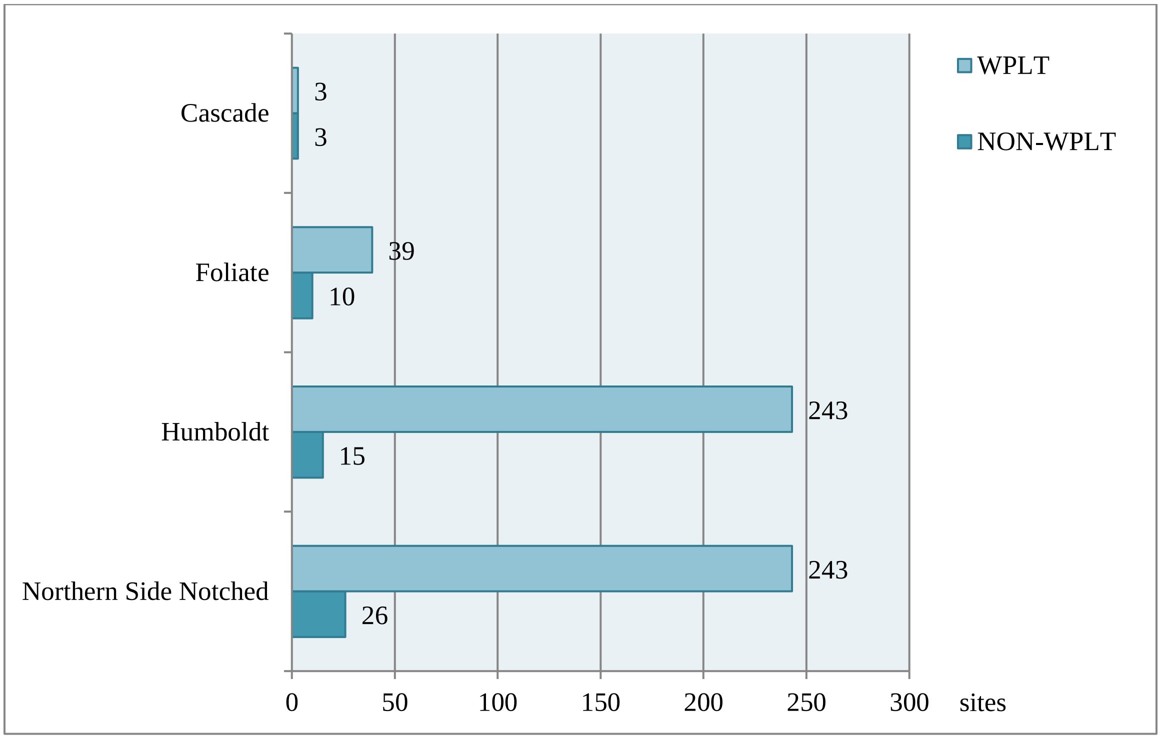


Figure 21. Frequency of later Holocene sites in the Western Pluvial Lakes Tradition region.

Some clear differences also exist between the study regions in regard to environmental features. The Columbia Plateau contains more streams and springs, while the Great Basin contains more area covered by pluvial lakes, playas, lakes, and marshes (see Figures 9–11). Similar divisions occur within WPLT region boundaries. All of the study area's pluvial lakes and the majority of playas, lakes, and marshes are contained within the WPLT portion of the study area. The WPLT region covers a smaller portion of the study area, but contains fewer streams and springs than the portion of the study area outside this boundary.

The frequency analyses indicate that CRM practices have favored survey in the Great Basin and WPLT portions of the study area. The history of CRM surveys has most likely influenced site discovery to some degree, but the number of archaeological sites recorded in the Great Basin and WPLT area is disproportionately high compared to the Columbia Plateau and non-WPLT areas. Based on the frequencies of wetlands in the study area, it appears that the environmental differences between the Columbia Plateau and Great Basin could be a factor in the archaeological site distributions. While the Columbia Plateau and non-WPLT areas contain more springs and streams than the Great Basin and WPLT regions, the Great Basin and WPLT regions have more hectares covered in pluvial lakes, playas, lakes, and marshes.

Nearest Neighbor Analysis

Nearest neighbor analyses were performed on all archaeological site types to discover how dispersed sites were across the study area (Table 12). Fluted, stemmed, crescent, and foliate sites are considered clustered, which justifies further investigation of dispersion patterns. P-values for most of these tests were extremely low (.00000), indicating that observed clustering is not random. Only Windust sites were found to be dispersed, but the low number of these sites (n=2) makes this conclusion unreliable as a representation of regional patterns. Black Rock Concave (n=14) and Cascade (n=6) sites were found to be randomly dispersed, possibly reflecting a more generalized settlement pattern than that associated with other early Holocene cultural traditions.

Table 12. Nearest Neighbor analysis statistics by site type.

Site Type	Dispersion Level	Observed Mean Distance	Expected Mean Distance	Nearest Neighbor Ratio	Z-Score	P-Value
Fluted	Clustered	9470 m	6102380 m	.001552	-10.462055	.000000
Black Rock Concave	Random	15675 m	15294 m	1.024955	.178630	.858229
Haskett	Clustered	417 m	1003 m	.416010	-2.736604	.006208
Parman	Clustered	7570 m	12614 m	.600166	-5.568635	.000000
Parman Square	Clustered	14330 m	20215 m	.708856	-2.894145	.003802
Parman, all	Clustered	3879 m	12216 m	.317541	-11.965952	.000000
Windust	Dispersed	88126 m	148 m	593.724747	1603.610682	.000000
Stemmed, unclassified	Clustered	10526 m	32459 m	.324289	-27.177104	.000000
Stemmed, all	Clustered	9050 m	31250 m	.289602	-31.287468	.000000
Crescent	Clustered	2011 m	5764 m	.348808	-13.532600	.000000
Cascade	Random	30024 m	34707 m	.865067	-.632302	.527190
Foliate	Clustered	5960 m	15835 m	.376406	-8.350855	.000000
Humboldt	Clustered	1455 m	5374 m	.270641	-22.455460	.000000
Northern Side Notched	Clustered	5444 m	19252 m	.282800	-22.628500	.000000
All Early Holocene	Clustered	1114 m	6637 m	.167909	-41.905242	.000000
All Later Holocene	Clustered	3042 m	13829 m	.219990	-34.385722	.000000
All Points	Clustered	718 m	4997 m	.143642	-57.292723	.000000

low artifact counts in the study area. In sum, these statistics indicate that further statistical analysis was warranted for fluted, Haskett, Parman, Parman Square, crescent, and foliate sites, and that more data are needed on Black Rock Concave, Cascade, and Windust sites in order to produce statistically significant results.

Ripley's K-Function Cluster Analysis

Ripley's K-Function analyses were performed to pinpoint the distances at which sites clustered (Tables 13–29; Figures 22–37). All site types were examined, although the small Windust dataset (n=2) was too small to be used in this analysis. As a sample size of 30 is ideal (ESRI 2012) for each of these analyses, only the following site types were reliably analyzed with this method: Parman, Parman Square, all combined Parman, unclassified Stemmed, all Stemmed, Crescent, foliate, and all early Holocene sites combined (Table 13). Observed distances were calculated at 20 band distances, beginning

Table 13. Ripley's K-Function cluster analysis summary.

Site Type	Sample Size	Ideal Sample Size?	Clustering Begins	Dispersion Begins
Fluted	27	N	1 km	105 km
Black Rock Concave	14	N	1 km	n/a
Haskett	6	N	1 km	n/a
Parman	52	Y	1 km	153 km
Parman Square	27	N	1 km	121 km
Parman, all	79	Y	1 km	137 km
Windust	2	N	1 km	145 km
Stemmed, unclassified	433	Y	1 km	153 km
Stemmed, all	520	Y	1 km	153 km
Crescent	118	Y	1 km	153 km
Cascade	6	N	1 km	81 km
Foliate	49	Y	1 km	129 km
Humboldt	258	Y	1 km	153 km
Northern Side Notched	269	Y	1 km	153 km
All Early Holocene	734	Y	1 km	153 km
All Later Holocene	527	Y	1 km	153 km
All Points	1261	Y	1 km	145 km

Table 14. Ripley's K-Function cluster analysis of Fluted sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	53	52	Clustered
9	58	49	Clustered
17	73	56	Clustered
25	79	54	Clustered
33	93	60	Clustered
41	93	52	Clustered
49	107	58	Clustered
57	110	53	Clustered
65	112	47	Clustered
73	112	39	Clustered
81	112	31	Clustered
89	112	23	Clustered
97	112	15	Clustered
105	113	8	Random
113	116	3	Random
121	116	-5	Random
129	117	-12	Dispersed
137	130	-7	Random
145	138	-7	Random
153	150	-4	Random

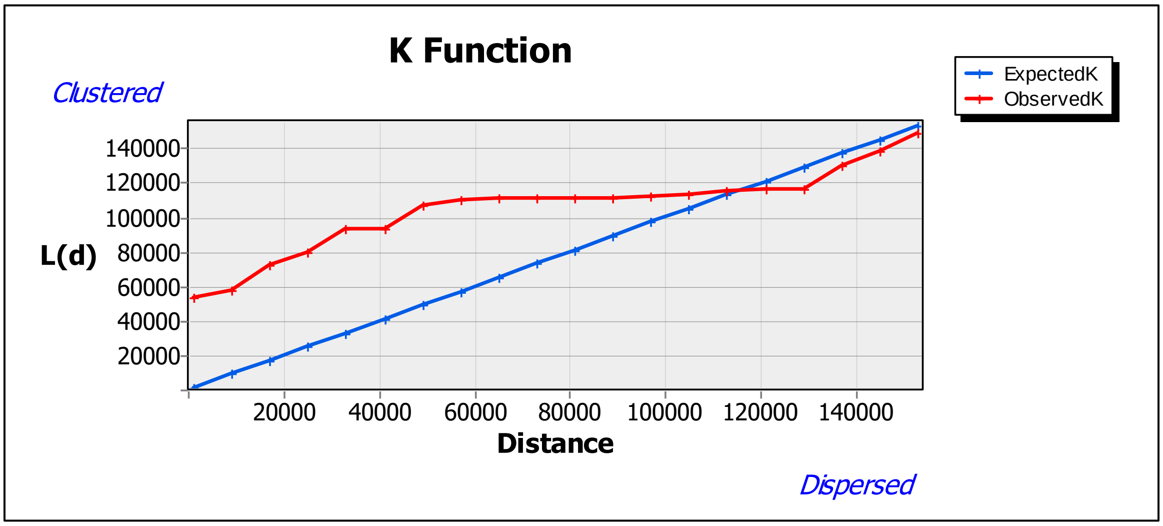


Figure 22. Ripley's K-Function cluster analysis of Fluted sites.
Note: Measurements in meters.

Table 15. Ripley's K-Function cluster analysis of Black Rock Concave sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	42	41	Clustered
9	57	48	Clustered
17	71	54	Clustered
25	79	54	Clustered
33	86	53	Clustered
41	88	47	Clustered
49	99	50	Clustered
57	100	43	Clustered
65	103	38	Clustered
73	104	32	Clustered
81	110	29	Clustered
89	129	40	Clustered
97	145	48	Clustered
105	148	43	Clustered
113	150	37	Clustered
121	154	33	Clustered
129	157	28	Clustered
137	159	22	Clustered
145	163	19	Clustered
153	163	11	Clustered

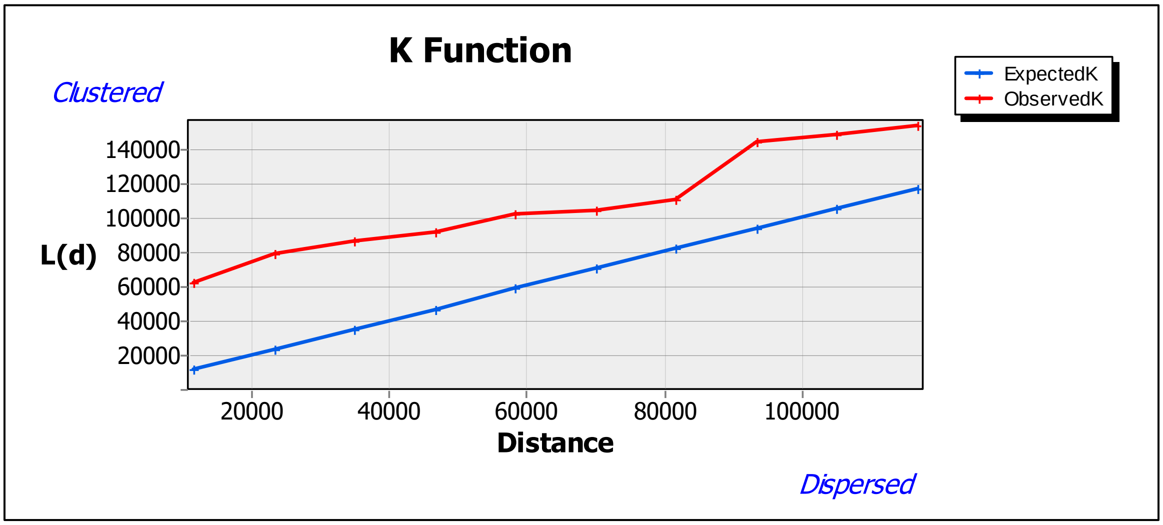


Figure 23. Ripley's K-Function cluster analysis of Black Rock Concave sites.
Note: Measurements in meters.

Table 16. Ripley's K-Function cluster analysis of Haskett sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	104	103	Clustered
9	112	103	Clustered
17	112	95	Clustered
25	147	122	Clustered
33	164	131	Clustered
41	164	123	Clustered
49	164	115	Clustered
57	164	107	Clustered
65	164	99	Clustered
73	164	91	Clustered
81	164	83	Clustered
89	164	75	Clustered
97	164	67	Clustered
105	164	59	Clustered
113	164	51	Clustered
121	164	43	Clustered
129	164	35	Clustered
137	164	27	Clustered
145	164	19	Clustered
153	164	11	Clustered

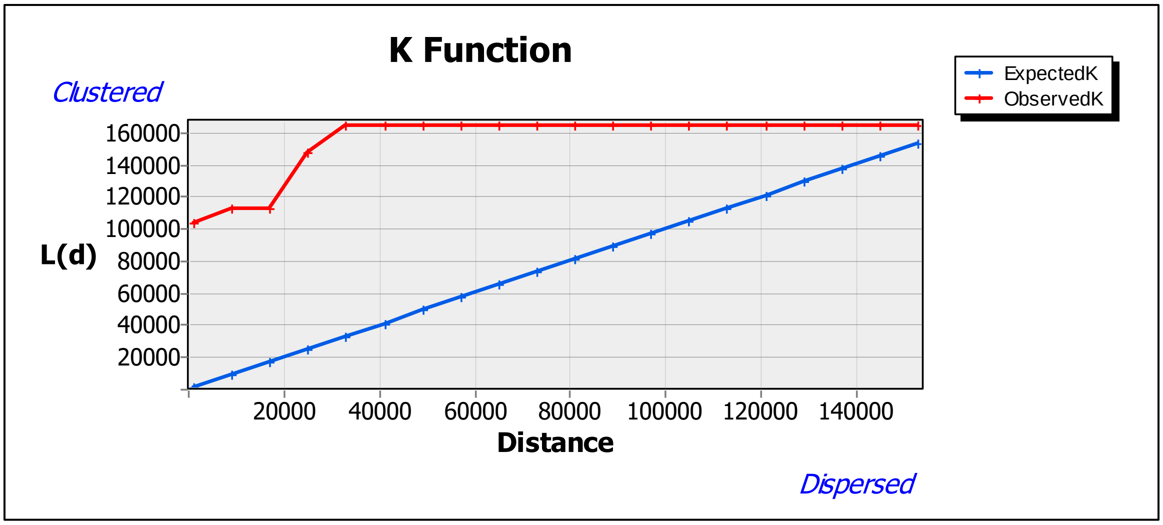


Figure 24. Ripley's K-Function cluster analysis of Haskett sites.
Note: Measurements in meters.

Table 17. Ripley's K-Function cluster analysis of Parman Stemmed sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	35	34	Clustered
9	48	39	Clustered
17	59	42	Clustered
25	75	50	Clustered
33	91	58	Clustered
41	95	54	Clustered
49	109	60	Clustered
57	112	55	Clustered
65	120	55	Clustered
73	122	50	Clustered
81	125	44	Clustered
89	131	42	Clustered
97	136	40	Clustered
105	139	34	Clustered
113	142	29	Clustered
121	144	23	Clustered
129	146	14	Clustered
137	152	15	Clustered
145	156	11	Clustered
153	159	6	Random

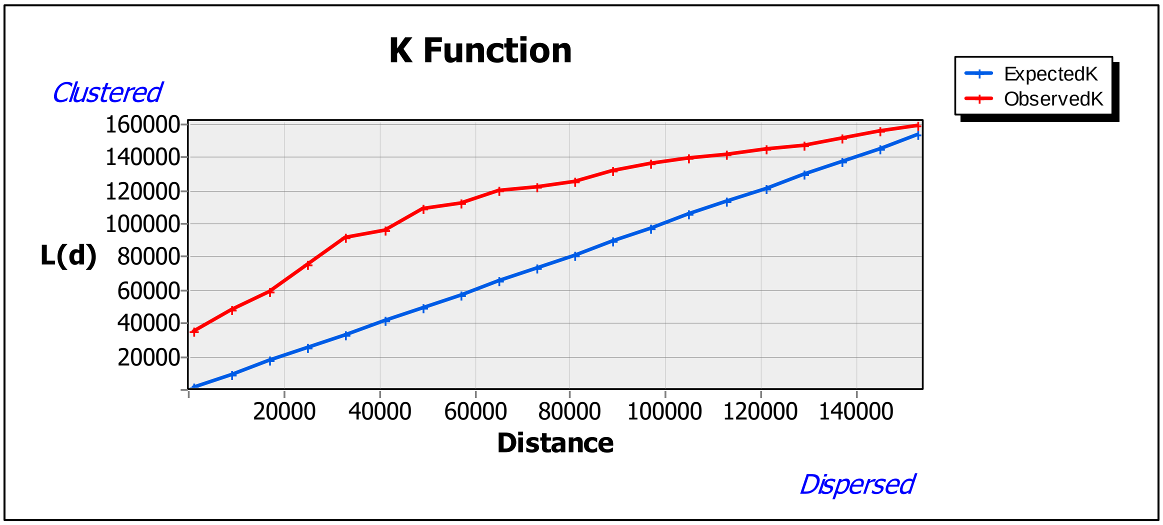


Figure 25. Ripley's K-Function cluster analysis of Parman Stemmed sites.
Note: Measurements in meters.

Table 18. Ripley's K-Function cluster analysis of Parman Square Stemmed sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	26	25	Clustered
9	37	28	Clustered
17	53	36	Clustered
25	56	31	Clustered
33	61	28	Clustered
41	68	27	Clustered
49	779	30	Clustered
57	82	24	Clustered
65	87	22	Clustered
73	94	21	Clustered
81	99	18	Clustered
89	109	20	Clustered
97	111	14	Clustered
105	115	10	Clustered
113	123	10	Clustered
121	128	7	Random
129	132	3	Random
137	138	1	Random
145	142	-3	Random
153	143	-10	Dispersed

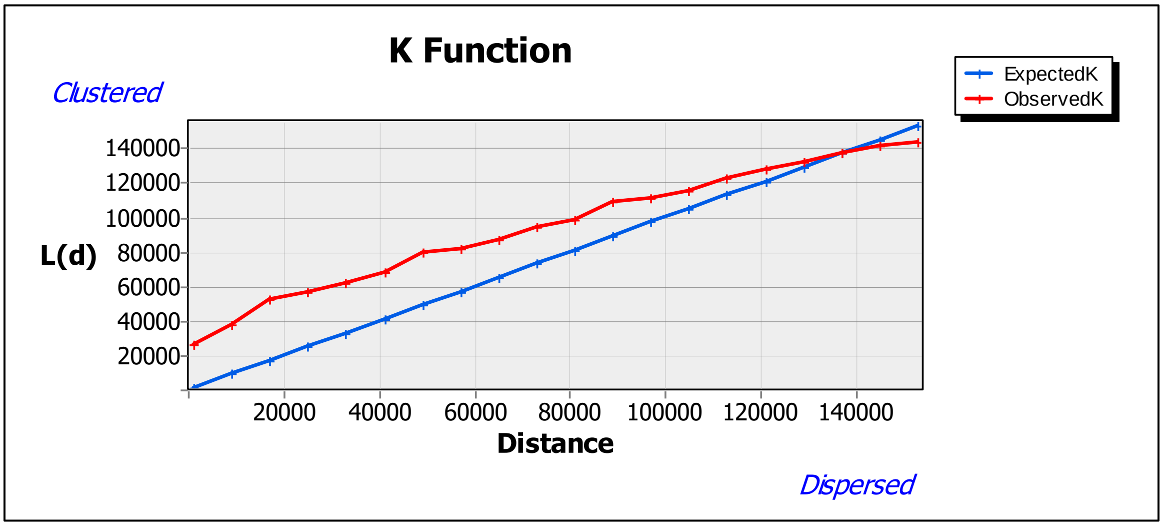


Figure 26. Ripley's K-Function cluster analysis of Parman Square Stemmed sites.
Note: Measurements in meters.

Table 19. Ripley's K-Function cluster analysis of all Parman Stemmed sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	30	29	Clustered
9	44	35	Clustered
17	57	40	Clustered
25	68	43	Clustered
33	81	48	Clustered
41	87	46	Clustered
49	99	50	Clustered
57	102	45	Clustered
65	109	44	Clustered
73	112	39	Clustered
81	116	35	Clustered
89	123	34	Clustered
97	128	31	Clustered
105	132	27	Clustered
113	136	23	Clustered
121	139	18	Clustered
129	142	13	Clustered
137	147	10	Clustered
145	151	6	Random
153	153	0	Random

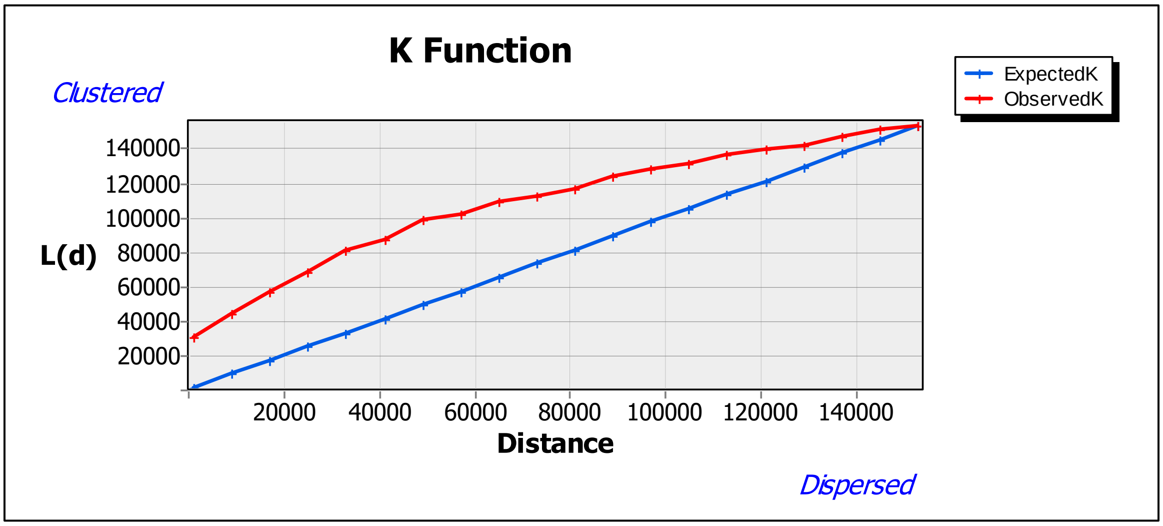


Figure 27. Ripley's K-Function cluster analysis of all Parman Stemmed sites.
Note: Measurements in meters.

Table 20. Ripley's K-Function cluster analysis of unclassified Stemmed sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	33	32	Clustered
9	50	41	Clustered
17	69	52	Clustered
25	76	51	Clustered
33	93	60	Clustered
41	104	63	Clustered
49	115	66	Clustered
57	120	62	Clustered
65	124	59	Clustered
73	131	58	Clustered
81	135	54	Clustered
89	140	52	Clustered
97	146	49	Clustered
105	150	44	Clustered
113	152	39	Clustered
121	155	34	Clustered
129	157	28	Clustered
137	159	22	Clustered
145	160	15	Clustered
153	161	8	Random

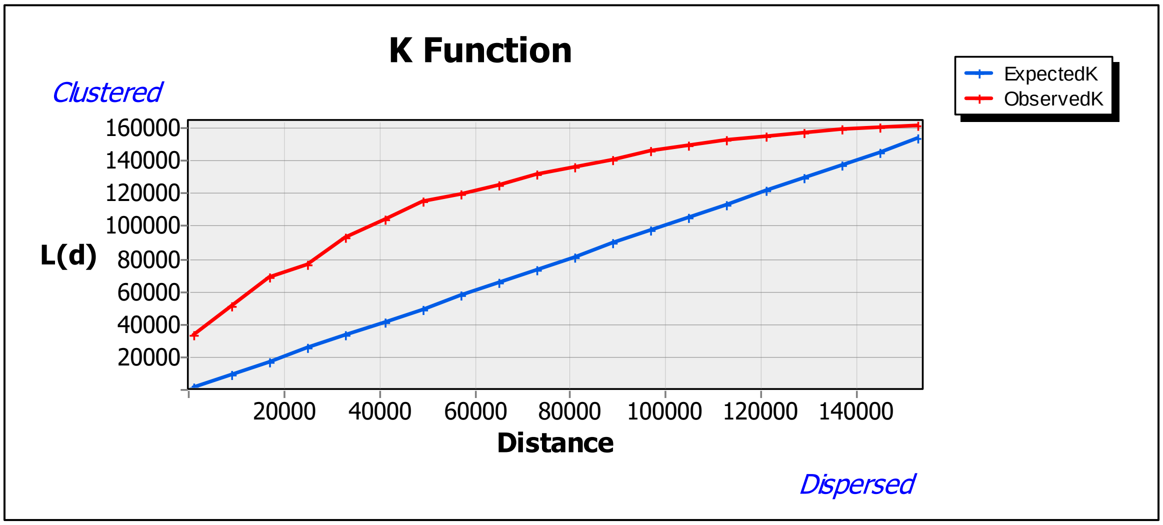


Figure 28. Ripley's K-Function Cluster Analysis of all unclassified Stemmed sites.
Note: Measurements in meters.

Table 21. Ripley's K-Function cluster analysis of all Stemmed sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	33	32	Clustered
9	49	40	Clustered
17	67	50	Clustered
25	76	51	Clustered
33	92	59	Clustered
41	102	61	Clustered
49	113	64	Clustered
57	117	60	Clustered
65	123	58	Clustered
73	129	56	Clustered
81	133	52	Clustered
89	138	50	Clustered
97	143	46	Clustered
105	146	41	Clustered
113	150	37	Clustered
121	152	31	Clustered
129	154	25	Clustered
137	157	20	Clustered
145	159	14	Clustered
153	160	7	Random

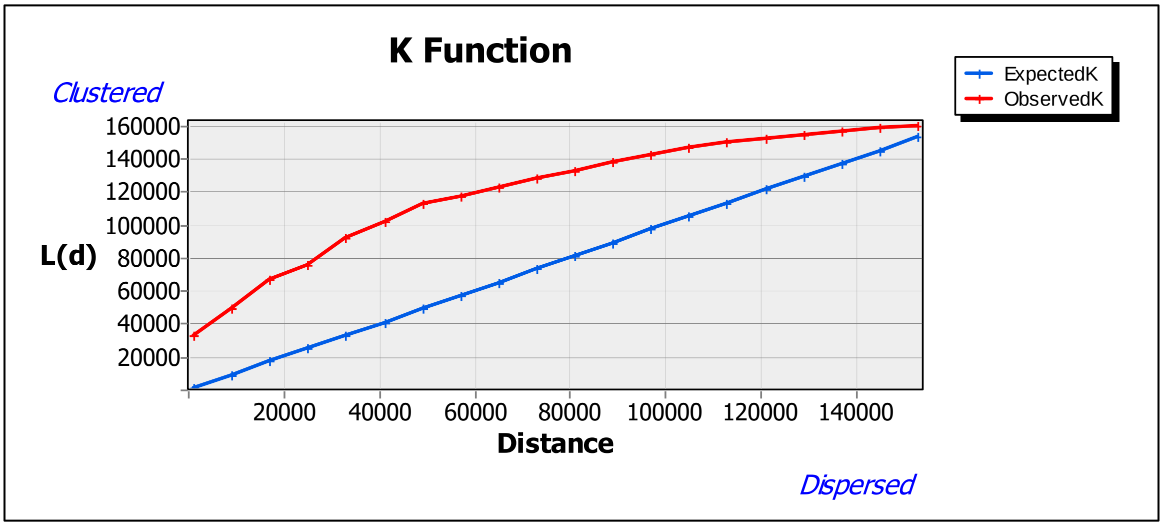


Figure 29. Ripley's K-Function cluster analysis of all Stemmed sites.
Note: Measurements in meters.

Table 22. Ripley's K-Function cluster analysis of Crescent sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	84	83	Clustered
9	91	82	Clustered
17	93	76	Clustered
25	117	92	Clustered
33	119	86	Clustered
41	121	81	Clustered
49	124	75	Clustered
57	125	68	Clustered
65	126	61	Clustered
73	128	55	Clustered
81	129	48	Clustered
89	129	40	Clustered
97	132	35	Clustered
105	139	34	Clustered
113	141	28	Clustered
121	141	20	Clustered
129	143	14	Clustered
137	151	14	Clustered
145	159	14	Clustered
153	160	8	Random

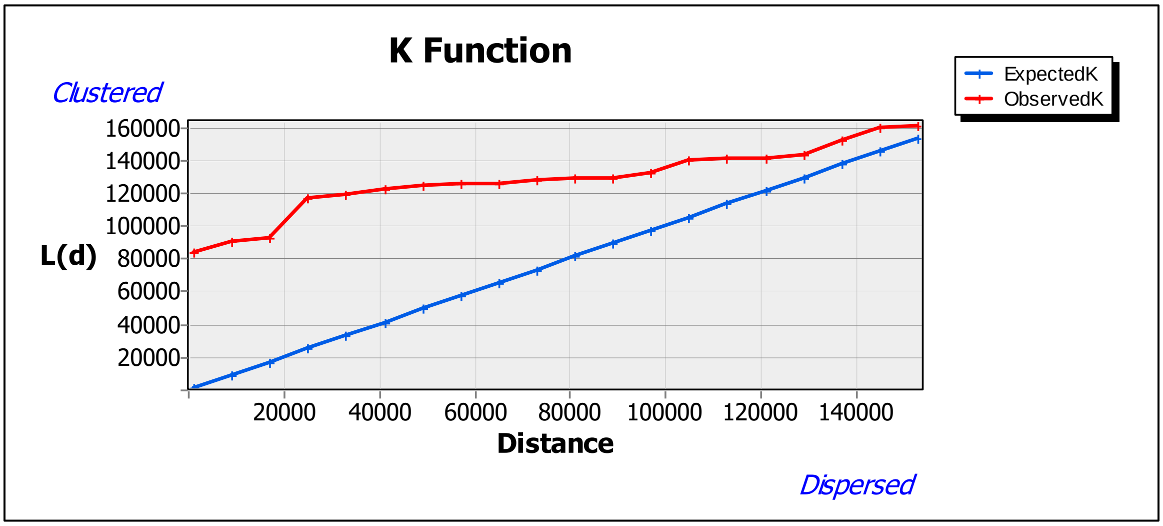


Figure 30. Ripley's K-Function cluster analysis of Crescent sites.
Note: Measurements in meters.

Table 23. Ripley's K-Function cluster analysis of Cascade sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	74	73	Clustered
9	74	65	Clustered
17	74	57	Clustered
25	85	60	Clustered
33	85	52	Clustered
41	85	44	Clustered
49	85	36	Clustered
57	85	28	Clustered
65	85	20	Clustered
73	85	12	Clustered
81	85	4	Random
89	85	-4	Random
97	85	-12	Dispersed
105	85	-20	Dispersed
113	85	-28	Dispersed
121	85	-36	Dispersed
129	85	-44	Dispersed
137	104	-33	Dispersed
145	104	-41	Dispersed
153	104	-49	Dispersed

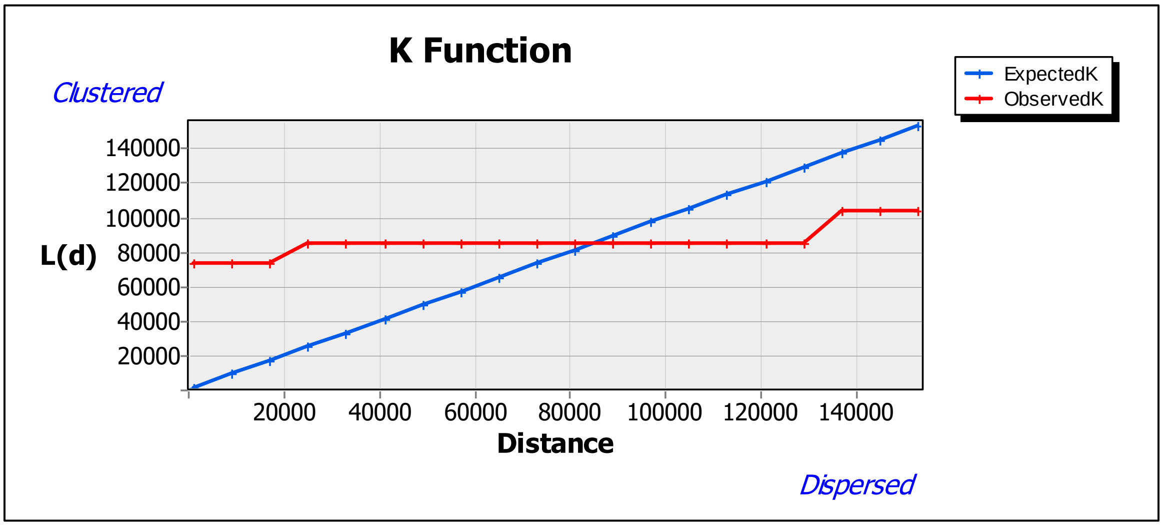


Figure 31. Ripley's K-Function cluster analysis of Cascade sites.
Note: Measurements in meters.

Table 24. Ripley's K-Function cluster analysis of Foliate sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	24	23	Clustered
9	36	27	Clustered
17	50	33	Clustered
25	57	32	Clustered
33	67	34	Clustered
41	78	37	Clustered
49	86	37	Clustered
57	90	33	Clustered
65	92	27	Clustered
73	96	23	Clustered
81	101	20	Clustered
89	109	20	Clustered
97	116	19	Clustered
105	123	18	Clustered
113	129	16	Clustered
121	134	13	Clustered
129	138	9	Random
137	142	5	Random
145	145	0	Random
153	148	-5	Random

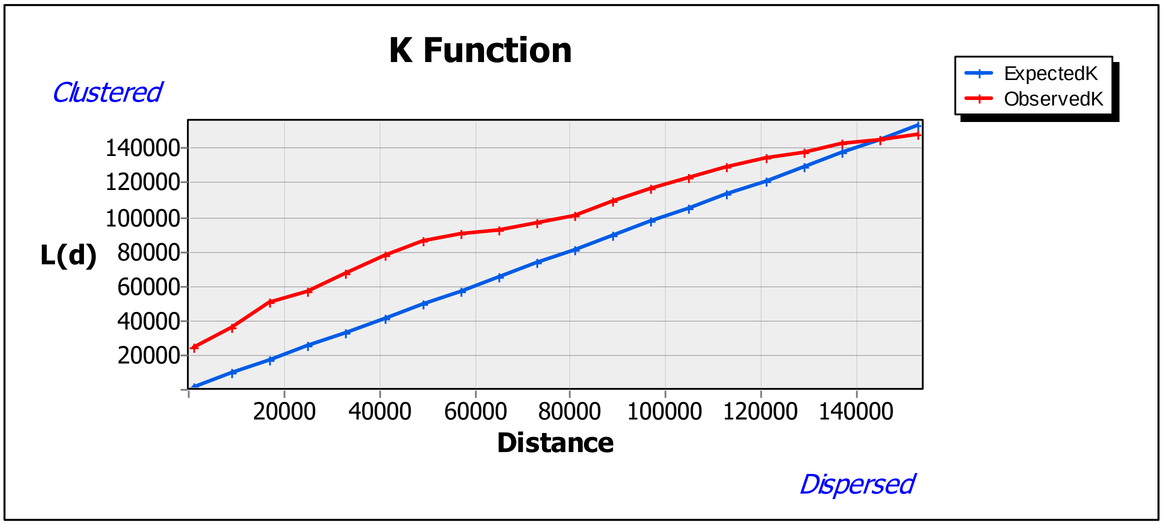


Figure 32. Ripley's K-Function cluster analysis of Foliate sites.
Note: Measurements in meters.

Table 25. Ripley's K-Function cluster analysis of Humboldt sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	26	25	Clustered
9	40	31	Clustered
17	53	36	Clustered
25	61	36	Clustered
33	76	43	Clustered
41	85	44	Clustered
49	95	46	Clustered
57	104	47	Clustered
65	111	46	Clustered
73	118	45	Clustered
81	125	44	Clustered
89	133	44	Clustered
97	140	43	Clustered
105	145	40	Clustered
113	148	34	Clustered
121	151	30	Clustered
129	154	25	Clustered
137	157	20	Clustered
145	159	14	Clustered
153	160	7	Random

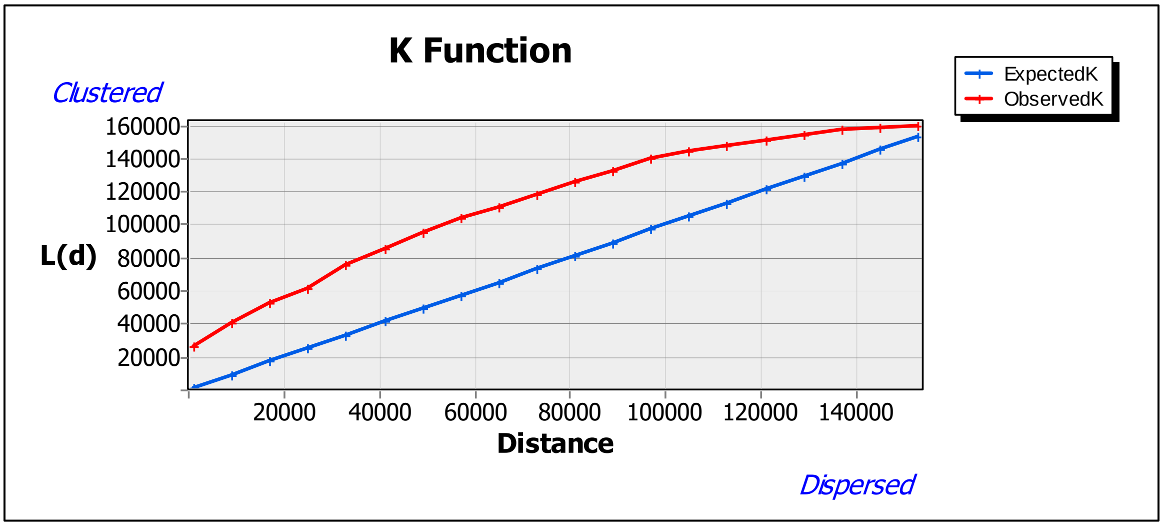


Figure 33. Ripley's K-Function cluster analysis of Humboldt sites.
Note: Measurements in meters.

Table 26. Ripley's K-Function cluster analysis of Northern Side Notched sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	19	18	Clustered
9	35	26	Clustered
17	51	34	Clustered
25	62	37	Clustered
33	73	40	Clustered
41	82	41	Clustered
49	95	46	Clustered
57	102	45	Clustered
65	109	44	Clustered
73	115	42	Clustered
81	123	42	Clustered
89	132	43	Clustered
97	140	43	Clustered
105	146	41	Clustered
113	151	38	Clustered
121	154	33	Clustered
129	158	29	Clustered
137	160	23	Clustered
145	161	16	Clustered
153	162	9	Random

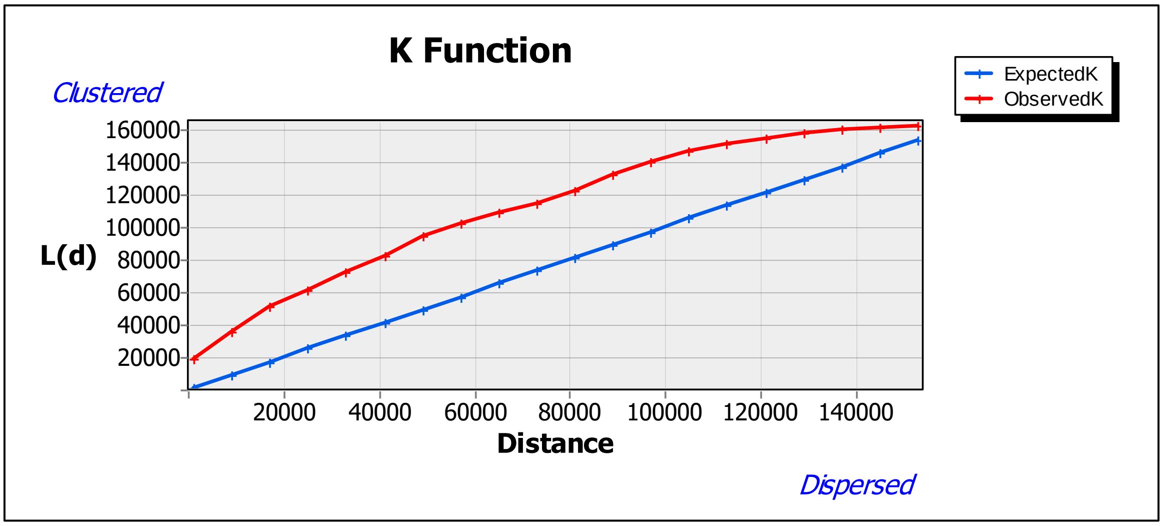


Figure 34. Ripley's K-Function cluster analysis of Northern Side Notched sites.
Note: Measurements in meters.

Table 27. Ripley's K-Function cluster analysis of all early Holocene sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	34	33	Clustered
9	48	39	Clustered
17	63	46	Clustered
25	72	47	Clustered
33	85	52	Clustered
41	94	53	Clustered
49	104	55	Clustered
57	108	51	Clustered
65	113	48	Clustered
73	119	46	Clustered
81	123	42	Clustered
89	127	38	Clustered
97	132	35	Clustered
105	137	32	Clustered
113	140	27	Clustered
121	142	21	Clustered
129	145	16	Clustered
137	151	14	Clustered
145	156	11	Clustered
153	158	5	Random

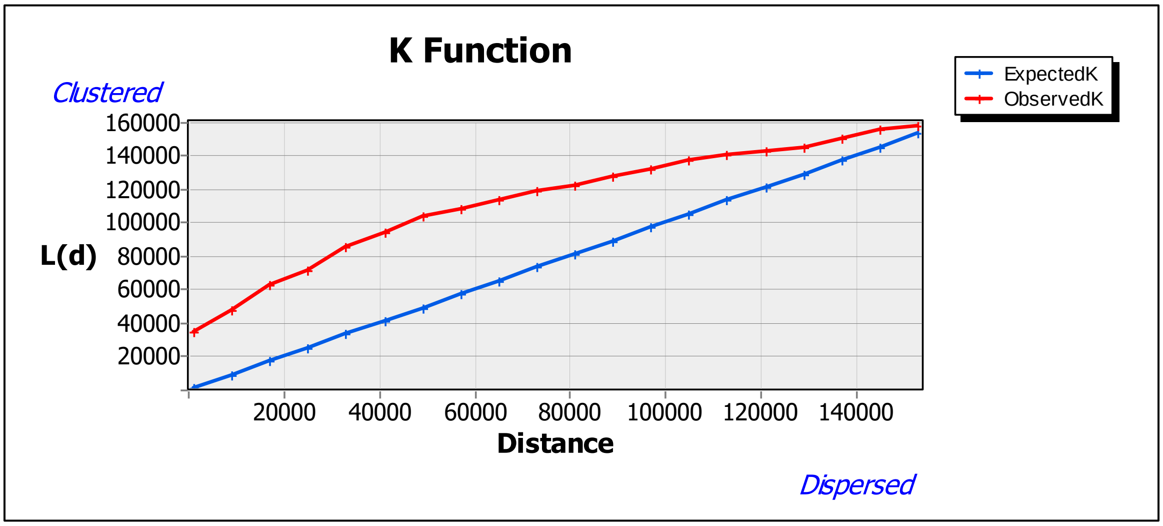


Figure 35. Ripley's K-Function cluster analysis of all early Holocene sites.
Note: Measurements in meters.

Table 28. Ripley's K-Function cluster analysis of all later Holocene sites.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	21	20	Clustered
9	35	26	Clustered
17	49	32	Clustered
25	59	34	Clustered
33	72	39	Clustered
41	82	41	Clustered
49	93	44	Clustered
57	101	44	Clustered
65	108	43	Clustered
73	114	41	Clustered
81	122	41	Clustered
89	130	41	Clustered
97	139	42	Clustered
105	144	39	Clustered
113	148	35	Clustered
121	152	31	Clustered
129	155	26	Clustered
137	158	21	Clustered
145	159	14	Clustered
153	160	7	Random

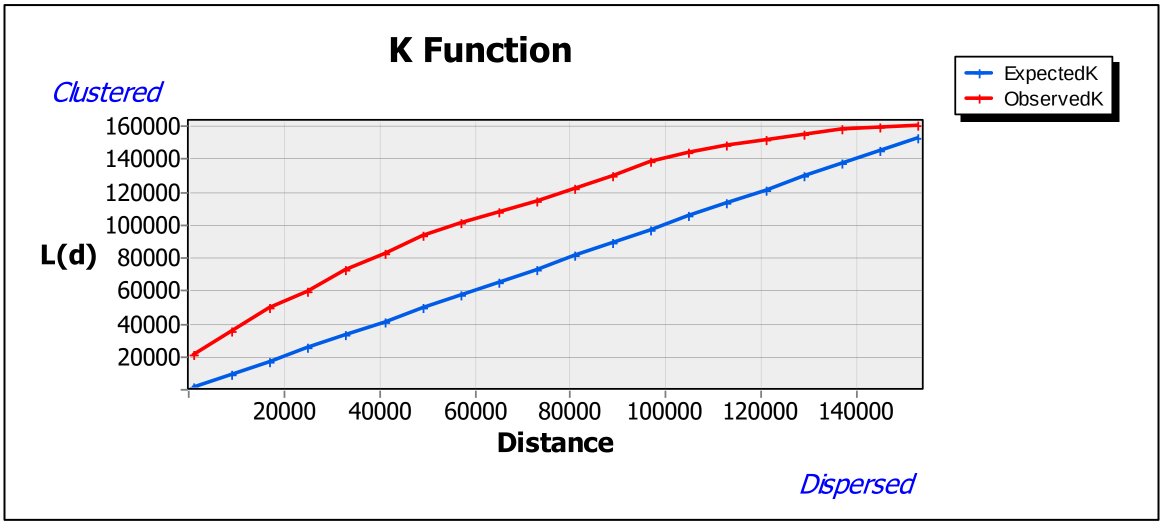


Figure 36. Ripley's K-Function cluster analysis of all later Holocene sites.
Note: Measurements in meters.

Table 29. Ripley's K-Function cluster analysis of all sites in study area.

Expected Distance (km)	Observed Distance (km)	Difference (km)	Dispersion Level
1	25	24	Clustered
9	38	29	Clustered
17	53	36	Clustered
25	62	37	Clustered
33	74	41	Clustered
41	84	43	Clustered
49	94	45	Clustered
57	101	44	Clustered
65	108	43	Clustered
73	114	41	Clustered
81	120	39	Clustered
89	127	38	Clustered
97	134	38	Clustered
105	140	35	Clustered
113	144	31	Clustered
121	147	26	Clustered
129	150	21	Clustered
137	154	17	Clustered
145	157	12	Clustered
153	159	6	Random

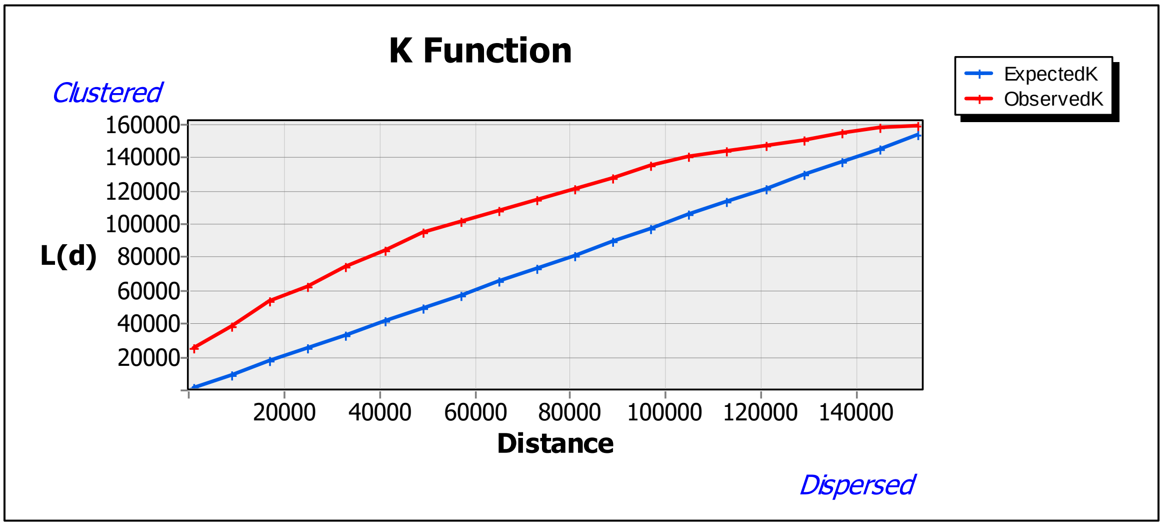


Figure 37. Ripley's K-Function cluster analysis of all sites in study area.
Note: Measurements in meters.

with 1 km and in 8 km increments thereafter. It was assumed that clustering might represent travel from base camps or resource concentrations. In his comprehensive overview of ethnographic hunter-gatherer patterning, Lewis Binford (2001:238) summarized foraging trip data collected on hunter-gatherers living in a variety of environments, and determined that male and female hunter-gatherers traveled an average of 8.28 km per day. Therefore, I assume in this study that 8 km is a rough estimate of the distance early hunter-gatherers might have traveled in a short period.

The variation in pattern search size that Ripley’s K-function analysis provides did not result in further clarification of dispersion patterns. In all cases clustering was detected at the smallest expected distance of 1 km. All of the site patterns reached a dispersed pattern between 81 and 153 km. Given that the study area is only 275 km across, a dispersed pattern is expected at a 137-km search radius. At this distance, the edge effect boundary problem degrades clustered patterning, as observed points do not exist outside the study area. In spatial analysis the problem of edge effect, which is caused by the unavailability of data outside the study area, results in biased patterns on the edges of a study area (Xu and Dowd 2012:115).

In four instances dispersion was noted at less than 137 km. Parman Square sites (dispersed at 121 km) and fluted sites (dispersed at 105 km) have smaller than ideal sample sizes, but appear to be exhibiting some regional clustering. The very small sample size of Cascade sites might be causing the apparent dispersion at 81 km, but it also suggests clustering in the study area. Foliate sites become dispersed at an expected distance of 129 km. The sample size makes this pattern significant, but this dispersion is not very interesting given the usual dispersion at about 137 km. Of these four site types, fluted and Cascade sites exhibited clustering patterns that are unusual for the datasets, although the sample sizes of these site types were not ideal. The Ripley’s K-function analyses in this study indicate that clustering occurs within a 1 km radius for all sites in the study area, confirming that some portions of the study area were frequented by early Holocene cultures.

Moran's I Spatial Autocorrelation Analysis

Moran's I analyses were performed to study the spatial autocorrelation of sites, environment features, and CRM surveys (Tables 30–31; Figures 38–63). Hydrologic units (basins, subbasins, watersheds, and subwatersheds) were used to summarize the distribution of data across the study area (Tables 30–31). Site and environment distributions were first visualized by dividing basin, subbasin, watershed, and subwatershed-level feature counts into five categories by natural breaks (Figures 38–63). Moran's I analyses were then performed for each data type, at all four hydrologic levels.

Some basin levels were better for detecting statistically significant patterning than others. In all cases site clustering appeared random at the basin level. Given the size of the study area, this grain size was not ideal for detecting site patterning. Basin-level analysis may be useful for larger regional studies, but was not useful in the present study. On the other end of the scale, subwatersheds were also poor at detecting site patterning because of low site numbers. Subwatersheds did detect environmental feature clustering in most cases. Summaries of features on the subbasin level were much better for detecting clustering, but watersheds were determined best for detecting statistically significant spatial patterning of archaeological sites. Clustering was evident in all site types, with the exception of Windust and Cascade sites, which had small data sets that complicated pattern recognition. Clustering was particularly evident in several areas within the WPLT region, including the Alvord Lake and Lake Malheur areas, where marshes cluster. Moran's I spatial autocorrelation provided useful for identifying site clustering at most of the levels of analysis, but I found that statistical correlation analyses were necessary to ascertain any true connections between environment features, site clustering, and survey biases.

Mean Center Analysis

Mean centers were calculated for survey coverage and archaeological site counts in order to explore how this statistic might summarize early site pattern central tendencies and survey bias in the study area (Table 32; Figures 64–84). All of the site types were skewed

Table 30. Moran's I Spatial Autocorrelation analysis of features by hydrologic unit.

Feature Type	Hydrologic Unit	Dispersion Level	Moran's Index	Z-Score	P-Value
Hydrologic Unit	Basin	Random	-.400939	-1.283960	.199156
	Sub-Basin	Random	.105444	1.240766	.214692
	Watershed	Clustered	.123822	2.807667	.004990
	Subwatershed	Clustered	.211347	10.820812	.000000
Surveys	Basin	Random	.108700	1.114322	.265141
	Subbasin	Clustered	.339095	4.731387	.000002
	Watershed	Clustered	.218490	7.269772	.000000
	Subwatershed	Clustered	.406202	22.405516	.000000
Pluvial Lakes	Basin	Random	-.010370	-1.093285	.274269
	Subbasin	Clustered	.346786	3.796379	.000147
	Watershed	Clustered	.570638	13.281478	.000000
	Subwatershed	Clustered	.359670	18.631475	.000000
Playas	Basin	Random	.115990	.945576	.344365
	Subbasin	Clustered	.365000	3.760483	.000170
	Watershed	Clustered	.323188	7.620007	.000000
	Subwatershed	Clustered	.265783	13.881012	.000000
Lakes	Basin	Clustered	.406051	3.034069	.002413
	Subbasin	Random	.017727	.528901	.596874
	Watershed	Random	.009130	1.535113	.124756
	Subwatershed	Clustered	.073336	5.563502	.000000
Marshes	Basin	Random	-.106791	-.212424	.831776
	Subbasin	Clustered	.209799	2.603806	.009219
	Watershed	Clustered	.290003	8.563878	.000000
	Subwatershed	Random	.019779	1.491605	.135803
Streams	Basin	Clustered	.492447	2.156559	.031040
	Subbasin	Random	.063331	.894928	.370825
	Watershed	Clustered	.350654	7.822079	.000000
	Subwatershed	Clustered	.427652	21.787655	.000000
Springs	Basin	Random	.272406	1.356702	.174876
	Subbasin	Random	.106891	1.266377	.205378
	Watershed	Clustered	.331390	7.452847	.000000
	Subwatershed	Clustered	.412845	21.180832	.000000

Table 31. Moran's I Spatial Autocorrelation analysis of archaeological sites by hydrologic unit.

Feature Type	Hydrologic Unit	Dispersion Level	Moran's Index	Z-Score	P-Value
Fluted	Basin	Random	-.008650	1.053757	.291994
	Subbasin	Random	.052912	.876215	.380913
	Watershed	Clustered	.206815	5.243272	.000000
	Subwatershed	Random	.013047	.809833	.418036
Black Rock Concave	Basin	Random	-.010012	.973505	.330302
	Subbasin	Clustered	.161210	2.226390	.025988
	Watershed	Clustered	.091832	2.507455	.012160
	Subwatershed	Clustered	.060053	3.850589	.000118
Crescents	Basin	Random	-.011119	1.076527	.281691
	Subbasin	Random	-.001669	.503600	.614542
	Watershed	Clustered	.127550	6.730017	.000000
	Subwatershed	Random	.002443	.414820	.678274
Haskett Stemmed	Basin	Random	-.010370	1.093285	.274269
	Subbasin	Random	-.018851	.311980	.755056
	Watershed	Clustered	.237129	11.490094	.000000
	Subwatershed	Random	-.001730	-.093423	.925567
Parman Stemmed	Basin	Random	-.011670	.799307	.424112
	Subbasin	Clustered	.106204	2.644655	.008177
	Watershed	Clustered	.309177	7.480718	.000000
	Subwatershed	Clustered	.058567	3.260144	.001114
Parman Square Stemmed	Basin	Random	-.020380	.343317	.731360
	Subbasin	Clustered	.112176	1.964134	.049515
	Watershed	Clustered	.155341	3.656764	.000255
	Subwatershed	Clustered	.119746	6.419866	.000000
Parman Stemmed, all	Basin	Random	-.015169	.606494	.544187
	Subbasin	Clustered	.110827	2.578843	.009913
	Watershed	Clustered	.306381	7.247374	.000000
	Subwatershed	Clustered	.097291	5.320113	.000000
Windust Stemmed	Basin	Random	-.010370	1.093285	.274269
	Subbasin	Random	-.025708	.007365	.994124
	Watershed	Random	-.011530	-.216124	.828891
	Subwatershed	Random	-.010370	1.093285	.274269
Stemmed, unclassified	Basin	Random	-.011162	1.032931	.301636
	Subbasin	Clustered	.230798	4.036979	.000054
	Watershed	Clustered	.351859	9.165341	.000000
	Subwatershed	Clustered	.127263	7.793620	.000000
Stemmed, all	Basin	Random	-.011426	.986188	.324041
	Subbasin	Clustered	.213145	4.002442	.000063
	Watershed	Clustered	.379366	9.867561	.000000
	Subwatershed	Clustered	.132108	8.053687	.000000
Stemmed and Crescents	Basin	Random	-.011429	1.011568	.311745
	Subbasin	Clustered	.198200	3.107754	.001885
	Watershed	Clustered	.297813	7.527859	.000000
	Subwatershed	Clustered	.103749	6.079796	.000000
Fluted and Black Rock Concave	Basin	Random	-.008837	1.044265	.296363
	Subbasin	Clustered	.181414	2.257612	.023970
	Watershed	Clustered	.193204	4.758830	.000002
	Subwatershed	Random	.015537	.932073	.351299
	Basin	Random	-.011277	1.014139	.310517

Feature Type	**Hydrologic Unit**	**Dispersion Level**	**Moran's Index**	**Z-Score**	**P-Value**
Pleistocene-Holocene Points	Subbasin	Clustered	.202260	3.139180	.001694
	Watershed	Clustered	.301781	7.658417	.000000
	Subwatershed	Clustered	.099783	5.885402	.000000
Cascade	Basin	Random	-.108579	-.175355	.860801
	Subbasin	Random	-.030675	-.053045	.957696
	Watershed	Random	-.013254	-.294811	.768139
	Subwatershed	Random	-.001507	-.047938	.961765
Foliate	Basin	Random	-.013713	.572007	.567317
	Subbasin	Clustered	.098248	1.860552	.062807
	Watershed	Clustered	.280402	6.980321	.000000
	Subwatershed	Clustered	.093522	5.150657	.000000
Cascade and Foliate	Basin	Random	-.024047	.448642	.653690
	Subbasin	Clustered	.103345	1.777202	.075535
	Watershed	Clustered	.233754	5.773340	.000000
	Subwatershed	Clustered	.076797	4.239538	.000022
Humboldt	Basin	Random	-.010761	.967289	.333400
	Subbasin	Clustered	.472719	5.464446	.000000
	Watershed	Clustered	.394200	9.502459	.000000
	Subwatershed	Clustered	.171460	10.091239	.000000
Northern Side-Notched	Basin	Random	-.011336	.854889	.392613
	Subbasin	Clustered	.432821	4.880756	.000001
	Watershed	Clustered	.407533	9.361567	.000000
	Subwatershed	Clustered	.220980	11.682470	.000000
Holocene Points	Basin	Random	-.011037	.912179	.361674
	Subbasin	Clustered	.484651	5.289408	.000000
	Watershed	Clustered	.445092	10.242234	.000000
	Subwatershed	Clustered	.214509	11.594153	.000000
All Points	Basin	Random	-.011118	.975658	.329234
	Subbasin	Clustered	.361776	4.468744	.000008
	Watershed	Clustered	.375667	8.925126	.000000
	Subwatershed	Clustered	.153552	8.501150	.000000

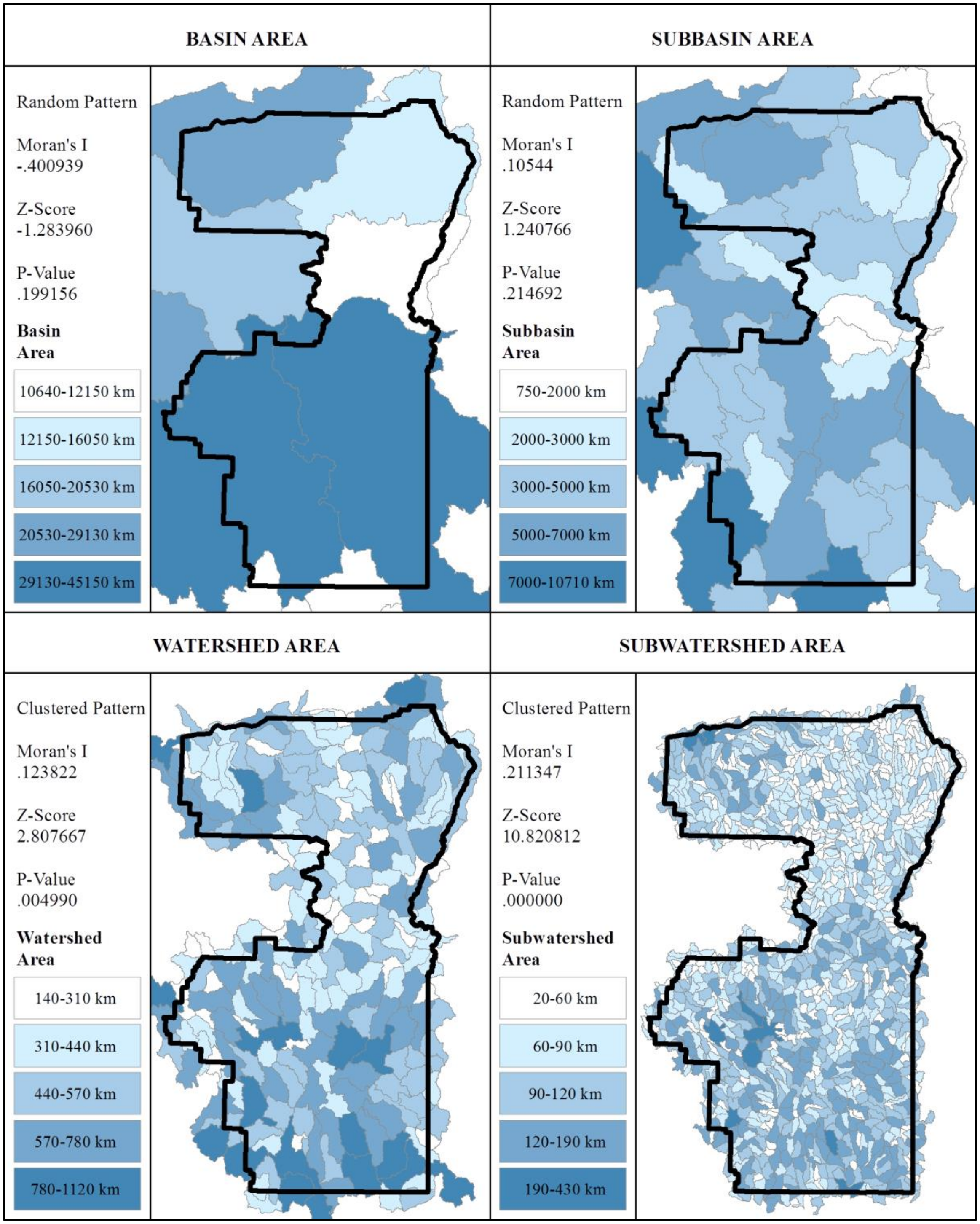


Figure 38. Cluster analysis of hydrologic unit area.

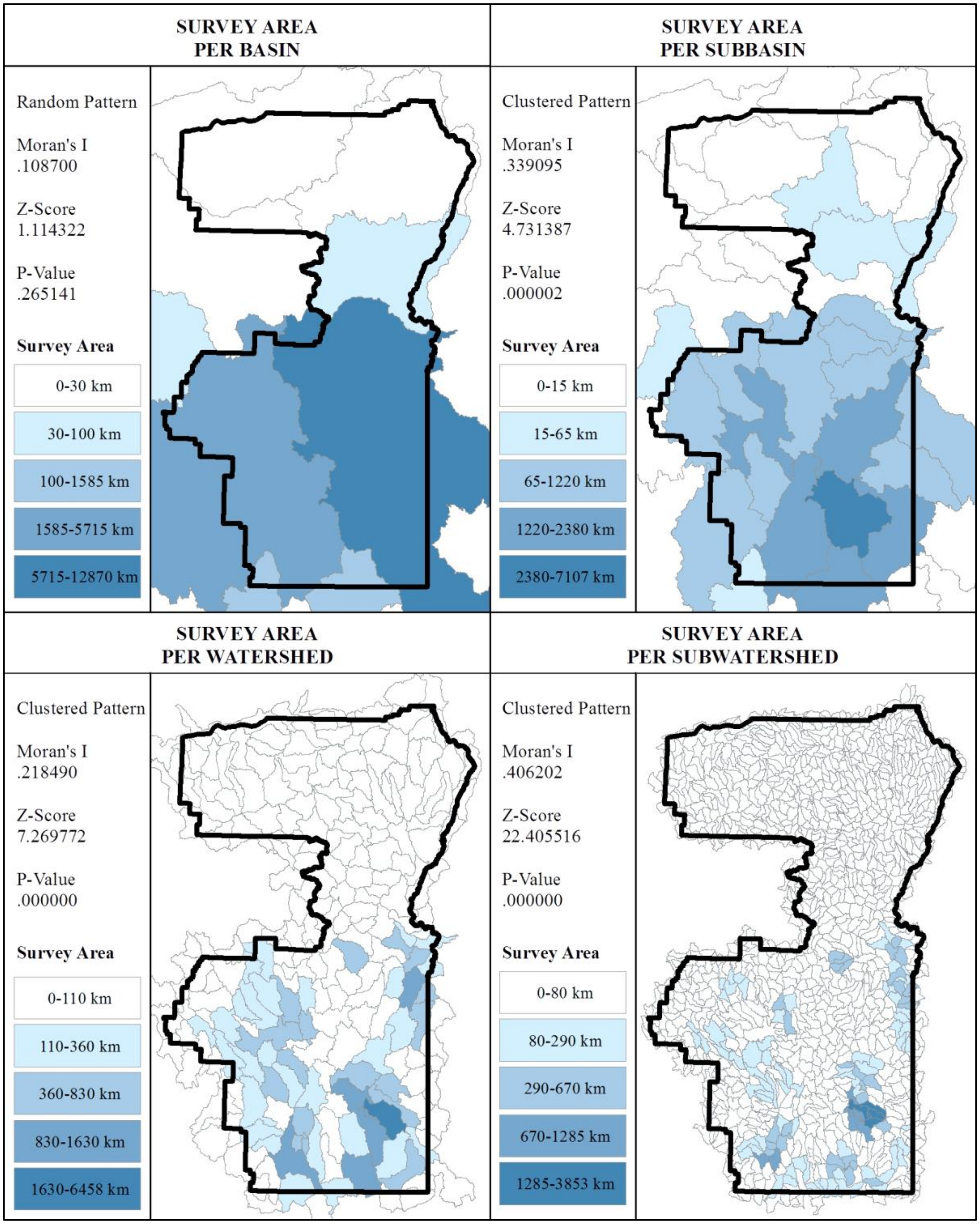


Figure 39. Cluster analysis of survey area by hydrologic unit.

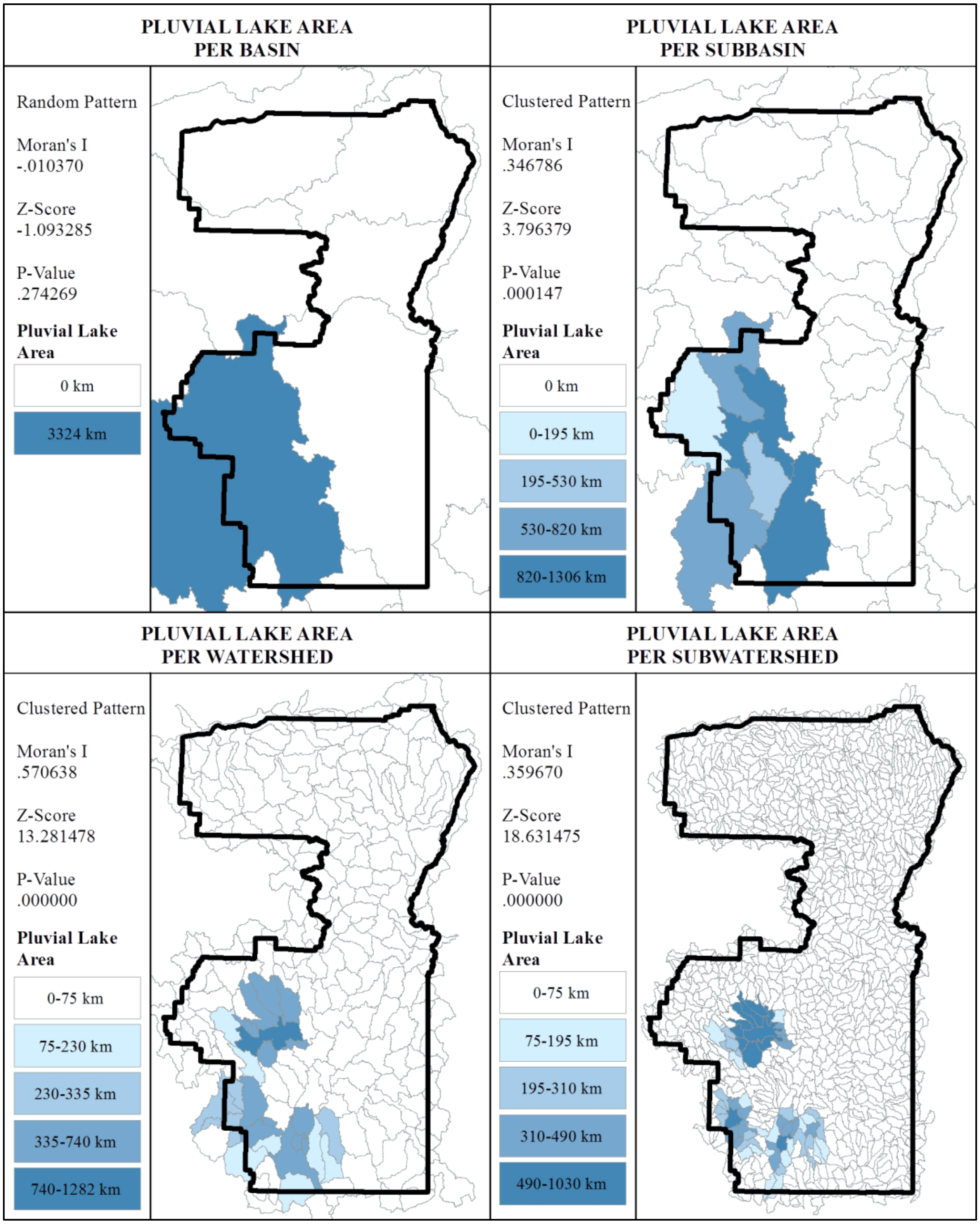


Figure 40. Cluster analysis of pluvial lake area by hydrologic unit.

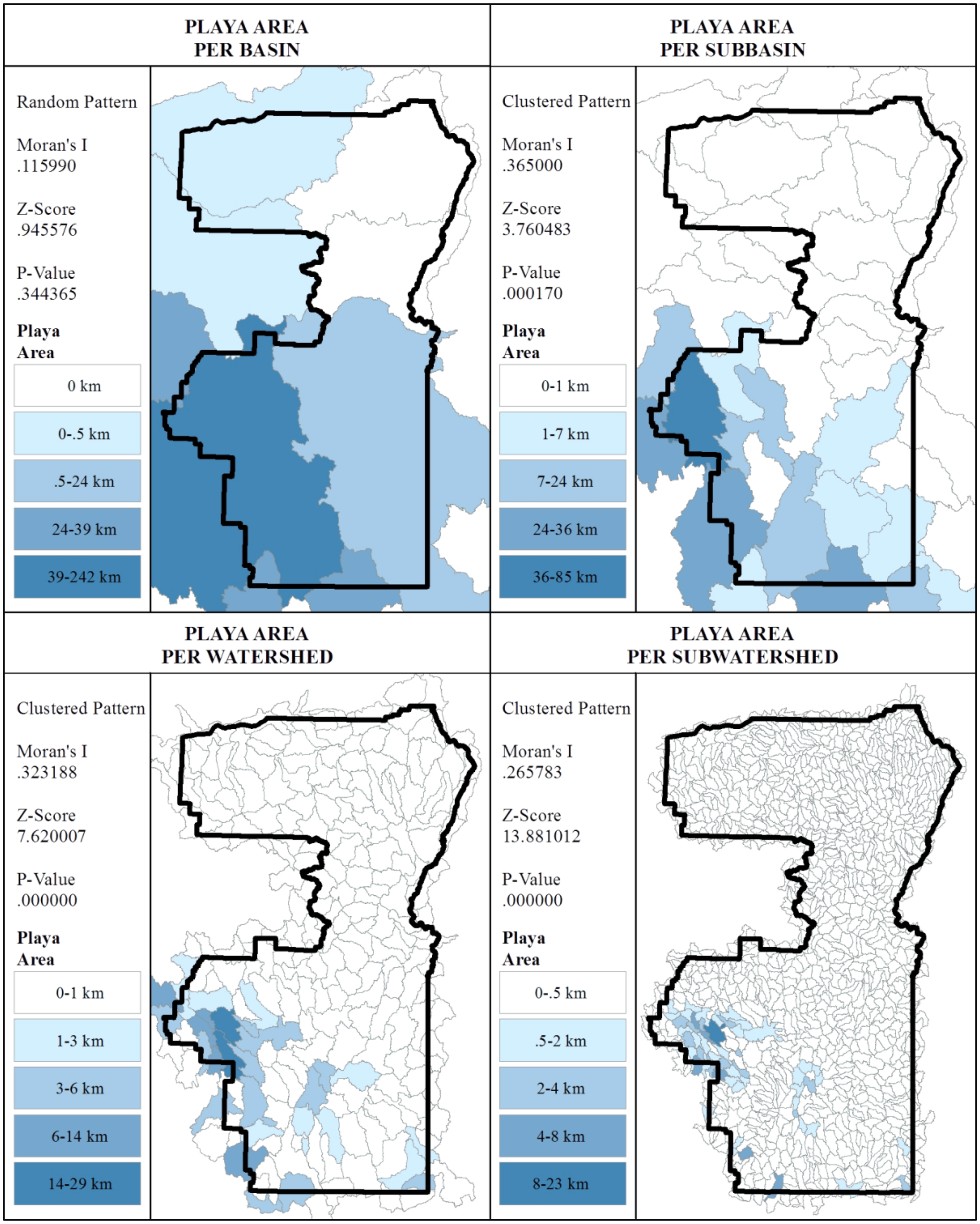


Figure 41. Cluster analysis of playa area by hydrologic unit.

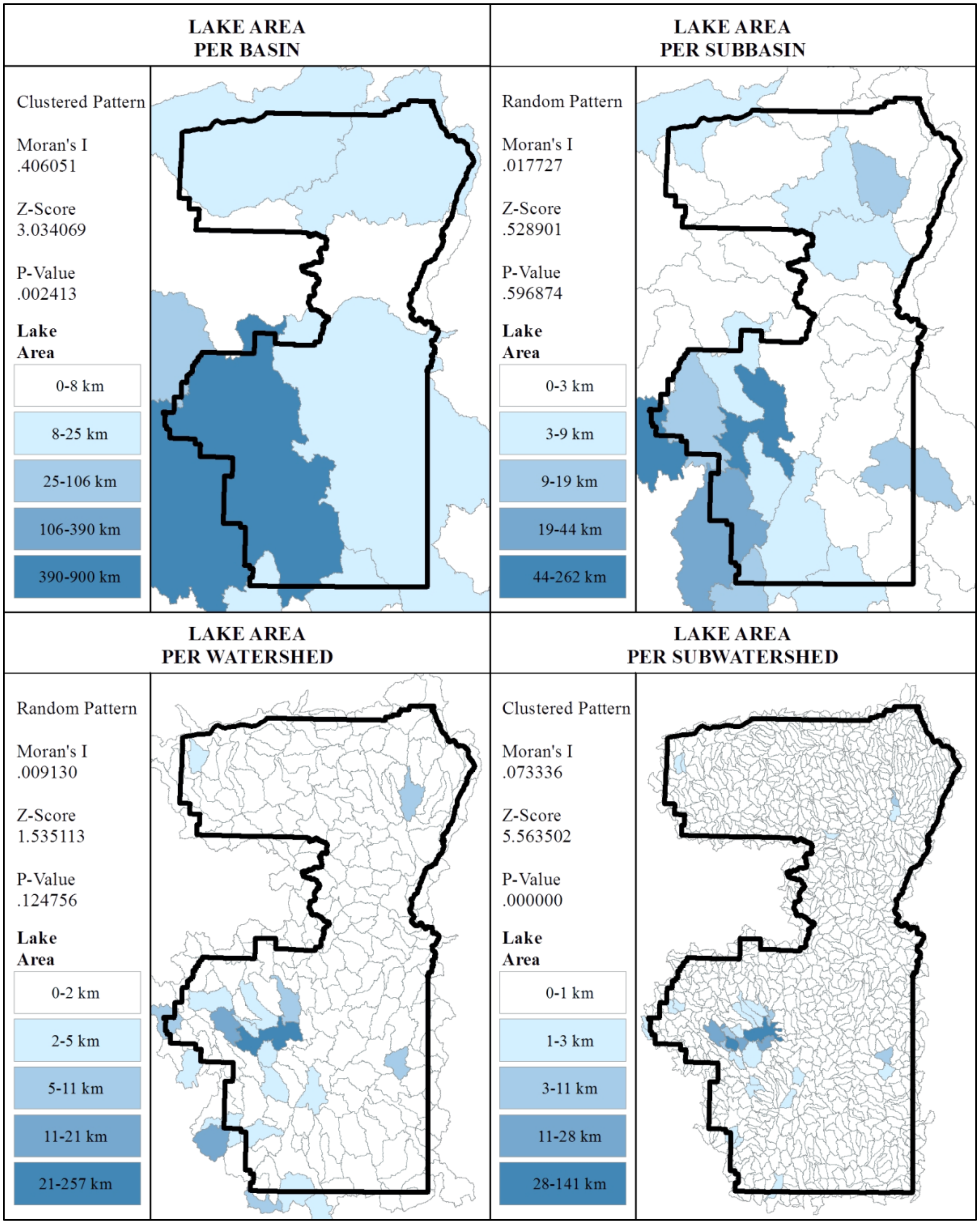


Figure 42. Cluster analysis of lake area by hydrologic unit.

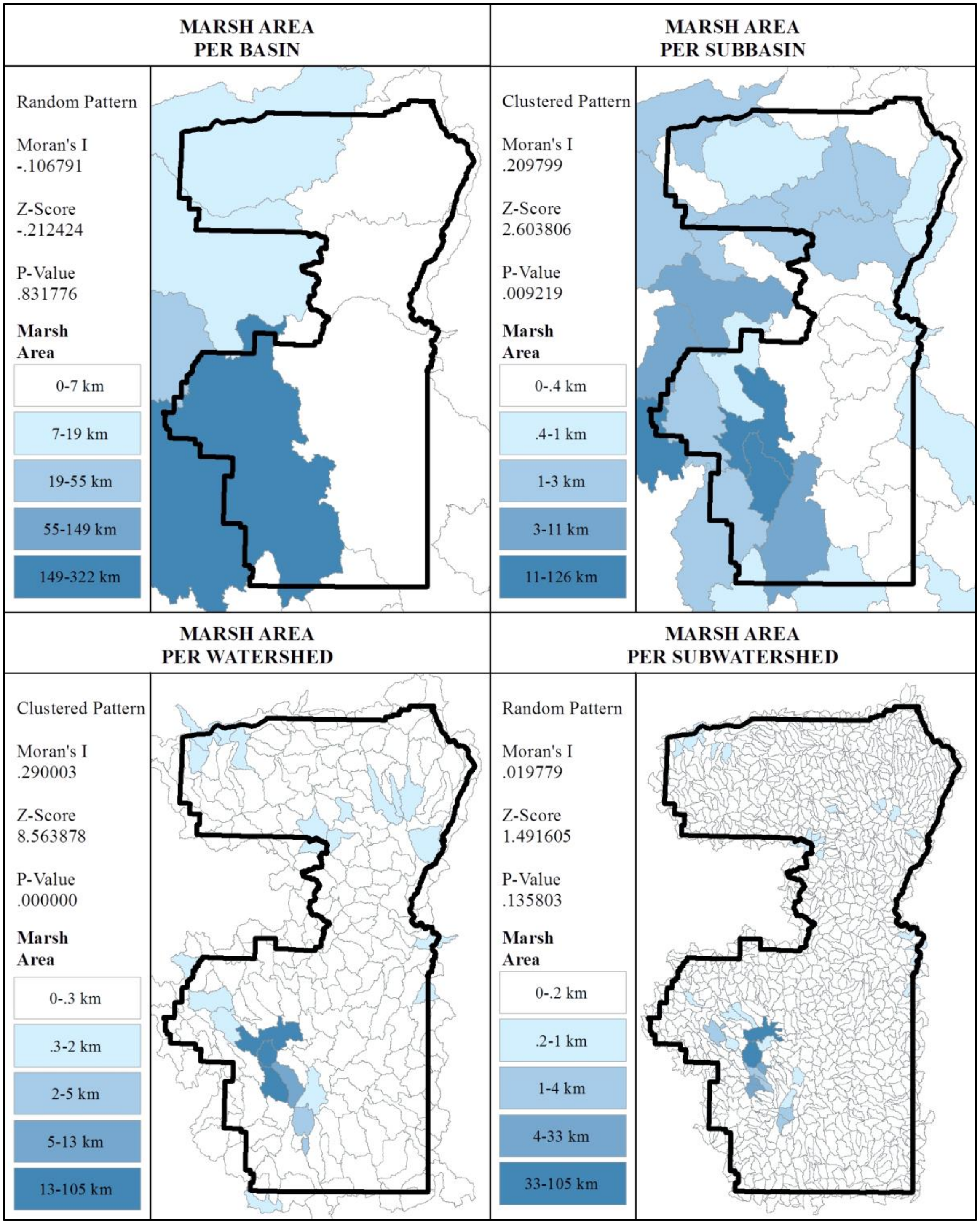


Figure 43. Cluster analysis of marsh area by hydrologic unit.

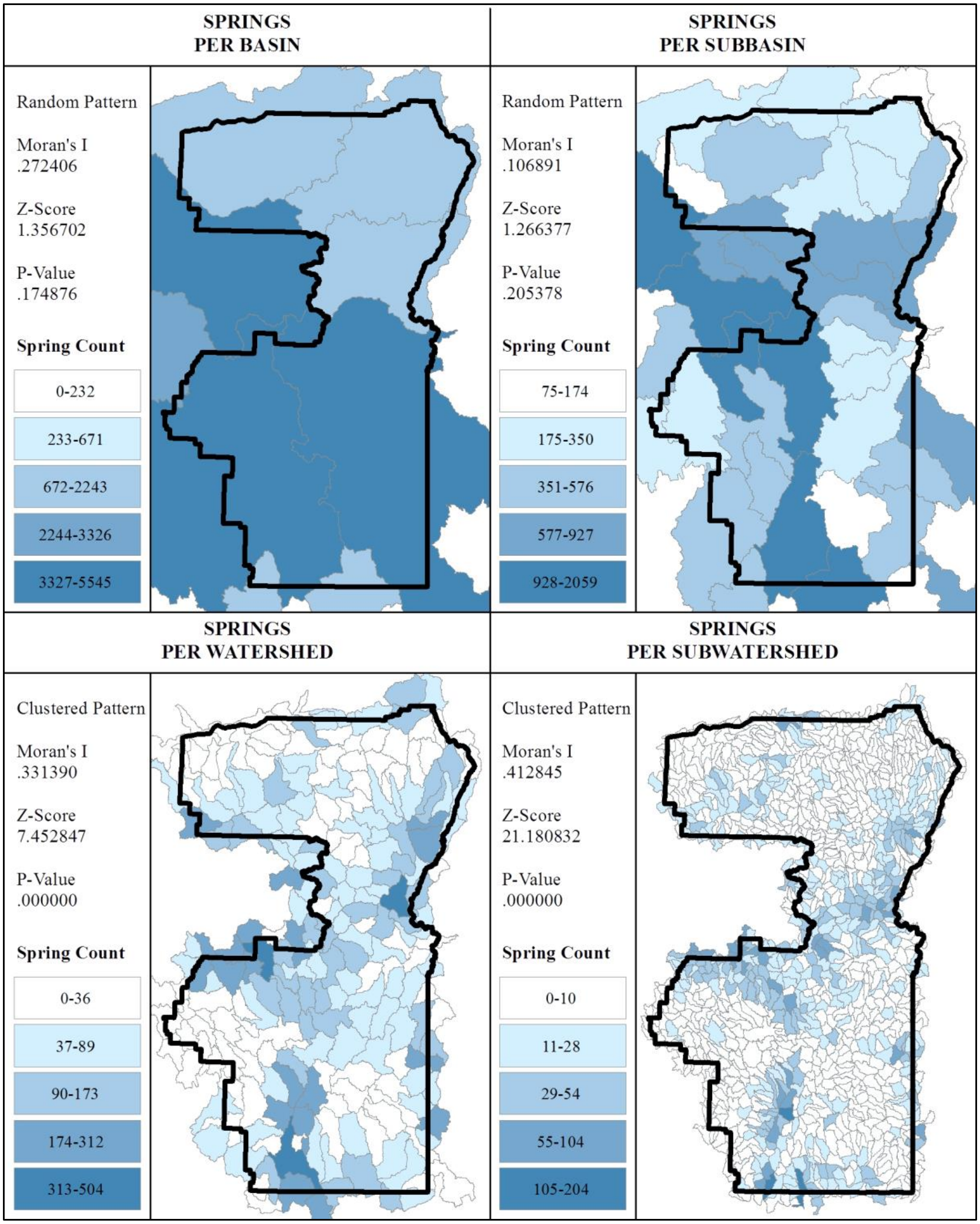


Figure 44. Cluster analysis of spring count by hydrologic unit.

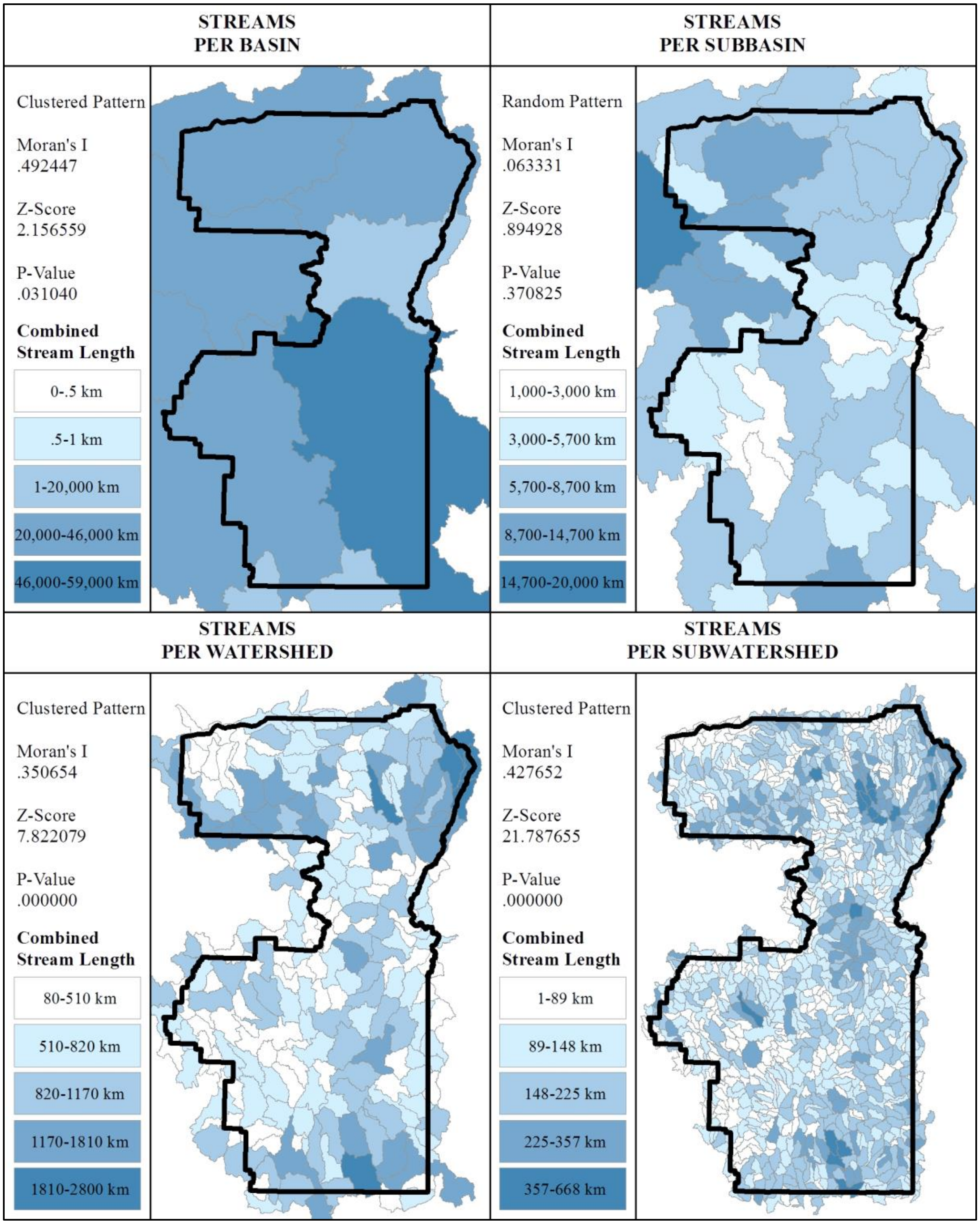


Figure 45. Cluster analysis of stream length by hydrologic unit.

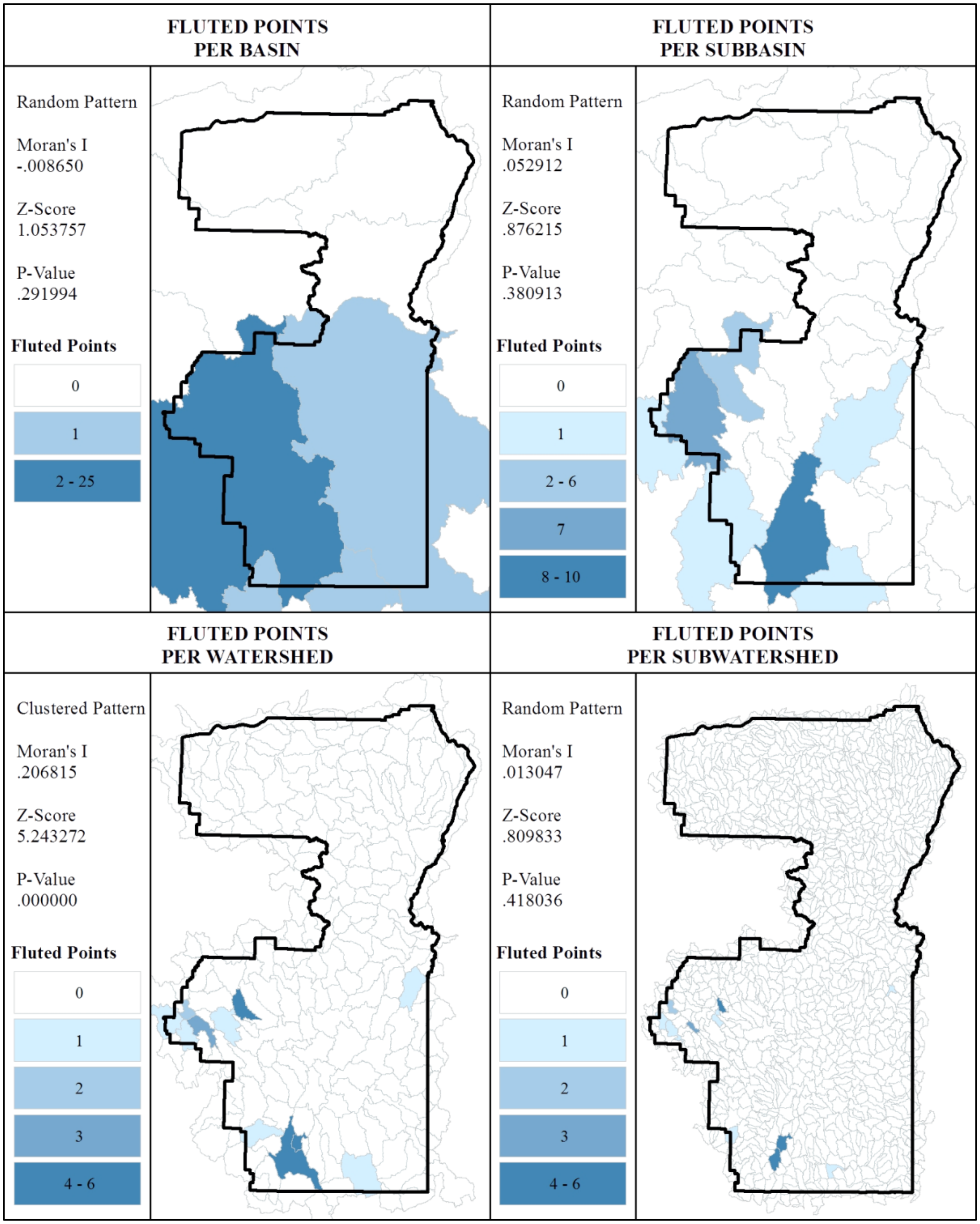


Figure 46. Cluster analysis of Fluted point counts by hydrologic unit.

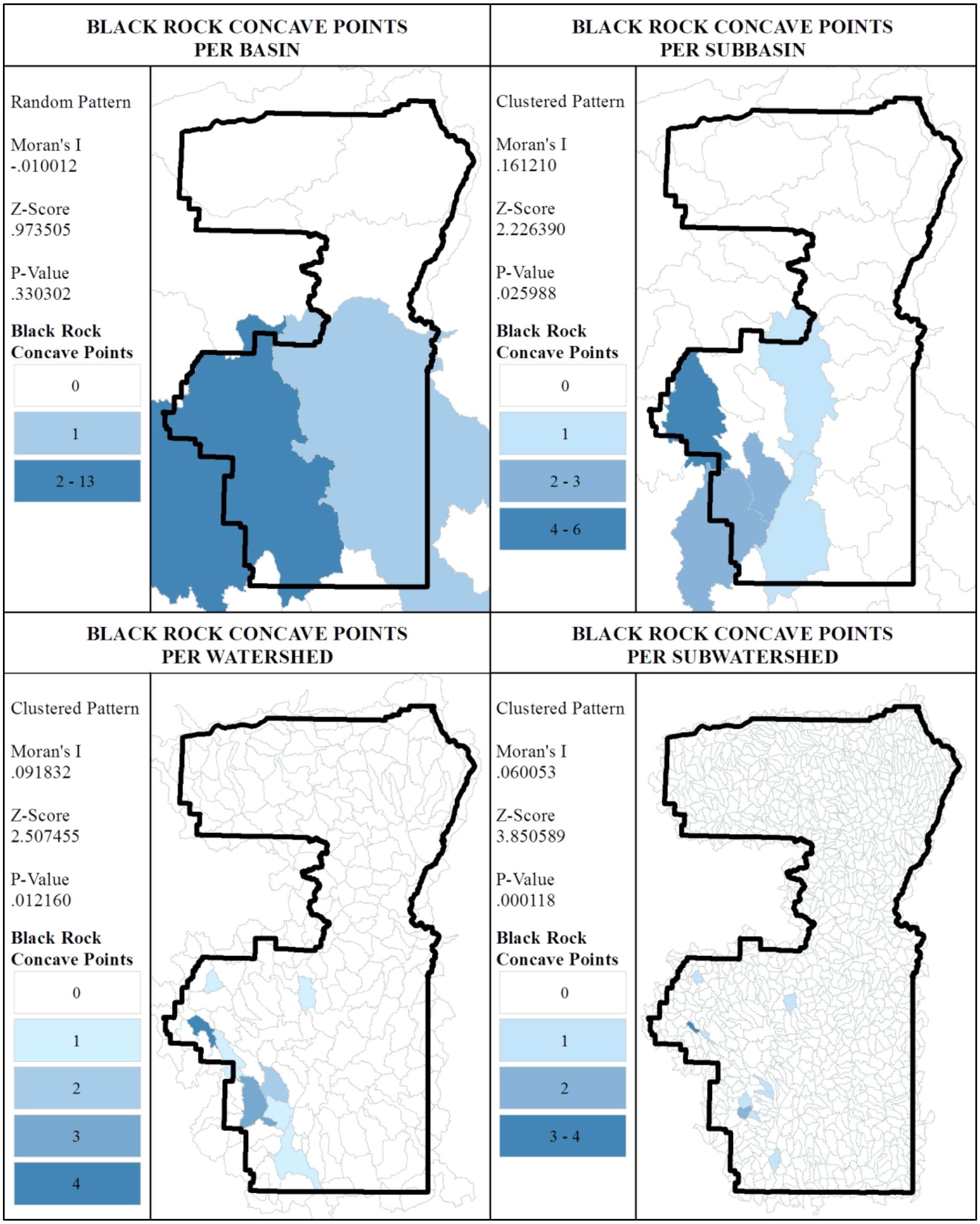


Figure 47. Cluster analysis of Black Rock Concave point counts by hydrologic unit.

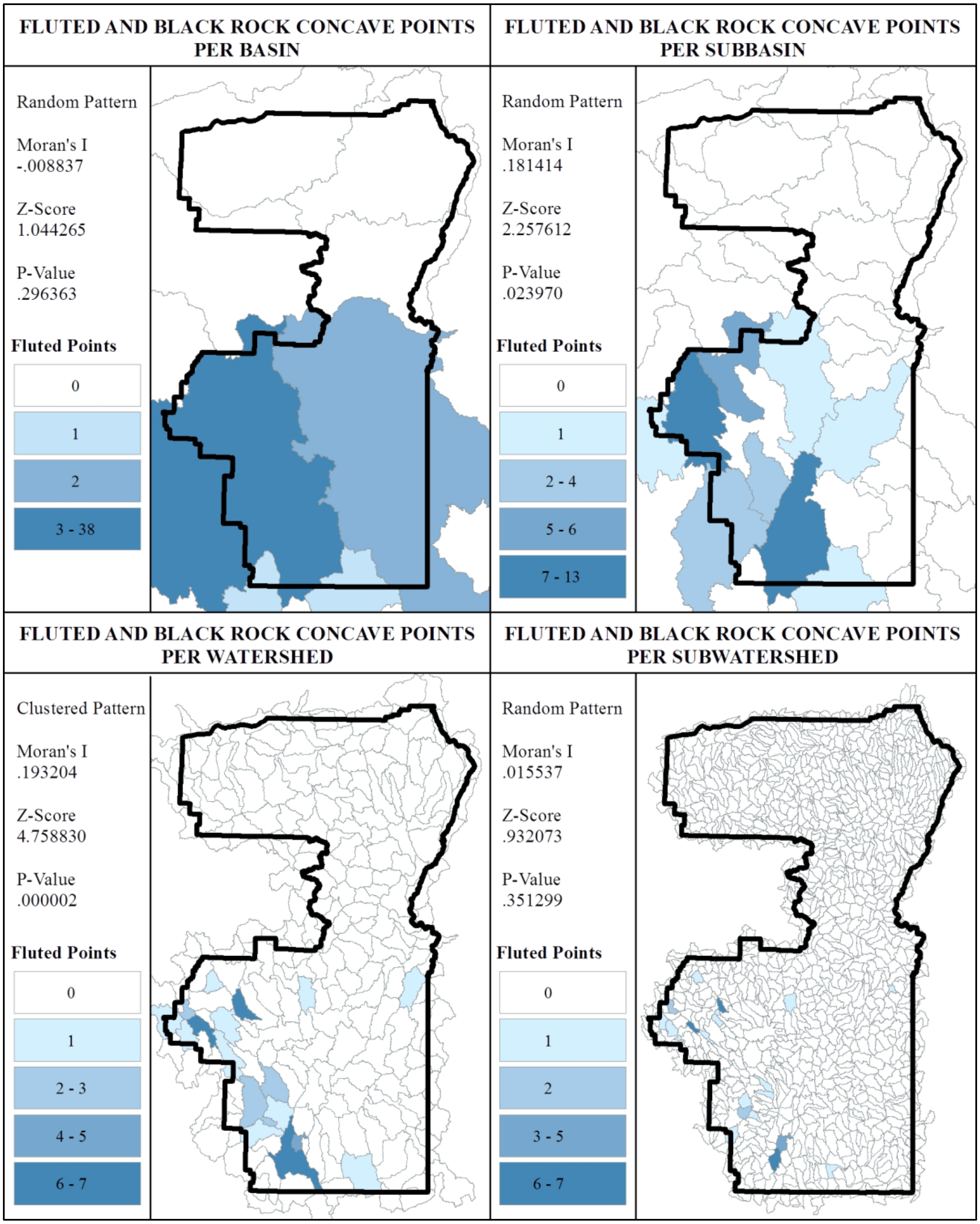


Figure 48. Cluster analysis of Fluted and Black Rock Concave point counts by hydrologic unit.

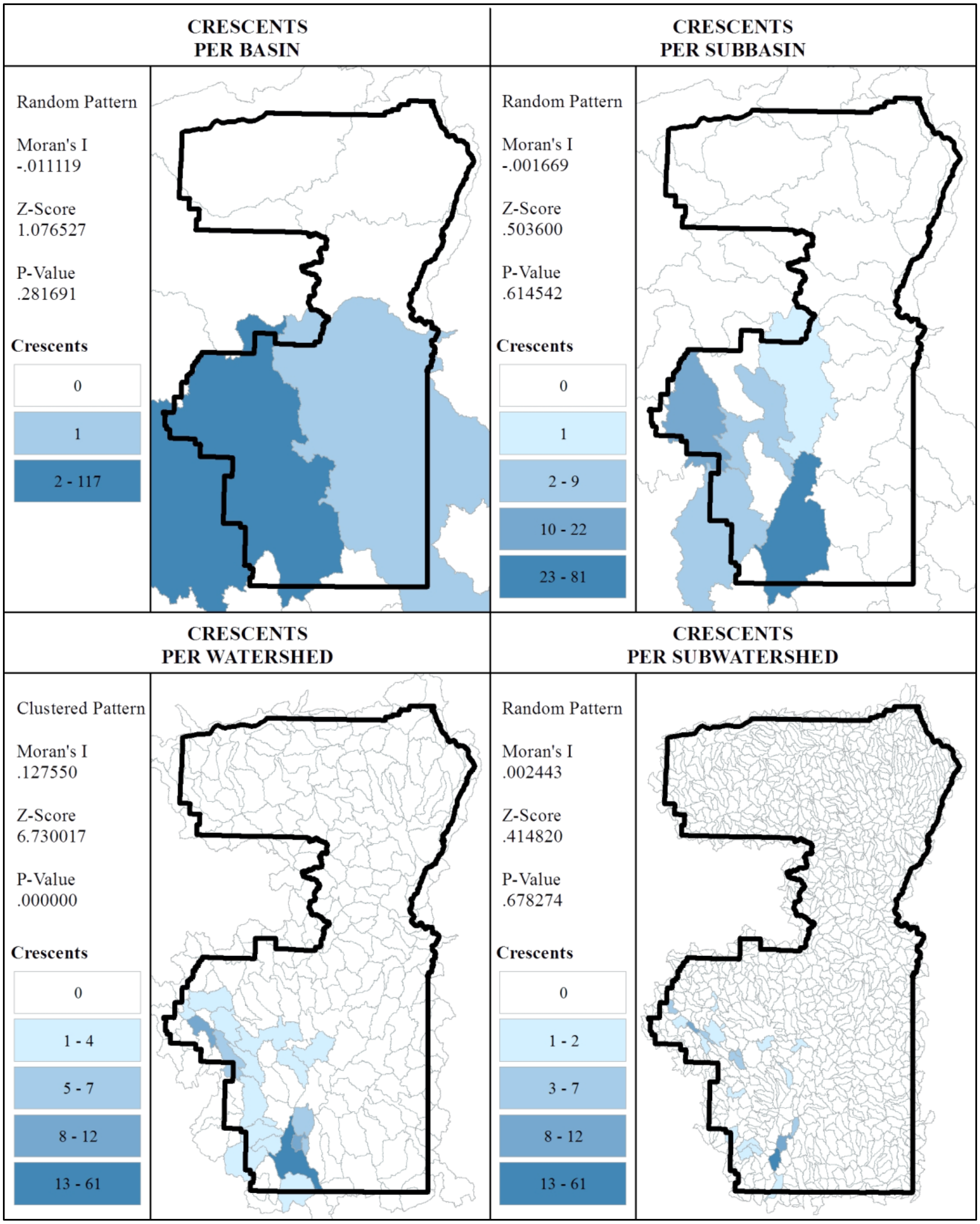


Figure 49. Cluster analysis of Crescent biface counts by hydrologic unit.

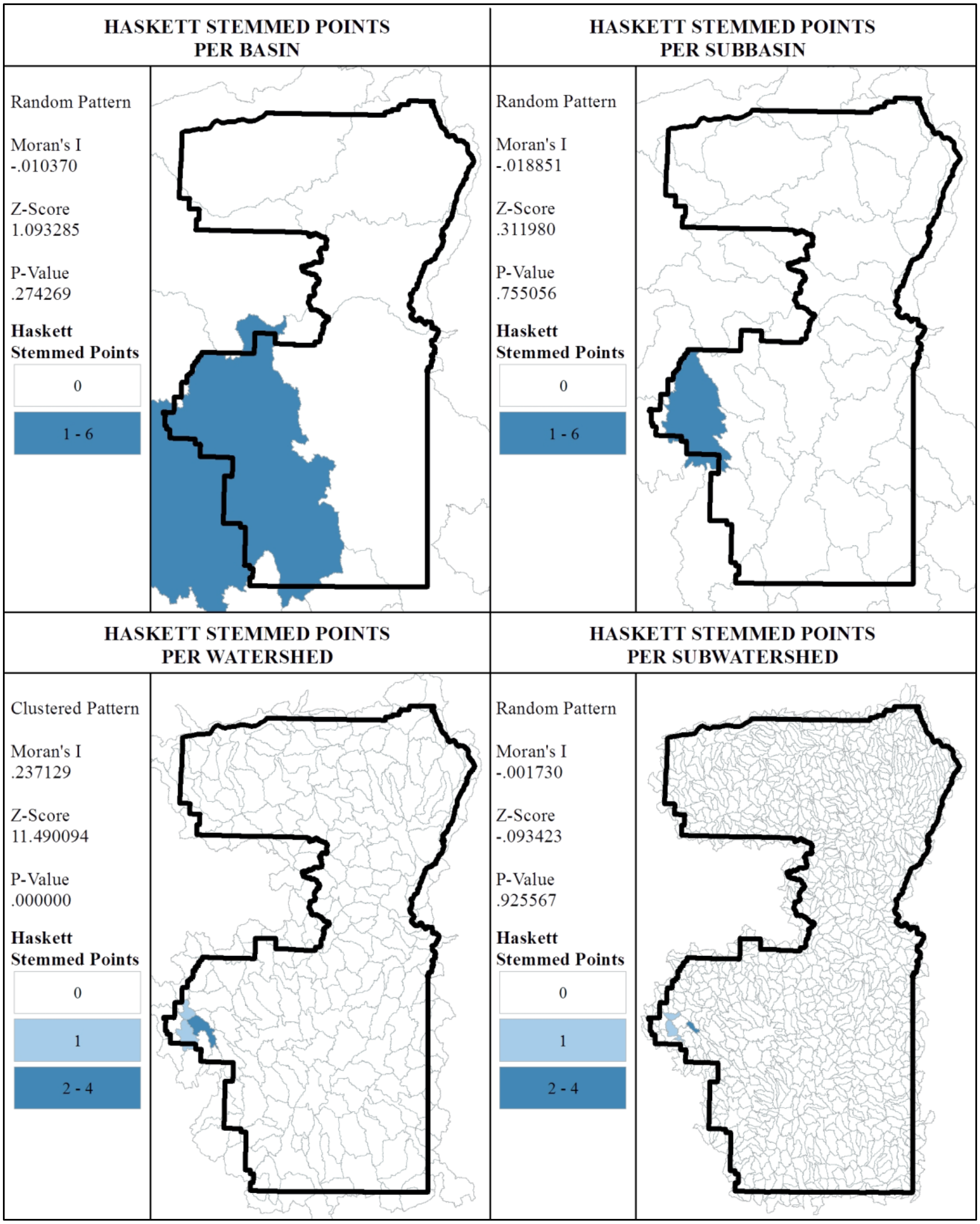


Figure 50. Cluster analysis of Haskett Stemmed point counts by hydrologic unit.

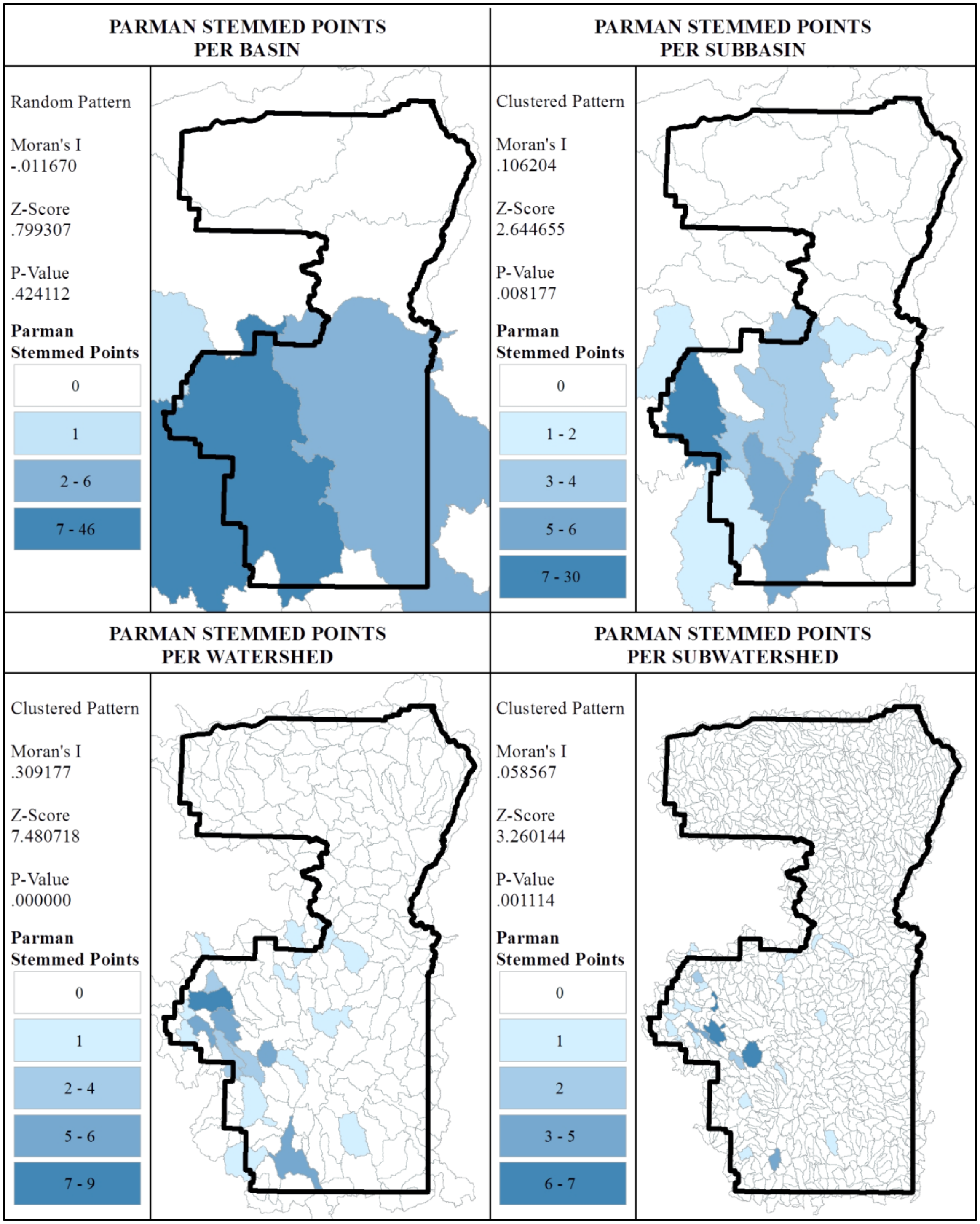


Figure 51. Cluster analysis of Parman Stemmed points by hydrologic unit.

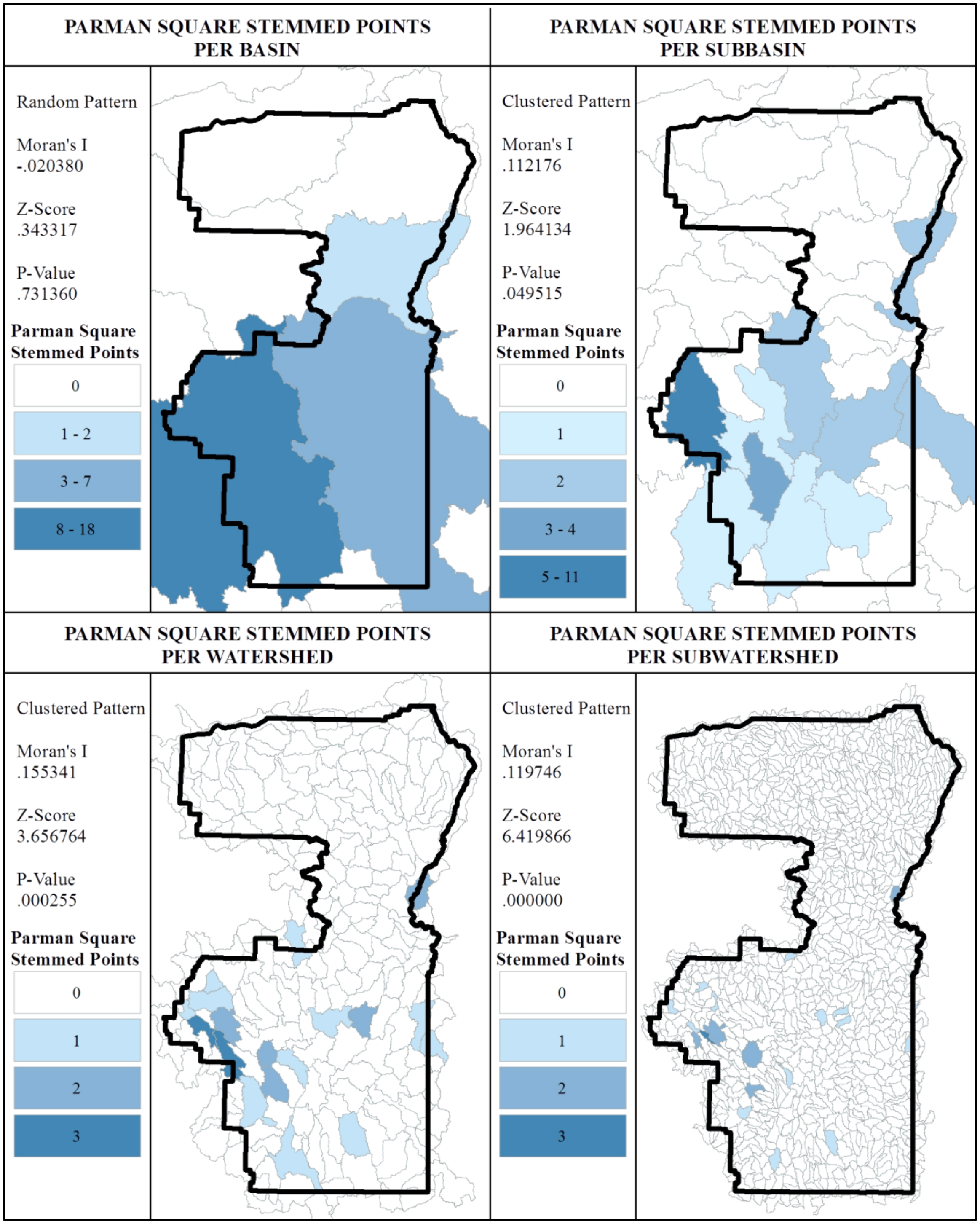
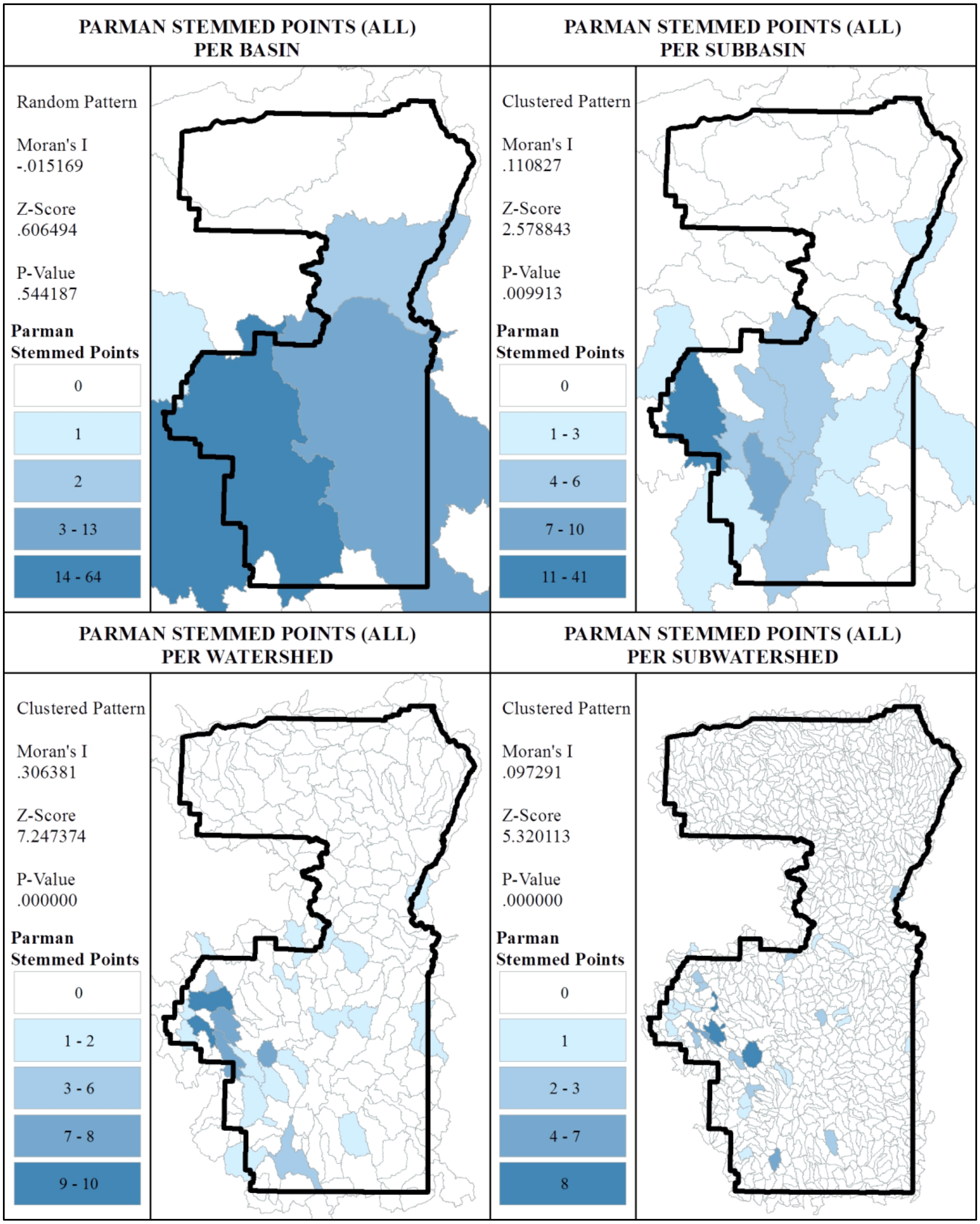


Figure 52. Cluster analysis of Parman Square Stemmed points by hydrologic unit.


PARMAN STEMMED POINTS (ALL) PER BASIN

PARMAN STEMMED POINTS (ALL) PER SUBBASIN

PARMAN STEMMED POINTS (ALL) PER WATERSHED

PARMAN STEMMED POINTS (ALL) PER SUBWATERSHED

Figure 53. Cluster analysis of all Parman Stemmed point counts by hydrologic unit.

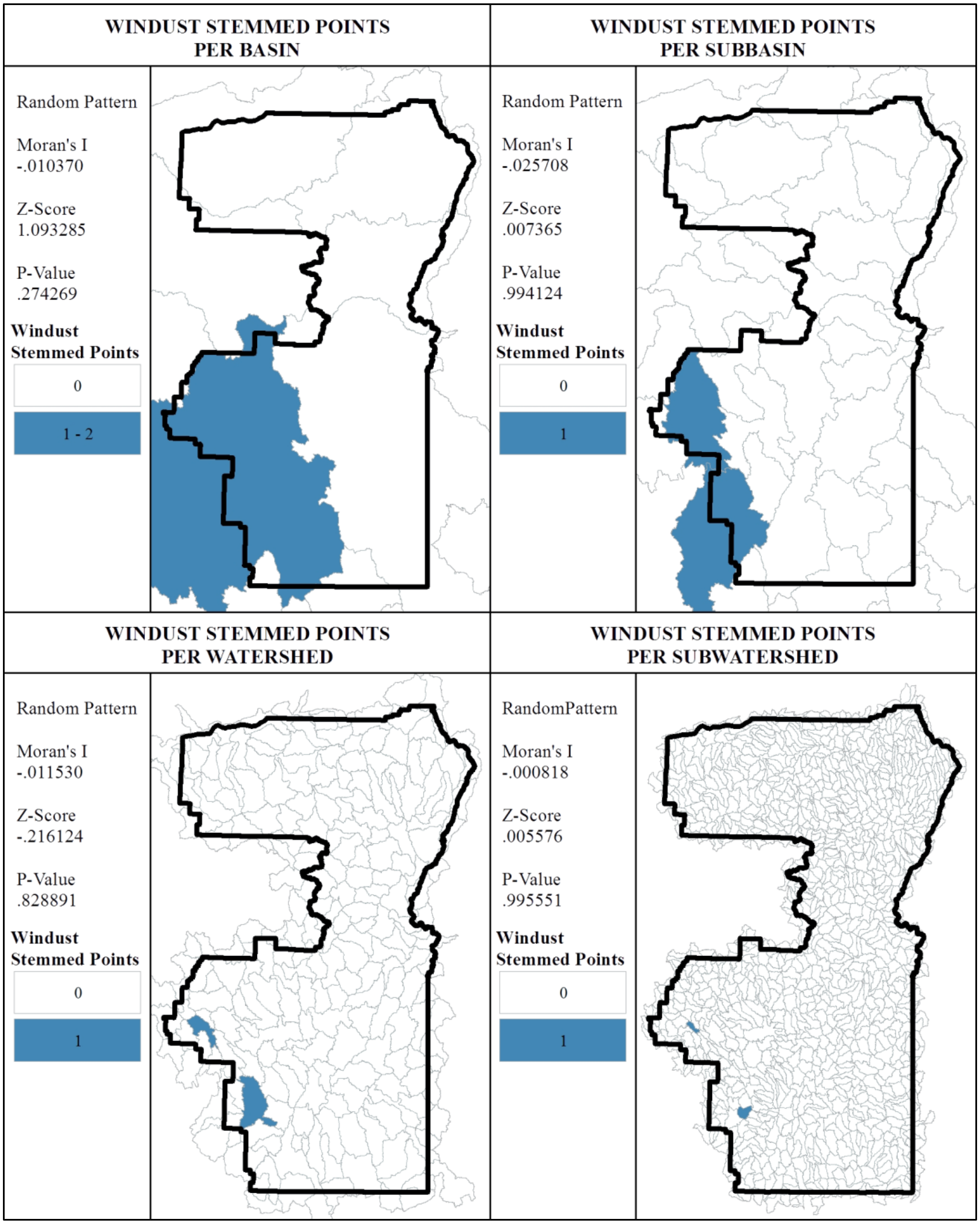


Figure 54. Cluster analysis of Windust Stemmed point counts by hydrologic unit.

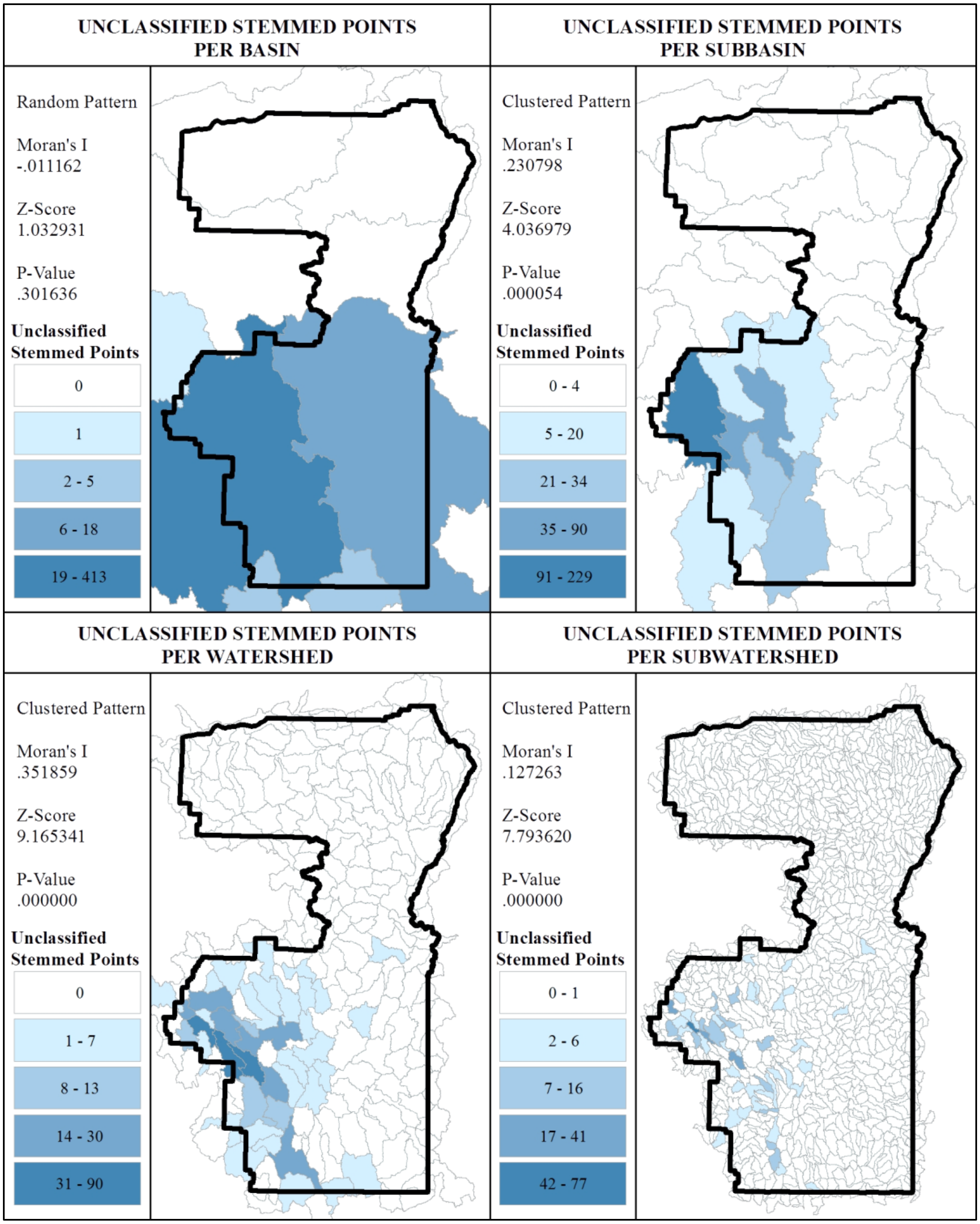


Figure 55. Cluster analysis of unclassified Stemmed point counts by hydrologic unit.

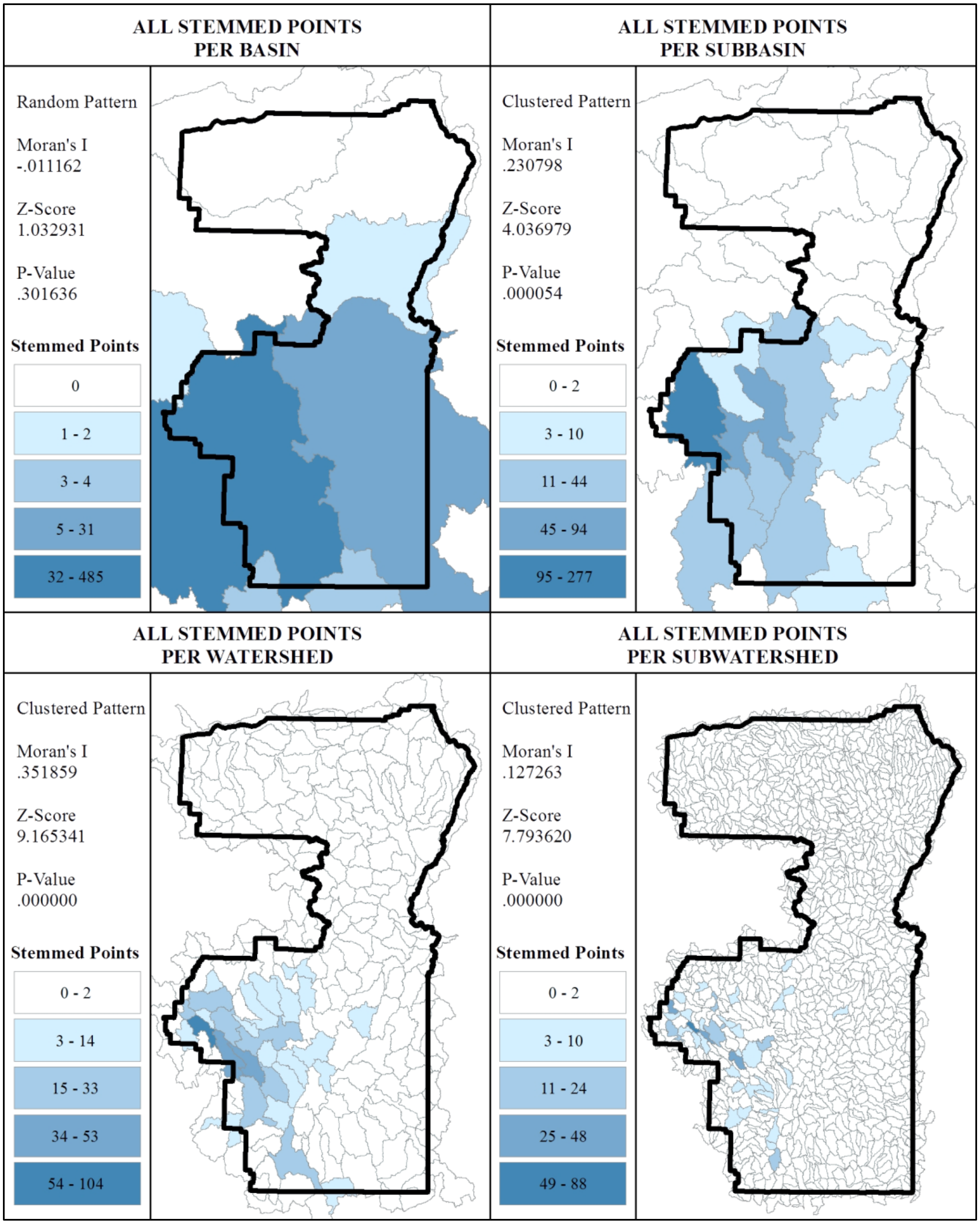


Figure 56. Cluster analysis of all Stemmed point counts by hydrologic unit.

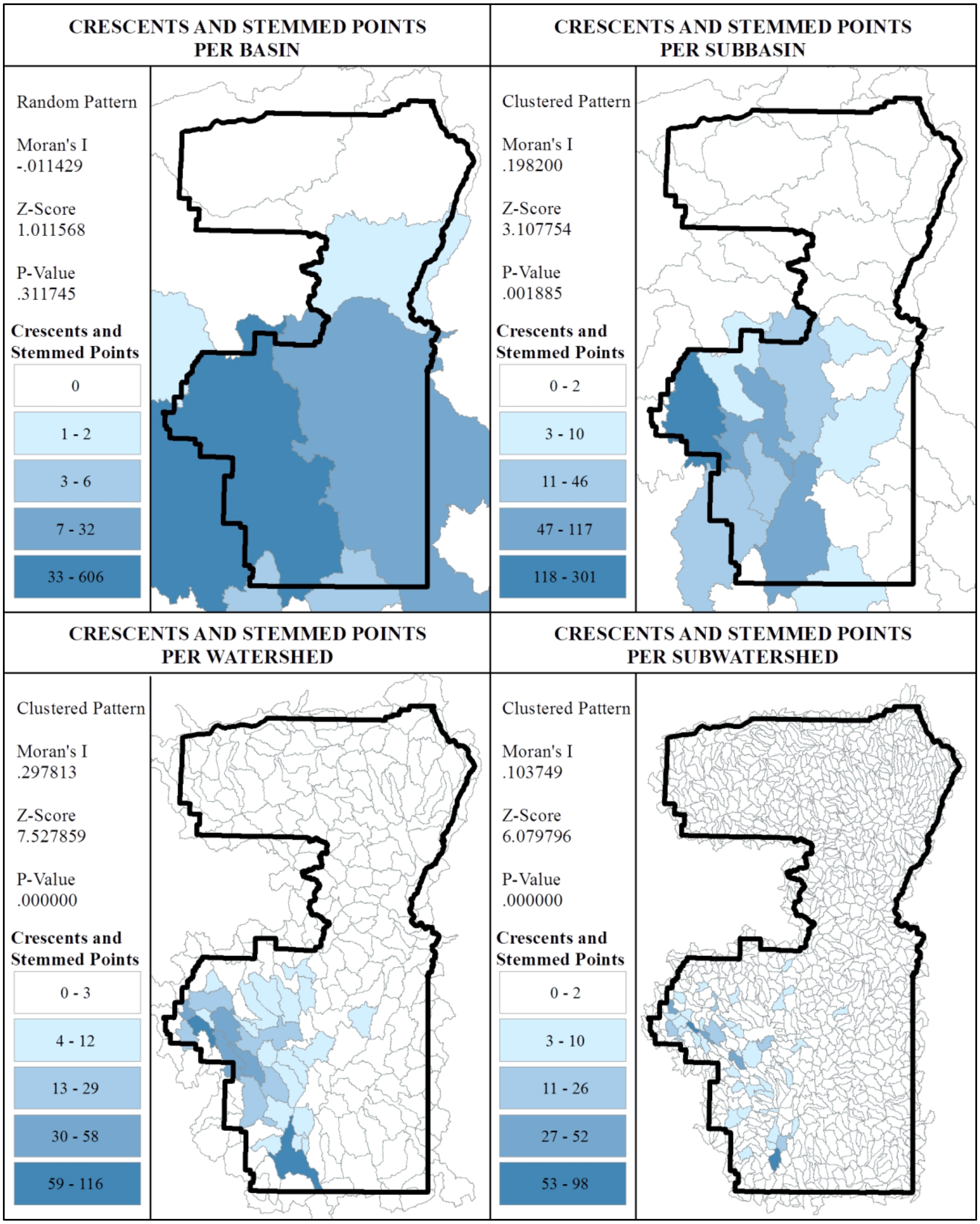


Figure 57. Cluster analysis of Crescent and Stemmed point counts by hydrologic unit.

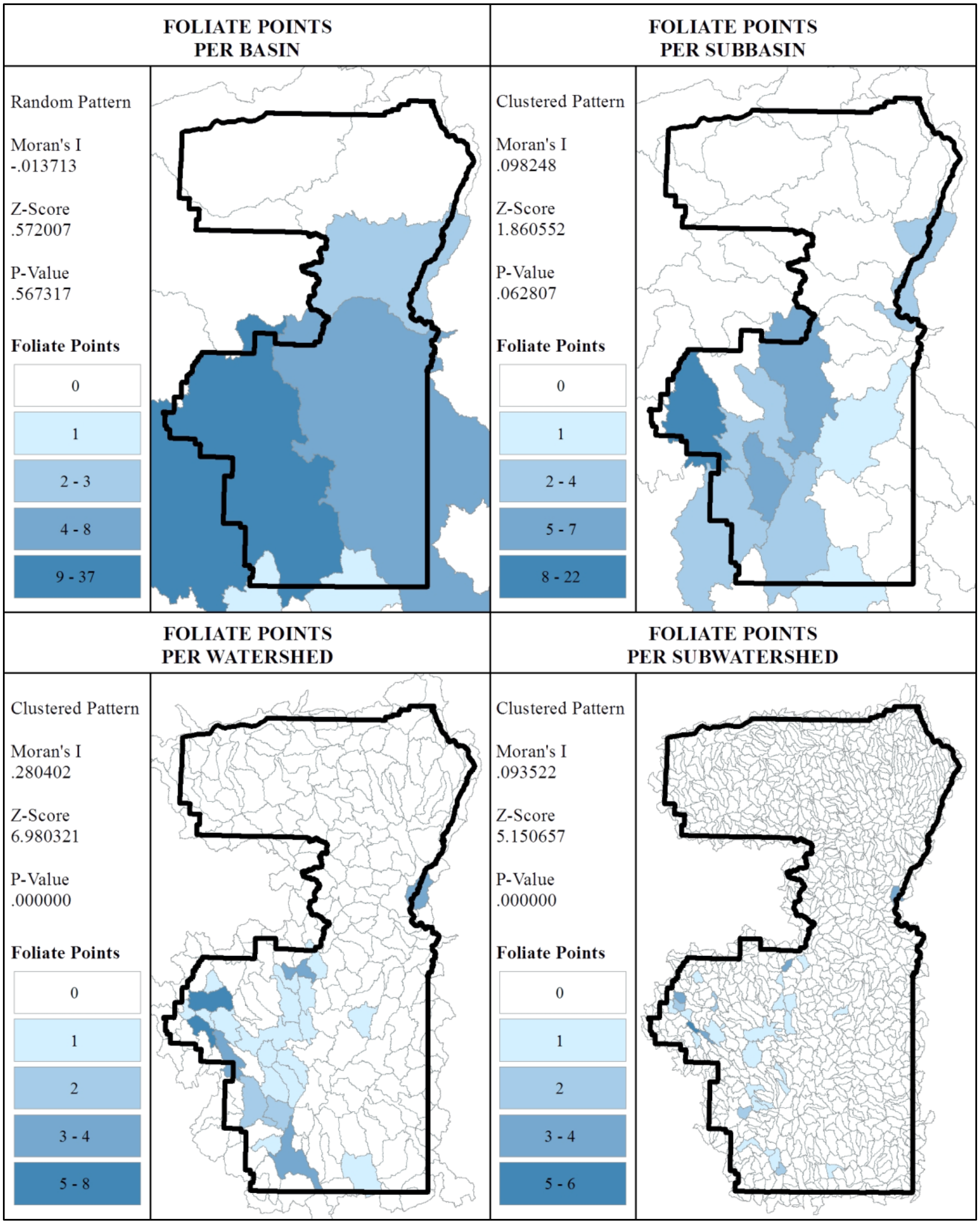


Figure 58. Cluster analysis of foliate point counts by hydrologic unit.

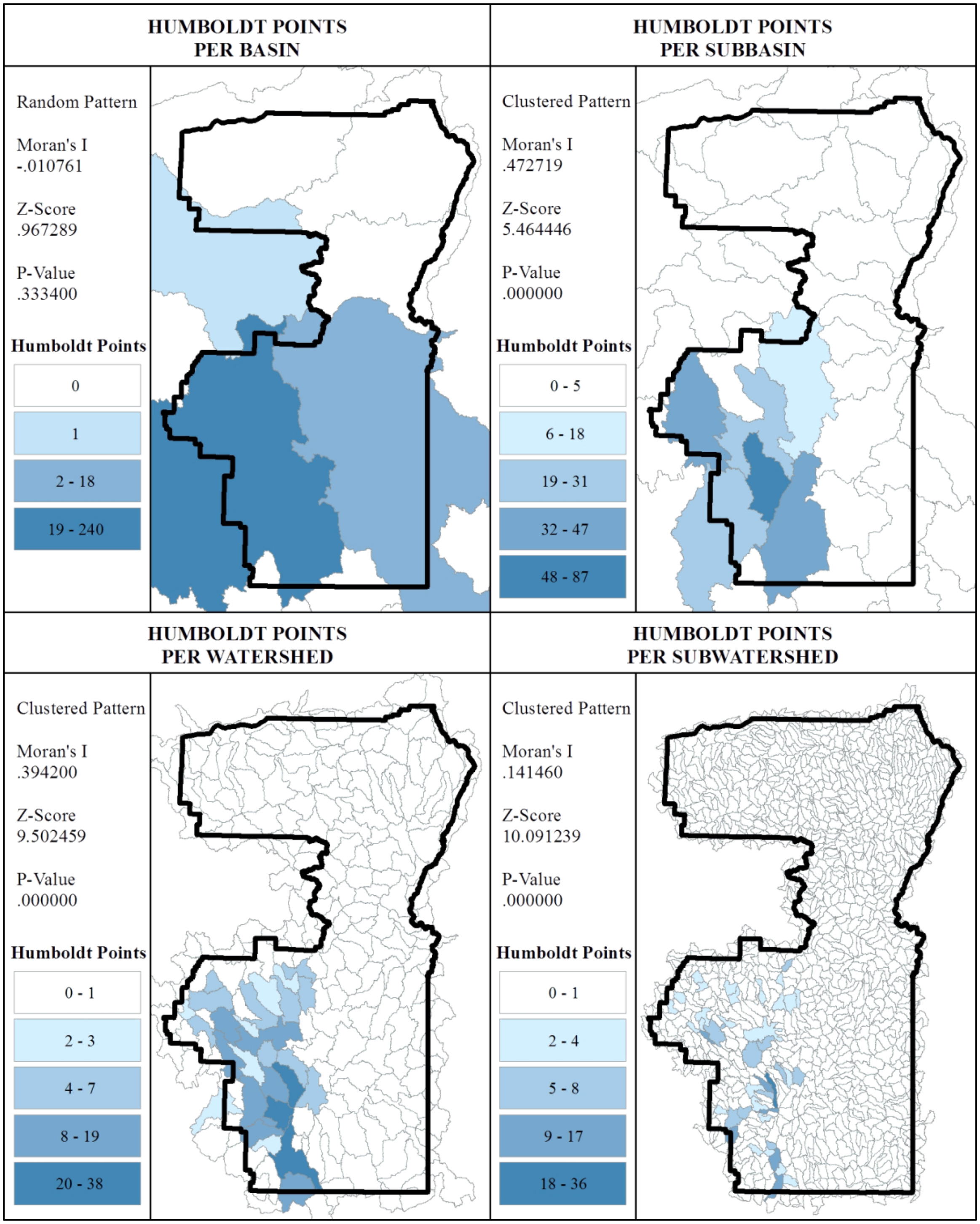


Figure 59. Cluster analysis of Humboldt point counts by hydrologic unit.

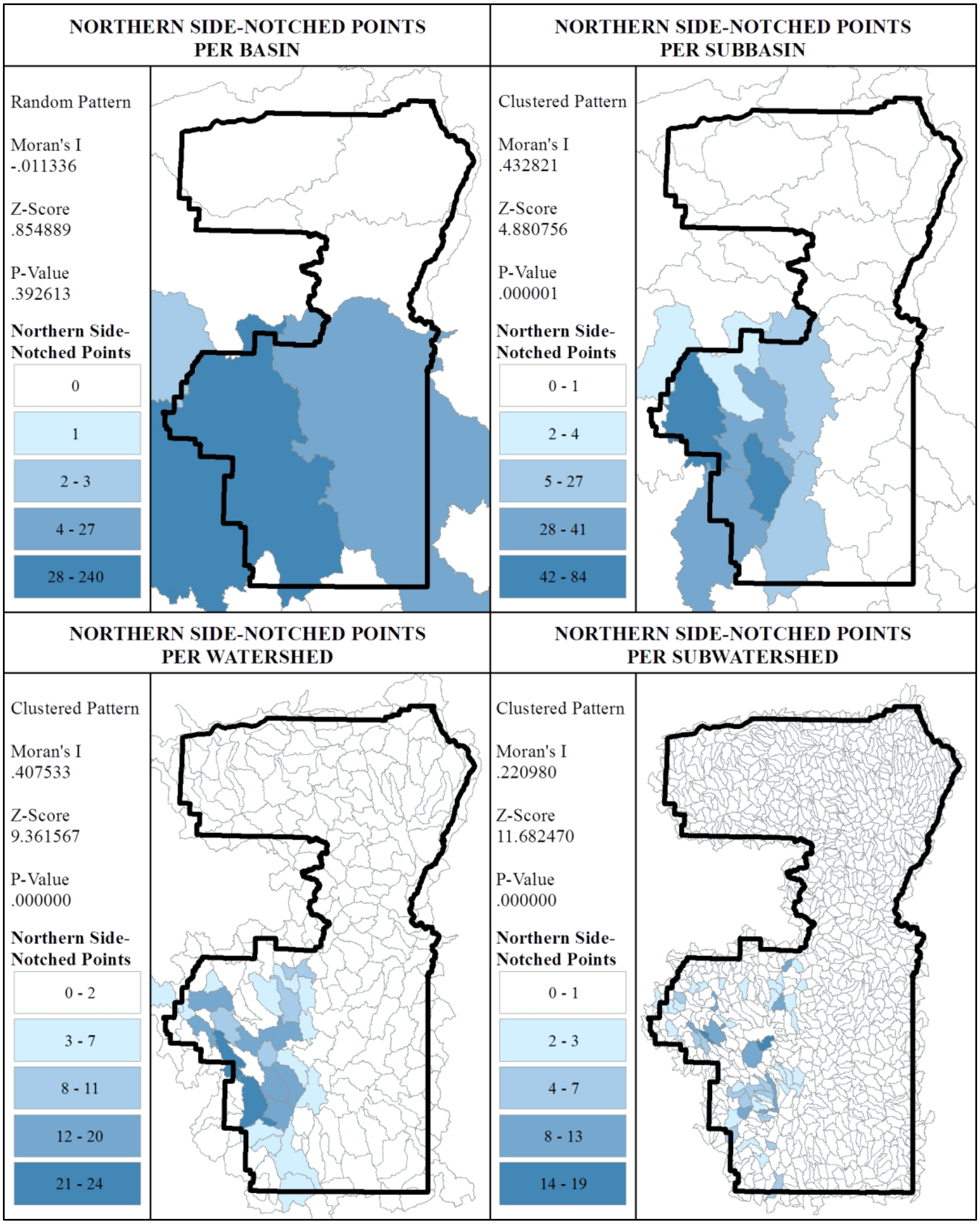


Figure 60. Cluster analysis of Northern Side Notched point counts by hydrologic unit.

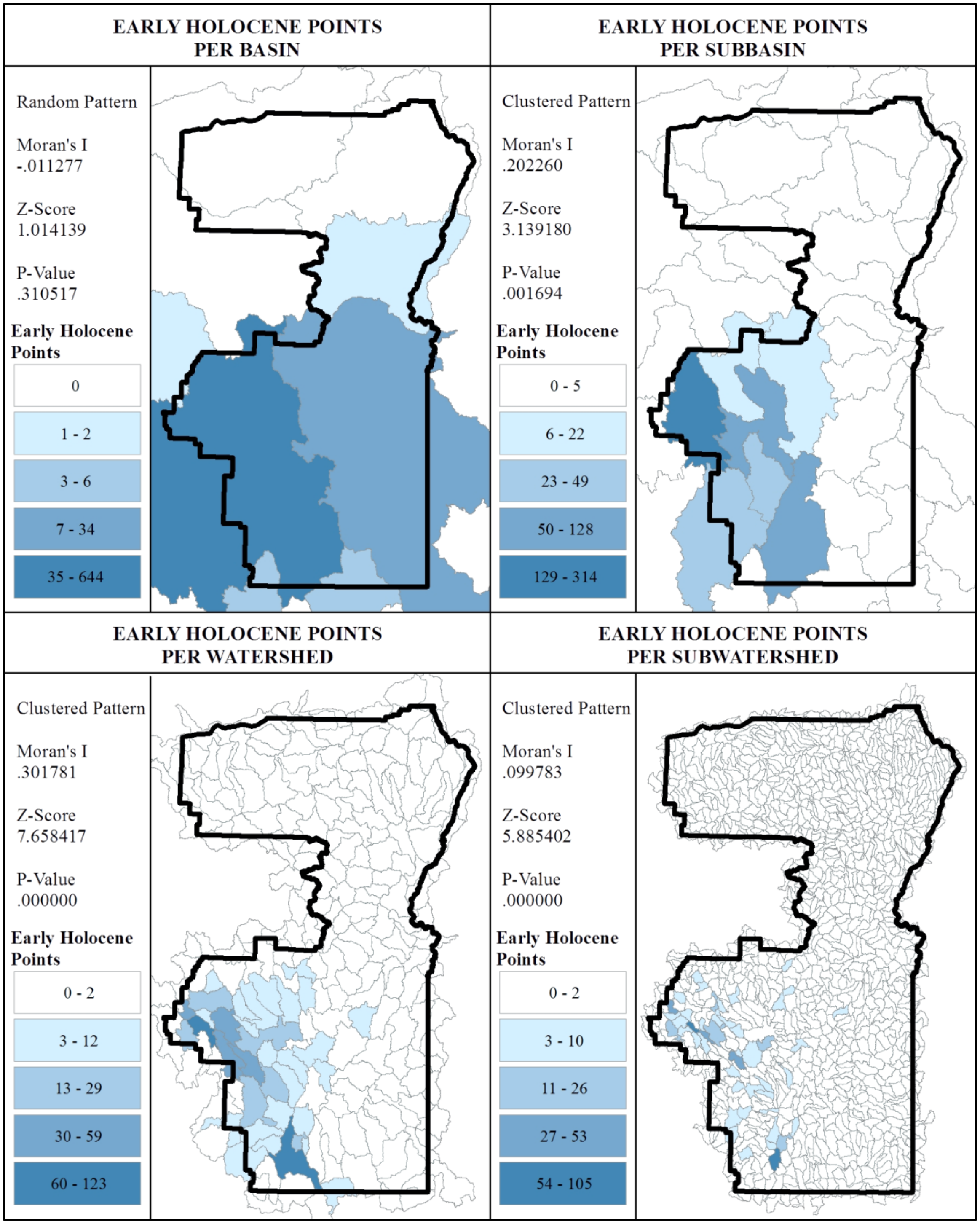


Figure 61. Cluster analysis of all early Holocene point counts by hydrologic unit.

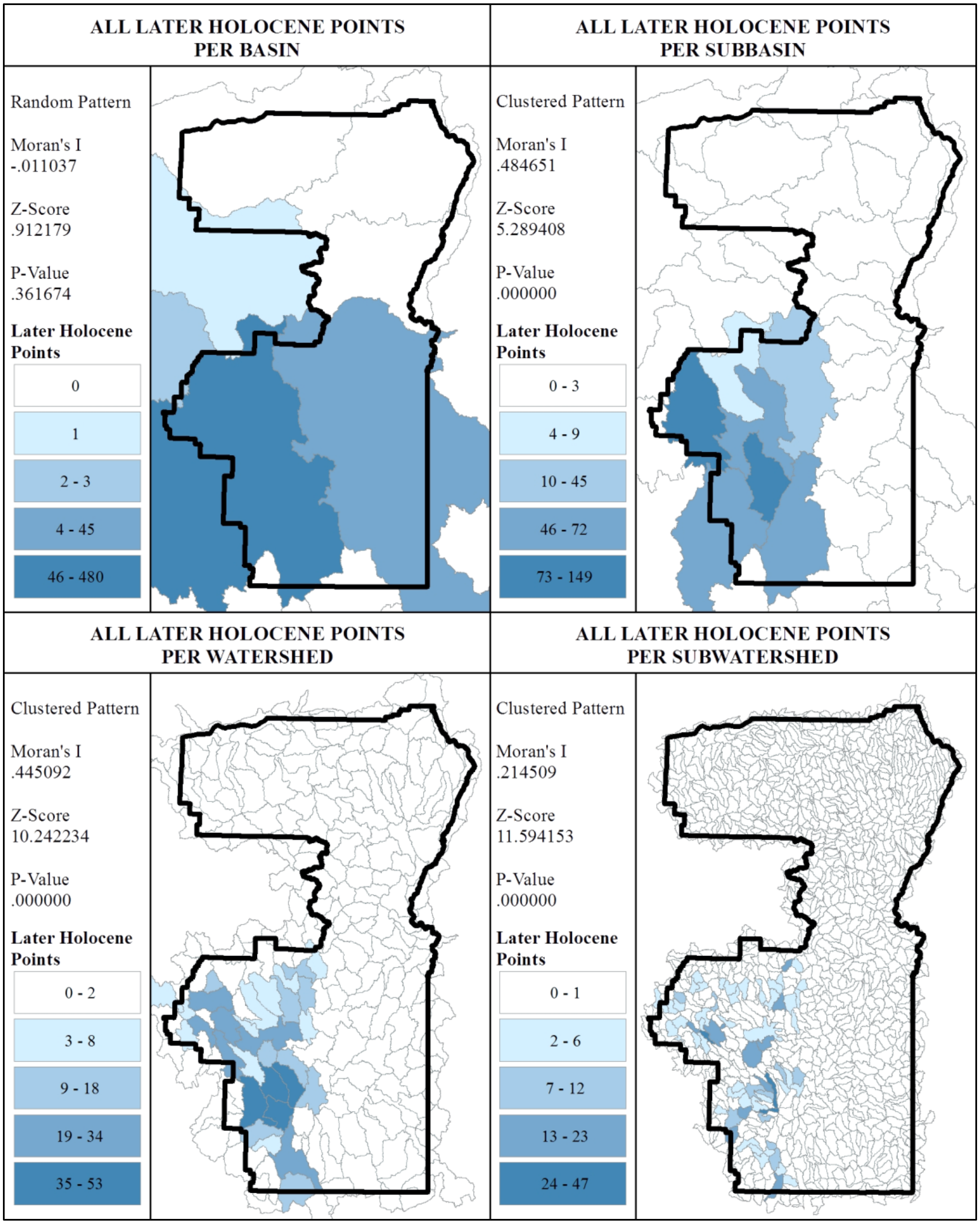


Figure 62. Cluster analysis of all later Holocene point counts by hydrologic unit.

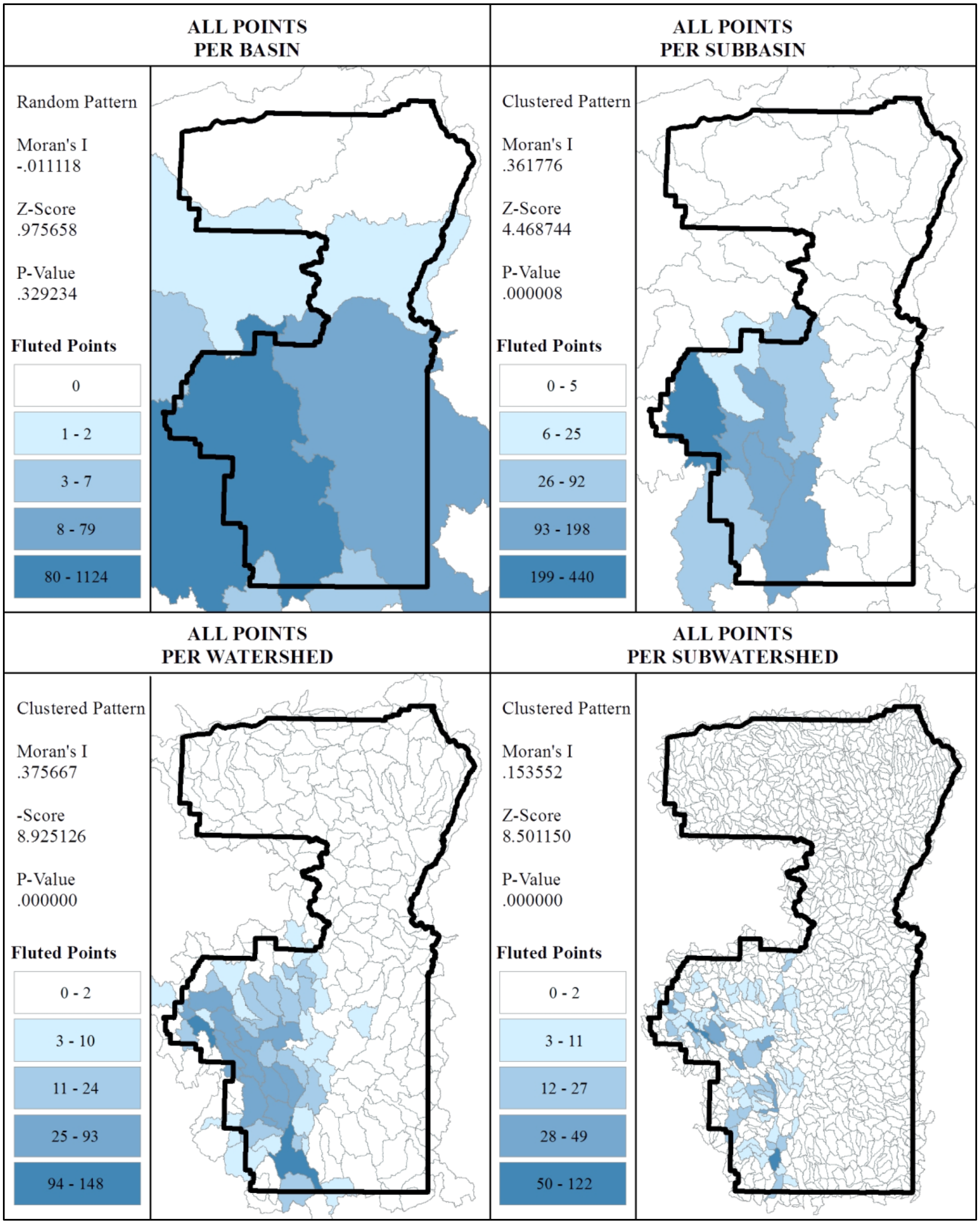


Figure 63. Cluster analysis of all point counts by hydrologic unit.

Table 32. Mean centers of archaeological sites in study.

Feature Type	Watershed Name
Surveys	Upper South Fork Malheur River
Fluted	Jackass Creek
Black Rock Concave	Jackass Creek
Fluted and Black Rock Concave	Jackass Creek
Haskett	Big Stick Creek
Parman	Harney Lake
Parman Square	Harney Lake
Parman, all	Harney Lake
Windust	Buzzard Creek
Stemmed, unclassified	Buzzard Creek
Stemmed, all	Jackass Creek
Crescent	Alvord Lake
Crescent and Stemmed	Jackass Creek
Cascade	Lower North Fork Malheur River
Foliate	Harney Lake
Cascade and Foliate	Lower Silvies River
Humboldt	Middle Donner und Blitzen River
Northern Side Notched	Lower Donner und Blitzen River
All Early Holocene	Jack Ass Creek
All Later Holocene	Lower Donner und Blitzen River
All Points	Jackass Creek

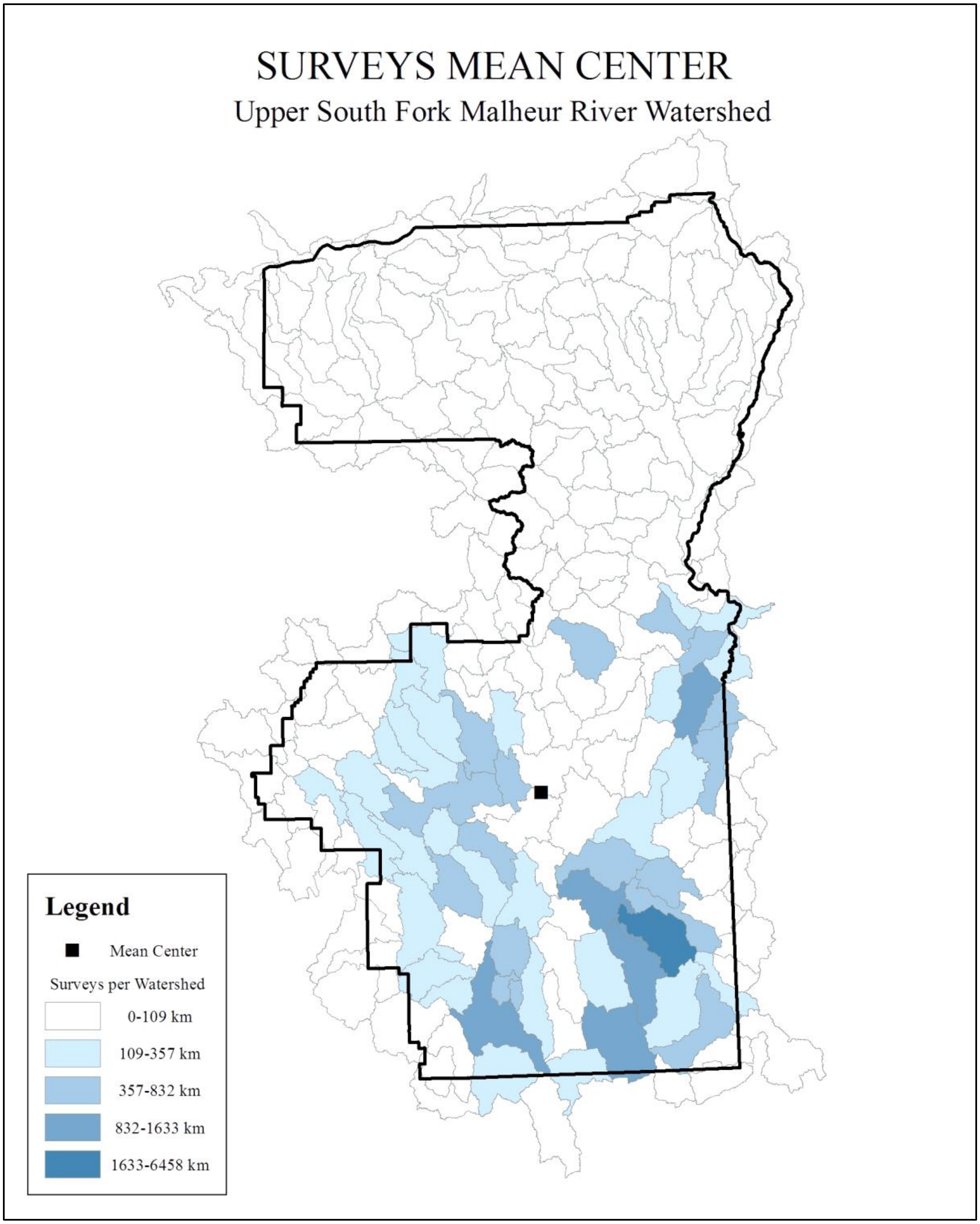


Figure 64. Mean center of surveys in study area.

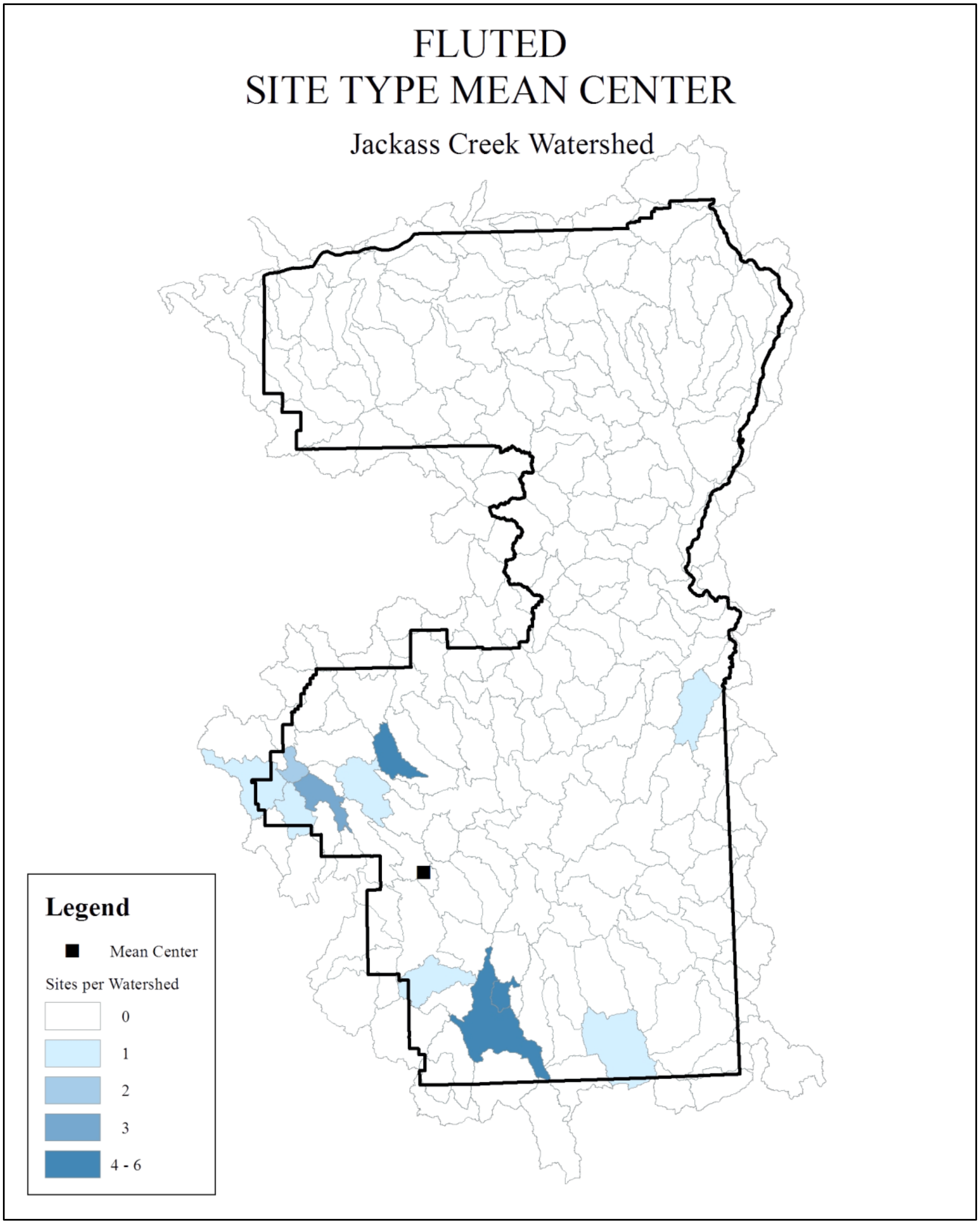


Figure 65. Mean center of fluted point sites in study area.

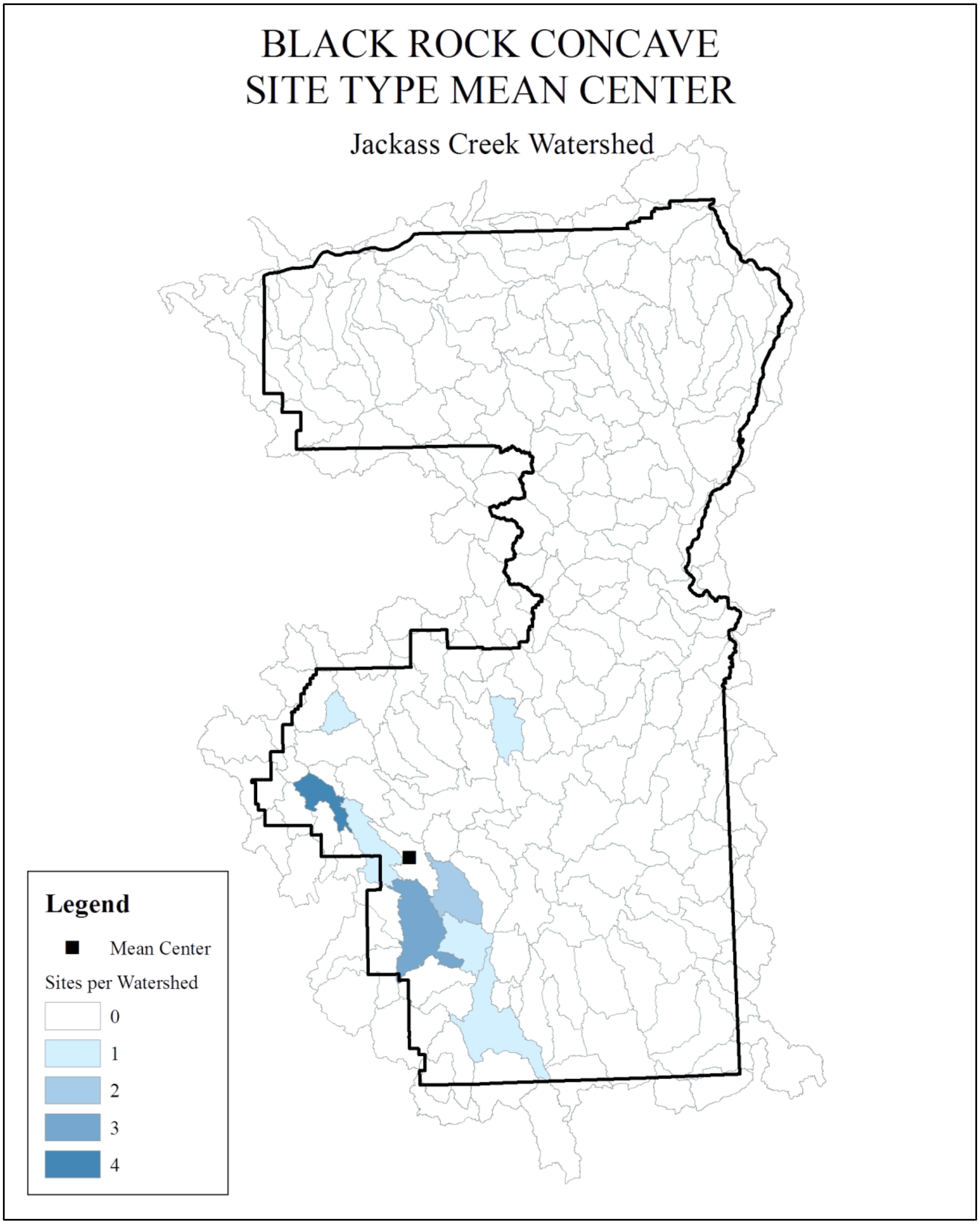


Figure 66. Mean center of Black Rock Concave point sites in study area.

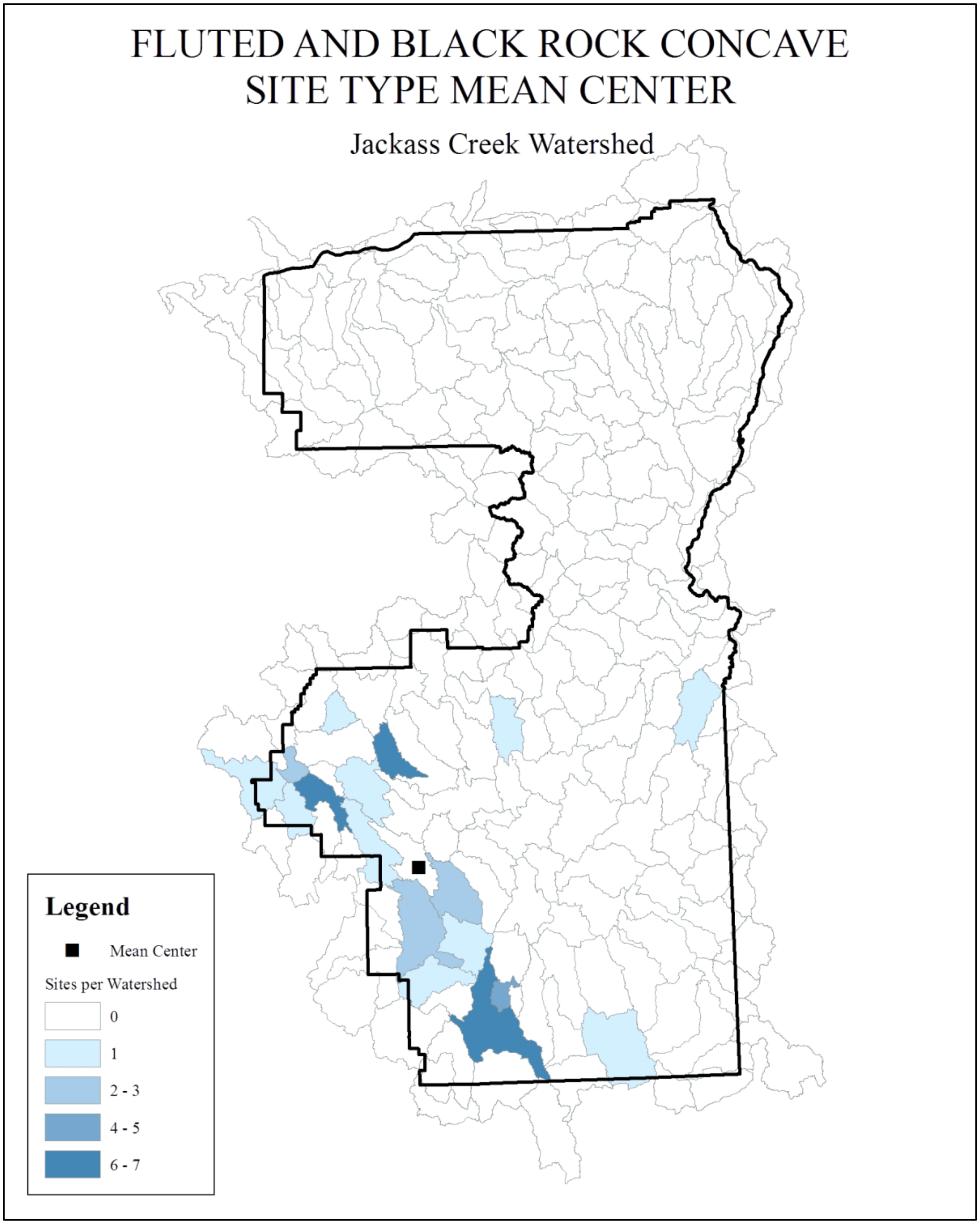


Figure 67. Mean center of Fluted and Black Rock Concave point sites in study area.

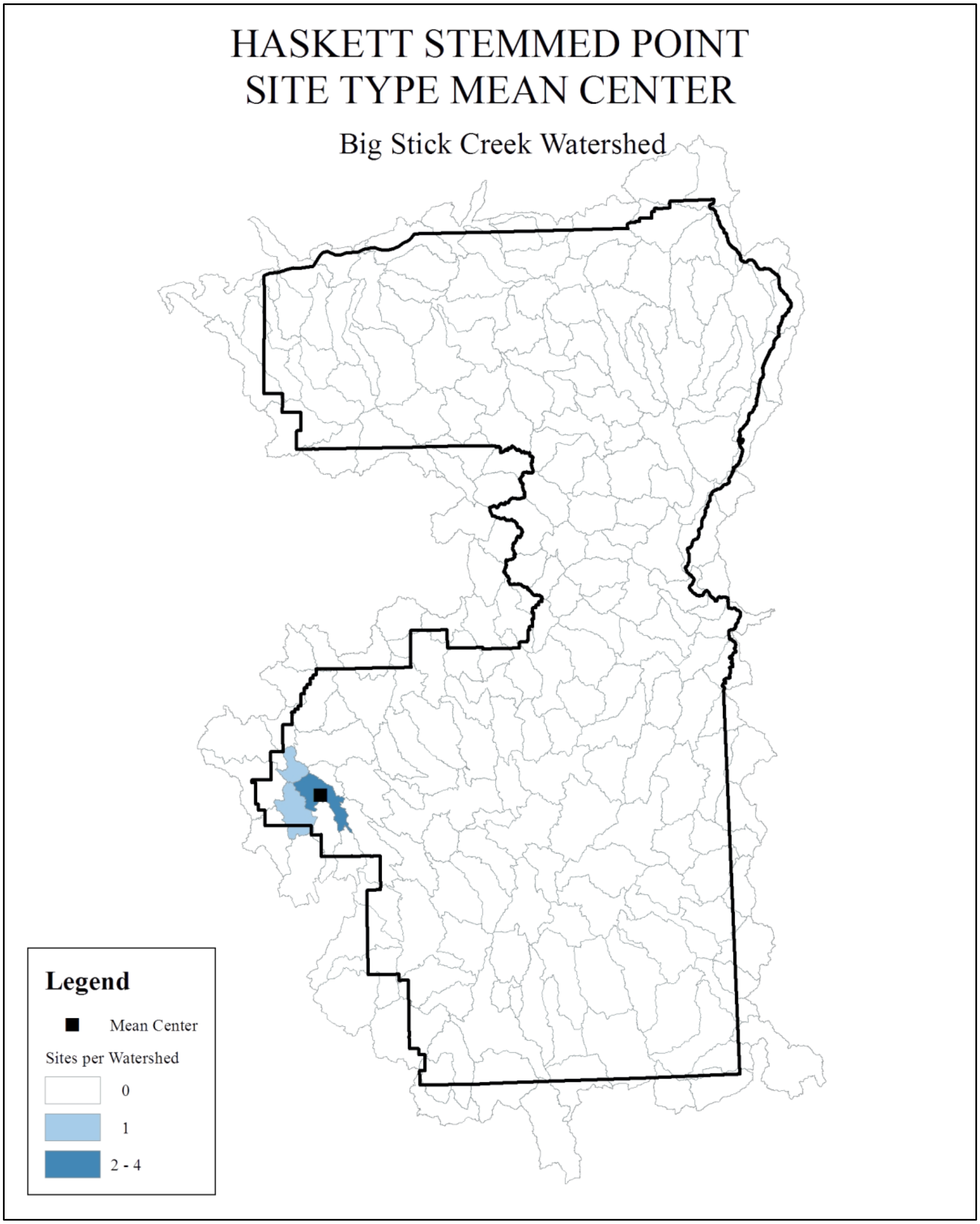


Figure 68. Mean center of Haskett Stemmed sites in study area.

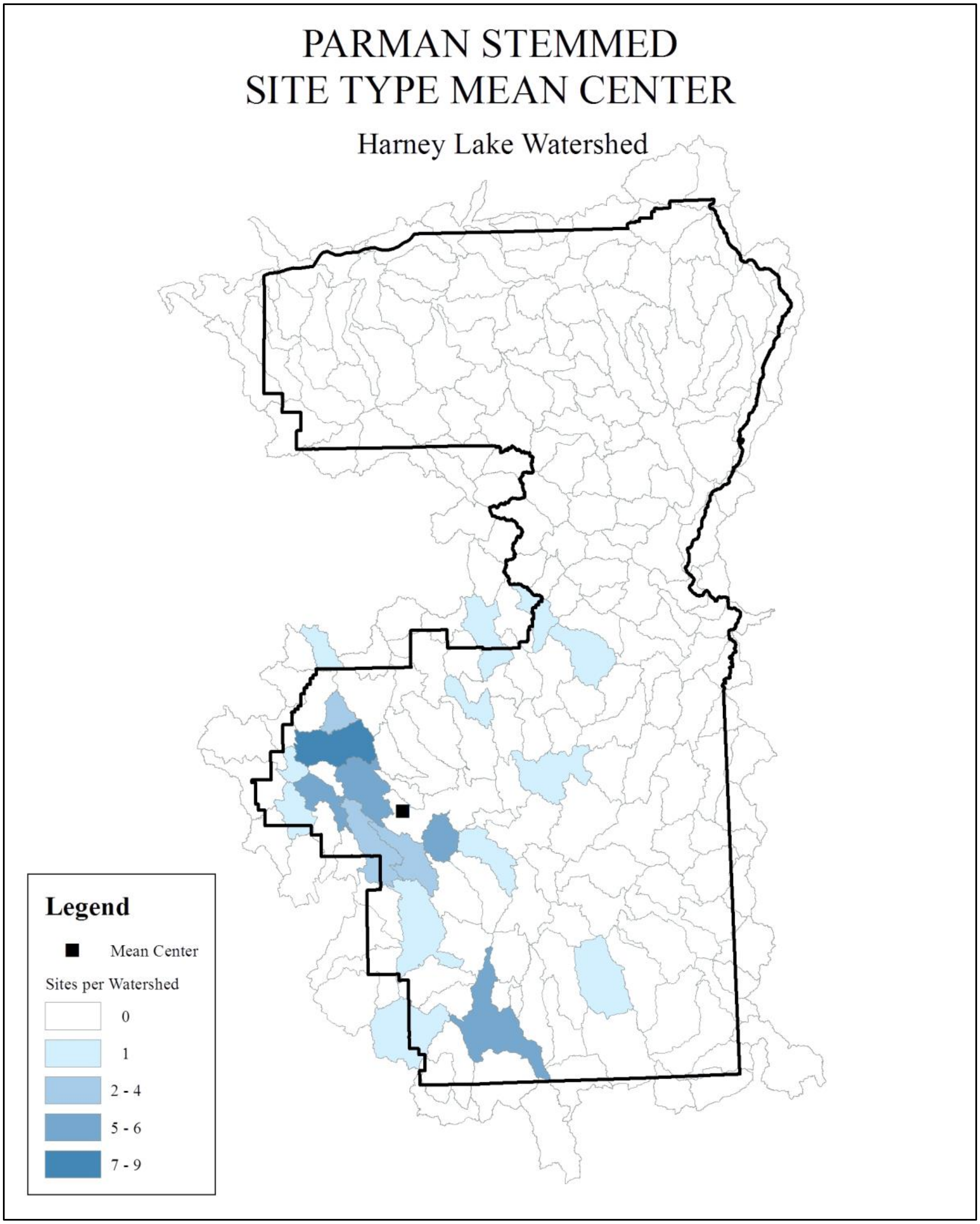


Figure 69. Mean center of Parman Stemmed sites in study area.

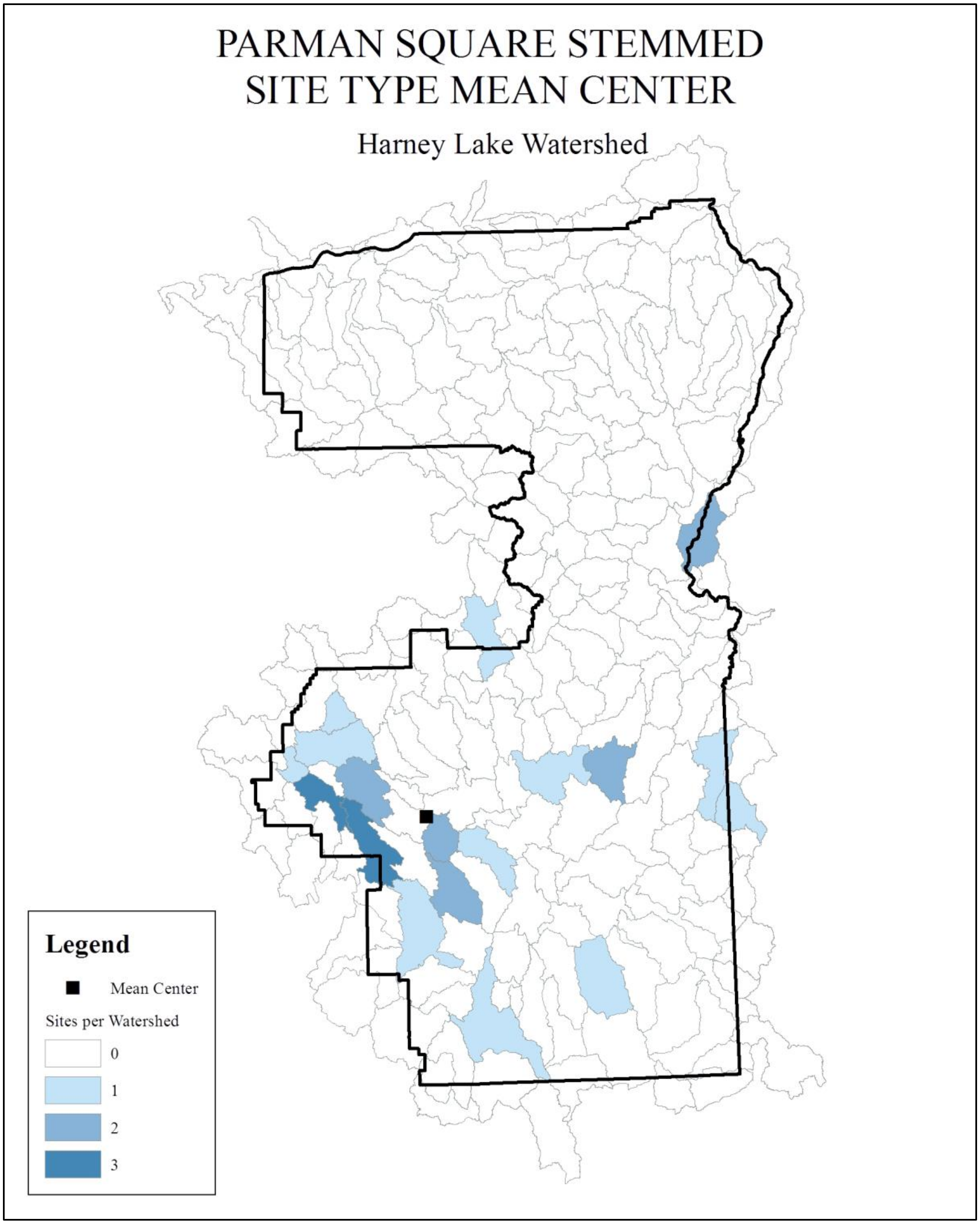


Figure 70. Mean center of Parman Square Stemmed sites in study area.

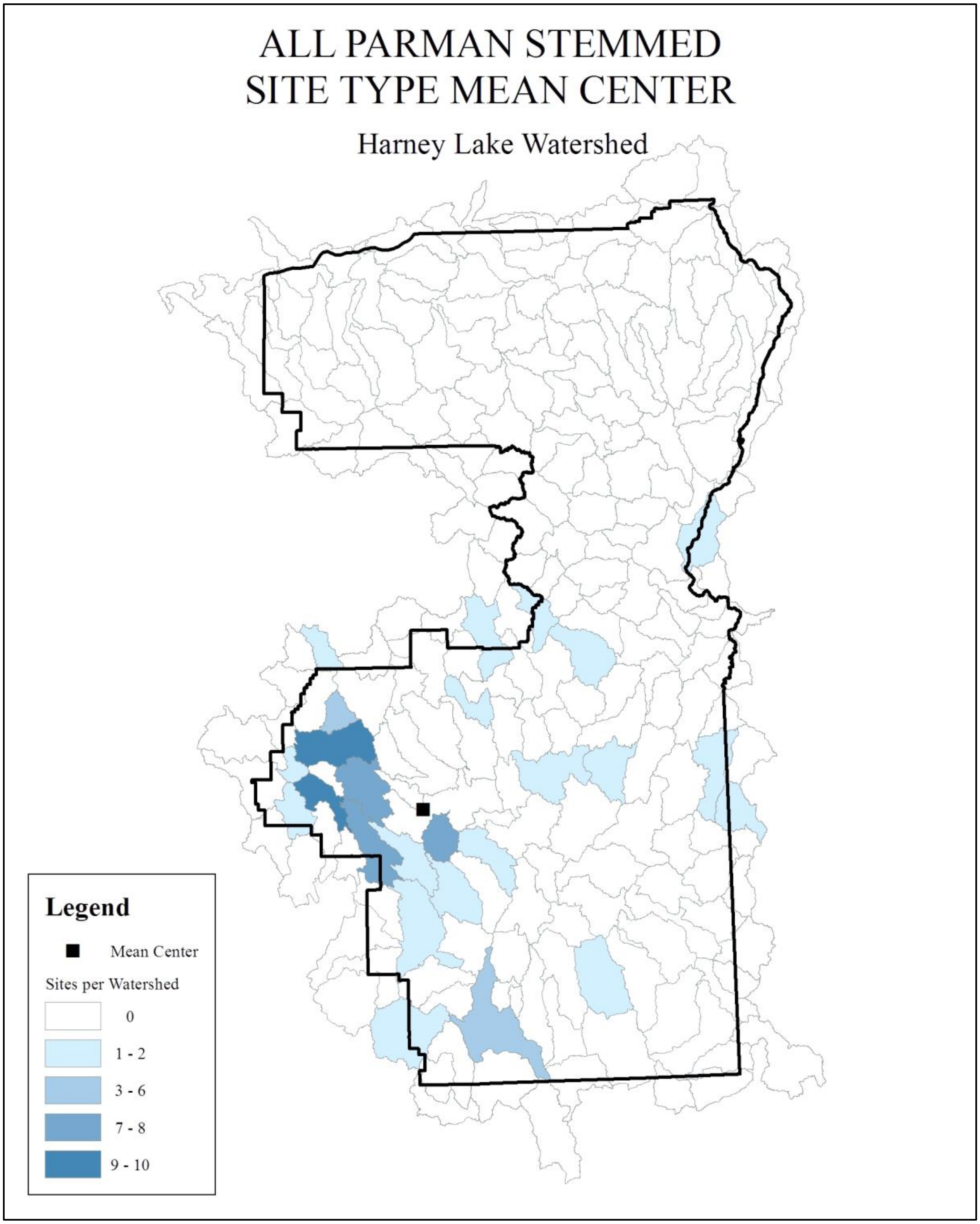


Figure 71. Mean center of all Parman Stemmed sites in study area.

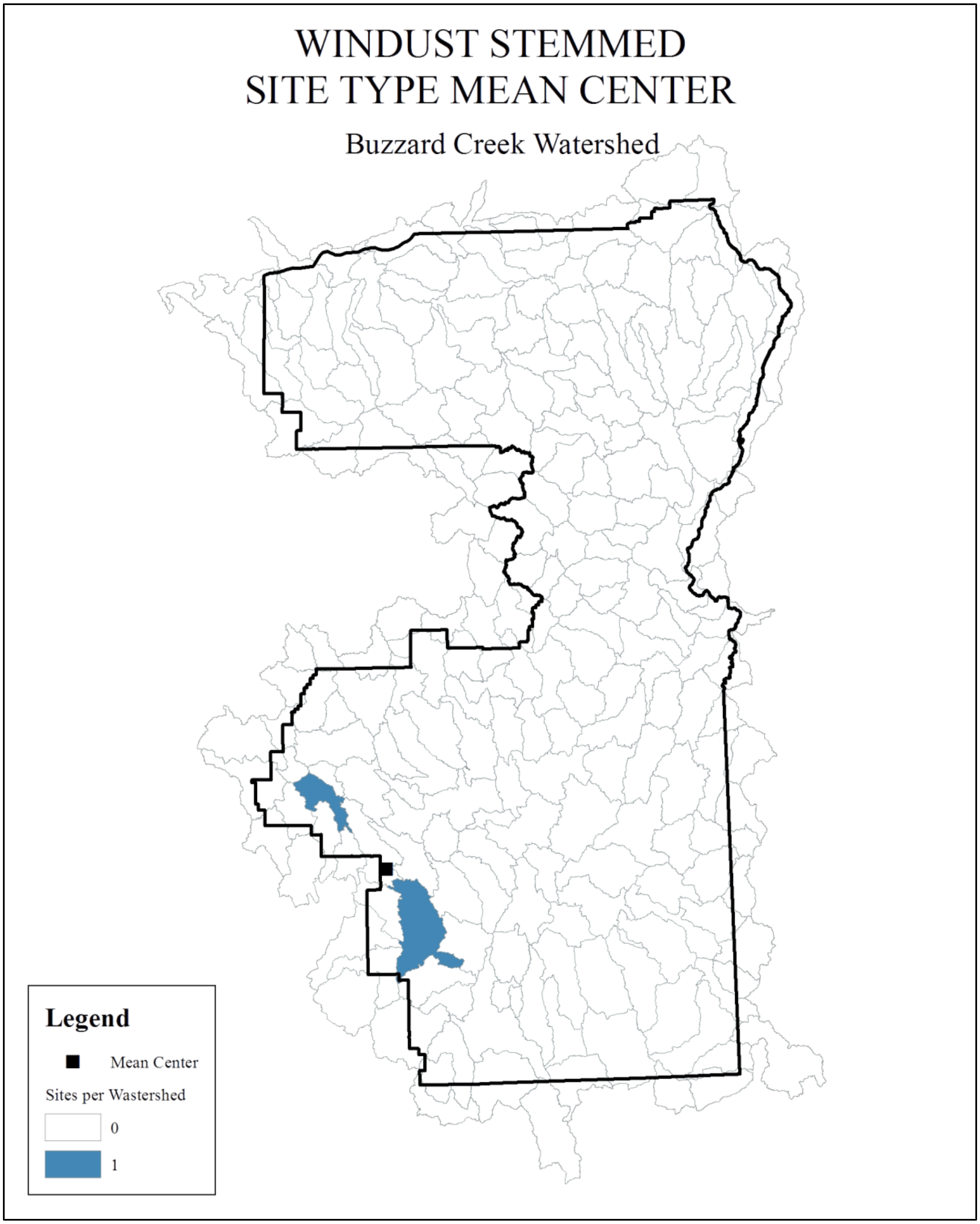


Figure 72. Mean center of Windust Stemmed sites in study area.

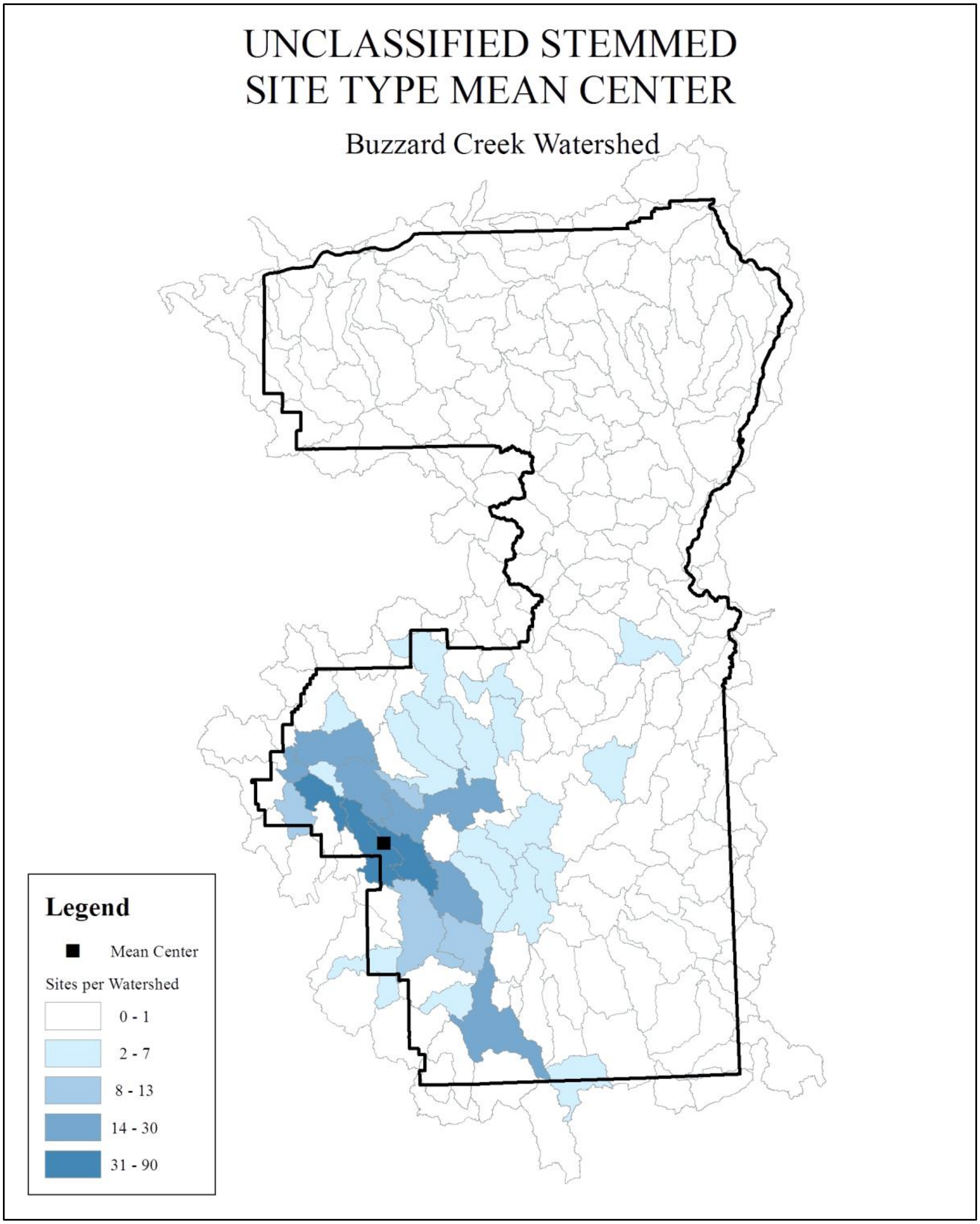


Figure 73. Mean center of unclassified stemmed sites in study area.

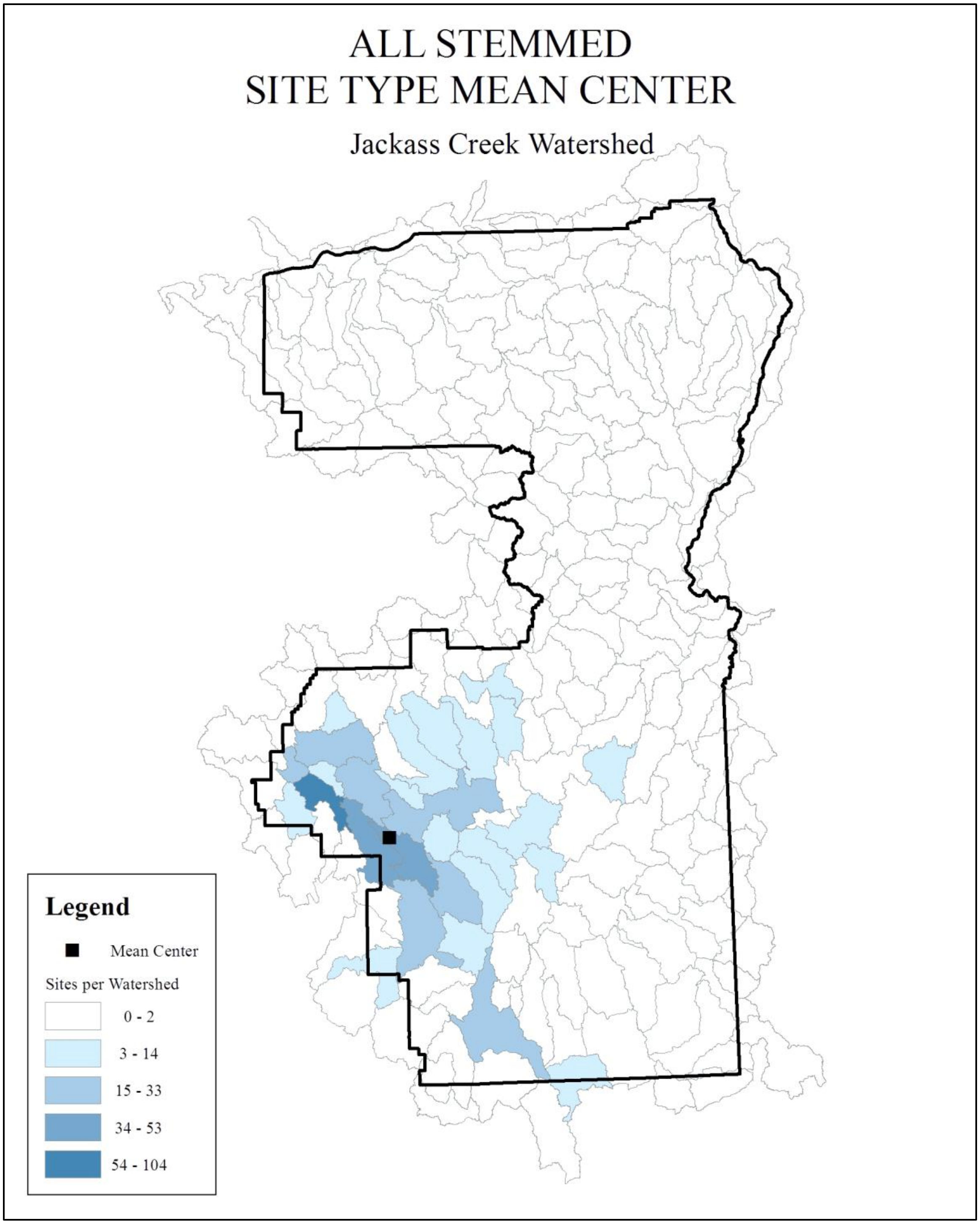


Figure 74. Mean center of all Stemmed sites in study area.

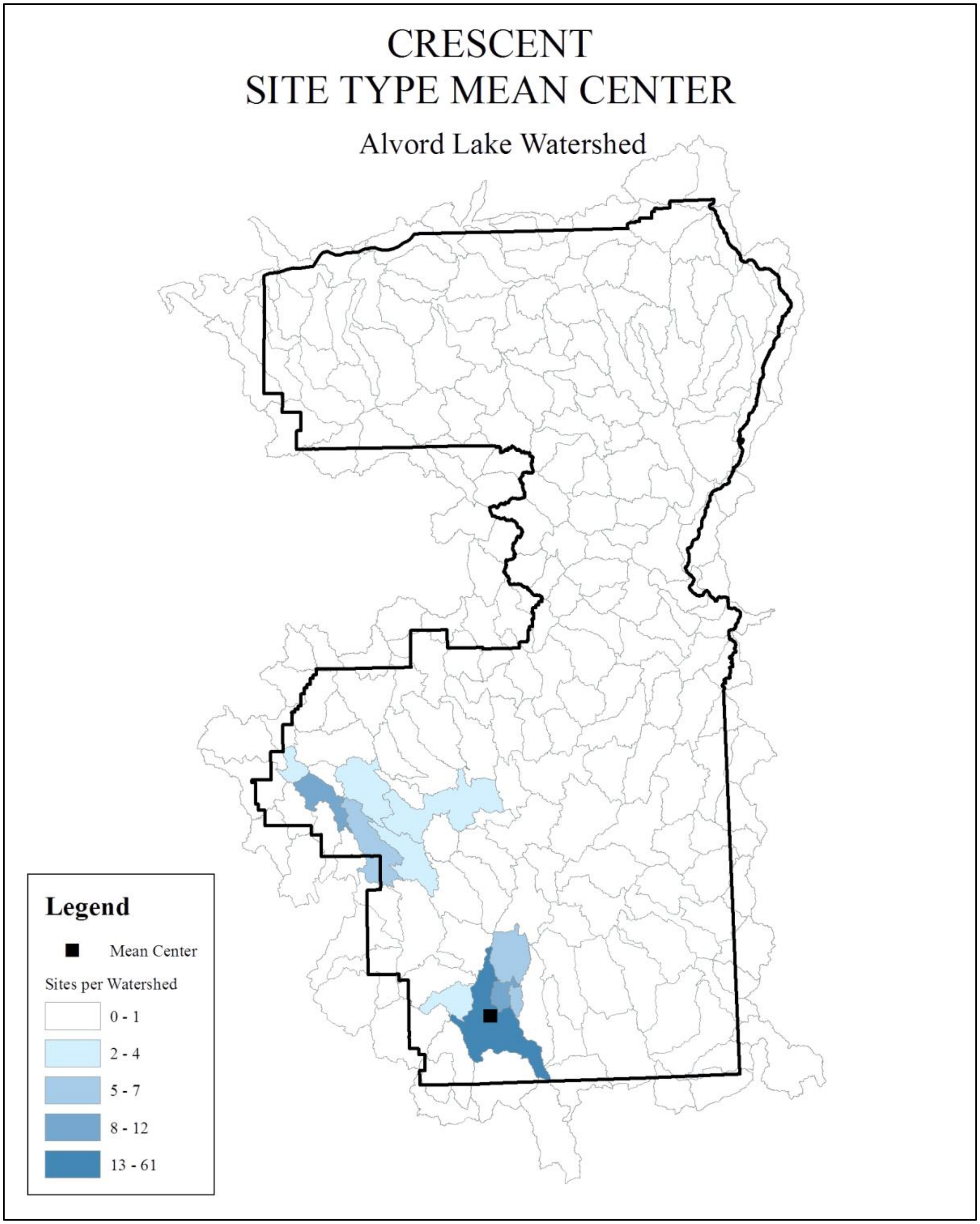


Figure 75. Mean center of Crescent sites in study area.

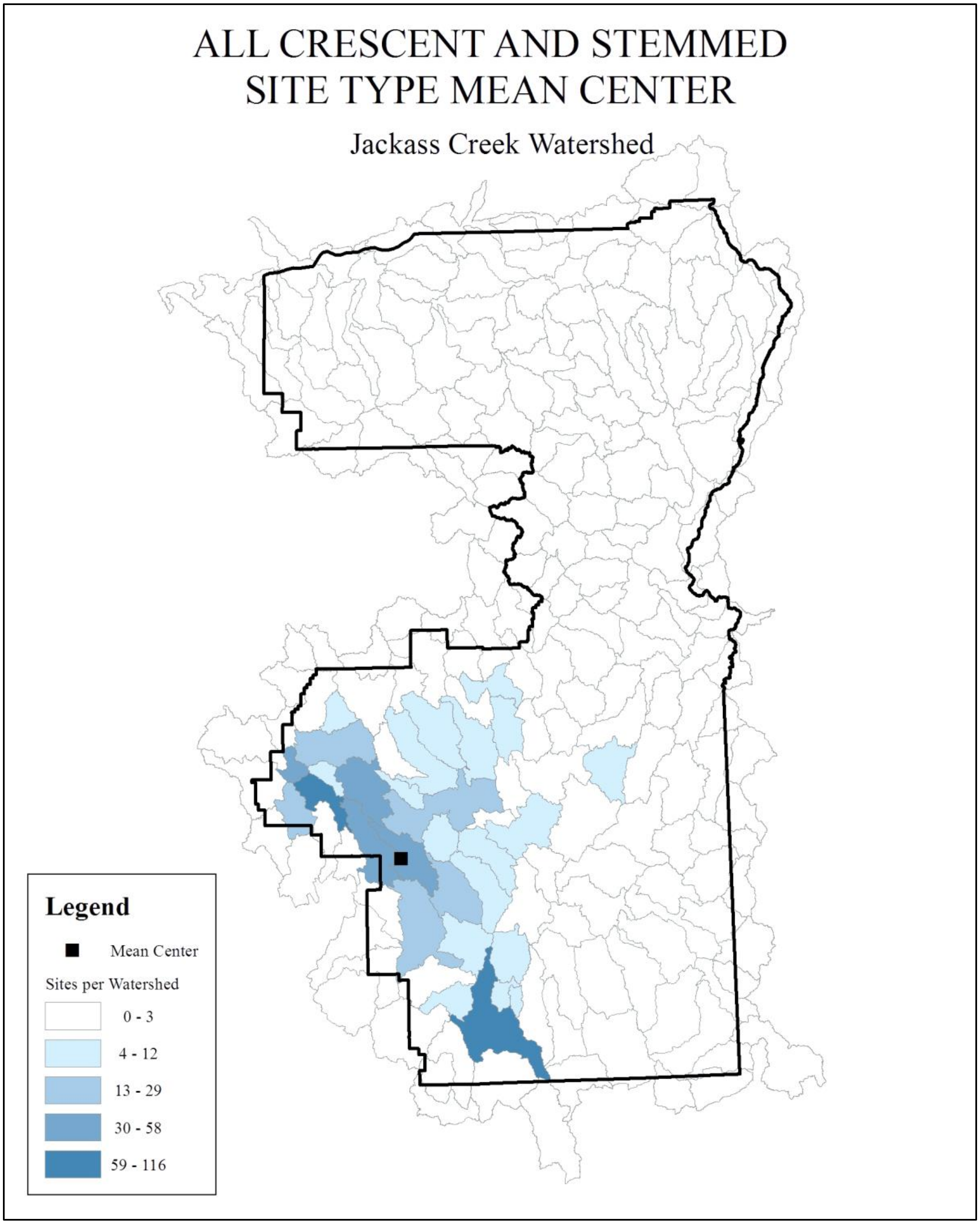


Figure 76. Mean center of all Crescent and Stemmed sites in study area.

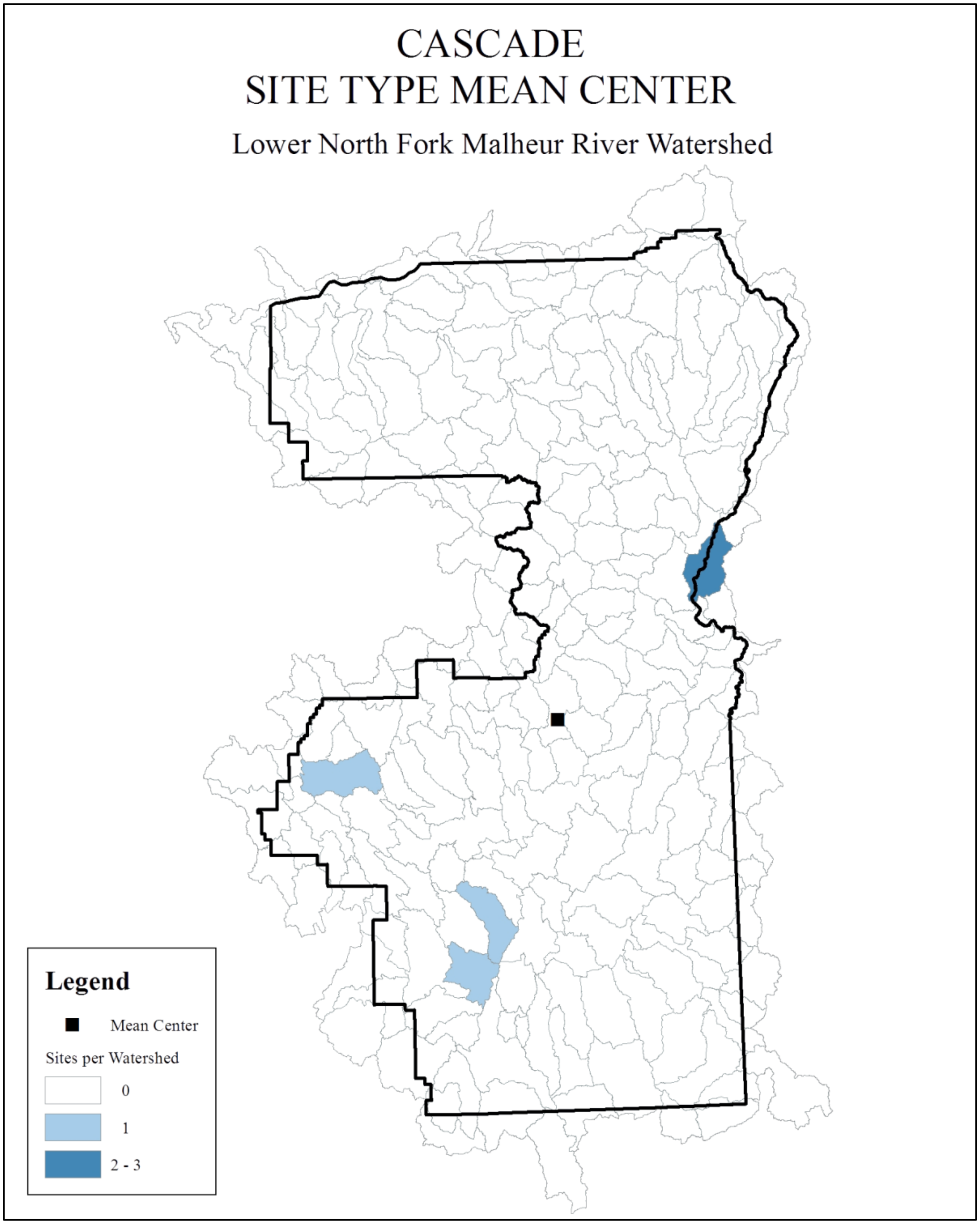


Figure 77. Mean center of Cascade sites in study area.

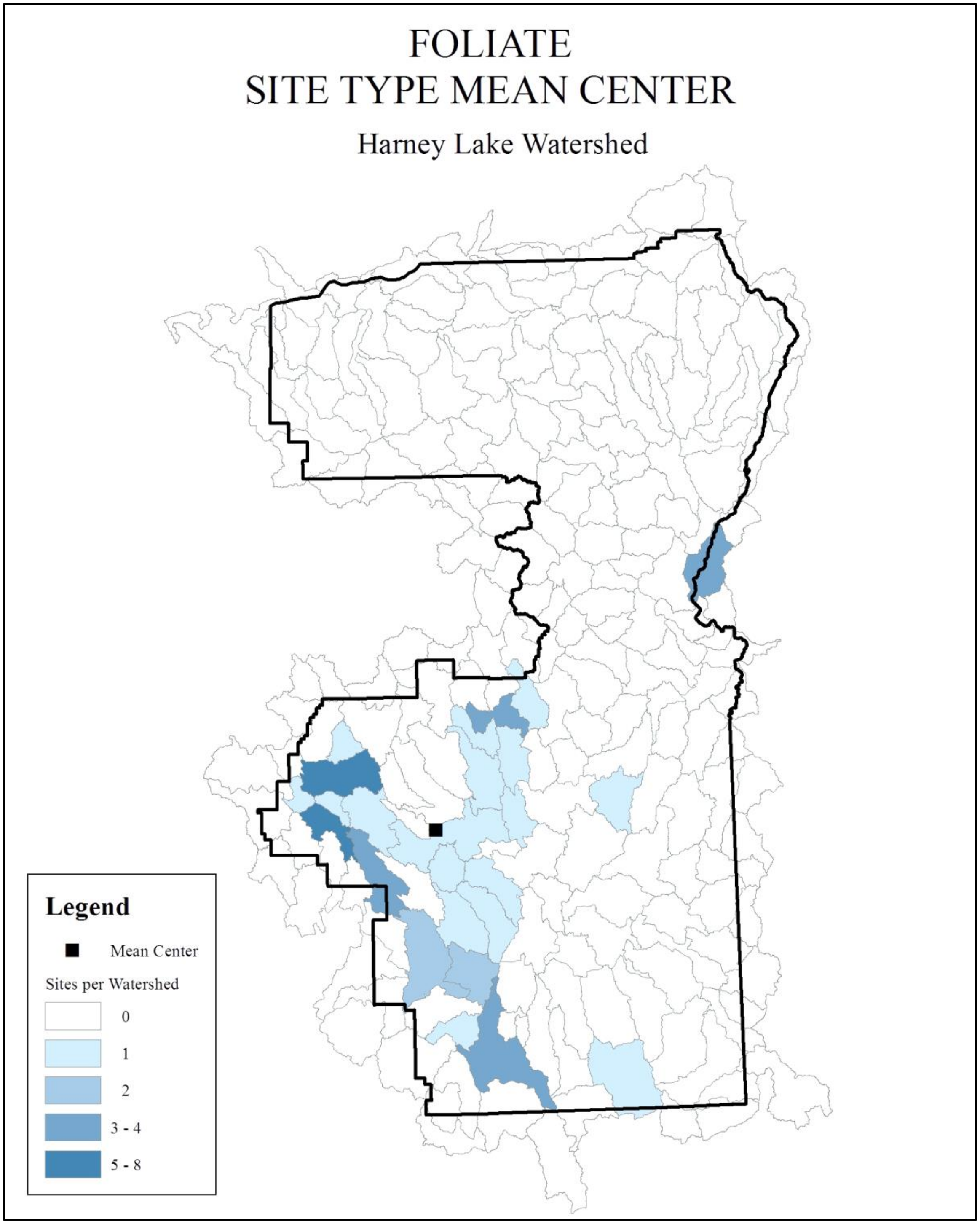


Figure 78. Mean center of Foliate sites in study area.

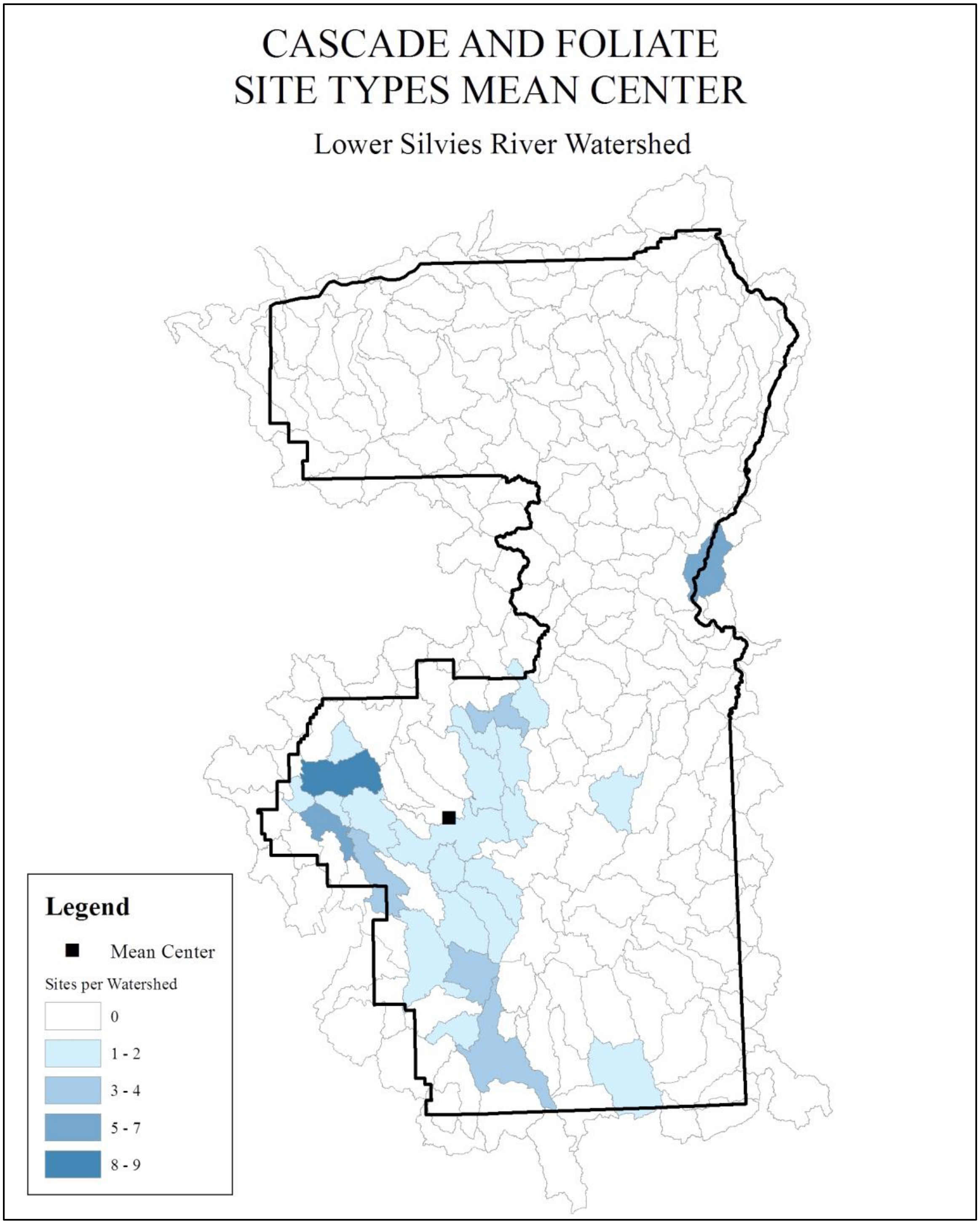


Figure 79. Mean center of Cascade and Foliate sites in study area.

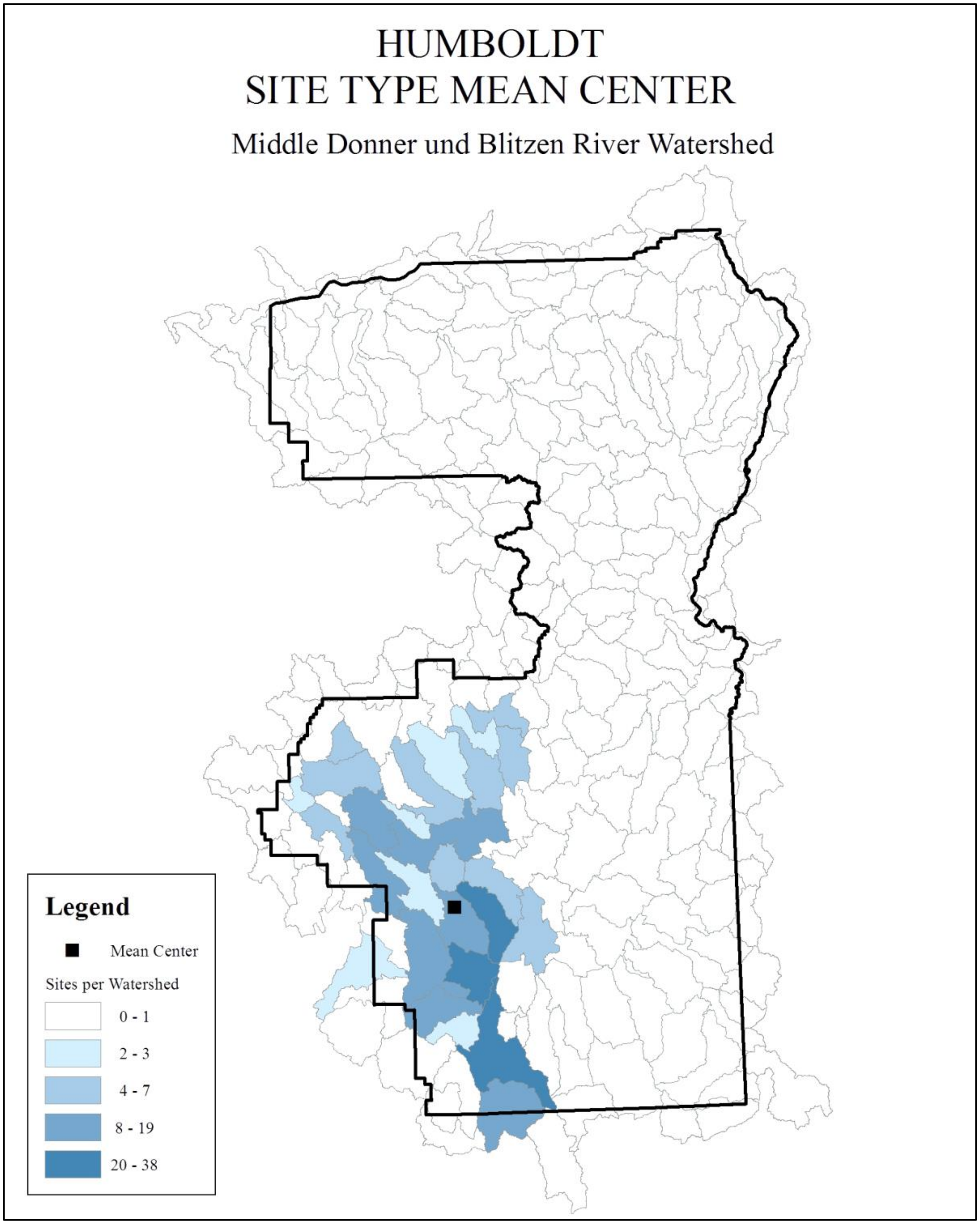


Figure 80. Mean center of Humboldt sites in study area.

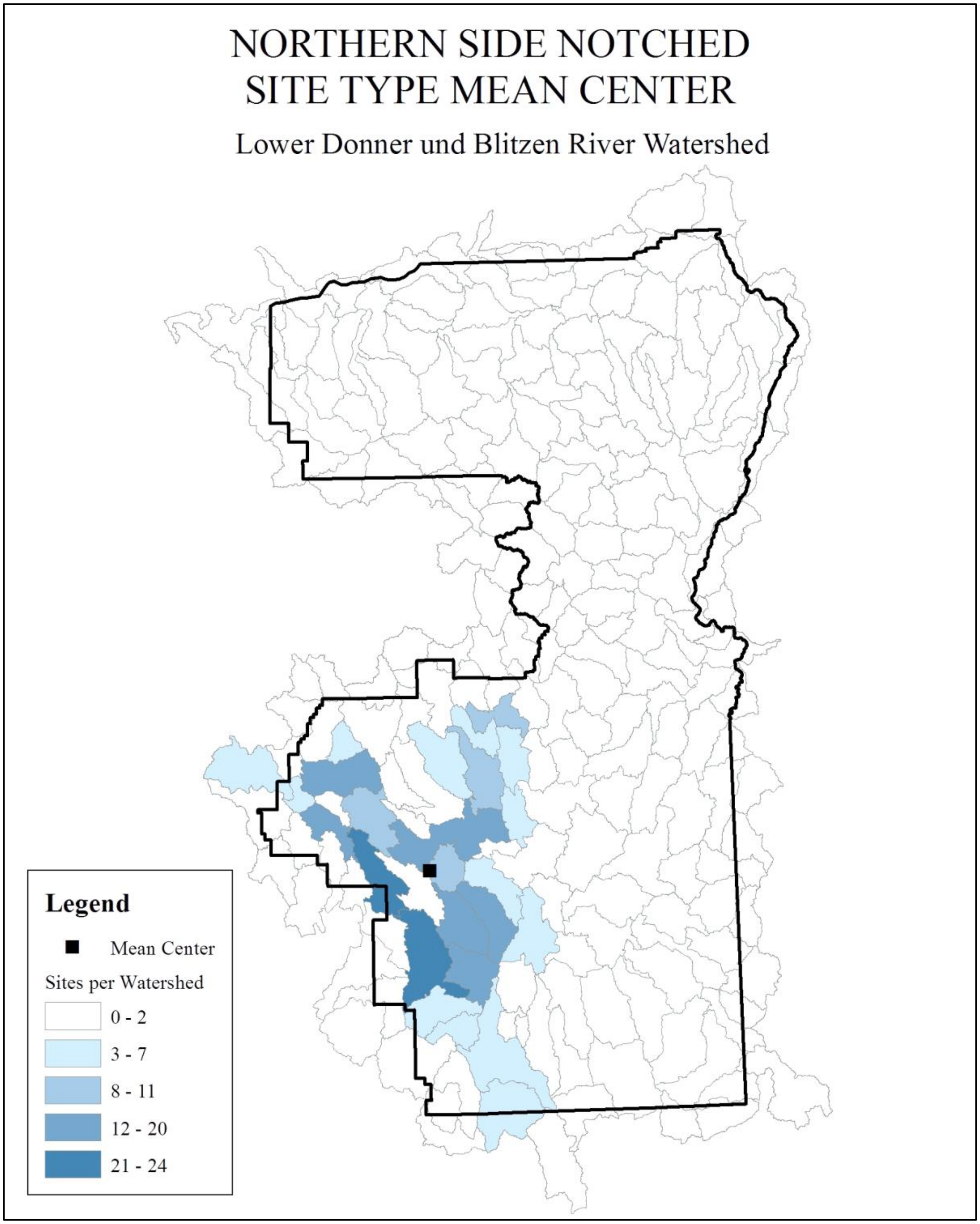


Figure 81. Mean center of Northern Side Notched sites in study area.

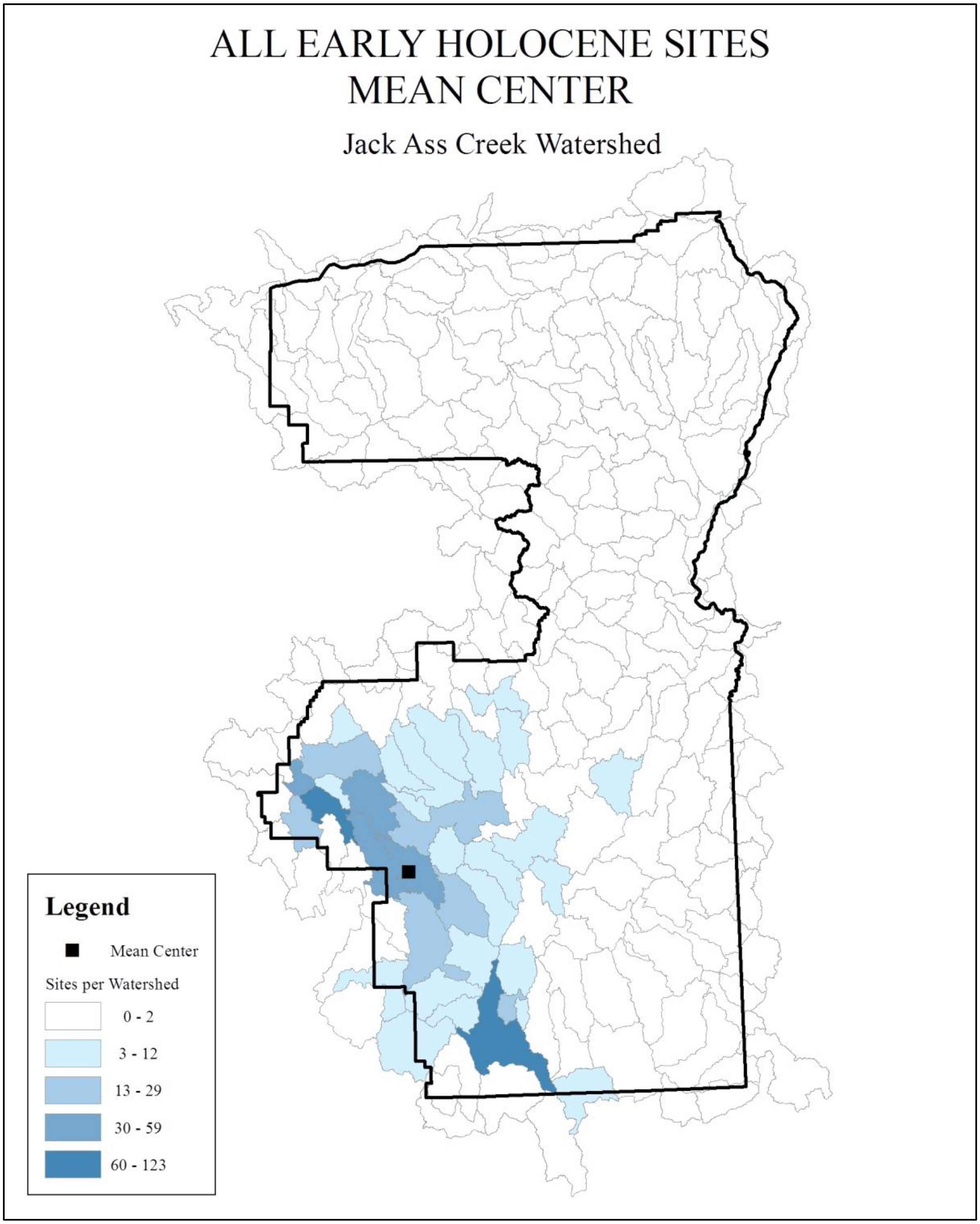


Figure 82. Mean center of all Early Holocene sites in study area.

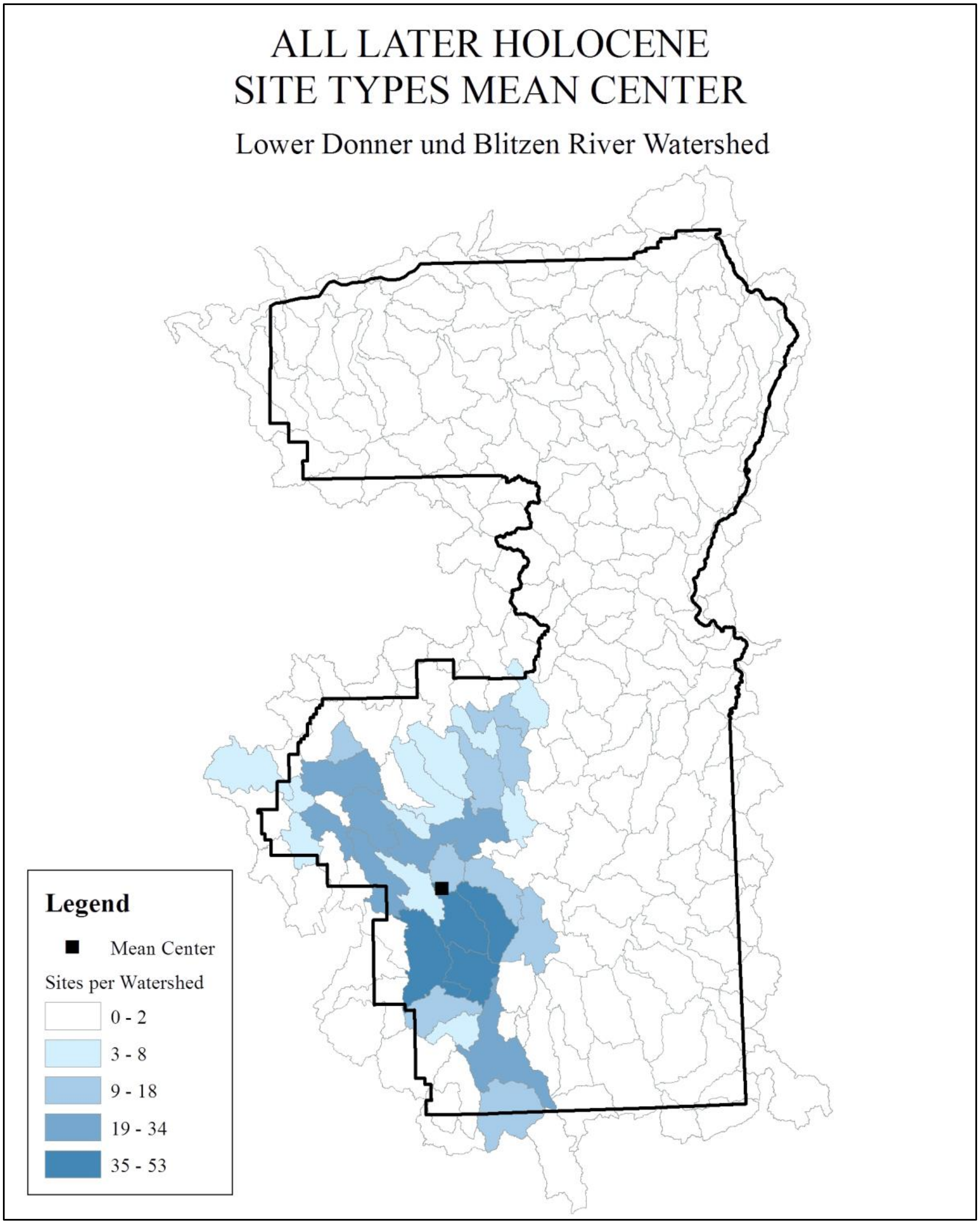


Figure 83. Mean center of all later Holocene sites in study area.

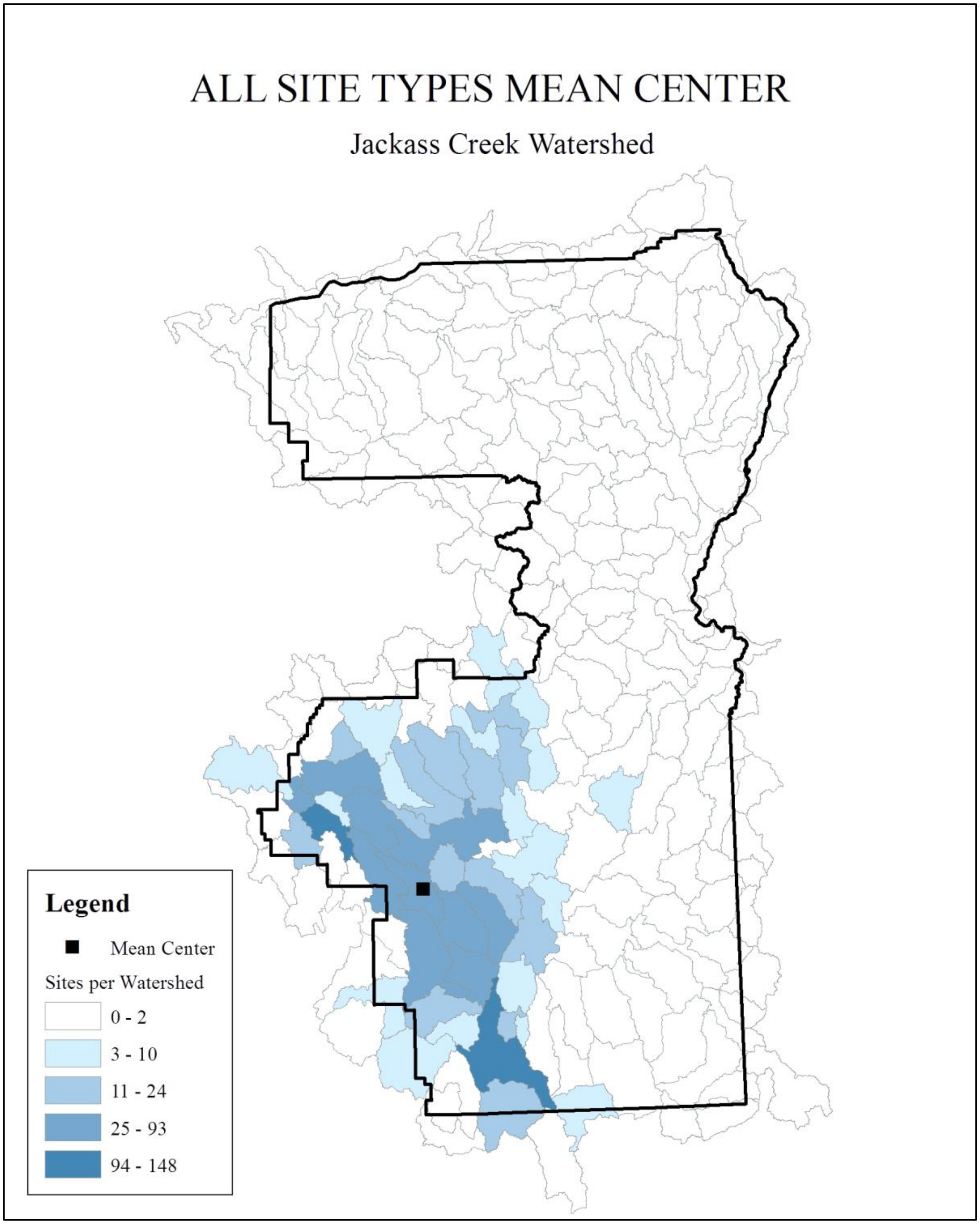


Figure 84. Mean center of all sites in study area.

toward the Great Basin, with many of the spatial centers recurring in Jackass Creek and Harney Lake watersheds (see Table 32). The clustering of sites in these contiguous watersheds suggests Pluvial Lake Harney was an important feature for Paleoindians in this region. In many instances there is no evidence that mean center watersheds were populated. For instance, fluted sites cluster to the northeast of Lake Malheur and near Lake Alvord, but the mean center watershed, Jackass Creek, contains no sites (see Figure 65). This also occurs with Black Rock Concave sites, Parman sites, Windust sites, Cascade, and foliate sites. This mean center may reflect an unidentified center of activity, but it is more likely that this statistic and the concept of regional central tendency are not good measures for predicting the locations of archaeological sites. Although the spatial mean center indicates very general settlement patterns within the study area, it did illustrate that survey coverage is most extensive in the southern portion of the study area (see Figure 64).

Average Distance between Archaeological Sites and Environments

To explore connections between site types and environment features, the average distance between archaeological sites and environment features was calculated (Table 33). On average, the distance between all site types and environment features was 9.5 km. This means that in many circumstances early Plateau-Basin hunter-gatherers could have encountered any one of these environment features in just over an average day of foraging. There is substantial variance among site-environment associations, ranging from less than 0.1km to 96 km, but the average proximity of this variety of environment features could explain the dense concentration of early sites within the study region.

Pluvial lakes, the largest but least common of the environmental features in this study, are at a greater average distance from most site types than other environmental features. On average, early sites are 25 km from pluvial lakes meaning these features could have been encountered within 3 days of typical foraging travel. Two sites types, crescents and Cascade, clearly deviate from this average. Crescents are found, on average, only 4.5 km from pluvial lakes, proving a much stronger association exists between crescents and pluvial lakes than all other early site types. Cascade sites, though relatively uncommon in the data set, are found at a much greater distance (96 km) from

Table 33. Average distance (m) between archaeological sites and environment features.

Site Type	Pluvial Lake	Playa	Lake	Marsh	Springs	Streams
Fluted	19681	6063	2182	12526	5192	440
Black Rock Concave	16837	6349	1441	10965	2996	321
Haskett	28514	227	562	15499	4909	374
Parman	21116	8596	1477	9193	3787	603
Parman Square	38380	19769	1869	11624	3445	609
Parman, all	26715	11977	1596	10028	3570	600
Windust	13241	2300	390	11753	3606	112
Stemmed, unclassified	17871	5268	1133	10309	4590	564
Stemmed, all	19360	6283	1196	10329	4450	566
Crescent	4454	2262	3091	5706	2750	595
Crescent and Stemmed	16655	5535	1543	9484	4121	571
Cascade	95874	69603	1264	19696	993	99
Foliate	32292	17587	1307	13322	3154	349
Cascade and Foliate	39228	23262	1303	14017	2918	322
Humboldt	16450	58637	1598	11433	3458	501
Northern Side Notched	17844	10116	1367	11478	3864	531
All Early Holocene	16777	5573	1566	9634	4140	561
All Later Holocene	17162	10501	1480	11456	3665	516
All Points	16944	7717	1529	10427	3934	541
Average	25021	14612	1468	11520	3660	462
Early Holocene Range	91420	69376	2701	13990	4199	510
Early Holocene Standard Deviation	20486	16525	611	3114	1003	170
Early Holocene Coefficient of Variation	1.22	2.97	.39	.32	.24	.30

pluvial lakes than all sites are on average. Removing these two extremes, the average distances between sites and pluvial lakes could have been traversed in 2 to 5 days based on the assumed average daily 8.28 km travel rate. While these huge pluvial lakes are the most dispersed of the environmental features in the study area, it might have been practical for mobile peoples to use pluvial lakes as base locations and travel to outlying foraging opportunities.

Streams, the most common environment features in the study area, are on average 462 m from any site type and no more than 609 m from any site type on average. The strongest association between streams and sites exists between Cascade sites (99 m) and Windust sites (112 m). As mentioned in previous analyses, these statistics are probably skewed because of a low sample size. However, the overall trend in this data set suggests that streams were a highly important feature for the makers of all of these tool traditions.

The strong associate between all site types and streams is followed by a connection to extant lakes. All sites were on average 0.4 km to 2.2 km from extant lakes. Smaller datasets again determined closer associations (i.e., Haskett and Windust), but most sites were on average only a portion of a day's travel from a lake. Interestingly, while the connection between most site types and extant lakes is much stronger than that between sites and pluvial lakes, crescents, which have the strongest connection to pluvial lakes, have the weakest connection to extant lakes in the data set.

Given the strong connections between early sites and lakes found in this study, it is surprising to find that the association between early sites and marshes is fairly weak. On average, all sites were within 11.5 km of marshes, which is one of the weakest associations in the entire data set. Crescent sites were the only site type with stronger than average associations with marshes, at an average distance of 5.7 km from marshes. Cascade points were the greatest outlier in the dataset at 19.7 km from marshes on average.

Springs appear to be moderately associated with early sites, with the average distance between springs and early sites being 3.6 km. Much like marshes, lakes, and streams, there is relatively low variation in associations, with distances ranging from 1km to 5.1 km. Cascade points show the strongest association with springs, while fluted, Haskett stemmed and unclassified stemmed sites are slightly farther from the average association.

Finally, large variations exist in the association between sites and playas, with average distances ranging from 227 m to 70 km. The average distance between all sites and playas is 5.5 km, making a trip to these features possible within 1 day of foraging. It is likely that some of the environment features modeled in this analysis were active lakes or marshes during the Pleistocene-Holocene transition while others were already dry playa. Regardless, these places were apparently less important than streams, lakes, or springs.

In sum, strong associations exist between Pleistocene-Holocene transition sites and lakes, marshes, spring, and streams, while the association between early sites and pluvial lakes and playas is weak. The close associations of crescent sites with pluvial lakes and marshes, Haskett sites with playas and lakes, Windust sites with lakes and streams, and Cascade sites with springs and streams warrant further analysis.

Frequency of Artifact-Environment Association

To clarify site-environment associations, the frequency at which sites were located within 1 km and 8.28 km of particular landscape types was also studied through bar graphs and tables (Tables 34–39; Figures 85–90). After Hoffman (1996:68), 1 km was selected as an arbitrary short distance at which a person could easily travel from a resource base or camp. As previously discussed, 8.28 km is used to approximate the distance a highly mobile hunter-gatherer could travel over the course of one day. These figures were used to estimate how often archaeological sites were located within a short travel time from environmental features.

Of all the site-environment associations, pluvial lakes had the weakest connections with archaeological sites (see Figure 85, Table 34). The analysis of distances between early Holocene sites and environments indicates that pluvial lakes were on average 17 km from archaeological sites. Likewise, the majority (67%) of early Holocene sites are located more than 8.28 km from pluvial lakes. As other statistics in this study show, the strongest site-environment connection was between lakes and crescents, with

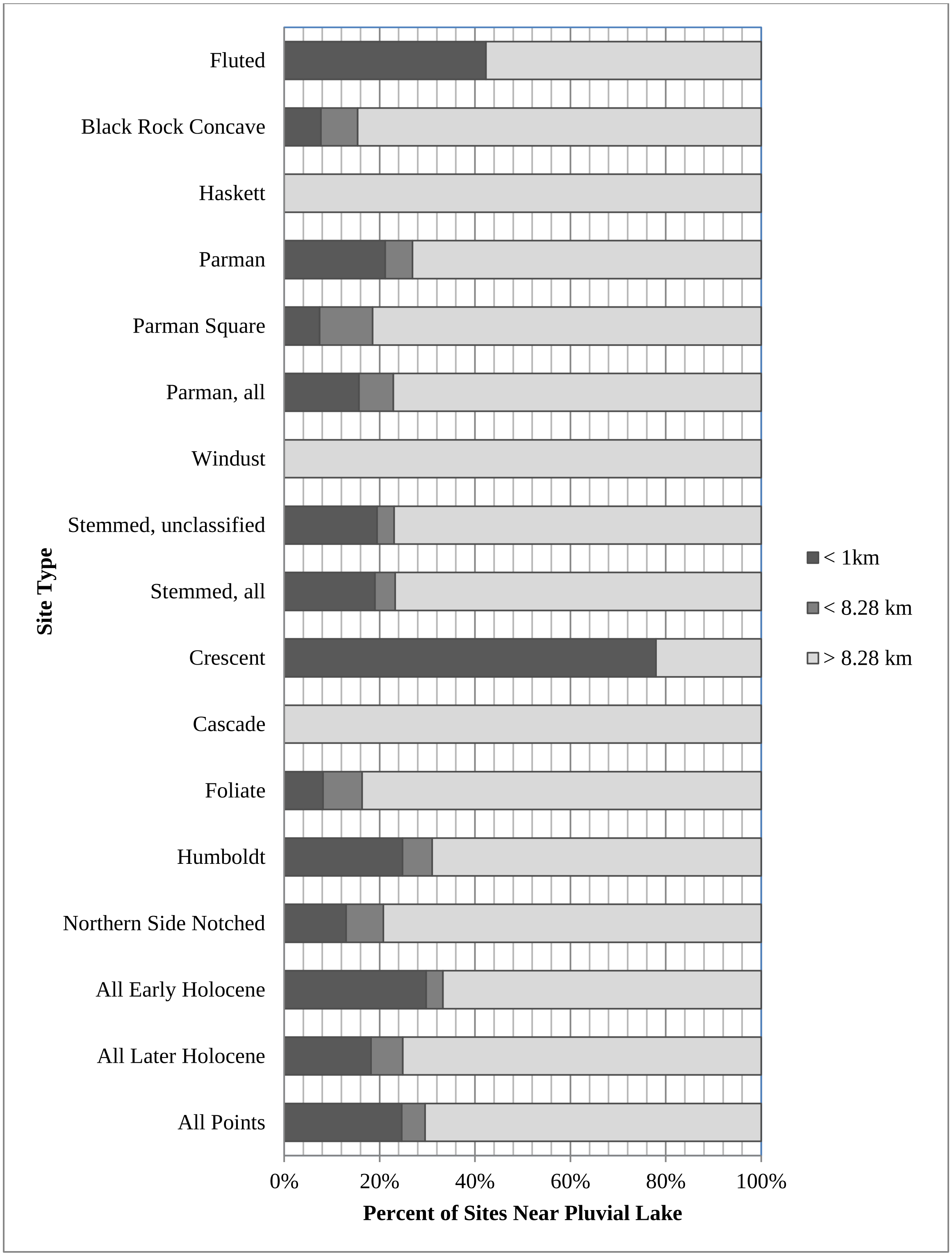


Figure 85. Percent of archaeological sites near pluvial lake.

Table 34. Percent of archaeological sites near pluvial lake.

Site Type	<1 km	<8.28 km	>8.28km
Fluted	42%	42%	58%
Black Rock Concave	8%	8%	85%
Haskett	0%	0%	100%
Parman	21%	6%	73%
Parman Square	7%	11%	81%
Parman, all	16%	23%	77%
Windust	0%	0%	100%
Stemmed, unclassified	19%	23%	77%
Stemmed, all	19%	23%	77%
Crescent	78%	78%	22%
Cascade	0%	0%	100%
Foliate	8%	16%	84%
Humboldt	25%	31%	69%
Northern Side Notched	13%	21%	79%
Early Holocene	30%	33%	67%
Later Holocene	18%	25%	75%
All Points	25%	30%	70%

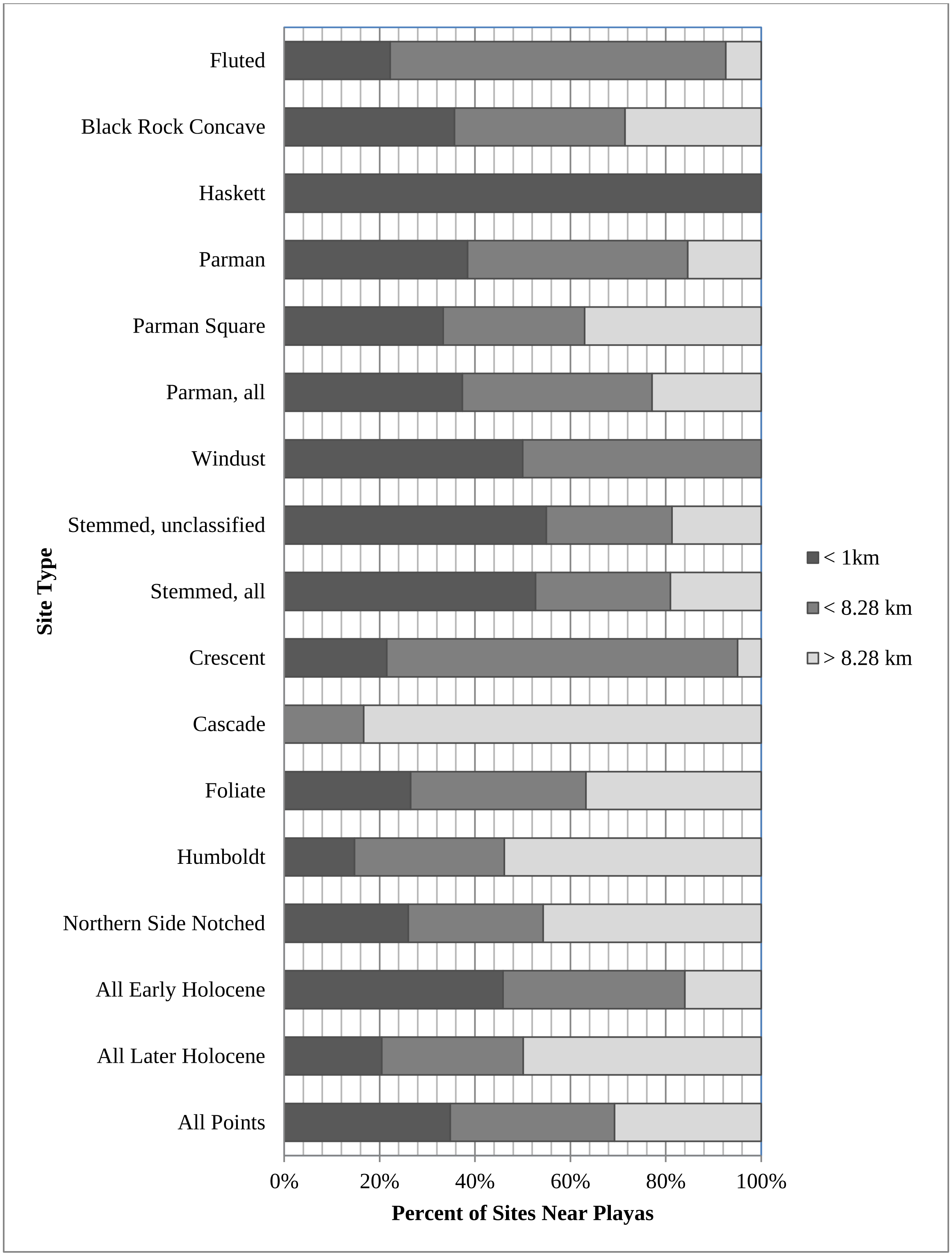


Figure 86. Percent of archaeological sites near playa.

Table 35. Percent of archaeological sites near playa.

Site Type	<1 km	<8.28 km	>8.28km
Fluted	22%	93%	7%
Black Rock Concave	33%	71%	29%
Haskett	100%	100%	0%
Parman	38%	85%	15%
Parman Square	33%	63%	37%
Parman, all	37%	77%	23%
Windust	50%	50%	0%
Stemmed, unclassified	55%	81%	19%
Stemmed, all	53%	81%	19%
Crescent	21%	95%	5%
Cascade	0%	17%	83%
Foliate	27%	63%	37%
Humboldt	15%	46%	54%
Northern Side Notched	26%	54%	46%
Early Holocene	46%	84%	16%
Later Holocene	20%	50%	50%
All Points	35%	69%	30%

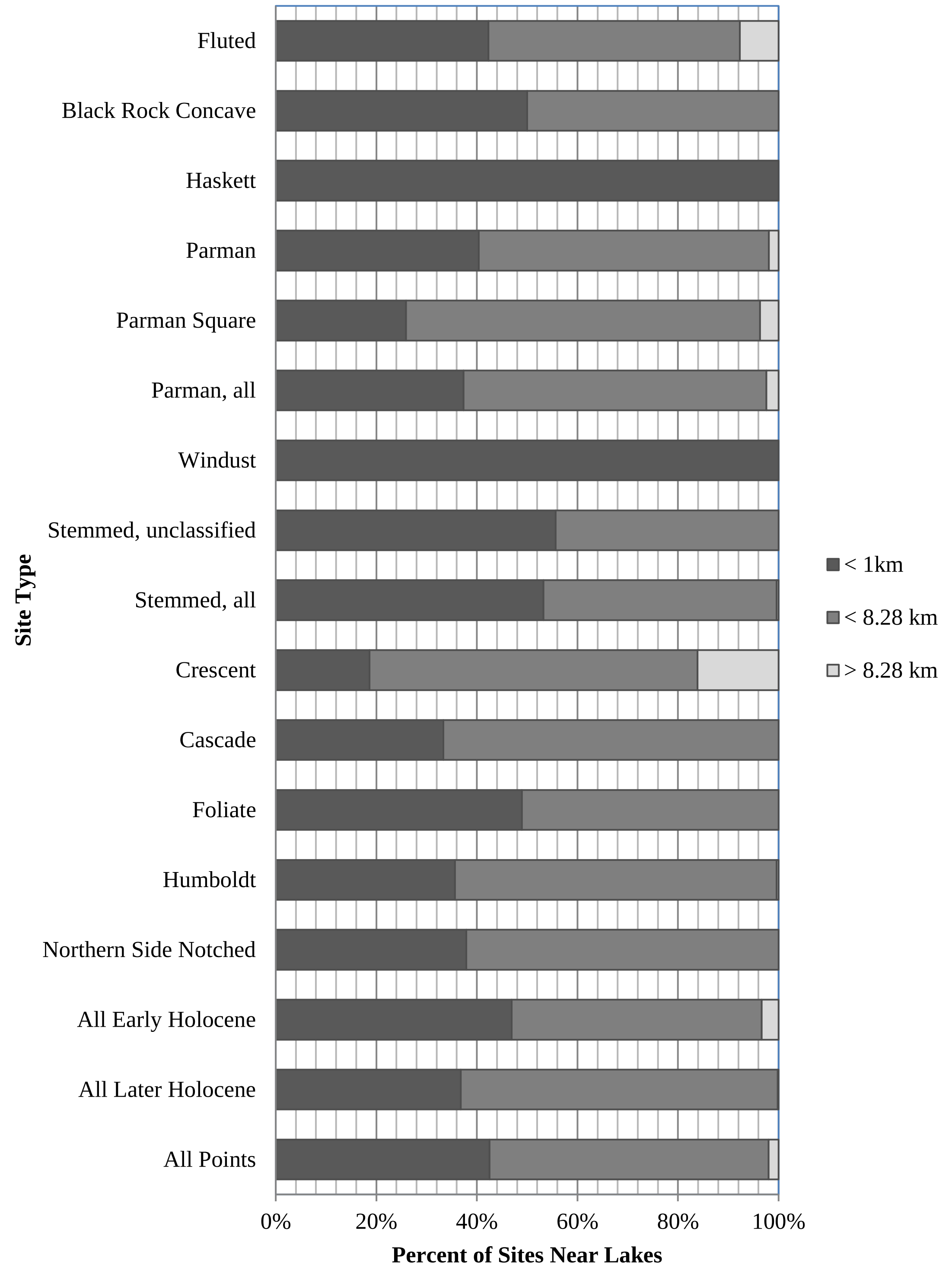


Figure 87. Percent of archaeological sites near lake.

Table 36. Percent of archaeological sites near lake.

Site Type	<1 km	<8.28 km	>8.28km
Fluted	42%	92%	8%
Black Rock Concave	50%	50%	0%
Haskett	100%	100%	0%
Parman	40%	98%	2%
Parman Square	26%	96%	4%
Parman, all	37%	98%	2%
Windust	100%	100%	0%
Stemmed, unclassified	56%	100%	0%
Stemmed, all	53%	100%	0%
Crescent	19%	84%	16%
Cascade	33%	100%	0%
Foliate	49%	100%	0%
Humboldt	36%	100%	0%
Northern Side Notched	38%	100%	0%
Early Holocene	47%	97%	3%
Later Holocene	37%	100%	0%
All Points	43%	98%	2%

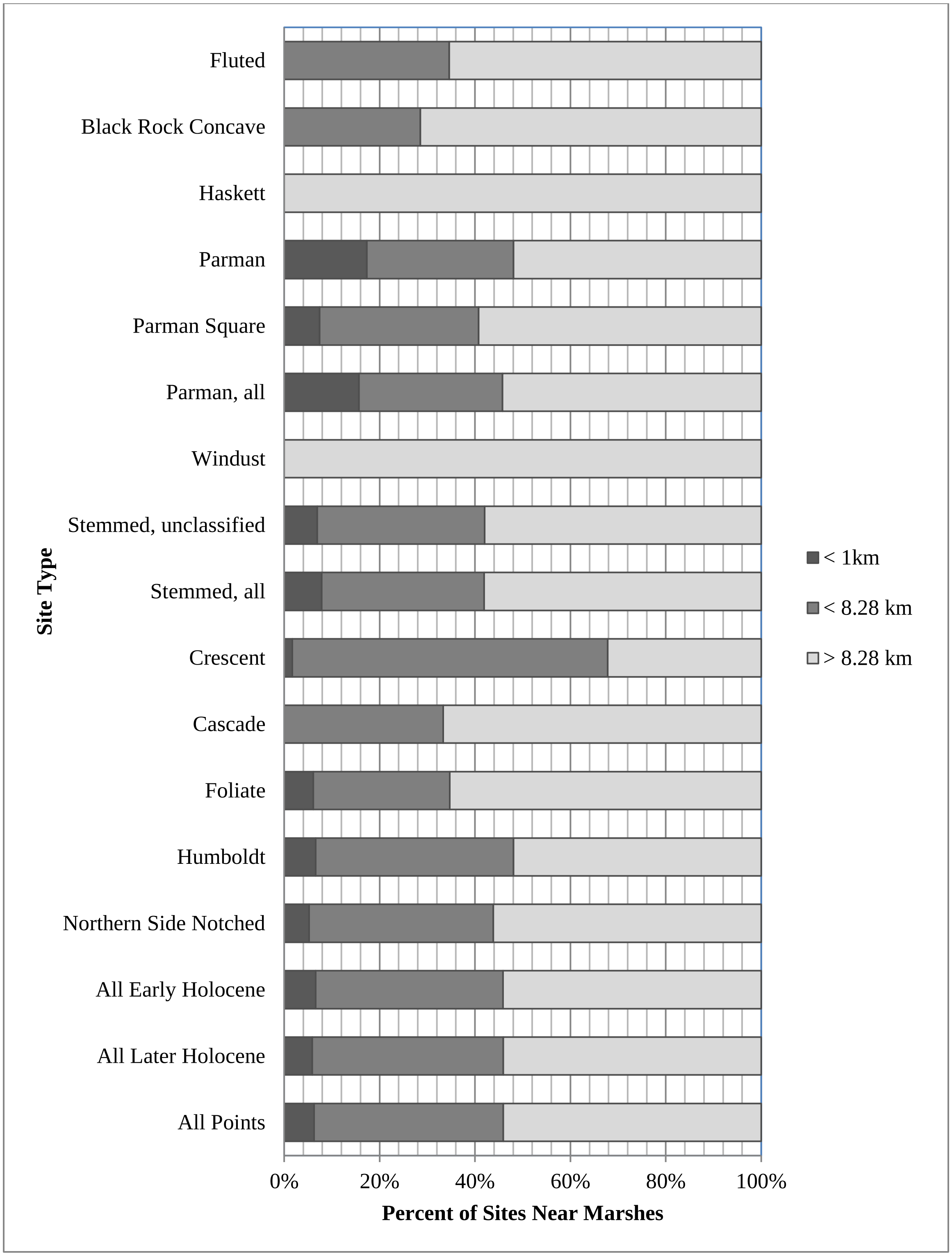


Figure 88. Percent of archaeological sites near marsh.

Table 37. Percent of archaeological sites near marsh.

Site Type	<1 km	<8.28 km	>8.28km
Fluted	0%	35%	65%
Black Rock Concave	0%	29%	71%
Haskett	0%	0%	100%
Parman	17%	48%	52%
Parman Square	7%	41%	59%
Parman, all	16%	46%	54%
Windust	0%	0%	100%
Stemmed, unclassified	7%	42%	58%
Stemmed, all	8%	42%	58%
Crescent	2%	68%	32%
Cascade	0%	33%	67%
Foliate	6%	35%	65%
Humboldt	7%	48%	52%
Northern Side Notched	5%	44%	56%
Early Holocene	7%	46%	54%
Later Holocene	6%	46%	54%
All Points	6%	46%	54%

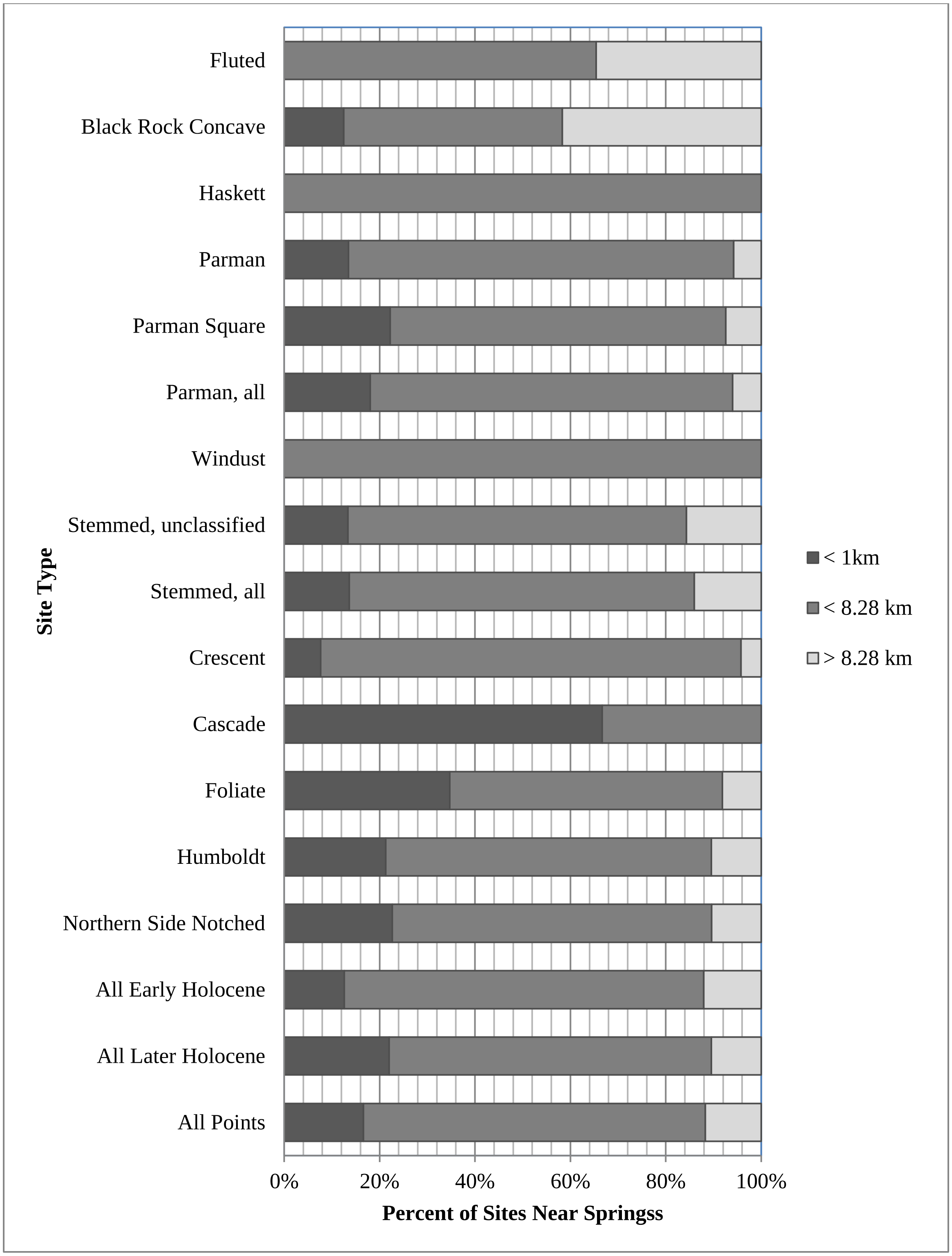


Figure 89. Percent of archaeological sites near spring.

Table 38. Percent of archaeological sites near spring.

Site Type	<1 km	<8.28 km	>8.28km
Fluted	0%	65%	35%
Black Rock Concave	21%	100%	72%
Haskett	0%	100%	0%
Parman	13%	94%	6%
Parman Square	22%	93%	7%
Parman, all	18%	94%	6%
Windust	0%	100%	0%
Stemmed, unclassified	13%	84%	16%
Stemmed, all	14%	86%	14%
Crescent	8%	96%	4%
Cascade	67%	100%	0%
Foliate	35%	92%	8%
Humboldt	21%	90%	10%
Northern Side Notched	23%	90%	10%
Early Holocene	13%	88%	12%
Later Holocene	22%	90%	10%
All Points	16%	88%	12%

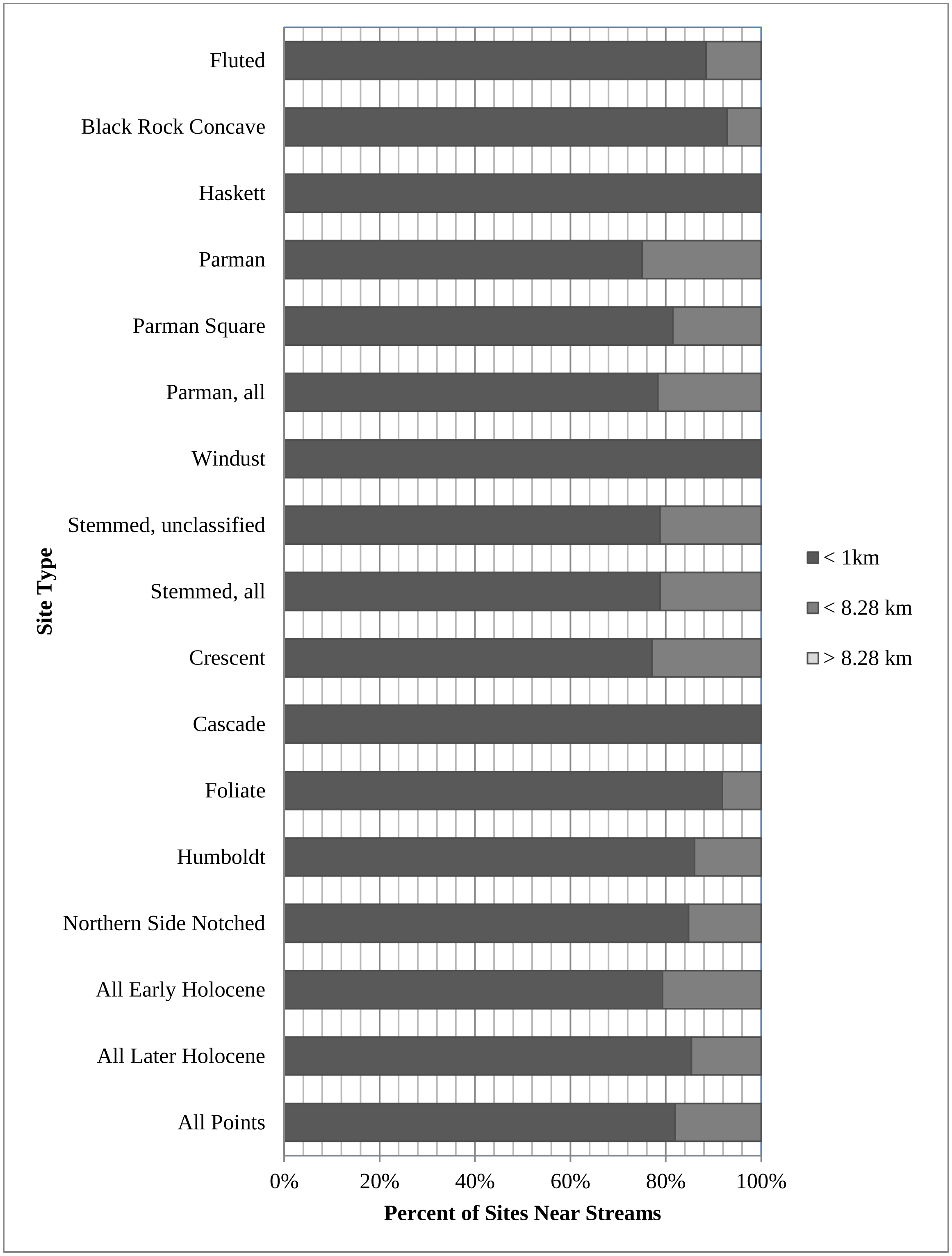


Figure 90. Percent of archaeological sites near stream.

Table 39. Percent of archaeological sites near stream.

Site Type	<1 km	<8.28 km	>8.28km
Fluted	88%	100%	0%
Black Rock Concave	93%	100%	0%
Haskett	100%	100%	0%
Parman	75%	100%	0%
Parman Square	81%	100%	0%
Parman, all	78%	100%	0%
Windust	100%	100%	0%
Stemmed, unclassified	79%	100%	0%
Stemmed, all	79%	100%	0%
Crescent	77%	100%	0%
Cascade	100%	100%	0%
Foliate	92%	100%	0%
Humboldt	86%	100%	0%
Northern Side Notched	85%	100%	0%
Early Holocene	79%	100%	0%
Later Holocene	85%	100%	0%
All Points	82%	100%	0%

78% of crescent sites being found within 1 km of pluvial lakes. Although the average distance measurements discussed in the previous section indicate fluted point sites were on average about 20 km from pluvial lakes, fluted point sites do show a strong association with pluvial lakes in this analysis, with 42% of these sites located within 1km of pluvial lakes.

Playas, which may represent pluvial lake locations, were on average 5.5 km from early sites. The majority of early Holocene sites (84%) are located within a day of travel to playas, while less than half (46%) of site types are within 1 km of playas (see Figure 86, Table 35). Few Haskett artifacts have been recorded in the study area, but they are located within 1 km of playas 100% of the time. The average distance calculations discussed in the previous section were also reflected in the weak connections between playas and Parman square stemmed and Cascade sites. The connection between playas and Cascade sites is particularly weak, with only 17% of sites located within 8.28 km of playas.

Lakes were on average only 1.5 km from all early sites in this dataset. This is reflected in the summaries of the rates at which sites are within 1 km (47%) or 8.28 km (97%) of lakes in the study area (see Figure 87, Table 36). Particularly strong connections between Haskett and Windust sites noted in the previous analysis section are supported in this analysis, with 100% of these sites located within 1 km of lakes. The weak connection between lakes and crescent sites noted in the average distance analysis is observed again in this artifact-environment frequency study. Crescents are the least likely to be located within 1 km of lakes, and are also most likely to be located at distances greater than 8.28 km.

In most cases there is a weak association between marshes and early sites based on the percent of sites within a small foraging radius of marshes (see Figure 88, Table 37). While marshes were on average 10 km from early sites, only 46% of sites are within 8.28 km of marshes in the study area. Only 6% of sites were within 1 km of marshes. Crescent sites were the only clear exception to this pattern, with 68% of sites being located within a one-day foraging radius. However, only 2% of crescent sites were within 1 km of marshes. Haskett and Windust sites were poorly predicted (0%) by marshes in this analysis. Though the previous analysis of average distances did suggest there was a poor connection between marshes and Haskett or Windust sites, distance frequency analysis further clarifies that these two site types are further afield from marshes than other site types.

Springs are 4 km from early sites on average, suggesting they are one of the better predictors of Pleistocene-Holocene transition site locations (see Figure 89, Table 38). The majority (88%) of early Holocene archaeological sites are also within a one-day foraging radius of springs, although only 13% are within 1 km of springs. Especially strong connections between Cascade sites and springs were suggested by the average distance analysis. This is upheld in the summary of sites within a one-day foraging radius of springs, with 67% percent of Cascades sites being within 1 km of springs while only 13% of early sites were this close to springs. Only fluted points were well below the average associations, with only an 8.28 km buffer predicting fluted point sites 65% of the time.

Streams showed the strongest connection to early sites in this analysis, with 100% of sites being located within 8.28 km of a stream (Figure 90, Table 39). Early sites were located within 1 km of streams 79% of the time, which is much higher than the range of 7–47% for other environment types. Cascade, Haskett, and Windust sites were all (100%) within 1 km of streams in the study area.

On average, sites were 9.5 km to the closest environment features, and this statistical method found that sites were located within one day of travel from specific environmental features anywhere from 33–100% of the time. Pluvial lakes were on average more than 8.28 km from early sites most (i.e. 67%) of the time. The previous analysis of the frequency at which early sites were within a one-day travel radius of pluvial lakes confirmed this weak connection. The average distance between early sites and playas showed a lot of variance, but analysis of the percent of sites within a one-day radius found that all early Holocene site types are closely connected to playa locations 84% of the time. Lakes and marshes were on average located within a half day of travel from early site locations, but the analysis of travel times found that many sites were only a short distance from lakes while only half were within 1 day of travel from marshes. Springs and streams were also very closely associated with early sites on average, but while 79% of early Holocene sites were within 1 km from streams only 13% percent were close to springs. Based on these statistics, I determined that further analysis of the correlation between specific site type counts and environment features could clarify some of the patterns observed here.

Correlation Analysis

The statistical analyses presented in this study have so far proved successful at recognizing some site patterning and identifying spatial connections between environments, sites, and survey bias. However, summarizing the correlations in a complex data set requires more sophisticated statistics to discover statistically significant connections. Archaeological sites and environment features were summarized by physiographic areas, culture regions, basins, subbasins, watersheds, and subwatersheds, and then Pearson's r correlation analyses were performed at each spatial level (Tables 40–50). These analyses included the following variables: number of sites by type (e.g., Fluted, Crescent, Haskett), pluvial lake area, playa area, lake area, marsh area, number of springs, combined stream distance, survey area, and spatial unit area. Environment and survey data were standardized by the unit of analysis (i.e., environment area was stated as a proportion of study unit size). Feature counts and area summaries included features on the border of the unit of analysis, meaning that one feature might be included in several study sub-areas, so that the size of these features was not underrepresented.

Like the autocorrelation analyses, Pearson's r correlation analyses allowed for the determination that some spatial units were better at finding correlations than others. When the study area was split into the four largest units of analysis (Columbia Plateau, Great Basin, Western Pluvial Lakes Tradition, and non-Western Pluvial Lakes Tradition), many site types are strongly ($p=.01$) positively correlated with pluvial lake indicators (see Table 40). The combined areas of pluvial lakes, extant playas, extant lakes, and extant marshes are strongly positively correlated with all early site types. Strong positive correlations are also found between these features and later Holocene site types, with the exception of Cascade and foliate sites. Springs and streams are not correlated with early sites in any instance (see Table 41). Strong and very strong positive correlations between early sites and survey coverage at the region level supports earlier conclusions that a

Table 40. Correlation between sites and pluvial lake indicators by region.

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Fluted	Pearson Correlation	.964*	.953*	.967*	.962*
	Significance (2-tailed)	.036	.047	.033	.038
Black Rock Concave	Pearson Correlation	.964*	.953*	.967*	.962*
	Significance (2-tailed)	.036	.047	.033	.038
Haskett	Pearson Correlation	.964*	.953*	.967*	.962*
	Significance (2-tailed)	.036	.047	.033	.038
Parman	Pearson Correlation	.972*	.963*	.974*	.971*
	Significance (2-tailed)	.028	.037	.026	.029
Parman Square	Pearson Correlation	.964*	.953*	.967*	.962*
	Significance (2-tailed)	.036	.047	.033	.038
Parman, all	Pearson Correlation	.970*	0961*	.973*	.969*
	Significance (2-tailed)	.030	.039	.027	.031
Windust	Pearson Correlation	.964*	.953*	.967*	.962*
	Significance (2-tailed)	.036	.047	.033	.038
Stemmed, unclassified	Pearson Correlation	.958*	.946*	.961*	.957*
	Significance (2-tailed)	.042	.054	.039	.043
Stemmed, all	Pearson Correlation	.960*	.948*	.963*	.958*
	Significance (2-tailed)	.040	.052	.037	.042
Crescent	Pearson Correlation	.962*	.951*	.965*	.961*
	Significance (2-tailed)	.038	.049	.035	.039

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Cascade	Pearson Correlation	n/a	n/a	n/a	n/a
	Significance (2-tailed)	-	-	-	-
Foliate	Pearson Correlation	.947	.933	.951*	.946
	Significance (2-tailed)	.053	.067	.049	.054
Humboldt	Pearson Correlation	.954*	.941	.958*	.953*
	Significance (2-tailed)	.046	.059	.042	.047
Northern Side Notched	Pearson Correlation	.951*	.938	.955*	.949
	Significance (2-tailed)	.049	.062	.045	.051
Early Holocene	Pearson Correlation	.960*	.949	.964*	.959*
	Significance (2-tailed)	.040	.051	.036	.041
Later Holocene	Pearson Correlation	.952*	.939	.956*	.951*
	Significance (2-tailed)	.048	.061	.036	.049
All Points	Pearson Correlation	.957*	.945	.961*	.956*
	Significance (2-tailed)	.043	.055	.039	.044

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.005 level.
n/a Cannot be computed because at least one of the variables is constant.

Table 41. Correlation between sites and non-pluvial lake features by region.

Site Type		Springs	Stream	Survey	Unit
Fluted	Pearson Correlation	.309	n/a	.991**	-.923
	Significance (2-tailed)	.691	-	.009	.077
Black Rock Concave	Pearson Correlation	.309	n/a	.991**	-.923
	Significance (2-tailed)	.691	-	.009	.077
Haskett	Pearson Correlation	.309	n/a	.991**	-.923
	Significance (2-tailed)	.691	-	.009	.077
Parman	Pearson Correlation	.353	n/a	.990*	-.941
	Significance (2-tailed)	.647	-	.010	.059
Parman Square	Pearson Correlation	.309	n/a	.991**	-.923
	Significance (2-tailed)	.691	-	.009	.077
Parman, all	Pearson Correlation	.344	n/a	.990**	-.937
	Significance (2-tailed)	.691	-	.010	.063
Windust	Pearson Correlation	.309	n/a	.991**	-.923
	Significance (2-tailed)	.691	-	.009	.077
Stemmed, unclassified	Pearson Correlation	.285	n/a	.990**	-.913
	Significance (2-tailed)	.715	-	.010	.087
Stemmed, all	Pearson Correlation	.292	n/a	.990**	-.916
	Significance (2-tailed)	.708	-	.010	.084
Crescent	Pearson Correlation	.301	n/a	.991**	-.920
	Significance (2-tailed)	.699	-	.009	.080

Site Type		Springs	Stream	Survey	Unit
Cascade	Pearson Correlation	n/a	n/a	n/a	n/a
	Significance (2-tailed)	-	-	-	-
Foliate	Pearson Correlation	.242	n/a	.988*	-.892
	Significance (2-tailed)	.758	-	.012	.108
Humboldt	Pearson Correlation	.268	n/a	.990*	-.905
	Significance (2-tailed)	.732	-	.010	.095
Northern Side Notched	Pearson Correlation	.256	n/a	.989*	-.899
	Significance (2-tailed)	.744	-	.011	.101
Early Holocene	Pearson Correlation	.295	n/a	.990**	-.917
	Significance (2-tailed)	.705	-	.010	.083
Later Holocene	Pearson Correlation	.262	n/a	.989*	-.902
	Significance (2-tailed)	.738	-	.011	.098
All Points	Pearson Correlation	.283	n/a	.990*	-.912
	Significance (2-tailed)	.717	-	.010	.088

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.005 level.
n/a Cannot be computed because at least one of the variables is constant.

Table 42. Correlation between sites and pluvial lake indicators by basin.

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Fluted	Pearson Correlation	.999**	.740*	.984**	.960**
	Significance (2-tailed)	.000	.036	.000	.000
Black Rock Concave	Pearson Correlation	.997**	.736*	.981**	.958**
	Significance (2-tailed)	.000	.037	.000	.000
Haskett	Pearson Correlation	1.000**	.758*	.987**	.967**
	Significance (2-tailed)	.000	.029	.000	.000
Parman	Pearson Correlation	.992**	.722*	.977**	.954**
	Significance (2-tailed)	.000	.043	.000	.000
Parman Square	Pearson Correlation	.925**	.607	.894**	.857**
	Significance (2-tailed)	.001	.110	.003	.007
Parman, all	Pearson Correlation	.980**	.695	.960**	.933**
	Significance (2-tailed)	.000	.056	.000	.001
Windust	Pearson Correlation	1.000**	.758*	.987**	.967**
	Significance (2-tailed)	.000	.029	.000	.000
Stemmed, unclassified	Pearson Correlation	.999**	.745*	.984**	.963
	Significance (2-tailed)	.000	.034	.000	.000
Stemmed, all	Pearson Correlation	.998**	.740*	.983**	.960**
	Significance (2-tailed)	.000	.036	.000	.000
Crescent	Pearson Correlation	1.000**	.756*	.986**	.966**
	Significance (2-tailed)	.000	.030	.000	.000

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Cascade	Pearson Correlation	.655	.524	.620	.590
	Significance (2-tailed)	.078	.183	.101	.124
Foliate	Pearson Correlation	.976**	.682	.952**	.920
	Significance (2-tailed)	.000	.062	.000	.001
Humboldt	Pearson Correlation	.997**	.737*	.981**	.958**
	Significance (2-tailed)	.000	.037	.000	.000
Northern Side Notched	Pearson Correlation	.994**	.727*	.978**	.955**
	Significance (2-tailed)	.000	.041	.000	.000
Early Holocene	Pearson Correlation	.999**	.743*	.984**	.962**
	Significance (2-tailed)	.000	.035	.000	.000
Later Holocene	Pearson Correlation	.996**	.732*	.980**	.957**
	Significance (2-tailed)	.000	.039	.000	.000
All Points	Pearson Correlation	.997	.737*	.981**	.959**
	Significance (2-tailed)	.000	.037	.000	.000

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 43. Correlation between sites and non-pluvial lake features by basin.

Site Type		Springs	Stream	Survey	Unit
Fluted	Pearson Correlation	-.166	-.580	.245	.620
	Significance (2-tailed)	.695	.132	.558	.101
Black Rock Concave	Pearson Correlation	-.171	-.585	.268	.655
	Significance (2-tailed)	.686	.128	.521	.078
Haskett	Pearson Correlation	-.162	-.565	.200	.610
	Significance (2-tailed)	.702	.145	.635	.109
Parman	Pearson Correlation	-.181	-.605	.310	.688
	Significance (2-tailed)	.668	.112	.454	.059
Parman Square	Pearson Correlation	-.156	-.646	.505	.756*
	Significance (2-tailed)	.713	.083	.201	.030
Parman, all	Pearson Correlation	-.175	-.622	.369	.713*
	Significance (2-tailed)	.678	.100	.369	.047
Windust	Pearson Correlation	-.162	-.565	.200	.610
	Significance (2-tailed)	.702	.145	.635	.109
Stemmed, unclassified	Pearson Correlation	-.167	-.579	.241	.633
	Significance (2-tailed)	.692	.133	.566	.092
Stemmed, all	Pearson Correlation	-.168	-.585	.257	.644
	Significance (2-tailed)	.690	.128	.539	.085
Crescent	Pearson Correlation	-.163	-.567	.208	.615
	Significance (2-tailed)	.700	.143	.622	.105

Site Type		Springs	Stream	Survey	Unit
Cascade	Pearson Correlation	.182	-.461	-.023	.116
	Significance (2-tailed)	.666	.250	.957	.785
Foliate	Pearson Correlation	-.153	-.628	.381	.689
	Significance (2-tailed)	.717	.096	.351	.059
Humboldt	Pearson Correlation	-.167	-.583	.266	.653
	Significance (2-tailed)	.692	.129	.525	.079
Northern Side Notched	Pearson Correlation	-.177	-.598	.297	.677
	Significance (2-tailed)	.675	.117	.475	.065
Early Holocene	Pearson Correlation	-.167	-.582	.248	.638
	Significance (2-tailed)	.692	.130	.554	.089
Later Holocene	Pearson Correlation	-.172	-.591	.281	.665
	Significance (2-tailed)	.683	.123	.500	.072
All Points	Pearson Correlation	-.168	-.587	.265	.650
	Significance (2-tailed)	.691	.126	.525	.081

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 44. Correlation between sites and pluvial lake indicators by subbasin.

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Fluted	Pearson Correlation	.460**	.163	-.007	-.060
	Significance (2-tailed)	.003	.322	.968	.718
Black Rock Concave	Pearson Correlation	.317*	.430**	.020	.322*
	Significance (2-tailed)	.049	.006	.903	.046
Haskett	Pearson Correlation	.029	.147	.013	-.033
	Significance (2-tailed)	.863	.372	.938	.840
Parman	Pearson Correlation	.234	.332*	.096	.167
	Significance (2-tailed)	.151	.039	.563	.309
Parman Square	Pearson Correlation	.230	.398*	.064	.269
	Significance (2-tailed)	.159	.012	.698	.098
Parman, all	Pearson Correlation	.236	.354*	.088	.198
	Significance (2-tailed)	.148	.027	.595	.227
Windust	Pearson Correlation	.128	.080	.033	-.052
	Significance (2-tailed)	.436	.630	.843	.752
Stemmed, unclassified	Pearson Correlation	.389*	.417**	.357*	.225
	Significance (2-tailed)	.014	.008	.026	.168
Stemmed, all	Pearson Correlation	.362*	.405*	.313	.217
	Significance (2-tailed)	.024	.011	.052	.185
Crescent	Pearson Correlation	.442**	.130	.080	.006
	Significance (2-tailed)	.005	.430	.627	.972

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Cascade	Pearson Correlation	.206	.459**	-.024	.453**
	Significance (2-tailed)	.207	.003	.883	.004
Foliate	Pearson Correlation	.254	.340*	.113	.180
	Significance (2-tailed)	.118	.034	.493	.273
Humboldt	Pearson Correlation	.747**	.807**	.270	.778**
	Significance (2-tailed)	.000	.000	.096	.000
Northern Side Notched	Pearson Correlation	.587**	.685**	.353*	.581**
	Significance (2-tailed)	.000	.000	.028	.000
Early Holocene	Pearson Correlation	.436**	.388*	.284	.189
	Significance (2-tailed)	.005	.015	.080	.250
Later Holocene	Pearson Correlation	.691**	.773**	.324*	.703**
	Significance (2-tailed)	.000	.000	.044	.000
All Points	Pearson Correlation	.567**	.570**	.316*	.412**
	Significance (2-tailed)	.000	.000	.050	.009

*   Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 45. Correlation between sites and non-pluvial lake features by subbasin.

Site Type		Springs	Stream	Survey	Unit
Fluted	Pearson Correlation	.161	-.224	.234	.138
	Significance (2-tailed)	.329	.171	.151	.404
Black Rock Concave	Pearson Correlation	-.072	-.286	.032	.089
	Significance (2-tailed)	.662	.078	.849	.589
Haskett	Pearson Correlation	-.138	-.140	-.011	.013
	Significance (2-tailed)	.401	.395	.945	.937
Parman	Pearson Correlation	-.078	-.226	.073	.024
	Significance (2-tailed)	.638	.166	.660	.884
Parman Square	Pearson Correlation	-.085	-.282	.137	.033
	Significance (2-tailed)	.607	.082	.405	.840
Parman, all	Pearson Correlation	-.081	-.245	.092	.027
	Significance (2-tailed)	.625	.134	.579	.870
Windust	Pearson Correlation	-.213	-.231	-.017	.196
	Significance (2-tailed)	.193	.156	.918	.232
Stemmed, unclassified	Pearson Correlation	-.093	-.258	.074	.024
	Significance (2-tailed)	.574	.112	.655	.883
Stemmed, all	Pearson Correlation	-.094	-.256	.075	.025
	Significance (2-tailed)	.571	.115	.650	.878
Crescent	Pearson Correlation	.088	-.175	.236	.116
	Significance (2-tailed)	.595	.286	.148	.482

Site Type		Springs	Stream	Survey	Unit
Cascade	Pearson Correlation	.100	-.127	-.053	-.131
	Significance (2-tailed)	.545	.440	.751	.428
Foliate	Pearson Correlation	-.039	-.267	.060	.082
	Significance (2-tailed)	.816	.100	.716	.619
Humboldt	Pearson Correlation	.126	-.339*	.152	.005
	Significance (2-tailed)	.445	.035	.356	.974
Northern Side Notched	Pearson Correlation	.000	-.348*	.087	.037
	Significance (2-tailed)	.999	.030	.596	.821
Early Holocene	Pearson Correlation	-.053	-.273	.130	.057
	Significance (2-tailed)	.748	.093	.431	.732
Later Holocene	Pearson Correlation	.064	-.356*	.124	.022
	Significance (2-tailed)	.697	.026	.453	.892
All Points	Pearson Correlation	-.008	-.324*	.134	.046
	Significance (2-tailed)	.961	.044	.418	.783

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 46. Correlation between sites and pluvial lake indicators by watershed.

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Fluted	Pearson Correlation	.336**	.152*	.001	-.019
	Significance (2-tailed)	.000	.022	.985	.781
Black Rock Concave	Pearson Correlation	.024	-.016	-.009	.114
	Significance (2-tailed)	.715	.815	.887	.087
Haskett	Pearson Correlation	-.023	-.014	-.008	-.013
	Significance (2-tailed)	.735	.832	.911	.851
Parman	Pearson Correlation	.096	.195**	.027	.292**
	Significance (2-tailed)	.151	.003	.682	.000
Parman Square	Pearson Correlation	.047	.156*	.019	.326**
	Significance (2-tailed)	.479	.019	.781	.000
Parman, all	Pearson Correlation	.087	.197*	.027	.326**
	Significance (2-tailed)	.190	.003	.690	.000
Windust	Pearson Correlation	.046	-.018	-.013	-.013
	Significance (2-tailed)	.489	.788	.841	.851
Stemmed, unclassified	Pearson Correlation	.094	.041	.173**	.108
	Significance (2-tailed)	.157	.543	.009	.104
Stemmed, all	Pearson Correlation	.094	.063	.154*	.141*
	Significance (2-tailed)	.157	.344	.021	.034
Crescent	Pearson Correlation	.194**	.070	.051	.017
	Significance (2-tailed)	.003	.294	.449	.803

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Cascade	Pearson Correlation	-.028	.009	-.012	.017
	Significance (2-tailed)	.678	.897	.859	.801
Foliate	Pearson Correlation	.033	.037	.070	.104
	Significance (2-tailed)	.625	.576	.298	.119
Humboldt	Pearson Correlation	.158*	.102	.195**	.319**
	Significance (2-tailed)	.018	.125	.003	.000
Northern Side Notched	Pearson Correlation	.151*	.138*	.289**	.361**
	Significance (2-tailed)	.023	.039	.000	.000
Early Holocene	Pearson Correlation	.157*	.080	.135*	.116
	Significance (2-tailed)	.018	.230	.043	.081
Later Holocene	Pearson Correlation	.165*	.127	.256**	.362**
	Significance (2-tailed)	.013	.056	.000	.000
All Points	Pearson Correlation	.173**	.107	.197**	.230**
	Significance (2-tailed)	.009	.108	.003	.000

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 47. Correlation between sites and non-pluvial lake features by watershed.

Site Type		Springs	Stream	Survey	Unit
Fluted	Pearson Correlation	-.015	-.107	.236**	.016
	Significance (2-tailed)	.819	.107	.000	.808
Black Rock Concave	Pearson Correlation	-.035	-.123	.040	.098
	Significance (2-tailed)	.598	.065	.546	.140
Haskett	Pearson Correlation	-.085	-.065	.017	-.082
	Significance (2-tailed)	.203	.332	.798	.218
Parman	Pearson Correlation	-.053	-.140*	.049	.111
	Significance (2-tailed)	.432	.036	.466	.095
Parman Square	Pearson Correlation	-.079	-.168*	.047	.105
	Significance (2-tailed)	.236	.012	.485	.114
Parman, all	Pearson Correlation	-.065	-.160*	.052	.118
	Significance (2-tailed)	.329	.016	.438	.076
Windust	Pearson Correlation	-.084	-.094	.010	.085
	Significance (2-tailed)	.210	.158	.883	.205
Stemmed, unclassified	Pearson Correlation	-.115	-.177**	.055	.075
	Significance (2-tailed)	.086	.007	.407	.261
Stemmed, all	Pearson Correlation	-.112	-.180**	.056	.081
	Significance (2-tailed)	.092	.007	.400	.227
Crescent	Pearson Correlation	.110	-.079	.167*	.204**
	Significance (2-tailed)	.100	.236	.012	.002

Site Type		Springs	Stream	Survey	Unit
Cascade	Pearson Correlation	.072	-.064	-.016	.067
	Significance (2-tailed)	.283	.339	.814	.315
Foliate	Pearson Correlation	-.021	-.158*	.061	.127
	Significance (2-tailed)	.750	.018	.359	.056
Humboldt	Pearson Correlation	.112	-.218**	.093	.228**
	Significance (2-tailed)	.094	.001	.163	.001
Northern Side Notched	Pearson Correlation	-.015	-.246**	.064	.202**
	Significance (2-tailed)	.828	.000	.339	.002
Early Holocene	Pearson Correlation	-.051	-.175**	.114	.135*
	Significance (2-tailed)	.446	.008	.087	.042
Later Holocene	Pearson Correlation	.054	-.247**	.084	.230**
	Significance (2-tailed)	.420	.000	.207	.000
All Points	Pearson Correlation	-.012	-.226**	.113	.191**
	Significance (2-tailed)	.855	.001	.090	.004

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 48. Correlation between sites and pluvial lake indicators by subwatershed.

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Fluted	Pearson Correlation	.091**	.022	-.004	-.006
	Significance (2-tailed)	.002	.459	.896	.854
Black Rock Concave	Pearson Correlation	.046	-.005	-.006	.009
	Significance (2-tailed)	.122	.876	.838	.769
Haskett	Pearson Correlation	-.008	-.002	-.002	-.004
	Significance (2-tailed)	.779	.937	.945	.903
Parman	Pearson Correlation	.044	.048	.022	.167**
	Significance (2-tailed)	.139	.111	.461	.000
Parman Square	Pearson Correlation	.027	.047	.017	.270**
	Significance (2-tailed)	.373	.118	.567	.000
Parman, all	Pearson Correlation	.043	.052	.023	.218**
	Significance (2-tailed)	.156	.083	.452	.000
Windust	Pearson Correlation	.072*	-.004	-.004	-.004
	Significance (2-tailed)	.016	.895	.900	.903
Stemmed, unclassified	Pearson Correlation	.059	.037	.030	.034
	Significance (2-tailed)	.050	.213	.322	.261
Stemmed, all	Pearson Correlation	.058	.041	.030	.063*
	Significance (2-tailed)	.051	.176	.316	.035
Crescent	Pearson Correlation	.118**	.041	.001	-.003
	Significance (2-tailed)	.000	.166	.982	.918

Site Type		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Cascade	Pearson Correlation	-.010	.019	-.003	-.004
	Significance (2-tailed)	.731	.532	.912	.903
Foliate	Pearson Correlation	.056	.017	.039	.125**
	Significance (2-tailed)	.062	.574	.190	.000
Humboldt	Pearson Correlation	.114**	.038	.043	.115**
	Significance (2-tailed)	.000	.205	.155	.000
Northern Side Notched	Pearson Correlation	.103**	.069	.052	.165**
	Significance (2-tailed)	.001	.022	.082	.000
Early Holocene	Pearson Correlation	.097**	.048	.022	.046
	Significance (2-tailed)	.001	.109	.459	.122
Later Holocene	Pearson Correlation	.119**	.057	.051	.150**
	Significance (2-tailed)	.000	.058	.087	.000
All Points	Pearson Correlation	.119**	.058	.038	.098**
	Significance (2-tailed)	.000	.053	.208	.001

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 49. Correlation between sites and non-pluvial lake features by subwatershed.

Site Type		Springs	Stream	Survey	Unit
Fluted	Pearson Correlation	-.024	-.045	.078**	.051
	Significance (2-tailed)	.426	.133	.009	.087
Black Rock Concave	Pearson Correlation	-.006	-.064*	.027	.017
	Significance (2-tailed)	.851	.032	.361	.561
Haskett	Pearson Correlation	-.026	-.038	.011	-.008
	Significance (2-tailed)	.385	.200	.715	.792
Parman	Pearson Correlation	-.030	-.075*	.033	.181**
	Significance (2-tailed)	.323	.012	.277	.000
Parman Square	Pearson Correlation	-.007	-.075*	.020	.161**
	Significance (2-tailed)	.809	.012	.514	.000
Parman, all	Pearson Correlation	-.025	-.082**	.031	.191**
	Significance (2-tailed)	.407	.006	.297	.000
Windust	Pearson Correlation	-.009	-.044	.007	.001
	Significance (2-tailed)	.767	.139	.814	.971
Stemmed, unclassified	Pearson Correlation	-.040	-.094**	.037	.054
	Significance (2-tailed)	.186	.002	.214	.070
Stemmed, all	Pearson Correlation	-.039	-.097**	.038	.077**
	Significance (2-tailed)	.188	.001	.206	.010
Crescent	Pearson Correlation	-.009	-.035	.086**	.074*
	Significance (2-tailed)	.759	.240	.004	.014

Site Type		Springs	Stream	Survey	Unit
Cascade	Pearson Correlation	.068*	-.029	-.004	.027
	Significance (2-tailed)	.024	.334	.882	.365
Foliate	Pearson Correlation	-.007	.098**	.039	.084*
	Significance (2-tailed)	.823	.001	.190	.005
Humboldt	Pearson Correlation	.055	-.112**	.064*	.158**
	Significance (2-tailed)	.065	.000	.033	.000
Northern Side Notched	Pearson Correlation	.024	.146**	.046	.145**
	Significance (2-tailed)	.418	.000	.122	.000
Early Holocene	Pearson Correlation	-.035	-.092**	.068*	.091**
	Significance (2-tailed)	.243	.002	.023	.002
Later Holocene	Pearson Correlation	.045	-.140**	.068*	.166**
	Significance (2-tailed)	.135	.000	.023	.000
All Points	Pearson Correlation	-.007	-.126**	.061*	.166**
	Significance (2-tailed)	.810	.000	.042	.000

*   Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

Table 50. Correlation between survey and pluvial lake indicators.

Hydrographic Unit Level		Pluvial Lake Area	Playa Area	Lake Area	Marsh Area
Region	Pearson Correlation	.981*	.972*	.984*	.980**
	Significance (2-tailed)	.019	.028	.016	.020
Basin	Pearson Correlation	.200	-.167	.161	.083
	Significance (2-tailed)	.635	.693	.703	.844
Subbasin	Pearson Correlation	.163	.080	.083	.131
	Significance (2-tailed)	.321	.629	.616	.427
Watershed	Pearson Correlation	.197**	.042	.017	.053
	Significance (2-tailed)	.003	.531	.804	.431
Subwatershed	Pearson Correlation	.053	.003	.005	.006
	Significance (2-tailed)	.076	.926	.857	.837

* Correlation is significant at the 0.01 level.
** Correlation is significant at the 0.05 level.

higher amount of survey in parts of the study area is influencing site discovery.

The percentage of area covered by pluvial lakes, playas, lakes, and marshes is also a good measure for predicting early site locations at the basin level (see Table 42). Pluvial lakes, lakes, and marshes are particularly strongly positively correlated with the number of early sites per basin. Playas are strongly positively correlated with sites in many instances but not all. Springs and streams were again not significantly correlated with any site types at the basin level of analysis (see Table 43). No site type is strongly correlated with survey coverage at the basin level, meaning that there may be some general regional bias in site discovery but this may not exist at a local scale.

Correlations between archaeological sites and environmental features were also identified at the watershed level, but correlations with early sites were sporadic and stronger between environmental features and later Holocene sites (see Tables 46–47). Survey coverage was only correlated with site discovery in a few instances. No early site type or environmental feature is consistently correlated with features or sites at the watershed-level.

Correlations between early sites and environmental features were infrequently discovered in the analyses at the subbasin and subwatershed level. Subbasin-level correlations discovered connections between some wetland indicators and early sites, however no clear correlation patterns emerged (Tables 45–46). Pluvial lakes and playas appear to be the best indicators for site discovery at the subbasin level. Correlations between early sites and environment features at the subwatershed level were slightly better at identifying connections between early site types and landscape features, but these correlations may be influenced by survey coverage rather than natural features Tables 48–49).

While none of these hydrologic unit correlation analyses indicated significant correlations for all archaeological site types, CRM survey areas and pluvial lake indicators do appear to be Pleistocene-Holocene transition site predictors in some instances. However, correlations between surveys and lakes indicate bias at the regional level suggesting the Great Basin, Columbia Plateau, and WPLT regions are poor units of analysis. While the correlation between sites and pluvial lake indicators seems to support the Western Pluvial Lakes tradition, survey coverage has biased site discovery in the study area. And although the connections are not strong across all site types, the Pearson’s r correlation analyses indicate moderate connections between early Holocene environments and early Holocene archaeological sites at the watershed level.

Analysis Discussion

In this study I used summary, spatial, and correlation statistics to examine the centrality of pluvial lakes in early subsistence-settlement strategies in the Plateau-Basin Interface. The statistical analyses of 744 early Holocene site locations in my study area were applied to the three research questions as follows:

Question 1: Did early Plateau-Basin cultures focus their subsistence-settlement practices in the Great Basin portion of the study area?

Summary statistics of site frequencies in the Great Basin and Western Pluvial Lakes portions of the study area confirm that early sites are more concentrated in these areas than in the Columbia Plateau. Likewise, the mean centers of archaeological site distributions tend to cluster in the Great Basin, and most frequently cluster near pluvial Lake Malheur. CRM surveys are also more frequent in these areas, and the survey mean center is also located near Lake Malheur. The Western Pluvial Lakes and Great Basin portions of the study area contain all of the pluvial lakes within the study area, and most of the marshes, lakes, and playas in the study area. The Columbia Plateau portion of the study area contains a much larger portion of the study area's streams and springs.

This research suggests that early Plateau-Basin cultures focused subsistence-settlement practices in the Great Basin, and confirms that this region contained a greater density and variety of wetlands than the Columbia Plateau was confirmed by this study. Though sites are concentrated in the Great Basin and Western Pluvial Lakes Tradition portions of the study area, the history of CRM in this area may be skewing these statistics. Regardless, the notion that early Plateau-Basin cultures focused subsistence-settlement practices in the wetland-rich Great Basin and Western Pluvial Lakes portions of the study area is confirmed by the data in this study.

Question 2: Were early Plateau-Basin hunter-gatherer foraging patterns tethered to wetland dense regions rather than locally concentrated around particular wetlands?

Early sites and wetland features appear to be concentrated within the Great Basin and Western Pluvial Lakes portions of the study area, but are sites actually located near wetlands? There are no close spatial relationships between early sites and pluvial lakes, with the exception of crescent artifact locales. The close association between crescents and pluvial lakes suggests the people who used these tools did focus some part of their subsistence-settlement strategies on or near pluvial lakes. On average, streams were actually more closely associated with early sites than any other wetland type. Lakes were the second closest feature, suggesting that while pluvial lakes were rare and not associated with most archaeological sites, lake environments were generally important in subsistence-settlement patterns. Early sites are much further from marshes on average, but this may mean that using modern marsh locations is a poor predictor of early site locations, and does not necessarily indicate that early sites were not located near marshes.

There is no clear indication that any of the wetland types or particular wetlands in this study were central to subsistence-settlement practices across the early Holocene. However, regional and local clustering is evident in the vicinity of pluvial lakes. These patterns support the notion that subsistence-settlement patterns were tethered to pluvial lake basins, but were not focused exclusively on limited resource extraction sites. Bedwell's (1973) hypothesis that WPLT peoples had no reason to leave the pluvial lake environment is supported on the regional scale, but locally it is apparent that people sought resources beyond the pluvial lake margins.

Question 3: Did early Plateau-Basin cultures focus their foraging activities on areas that were particularly dense with wetland concentrations?

Based on the above statistical analyses, it appears early groups preferred the Great Basin and Western Pluvial Lakes regions over other portions of the study area, and that this may have been because of a concentration of wetland environments in this region. Archaeological sites are concentrated in the wetland dense portions of the study area at the regional level, but there are no clearly redundant patterns at specific wetlands or among wetland categories. The Ripley's k-function analysis undertaken in this study showed that early artifact locations do in fact cluster, forming small local sites. Tradition regions were also evident across much of the study area. Moran's I analysis results also indicate that clustering was best detected on a broad regional scale and among watersheds. And the Pearson's r correlation analyses performed in this study show that watersheds with high concentrations of early sites also had high concentrations of pluvial lakes and lakes, suggesting that local site clustering can be associated with these types of wetland features even if they are not located at a short distance from these features on average.

It appears that portions of the study area that were wetland dense are also rich in early Holocene archaeological sites. Although no simple predictors of site locations were identified in this study, it does appear that early Plateau-Basin cultures focused their activities on wetland concentrations regionally within northern Great Basin basins. The notion that cultures focused their foraging activities on areas that were particularly dense with wetlands was confirmed in this study through the high number of early Holocene archaeological sites in the vicinity of wetland concentrations. While wetlands appear to be an important predictor for regional site patterns, the correlations presented in this study indicate that early Holocene cultures did not focus subsistence-settlement practices exclusively on pluvial lake margins. Thus, the concept of the Western Pluvial Lakes Tradition should be modified to include a broader use of the landscape than was suggested by Bedwell's (1973) definition of a lake-marsh-grassland adaptation.

Chapter Summary

In this chapter I described my statistical analysis procedures, and used the results of these analyses to consider spatial patterning and correlations in the datasets. I studied the distribution of Western Fluted, Black Rock Concave, crescentic, Haskett, Parman, Windust, and other Great Basin Stemmed artifacts in the southern Columbia Plateau and northern Great Basin. Three research questions were developed and tested through statistical analyses as a means to investigate early Holocene site patterning in the study area. These three questions were aimed at discovering spatial characteristics of early Holocene Plateau-Basin sites, rather than simply rejecting or confirming the complex Western Pluvial Lakes Tradition hypothesis. In designing these research questions and statistical tests, it was assumed that a deductive approach to analyzing an important subsistence-settlement theory had the potential to fine-tune knowledge of settlement motivators in the region, as well as inform archaeological predictive modeling in the study area. The statistics in this study suggest that early Holocene cultures preferred wetland dense areas, but were not focused exclusively on pluvial lakes or other wetland environments.

Chapter 5: Paleoindian Land-Use Patterns on the Plateau-Basin Interface

In this thesis I used spatial analysis and correlation statistics to explore the validity of the Western Pluvial Lakes Tradition hypothesis in the southern Columbia Plateau and northern Great Basin regions of North America. This was accomplished by addressing three research questions aimed at finding potential local and regional site patterns. The primary goal of this research was to observe the strength of associations between wetland environments and early Holocene sites, but the statistical analyses also provided information on the patterning of each of the early Holocene site types (i.e., Western Fluted, Black Rock Concave, Western Stemmed, Old Cordilleran, and later Holocene sites). In this final chapter, I discuss the spatial patterns and environment correlations observed for early Holocene sites, and relate these observed patterns to what is known about the subsistence-settlement strategies of these early Holocene cultures. I conclude with discussion of the challenges and limitations of this research project, with recommendations for future research that might correct the research limitations and clarify observations made in this study.

Revising the Western Pluvial Lakes Tradition Hypothesis

Bedwell (1973:170) proposed that Western Pluvial Lakes Tradition hunter-gatherers followed a unique adaptation that allowed them to “never leave the lacustrine environment which the hundreds of viable lakes at that time provided.” The analyses presented in this thesis support the concept that early Plateau-Basin cultures focused their subsistence-settlement strategies on the portion of the study area that contains pluvial lakes, but it appears that activities on the landscape were tethered to these places rather than focused exclusively on them. Spatial aspects of Western Fluted, Black Rock Concave Base, Western Stemmed, Old Cordilleran, and later Holocene sites are discussed here individually, before considering what the data indicate about the Western Pluvial Lakes Tradition.

Western Fluted Point Tradition Site Patterns

Western Fluted and Western Stemmed points appear to coincide in both time and space in the Great Basin, but are regarded as separate cultural traditions (Goebel and Keene 2013:52-53). The chronology of the Western Fluted Point Tradition is poorly understood in the North American west, but it is assumed that fluted artifacts date to roughly 13,250-12,800 cal yrs BP in this region (Waters and Stafford 2007:1123). The Western Fluted Point culture appears in the archaeological record shortly before the Younger Dryas (12,900–11,600 cal yrs BP), when the climate shifted from a very dry and warm period to a cool and moist climate which caused a rebound of the Great Basins' wetlands and pluvial lakes (Goebel et al. 2011:482). Given that there is evidence in other parts of North America that Paleoindian groups used wetlands regularly as a part of a broad-spectrum strategy for hunting and gathering (e.g., Custer and Mellin 1991; Nicholas 1990:127; Yansa et al. 2006), it is possible that pluvial lakes and wetlands were included in the Plateau-Basin Western Fluted Point foraging activities.

Only 27 fluted point sites have been recorded in the study area, but these sites did produce statistically significant patterns that suggest the Western Fluted Point Tradition was more focused on pluvial lakes than any of the other early Holocene traditions. Did the Western Fluted Point Tradition focus subsistence-settlement practices in the Great Basin portion of the study area? If so, did the abundance of wetlands in the northern Great Basin influence Western Fluted Point Tradition land-use patterns? Like most of the other site types in this study, fluted point sites cluster within the study area and are highly concentrated in watersheds near Lake Malheur and Lake Alvord. This regional clustering indicates not only a preference for the Great Basin, but also for the pluvial lake watersheds.

Western Fluted Point sites cluster in pluvial lake watersheds within the Great Basin, but do these sites exhibit a tethered pattern, with pluvial lakes serving as regional anchors? The average distance between Western Fluted Point sites and pluvial lakes (i.e., 19.681 km) is also the second closest connection between pluvial lakes and any of the early Holocene site types (see Table 33). Although this average distance does not in itself indicate a close connection between pluvial lakes and fluted point sites, the frequency at which fluted point sites are located within 1 km of pluvial lakes (i.e., 42%) does suggest these places were important to the Western Fluted Point Tradition (see Table 34). Pluvial lake environments appear to have been important for the Western Fluted Point Tradition, but as is the case with all of the early Holocene tool types studied in this thesis, fluted point sites are on average much closer to streams than they are to any other type of watered place. Western Fluted Point sites are located 440 m from streams on average, but are only located within 1 km of a stream 12% of the time (see Tables 14, 39).

Of all the wetland types included in my analyses, Western Fluted Point sites were most often associated with pluvial lakes and streams on a local level. Regionally, did Western Fluted Point makers focus their foraging activities on areas that were particularly dense with any of the wetland types? There is a significant moderate correlation between the number of fluted sites and the density of pluvial lakes in these watersheds (see Tables 42, 44, 46, 48), which is the strongest and most consistent link between pluvial lakes and any of the site types.

It is possible that the relatively small sample size of the Western Fluted Point site dataset allows the few clusters near streams and pluvial lakes Malheur and Alvord to skew the observed patterns. However, these associations are some of the strongest in this study, suggesting more attention should be paid to the potential to locate Western Fluted Point Tradition sites near streams and pluvial lakes.

Black Rock Concave Base Point Site Patterns

Black Rock Concave Base artifacts (13,000–7,000 cal yrs BP) have so far not been associated with any subsistence-settlement practices in archaeological literature (Justice 2002:81; Heizer and Hester 1978:14), and little additional information was discovered about Black Rock Concave Base sites in my research. Black Rock Concave Base points are rarer (n=14) than fluted artifacts in the study area, and thus produced few statistically significant results in this analysis. However, Black Rock Concave Base point sites do exhibit local and regional patterns that are consistent with Western Fluted Point site patterns.

Are Black Rock Concave Base Point sites concentrated in the northern Great Basin portion of the study area, and if so, are these sites locally concentrated in wetland-abundant portions of the study area? The majority (i.e., 93%) of Black Rock Concave Base sites are located in the Great Basin portion of the study area (see Table 11), and these sites cluster in basins that contain pluvial lakes. Although the Black Rock Concave Base sites do cluster in the pluvial lakes portion of the study area, does the site pattern indicate subsistence-settlement activities were merely tethered to pluvial lake basins rather than concentrated on pluvial lake margins on a local level? Some site clustering was observed at the subbasin, watershed, and subwatershed levels in the vicinity of Lake Malheur and Lake Alvord, but the Black Rock Concave Base sites were among the most dispersed site types in the entire study. As with the Western Fluted Point sites, there does appear to be a strong connection between Black Rock Concave Base sites, and pluvial lakes and streams. Black Rock Concave Base sites have the smallest average distance to pluvial lakes and streams of any of the early Holocene site type in the study (i.e., 16.837 km and 321 m, respectively), but they are rarely within 1 km of pluvial lakes (i.e., 8%), streams (7%), or any other wetland environment type (see Tables 33, 34, 39).

Finally, are Black Rock Concave Base sites locally concentrated in areas that were particularly dense with wetland concentrations? Positive correlations were observed between Black Rock Concave Base sites and pluvial lake, lake, and marsh indicators at the basin level (see Table 42). Pluvial lake and marsh indicators were also positively correlated with Black Rock Concave Base sites at the subbasin level, however no further local correlations were observed (see Table 44).

The Black Rock Concave Base site patterns are similar to those noted in the Western Fluted Point tradition in this study, which is interesting given that Black Rock Concave Base technology may have developed from the Western Fluted Point tradition (Justice 2002:80-81). These site distributions might be studied in tandem to identify the connection between the two traditions.

Western Stemmed Tradition Site Patterns

The Western Stemmed Tradition (WST) is the technological equivalent of the Western Pluvial Lakes Tradition (Bedwell 1973). The WST is dated to 14,500–8,200 cal yrs BP, and spans the Paisley, Fort Rock, and Lunette Lake Periods (Aikens et al. 2011:45–49; Lyman 2013:227). In this study, the WST is represented by Parman (n=79), Haskett (n=6), Windust (n=2), Great Basin Transverse/Crescentic (n=118), and unclassified stemmed point (n=433) sites. The Western Stemmed complex tools are thought to have been used as multipurpose tools, likely for hunting and many other tasks (Lafayette 2006). The Paisley Period (15,700–12,900 cal yrs BP) is marked by both fluted and stemmed artifacts, and sites from this period are noted to be closely associated with water sources that were apparently frequently revisited (Aikens et al. 2011:59–60). The use of WST tools continues into the Fort Rock Period (12,900–9,000 cal yrs BP), when the population appears to have followed seasonal rounds to hunt and gather a broad range of resources (Aikens et al. 2011:71–72). The population appears to decrease during the Lunette Lake Period (9,000–6,000 cal yrs BP), when the pluvial lakes in the northern Great Basin begin to dry (Aikens et al. 2011:74–79). Lunette Lake Period site assemblages indicate that wetlands continued to be an important part of the economy, but that they were only occupied briefly during foraging tasks (Aikens et al. 2011:77). It was expected that the patterning of WST sites in the study area should show some evidence for intensive use of pluvial Lakes Alvord, Catlow, Coyote, and Malheur, but that sites should also be correlated with other wetlands in the study.

Did the Western Stemmed Tradition culture focus their subsistence-settlement practices in the Great Basin portion of the study area? The distribution of Western Stemmed Tradition tools in my study is largely limited to the Great Basin/WPLT portion of the study area. Did the abundance of wetlands in the northern Great Basin influence early Plateau-Basin land-use patterns? All Western Stemmed Tradition point sites cluster at the level of the subbasin, watershed, and subwatershed, and are most prevalent in the western half of the study area where pluvial lakes are also concentrated (see Figures 40, 57).

While Western Stemmed Tradition sites are clustered in pluvial lake basins, are these sites tethered to wetland dense regions rather than locally concentrated around particular wetlands? While Western Stemmed Tradition sites do cluster regionally in the pluvial lake dense western portion of the study area, the average distances between WST sites and wetland environments appear to support the concept of a broad use of landscapes, with a stronger focus on lake and stream environments. As with all other site types in this study, most (i.e., 79%) WST sites were located within 1 km of a stream (see Table 39). Correlations between WST sites and streams are very weakly negative at all of the study levels (see Figures 41, 43, 45, 47, 49), which indicates that there are no portions of the study that were favored for their concentrations of streams or springs. However, the average distances between WST sites and streams range between 112 to 609 meters, which suggests streams were moderately important in subsistence-settlement strategies (see Table 33). A similar pattern is observed for the associations between WST sites and extant lakes, which are located within 1 km of lakes a majority (i.e., 53%) of the time (see Table 36). The average distance between WST sites and extant lakes ranges between 390 to 1,869 m (see Table 33), suggesting lakes may have been slightly less important than streams for WST foraging activities. The associations between WST sites and marshes and springs are comparatively poor, with marshes being located within 1 km of WST sites only 8% of the time, and springs being located within 1km of WST sites only 14% of the time (see Tables 37, 38).

Did early Plateau-Basin peoples focus their foraging activities on areas that were particularly dense with wetland concentrations? At the basin level of analysis, there are moderate positive correlations between pluvial lake indicators (postulated pluvial lakes, as well as extant playas, lakes, and marshes) and WST sites. However, when studied at the subbasin and watershed levels, the correlations are weak (see Tables 42, 44, 46). At the subwatershed level there are also very weak correlations between Parman sites and marshes, but no other correlations are found (see Figure 48). These findings suggest there is some potential to use pluvial lake indicators to predict WST site concentrations, but the correlations between WST sites and most wetland environments are fairly weak, which supports the concept that the WST foraging activities occurred in many settings within the study area.

Great Basin Transverse biface (n=118) site distribution patterns exhibit more of a connection with pluvial lakes than any of the WST sites. These artifacts were located almost exclusively (99%) in the Great Basin and Western Pluvial Lakes regions. Although not limited to the four pluvial lake subwatersheds in the study area, they are most often (i.e., 78% of the time) located within 1 km of a pluvial lake (see Figures 13, 49, Table 34). On average, crescent sites are located only about 4.5 km from pluvial lake shorelines, which is significant given the average distance of any WST site to pluvial lakes is 16.655 km (see Figure 34). These spatial associations suggest that crescent sites are likely to be found near pluvial lake shorelines, which supports Tadlock's (1966:664) hypothesis that crescents were used during specialized aquatic resource extraction activities.

My spatial analyses suggest that while the Western Stemmed Tradition may have been drawn to the pluvial lake dense portion of the study area, the subsistence-settlement pattern was nonetheless diverse. Western Stemmed Tradition sites are often located near large pluvial lakes, lakes, and streams, and crescent sites are particularly closely connected with pluvial lake environments. Although the WST extends over 6,000 years in the early Holocene, little can be gleaned about spatio-temporal patterns in the study area. The Western Fluted Point and Black Rock Concave Base sites, which are associated with the Paisley Period, appear to be closely associated with pluvial lakes and streams in this study, which confirms the Paisley Period pattern of repetitive visits to water sources during foraging rounds noted by Aikens et al. (2011:59). The Western Stemmed Tradition spatial patterns appear to include specialized activities on large pluvial lakes, represented in the archaeological record by crescentic bifaces. WST site distribution patterns also indicate some preference for streams and lakes, but in general the WST patterns are not strongly correlated with particular environments. This pattern supports the concept outlined by Aikens et al. (2011:71–77) that wetland environments were important to Fort Rock and Lunette Lake Period hunter-gatherers, but that wetlands were only a part of a broad spectrum adaptation.

Old Cordilleran Tradition Site Patterns

Old Cordilleran Tradition (OCT) sites are represented by Cascade points in the Columbia Plateau, which are believed to date between 10,600–5,000 cal yrs BP (Chatters et al 2012:46; Smith et al. 2012:29). The Cascade culture is thought to have been highly residentially mobile, with repeated short stays in mountains and river corridors (Chatters et al 2012:44, Ozbun and Fagan 2010:4). Based on this pattern, I expected that OCT sites would cluster in the Columbia Plateau portion of the study area, and that they would often be located near streams.

Despite the small number of Cascade artifacts in this study (n=6), there are some indications that their distribution is unique from that of other early Holocene sites. Like other early traditions in the region, OCT site patterns suggest these groups followed a highly mobile lifestyle, although some resource locations may have been revisited often.

Were OCT sites concentrated in the Great Basin portion of the study area? Cluster analysis indicates that Cascade sites are randomly scattered across the study area, in both the Great Basin and Columbia Plateau. Did the abundance of wetlands in the northern Great Basin influence OCT site patterns, and do sites appear to be tethered to wetlands? Clearly different from the other early Holocene patterns, these sites are on average located 96 km from pluvial lakes (see Table 33). Finally, were OCT sites located in wetland dense portions of the study area? Most of the correlations between wetland environments and Cascades sites are very weak. Playas and marshes are moderately positively correlated with Cascade sites at the subbasin level (see Table 44). On average, Cascade sites are located much closer to streams and springs (99 m and 993 m, respectively) than any of the early Holocene site types (see Figure 33). The random patterning and apparent association with nearly all environment types could suggest a diverse subsistence-settlement pattern.

Later Holocene Site Patterns

Later Holocene sites (foliate, Humboldt, and Northern Side Notched) were included in this study to provide comparisons between early and later Holocene site patterns. Like the early Holocene sites, all later Holocene sites (foliate, Humboldt, Northern Side Notched) exhibit clustering within the western portion of the study area, which suggests that there is either a bias toward site discovery in the western portion of the study area, or that the resources of the northern Great Basin attracted foragers throughout the early- to mid-Holocene period. As with many of the earlier site types, there are strong correlations between pluvial lake basins and later Holocene sites (see Figures 78–81, 83, Tables 42, 43). The later Holocene sites had much stronger correlations with pluvial lake indicators at the subbasin and subwatershed levels than earlier Holocene sites, but had even stronger correlations with springs and streams (see Tables 44, 45). The average distances between later Holocene sites and environment features also suggest the later Holocene subsistence-settlement strategies were slightly more broad-spectrum than the early Holocene patterns. The frequency with which later Holocene sites are located within 1 km of streams and springs increases from the average early Holocene distances (see Tables 45–46), while the frequency with which later Holocene sites are located within 1 km of marshes, lakes, playas, and pluvial lakes decreases (see Tables 85–88). These increasingly dispersed patterns support the concept that both early Holocene and Archaic cultures both practiced broad-spectrum adaptive strategies in this region (e.g., Graf and Schmidt 2007:xvi).

The Western Pluvial Lakes Tradition Site Patterns

Although the northern Great Basin pluvial lakes may have provided abundant opportunity for foraging, the statistics presented in this thesis indicate that early Holocene hunter-gatherers did in fact leave the lacustrine environment. The summary statistics of landscape features in the study area indicate that a variety of wetland environments were available within a one-day foraging radius of the sites in the study area, and that pluvial lakes, smaller lakes, marshes, streams, and springs are all correlated with early sites, to varying degrees. With the exception of crescent artifacts, there is no clear correlation between pluvial lake margins and early site types. The only correlations appear to be regional, with high archaeological site densities occurring in the general proximity of pluvial lakes. The early Holocene site distribution patterns seem to support the concept of an economy that was tethered to the pluvial lake environment in the northern Great

Basin, but indicate that subsistence-settlement strategies were not exclusively associated with lakes or any other type of watered place.

Bedwell (1973:170) proposed that Western Pluvial Lakes Tradition hunter-gatherers never had to “leave the lacustrine environment which the hundreds of viable lakes at that time provided.” Hoffman (1996:107) suggested abandoning this concept, based on his observation that WST sites were not closely associated with marsh and lake locations in northwestern Nevada. He observed that both uplands and lowlands were important places, suggesting that no part of the environment was excluded from foraging rounds, and that WST site patterns are the result of early Holocene people seeking high ranked resources in many habitats. While my results support Hoffman’s conclusion that early Holocene people did not limit foraging to any particular environment, I recommend revising the Western Pluvial Lakes Tradition subsistence-settlement pattern hypothesis to account for the apparent regional importance of pluvial lakes and the diversity of site-environment correlations. It appears that the diversity of the early Holocene northern Great Basin environment supported the broad spectrum economy of the Western Pluvial Lakes Tradition.

Future Research

A variety of challenges emerged during the data collection and analysis stages of this study, and after addressing the three research questions presented in this thesis, new research questions have emerged. In this section I consider types of data, additional methods, and research questions that could be used to expand upon the early Holocene Plateau-Basin subsistence-settlement patterns observed in this thesis. I also suggest the paleoenvironmental and archaeological site data might be fine-tuned to discover additional early Holocene site-environment correlations in the Columbia Plateau and Great Basin. Finally, I reflect on what this study indicates about the status of cultural resource management databases.

Paleoenvironment Modeling in the Columbia Plateau and Great Basin

In the course of this research I discovered that the models of late Pleistocene pluvial lakes commonly used in discussions of the early archaeology of the Great Basin over-represent the size of the pluvial lakes in the early Holocene. In my study, pluvial lakes were modeled after the early Holocene elevations of Lakes Alvord, Catlow, Coyote, and Malheur, as reported by researchers who have studied the pluvial lake shoreline chronologies (Carter et al. 2006; Dugas 1998; Gehr 1980; McDowell 1992; Raven 1992; Wriston 2003). Although the models used in this thesis simplify the extent of northern Great Basin pluvial lakes over thousands of years, they were considered to be closer approximations of the early Holocene pluvial lake shorelines than the Reheis (1999) late Pleistocene model. Given that the climate was volatile over the 7,500-year period of the study, these models are simplified representations of the pluvial lakes through the entire early Holocene. Lakes Alvord, Catlow, Coyote, and Malheur would have fluctuated seasonally and in response to climate fluctuations, which at times would have resulted in significant changes to the size of these pluvial lakes (e.g., McDowell 1992:31). However, additional palynology and radiocarbon studies of the early Holocene pluvial lake shorelines could allow for more detailed studies of the relationship between archaeological site locations and pluvial lakes through all periods of the Holocene. This could clarify which parts of the pluvial lake shoreline environment might have populated, and how land use may have changed through the early Holocene.

Due to a lack of fine-grained representations of paleoenvironment features, the boundaries of extant playas, marshes, lakes, springs, and streams were used in this study to approximate the early Holocene extents of wetland environments in the study area. I assumed that the topography of the study area has remained relatively stable since the late Pleistocene, and that the early Holocene environment was generally wetter than contemporary conditions. Therefore, the boundaries of extant playas, marshes, lakes, springs, and streams represent the minimum extent of lakes and wetlands in the early Holocene. As with the pluvial lakes in the study area, these landscape features would have shifted throughout the early Holocene in reaction to seasonal or long-term changes in the local climate. Further research on the composition, extent, and age of wetlands and other habitats in both the Columbia Plateau and Great Basin would produce more detailed environment histories that could be correlated with early Holocene archaeological site locations in order to provide additional insights on the subsistence-settlement pattern motivators in this region.

Site Discovery Biases

The archaeological data utilized in this study was comprised of surface isolate Paleoindian artifact information collected in a CRM environment, which means that potential biases in the data collection process have influenced the site discovery process. Studies of Paleoindian site patterns in other parts of the United States suggest that there are sampling biases in site survey and recordation that are the result of population densities and land-use history (e.g., Buchanan 2003; Seeman and Prufer 1984). In this study I assumed that the distribution of CRM project areas had the potential to influence site discovery. After studying the distribution of survey areas in this study, it appears that the land management history of the Burns and Vale BLM has resulted in more surveys in the Great Basin portion of the study area, even though most of the study area is actually in the Columbia Plateau (see Figures 10, 16, 39). Due to the history of cultural resource management practices in the study area, only 2% of the Columbia Plateau portion of the study area has been surveyed in comparison to 7% of the Great Basin. Survey coverage was greatest in the southern part of the study area, although there are no strong correlations between the number of recorded sites and the amount of survey coverage at the basin, subbasin, watershed, or subwatershed levels of analysis (see Table 30, Figure 39). Future studies of early Holocene site distribution might work to correct this imbalance by focusing additional research in the Columbia Plateau portion of the study area or by more equally sampling from both the Columbia Plateau and Great Basin regions.

Isolate Archaeological Sites

Archaeological isolates have the potential to contribute valuable information to a region's archaeological record, but this type of archaeological site often lacks enough information to be included in archaeological studies. Although my study benefited from a large database of isolate artifact information, the CRM industry generally favors the identification of large and significant archaeological sites. Survey transect spacing, the restrictions of pedestrian survey, and the imperfect human eye limit the ability to identify isolate artifacts. And as cultural resource managers are tasked with identifying archaeological sites that are eligible for the National Register of Historic Places, isolate artifacts may be observed in the field but are not always recorded or researched. The 744 site locations identified in this study indicate that while isolate artifacts may not individually contribute to subsistence-settlement theories they do have the power to illustrate patterns across a region and should be considered among other site data in settlement pattern studies.

Cultural Resource Management Geographic Information Systems

Despite some progress in developing statewide databases in the United States, many CRM agencies are still in the process of digitizing legacy site data. As agencies continue to build CRM GIS, the possibility for refining subsistence-settlement strategies with large databases of archaeological site information increases. This study benefited from data collected by the Burns and Vale districts of the BLM. During my data collection in the summer of 2010, the Oregon State Historic Preservation Office was in the process of developing a statewide database and many agencies were storing site data in hardcopy files. The process of searching and digitizing the data only consumed a few days of my time, but as CRM databases are refined the possibilities for easily studying settlement pattern theories improves.

One of the many benefits of a GIS is that large amounts of data can be explored easily, allowing researchers to form hypotheses through exploratory spatial data analysis and by testing theories with readily available data. For example, in this thesis I produced 1,538 statistics in 124 tables and figures from a database containing only 744 site locations. Even without expanding this database, it is possible to use these data to complete additional studies of site patterning and subsistence-settlement theories by analyzing sub-divisions or samples within the study area and grouping archaeological sites into use areas or culture regions for further statistical analyses. Given the malleability of geospatial data, there is great potential to not only expand on the statistics and hypotheses I have presented in this study, but to build on site patterns and predictive models in general.

Expanding the Study Boundaries and Dataset

Although I had anticipated observing correlations between archaeological sites and environments on the subwatershed level of analysis, it became apparent through the course of this study that some of the more interesting correlation findings were evident at the level of the basin. This begs the question of how land-use patterns might be revealed if the boundaries of the study area were expanded to include surrounding regions. I suggest that future research that expands spatial analysis beyond the boundaries of my study area could not only correct the bias operating at the boundaries of this study, but could illustrate potential differences between physiographic regions of western North America.

The problem of biased site discovery patterns within the study area could be improved with the addition of more archaeological sites. Observations can appear to cluster when there is little data in a dataset (Banning 2002:50), meaning that apparent clusters of early Holocene archaeological sites in this study area might be the result of clusters of CRM activities rather than evidence of early Holocene subsistence-settlement patterns. In my dataset, several categories of archaeological sites (e.g., Parman, Haskett, and Cascade) were not large enough to produce statistically significant results, while other small data sets (e.g., fluted) produced statistics that appear inconclusive. It was recognized that the addition of more sites would increase the robustness of these analyses and potentially lead to much stronger conclusions about early Holocene site patterns. While more archaeological sites will be discovered in the course of CRM in the study area over time, additional archaeological sites might be added to the dataset by expanding the study area and seeking early Holocene site information from the Oregon State Historic Preservation Office database, other local land management offices, and private artifact collections.

Conclusion

The goal of this thesis was to study the spatial distribution of Paleoindian sites in a portion of the northern Great Basin and southern Columbia Plateau, in order to address a long-held belief that Great Basin Paleoindians focused their subsistence-settlement practices on pluvial lakes (i.e., the Western Pluvial Lake Tradition). Research into North American Paleoindian site patterns indicates that wetlands appear to have been important places for Paleoindians in North America. This pattern is also documented in the Great Basin, where regional archaeological research often concludes that lakes were very significant places for Paleoindians. After analyzing early Holocene site-environment associations in the southern Columbia Plateau and northern Great Basin, I concur with Hoffman's (1996) conclusion that the Western Stemmed Tradition economy was not solely focused on lake resources. While the earlier Western Fluted and Black Rock Concave sites are found near pluvial lake margins, Western Stemmed Tradition sites are more evenly distributed across the study area. Western Stemmed Tradition patterns indicate that crescent bifaces were used for specialized tasks near pluvial lakes, but the distribution pattern of other Western Stemmed Tradition isolate types demonstrates that Western Pluvial Lakes Tradition peoples utilized environments outside pluvial lake basins.

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