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Obsidian Source Distribution and Prehistoric Settlement Patterns at Mono Lake, Eastern California

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Hunter-gatherer settlement studies often use toolstone diversity to measure the degree to which mobility was regular, expansive, or localized. The results of a 10 km.^{2} probabilistic survey investigating prehistoric wetland use at Mono Lake demonstrate a pattern that is counter-intuitive to preconceived notions. Diachronic change in landscape use is investigated with a combination of obsidian sourcing and hydration analyses. Rather than conforming to a linear distance-decay model, source distributions appear to reflect differential patch-choice among lakeside habitats. Comparisons with environmental and paleoenvironmental data underscore changes in the use of wetland habitats and highlight the utility of surface survey and obsidian data for understanding past settlement-subsistence patterns.

Obsidian sourcing and hydration studies have a long history of use to support arguments for differences in past hunter-gatherer mobility, social organization, and trade relations in the Inyo-Mono region of eastern California (Basgall 1989; Basgall and Delacorte 2003; Basgall and McGuire 1988; Basgall et al. 2003; Bouey and Basgall 1984; Delacorte 1999; Gilreath and Hildebrandt 1997; Hull 2002; King et al. 2001; Singer and Ericson 1977; Zeanah and Leigh 2002). Obsidian hydration data may be used as another line of evidence to test presumptions about chronology. Moreover, in localities with well-documented obsidian sources, the study of toolstone distributions can be used to identify patterns of mobility and social interaction for people in the past (Basgall 1989; Bouey and Basgall 1984; Eerkens et al. 2007, 2008a; Hughes 1986; Jones et al. 2003; McGuire 2002; Smith 2010).

The distribution of obsidian toolstone is frequently used to study patterns of lithic conveyance, which is often viewed as a rough indicator of mobility range (Basgall 1989; Hughes 1986; Jones et al. 2003; McGuire 2002; Smith 2007, 2010 — but see Close 2000). Used in conjunction with technological analyses, source provenance studies can illustrate patterns of tool manufacture and toolstone conservation that reflect mobility decisions (Beck 2008) and toolstone availability (Andrefsky 1991:131, 1994a). The type of mobility practiced, whether residential or logistical (cf. Binford 1980; Kelly 1992), can complicate interpretations as populations may be less residentially mobile, but still retain access to distant lithic resources through logistical movement. Likewise, trade and exchange may also affect the distribution of lithic raw materials (Davis 1961; Ericson 1981; Whitaker et al. 2008), though its relative importance likely fluctuated throughout prehistory.

In general, a lithic distance-decay model is argued to be applicable to understanding toolstone source distributions (Giambastiani 2004; Jones et al. 2003). The model has two assumptions. The first is that the prevalence of a given source decreases as distance to the raw material source increases (Brantingham 2006). With greater distance there is an increase in the number of finished tools relative to the amount of unmodified flakes and simple tools (Andrefsky 1994a; Kuhn 1991; Ricklis and Cox 1993), or items such as cores are more intensively used (Kuhn 1995). A second implication is that flake and tool size will decrease with distance to the source (Eerkens et al. 2008a; Newman 1994; Ricklis and Cox 1993, but see Close 1999).

Intrinsic characteristics of a toolstone may make one source particularly more attractive than another (Andrefsky 1994b; Elston 1992; Wilson 2007) and are suggested to account for certain spatio-temporal changes in obsidian source profiles in central-eastern California

(Basgall 1989:116; Bettinger 1981:54; Eerkens et al. 2008a:676; Stevens 2005). The presence or absence of locally available stone material will also affect patterns of stone tool use and conservation (Andrefsky 1994a; Bamforth 1986, 1991; Torrence 1989).

Situations where distance-decay model expectations are not met may be better explained through differences in settlement and mobility organization (Eerkens et al. 2008a; Henry 1992; Hildebrandt and McGuire 2002; McGuire and Hildebrandt 2005; Milliken 1998) or social interaction (McGuire 2002; Whitaker et al. 2008). The distance-decay model should be expected to fail at times due to the complexities of past hunter-gatherer mobility (Kelly 1983, 1992, 1995) and toolstone acquisition strategies (Beck et al. 2002; Binford 1979; Gilreath and Hildebrandt 1997; Halford 2008). In many ways, failures of the model are more instructive than successes.

The distance-decay model applied to the present context is relatively simple in that it posits that material from the nearest obsidian source will comprise the greatest amount of the assemblage, while other, more distant obsidian sources will be represented in decreased quantities (cf. Eerkens et al. 2010; Fredrickson 1989). Of course, rather than strict linear direction, stone material prevalence may also be affected by other factors, such as the mode of procurement (direct, embedded [*sensu* Binford 1979], or indirect [Whitaker et al. 2008]), direction of travel (King et al. 2001), and encounter rate with additional sources of toolstone (Ingbar 1994).

A second issue pertinent to the present study relates to the use of wetland habitats in the Great Basin. The role of wetlands within the subsistence-settlement patterns of Great Basin hunter-gatherers has been a topic of debate and study for several decades (Bettinger 1993; Hemphill and Larson 1999; Janetski and Madsen 1990; Kelly 2001; Madsen 1982, 2002, 2007; Zeanah 2004; Zeanah et al. 1995). The basic argument is whether wetlands were optimal habitats for hunter-gatherers to exploit and were unsurpassed by other dry land desert scrub or upland zones (Heizer 1967; Heizer and Napton 1970), or whether the fluctuating characteristics of Great Basin wetlands would have made them important areas only at times of higher productivity (Kelly 1985; Thomas 1985). Research and discourse has led to the conclusion that, at times, wetlands were in fact important habitats and that people could reside near them for long periods of time (Kelly 2001; Zeanah 2004); however, the importance that they had within a regional system might vary relative to the productivity of other areas such as uplands (Cannon et al. 1990; Delacorte 2002; Madsen 2002, 2007), and in relation to the overall subsistence-settlement strategy practiced by people at the time.

The present study uses data collected during the Mono Lake Wetland Survey (MLWS), a probabilistic survey designed to investigate prehistoric hunter-gatherer land use relative to wetland habitats in the Mono Lake basin of eastern California (Brady 2007). In particular, the manner in which mobility is reflected in spatial and temporal patterns of toolstone dispersion is examined. Moving beyond simple raw material distributions, the study further identifies divergent settlement strategies practiced in different lakeshore wetland habitats.

ENVIRONMENTAL CONTEXT

Adjacent to and east of the Sierra Nevada Mountains, the Mono Basin is an ideal place to apply obsidian source provenance and hydration studies to help in understanding regional settlement and mobility patterns (Fig. 1). The basin itself is a relatively discrete depression covering over 650 km.^{2} (Stine 1987:14). Located in the central-western area, Mono Lake is a large saline body of water that provides wetland habitats bordering its shoreline. The wetlands support a range of economically important plant and animal species. Due to resources available there, the wetlands presumably served as key resource patches for hunter-gatherers throughout the Holocene (Brady 2007).

Unique hydrological and geographic factors have created wetland habitats which can be distinguished through vegetation distributions, slope gradient, type of freshwater inflow, as well as soil alkalinity and leaching capabilities (Jones and Stokes Associates 1993; Stine 1993). For the present study, the wetlands were grouped into three classes: freshwater, brackish, and remaining. The freshwater habitats contain the greatest diversity and density of vegetation relative to the saline areas (Brady 2007:Table 2.1). The saline habitat is more restricted to halophytic vegetation, whereas the freshwater habitat contains a greater variety of plants that includes grasses, forbs, and fewer xerophytic plants. Vegetation surveys identify more barren land in the saline wetlands and

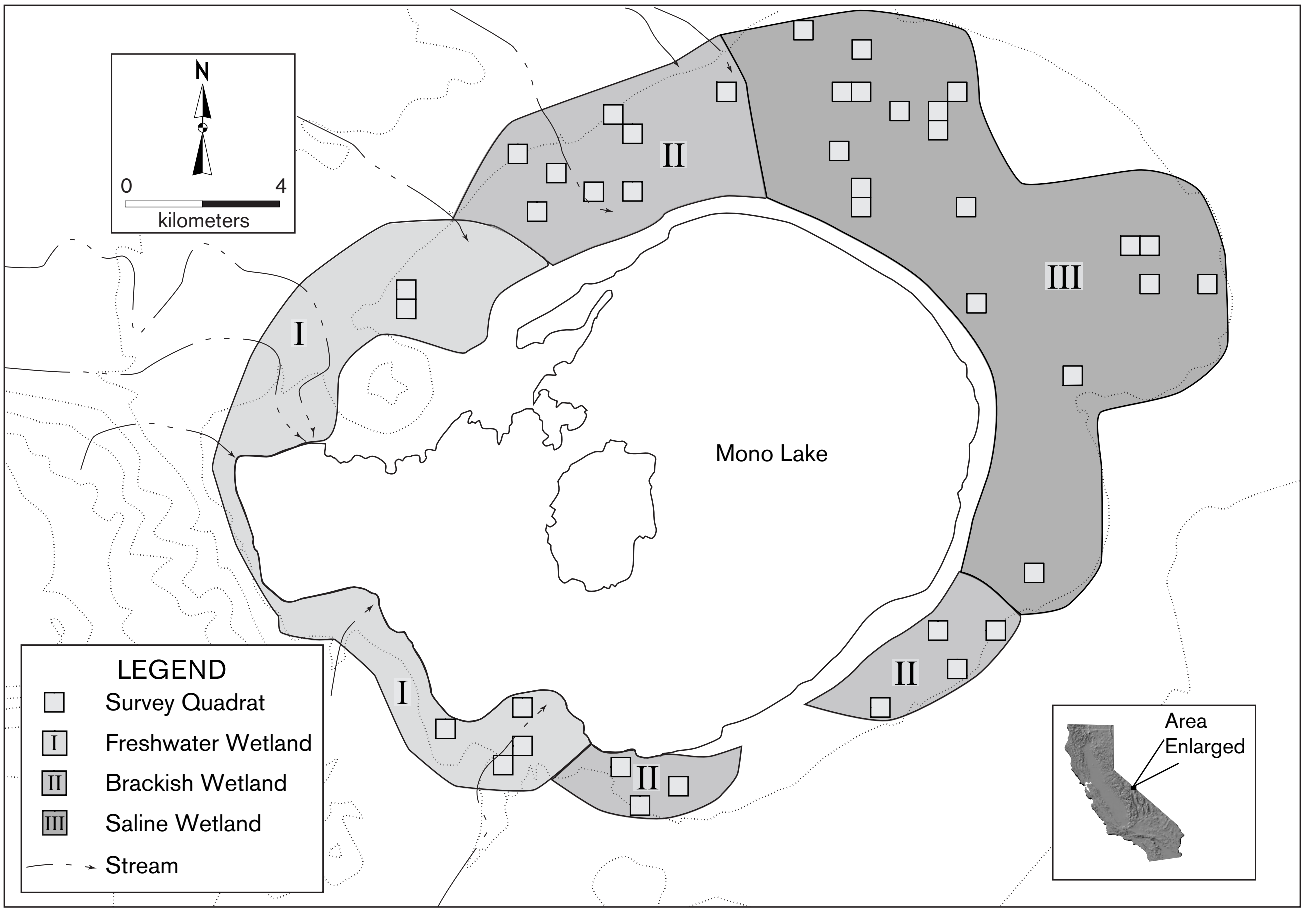
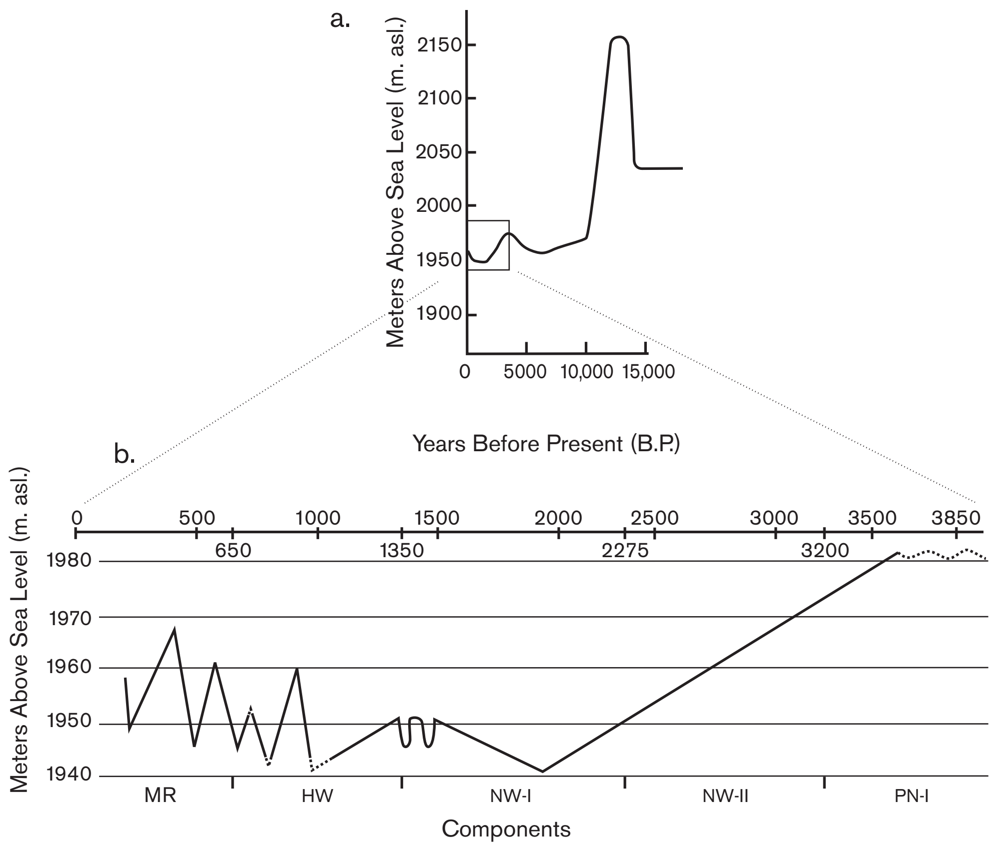


Figure 1. Mono Lake Wetland Survey (MLWS) study area with wetlands and surveyed quadrats.

denser flora in the freshwater ones (National Academy of Sciences 1987). Similarly, the mammalian fauna found in the three wetland habitats is richer in the freshwater and least so in the saline habitats (Brady 2007:Table 2.2). Brackish wetlands are intermediary to the other two in both instances. Species richness is viewed as a rough indicator of environmental productivity. Due to greater potential foraging returns, it was assumed that areas with increased richness and density of plants and animals would hold greater importance for hunter-gatherers undertaking foraging activities in the basin (Madsen 1982:212).

Prehistoric fluctuations of Mono Lake's shoreline have been reported by Stine (1987, 1990) for the last ca. 4,000 years and farther back into the Pleistocene by others (Benson et al. 1990; Lajoie 1968; Russell 1889) (Fig. 2). Prior to water diversion that began in the early 1900's, the lake fluctuations occurred in direct response to environmental conditions, such as variations in water inflow and rates of evapotranspiration (Stine 1987, 1990; Vorster 1985). Past lake fluctuations surely affected Mono Lake's near-shore wetland habitats (JSA 1993; Stine 1993), along with potential foraging opportunities.

The geographic distribution of wetland flora and fauna changes as the lake experiences transgressions or recessions (cf. Raymond and Parks 1990:Fig. 4). Each wetland class reacts differently over time as a result of differences in hydrology and geomorphology (Brady 2007; Cohen 2003; Stine 1993). The freshwater wetland migrates more readily with changes in lake elevation due to physical characteristics. By contrast, the saline habitat remains as exposed playa for longer periods during a lakeshore recession; however, emergent marshes form along the shoreline during lake transgressions or times of stability. Like the freshwater wetlands, the brackish wetlands will more easily track changes in lake elevation. Clearly, the paleoenvironmental record is important in understanding temporal changes in hunter-gatherer wetland use.



Components: MR=Marana (Historic–650 B.P.); HW=Haiwee (650–1,350 B.P.) NW-I=Newberry I (1,350–2,275 B.P.); NW-II=Newberry II (2,275–3,200 B.P.); PN-I=pre-Newberry I (3,200–4,000 B.P.).

Figure 2. Past Shoreline Elevation Changes at Mono Lake (a. after Benson et al. 1990; b. after Stine 1987).

OBSIDIAN STUDIES

Six geochemically distinct sources of obsidian are more widely dispersed in and around the basin. Source location, depicted with a 20 km. radius, illustrates differences between proximal and distant sources relative to the study area (Fig. 3). The most local source, Mono Craters (MC) (Sieh and Bursik 1986; Wood 1977), is often considered to be of poor quality when compared with other obsidian sources such as Bodie Hills (BH) or Casa Diablo (CD). This is based on MC's rather restricted spatial distribution within regional archaeological sites, being found within the Mono Basin (Arkush 1995; Bettinger 1981; Carpenter 2001; Wickstrom and Jackson 1993), but not as commonly in more outlying areas where other obsidian sources predominate (Basgall 1983; Fredrickson 1991; Goldberg et al. 1990; Rosenthal 2011). It has also been posited that artifact quality obsidian was not present until more recent times (Hull 2002; King et al. 2011:211).

The remaining five obsidian sources are more commonly represented in regional archaeological deposits, are prevalent in near-source contexts, and yet are less represented at greater distances. This pattern of linear decay has been identified at multiple quarry-related and other contexts in the Inyo-Mono region (Basgall 1983, 1984, 1998; Bieling 1992; Fredrickson 1991; Giambastiani 1998, 2004; Gilreath 2001; Gilreath and Hildebrandt 1997; Goldberg et al. 1990; Halford 1998; Jackson 1985; King et al. 2001; Overly 2002, 2004; Ramos 2008; Richman and Basgall 1998).

In the Mono Basin, Richman and Basgall (1998) found a linear distance-decay model to be applicable. Based on XRF-sourced samples collected during surface survey, sites in the southern basin were recognized

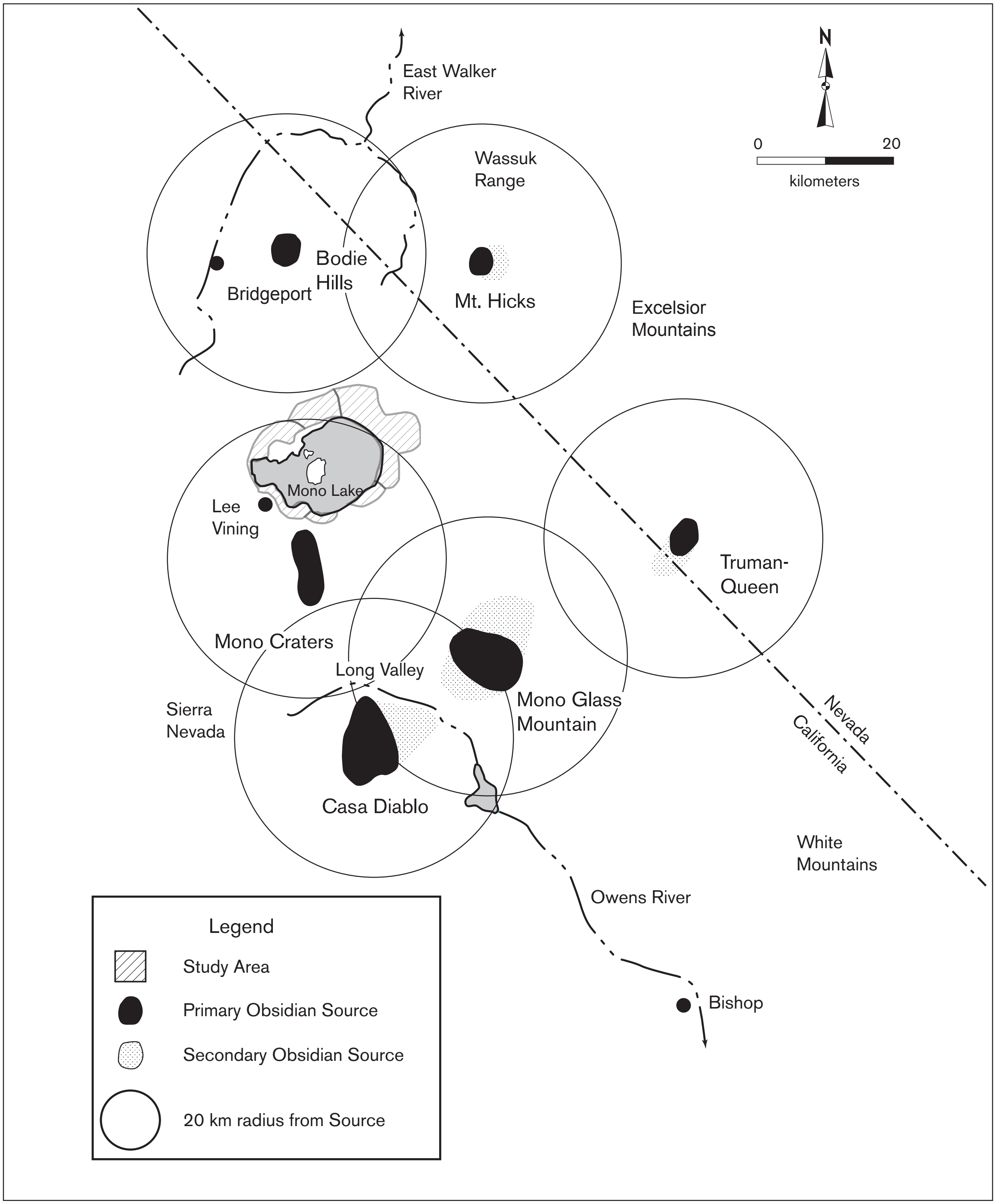


Figure 3. Obsidian Source Locations (adapted from Carpenter 2001:Fig. 3).

to more frequently contain Mono Glass Mountain (MGM) obsidian, followed by CD and MC. In the north, BH obsidian was more common, with MC being of secondary importance.

General patterns of source material distribution have been identified from an atemporal framework, yet when attention turns to obsidian hydration data, there also appear to be temporal changes in the use of particular obsidian sources. At the Lee Vining Creek site in the southwestern Mono Basin, Bettinger (1981) identified two components that demonstrate differences in source use. The lower component (>50 cm.), dated to the middle Archaic (2,950–1,250 B.P.), is predominantly composed of CD obsidian. The upper, late Archaic component (1,250 B.P.–contact [100 B.P.]) has a greater frequency of MC/MGM obsidian. A similar shift in the prevalence of CD and MC is identified from dated components in Yosemite, immediately west of Mono Basin (Hull 2002)

These studies show that CD obsidian, representing a distant obsidian source, is more common during earlier times. It follows that a greater presence of extra-local rather than local obsidian suggests more expansive travel and stone transport among the consumers. In late prehistoric times, people appear to have practiced more constrained mobility, relying instead on local MC obsidian to fulfill toolstone provisioning requirements. Similar changes in source prevalence have been noted at other sites in the southwestern Mono Basin (Carpenter 2001; Gilreath 1996; McGuire 1994; Wickstrom and Jackson 1993).[1]

Gilreath (2001), investigating this pattern, compiled hydration values for CD, BH, and MC/MGM from sites in the Mono Basin (Fig. 4). In alignment with earlier propositions, the histograms show a greater use of extra-local sources (CD, BH) in the middle Archaic (3,500–1,350 B.P.), with an increased use of MC/MGM obsidian in more recent times, as shown by smaller micron values.

Further support for a temporal change in source use is found at CA-MNO-891 in the southwestern Mono Basin (Carpenter 2001). XRF-sourced obsidian attributable to the middle Archaic component (3,500–1,350 B.P.) had the greatest quantity of CD (n=19; 46%) and other extra-local sources, while only 9% (n=4) was attributed to MC. In contrast, the late Archaic (post

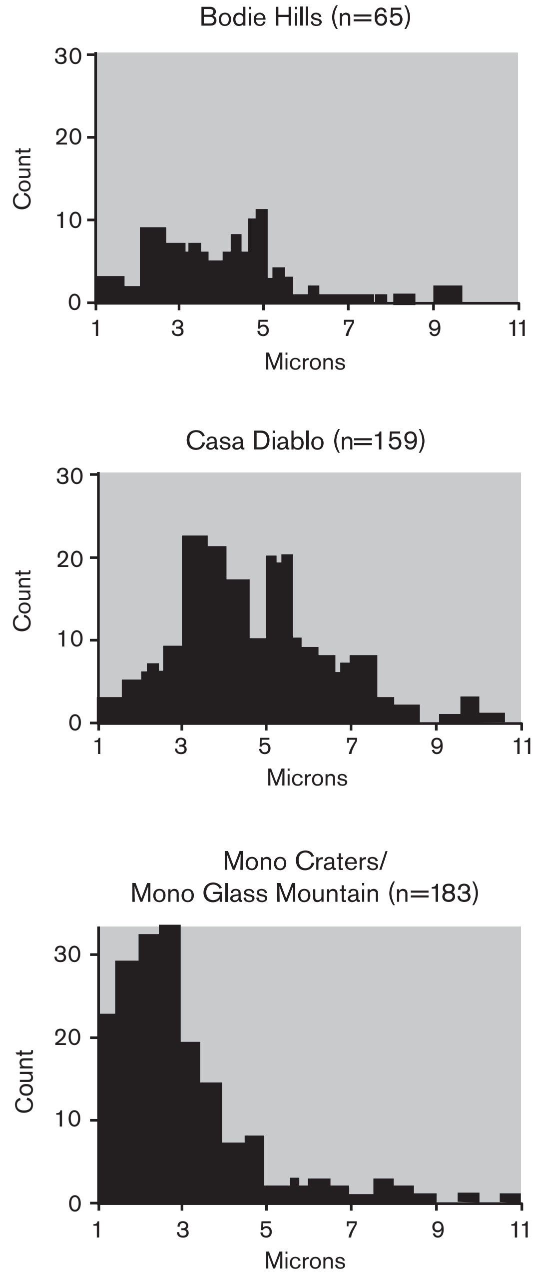


Figure 4. Frequency of XRF source determined items from Mono Basin sites (adapted from Carpenter et al. 2001:Fig. 29).

1,350 B.P.) loci contained an overwhelming majority of MC obsidian (n=15; 75%). Additional evidence for a shift in obsidian source use through time is found at CA-MNO-2122 in the southeastern Mono Basin, where 73.3% (n=11) of XRF-sourced debitage from post-850 B.P contexts is attributable to MC (Arkush 1995). No MC material was identified in the five sourced specimens from earlier contexts (CD=2, Mt. Hicks [MH]=3).

Applying these data to the prehistoric use of Mono Lake's wetlands, one may develop expectations about source distributions around the lake along with changes in source prevalence through time. Predictions are that BH would be predominant in the northwest, MH in the northeast, and CD in the south during earlier time periods. Hydration measurements with smaller values should be more commonly found on Mono Craters obsidian, with larger bands on more extra-local sources.[2]

METHODS

Surface Survey

To obtain information about how the wetlands were used in the past, the three habitats described above were randomly sampled using a distributional survey of forty 500 x 500 m. quadrats covering 10 km.^{2}, comprising 8.7% of the 115 km.^{2} study area (Fig. 1). The number of quadrats surveyed in each habitat was weighted to the relative presence of each wetland class within the study area. All flaked stone tools encountered on transect were collected, and ground stone artifacts were field recorded. Debitage, while noted during the general survey, was only collected in the debitage collection unit for each quadrat.[3]

Obsidian Source Determinations

Previous efforts at visually segregating Mono Basin sources have proved problematic due to the overlapping of certain visual characteristics (cf. Bettinger et al. 1984; Carpenter 2001; Wickstrom and Jackson 1993). As a result, low accuracy is reported for earlier visual sourcing efforts in the basin (Gilreath 2001:80–81). With this in mind, the visual sourcing program was based on attributes derived from the study of geochemically source-determined artifacts from curated archaeological collections. Visual ascriptions were tested by submitting two rounds of samples, totaling 80 specimens, for XRF analysis. The first test of 50 specimens produced unsatisfactory results (57%) and instigated a reassessment of the criteria for segregating each material type. The second test (n=30), using modified criteria that accounted for greater variability of MC visual characteristics, achieved a 90% accuracy rate, arguing for the accuracy of the remaining visual calls (Brady 2007:112–118).

In addition to using raw counts and percentages, toolstone source diversity was expressed using the complement of Simpson's index (1-D). This index is viewed as a good measure of diversity because it is not as affected by sample size as others (Magurran 2004:115). D is calculated as:

$$D = \sum \left(\frac{n_i\,[n_i - 1]}{N[N-1]} \right)$$

In the calculation, n_i= total number of items for each toolstone type, N=total number of items for all toolstone types. Values for D range between 0 and 1. With the complement of D, values closer to 0 represent low diversity, while those trending toward 1 represent infinite diversity. Additional measures are source richness (s) and evenness (E) (Magurran 2004).[4]

Obsidian Hydration Analysis

Each of the 214 collected obsidian artifacts was subjected to obsidian hydration analysis, yielding 256 hydration rims. Several variables have been identified that affect the hydration rate of a given obsidian source, including (but not limited to) the geochemical composition, relative humidity, intrinsic water content, and air temperature (Friedman and Long 1976; Friedman and Smith 1960; Friedman et al. 1997; Hull 2001; Rogers 2007, 2008, 2010; Stevens 2005; Stevenson et al. 1993, 1998; Tremaine 1993). Due to the fact that individual sources are known to hydrate at different rates, previously developed source-specific rates were implemented for the present effort (Table 1).

Based on empirical tests, correcting for effective hydration temperature (EHT) provides adequate results when comparing obsidian samples from different environmental contexts (Basgall 1990; Hull 2001; Rogers 2007; Stevens 2005). The hydration rates used in the present study were formulated in different environmental contexts; therefore, it is important to calculate an EHT correction so that each rate may be applied to Mono Basin hydration measurements. The EHT was calculated following the method proposed by Rogers (2007)[5], which includes multiple variables to characterize each temperature regime, and which has been shown to provide reasonable results when compared with other chronometric information (Eerkens et al. 2008b; Farquhar et al. 2011).

Table 1

TEMPORAL UNITS AND HYDRATION MEASUREMENT RANGES*

Temporal Units	Hydration Rate			
	Casa Diablo yBP=129.656x$^{1.826}$	Mono Craters yBP=1000(x^2/14.7)	Mono Glass Mtn. yBP=129.656(0.8x)$^{1.826}$	Truman-Queen yBP=82.74x$^{2.06}$
Marana (100–650 B.P.)	0.9–2.5µ	1.2–3.1µ	1.1–3.0µ	1.1–2.7µ
Haiwee (650–1,350 B.P.)	2.6–3.6µ	3.2–4.5µ	3.1–4.5µ	2.8–3.8µ
Newberry I (1,350–2,275 B.P.)	3.7–4.7µ	4.6–5.7µ	4.6–6.0µ	3.9–5.0µ
Newberry II (2,275–3,200 B.P.)	4.8–5.7µ	5.8–6.8µ	6.1–7.2µ	5.1–5.9µ
Pre-Newberry I (3,200–4,000 B.P.)	5.8–6.5µ	6.9–7.6µ	7.3–8.2µ	6.0–6.5µ
Pre-Newberry II (4,000–5,000 B.P.)	6.6–7.4µ	7.7–8.5µ	8.3–9.2µ	6.6–7.3µ
Pre-Newberry III (5,000–6,000 B.P.)	7.4–8.1µ	8.6–9.3µ	9.3–10.2µ	7.4–8.0µ
Pre-Newberry IV (6,000–7,500 B.P.)	8.2–9.2µ	9.4–10.5µ	10.3–11.5µ	8.1–8.9µ
Terminal Pleistocene/Early Holocene (7,500–13,500 B.P.)	9.2–12.2µ	10.6–13.5µ	11.6–15.2µ	9.0–11.4µ

*Temperature corrected. Rates derived from: Hall and Jackson 1989 (CD; also used for BH and MH); Onken 1991 (MC); Overly 2003 (MGM); Basgall and Giambastiani 1995 (TQ).

Using this method, the EHT across the study area varies no more than 0.06 °C, and is therefore essentially the same. Temperature data used to calculate the EHT comes from weather stations at Mono Lake, Cal. and Bishop, Cal. (Western Regional Climate Center 2008). The EHT for the Mono Basin is 11.81 °C. at Mono Lake and is the same for MC, since that is where the rate formulation was made (Onken 1991). The Truman-Queen (TQ) EHT is 17.2 °C., and is based on temperature data from Bishop, Cal,. since the TQ rate was developed in the nearby Volcanic Tablelands (Basgall and Giambastiani 1995). The EHT for CD in Long Valley is 16.6 °C., based on elevation corrected temperature data from Bishop. This value is also used for MGM, BH, and MH, as the sources are from higher elevations fringing the Mono Basin, and age estimates use the CD rate (or a variant of it).

Due to uncertainties regarding the accuracy of year-specific calculations from hydration data, converted hydration measurements were grouped into temporal units commonly applied to the Owens Valley, located to the south (Basgall et al. 2003; Delacorte 1999; Zeanah and Leigh 2002) (Table 1). This includes terminal Pleistocene/early Holocene (TP/EH), pre-Newberry (PN), Newberry (NW), Haiwee (HW), and Marana (MR) periods. Unexpectedly over one quarter of the readings corresponded to the PN and TP/EH time periods. To better recognize changes in land use through time, the NW and PN periods were split into six separate groups (two and four respectively). The categories show that extra-local sources are present in both early and late contexts.

Since the temporal components represent age ranges between 500 and 6,000 years, hydration counts per component were corrected to account for the variable time spans represented. The correction was made by using a simple proportion of the count of hydration measurements per component, multiplied by 6,000 and divided by the component time span. In this way, the numbers were weighted for the length of each component time span (cf. Hockett 2005, Laylander 2002). The corrected obsidian hydration data was analyzed using a chi-square test followed by a calculation of adjusted residuals.

When using contingency tables, after a significant chi-square value is recognized, adjusted residuals provide a statistical means to identify cells that are responsible for the significant value (Everitt 1992:46). Adjusted residuals are calculated as:

$$d_{ij} = e_{ij} / \sqrt{[(1 - n_{i.}/N)(1 - n_{.j}/N)]}$$

where N = total number of observations in the table; $n_{i.}$ = sum of the row total for the cell in question; $n_{.j}$ = sum of the column total for the cell in question; and e_{ij} = the expected frequency for a given cell. The expected frequency e_{ij} is calculated as:

$$e_{ij} = (\mathrm{n}_{ij} - \mathrm{E}_{ij}) / \sqrt{\mathrm{E}_{ij}}$$

where n_{ij} = the number in a given cell and $\mathrm{E}_{ij} = n_{i.}n_{.j}/N$. Significant values exceed 1.96 and illustrate instances where the phenomenon measured is significantly contributing (>1.96) or not contributing (<1.96) to the pattern being measured. Adjusted residuals have been successfully applied to regional archaeological data in order to identify changes in prehistoric settlement and technological organization (Basgall 2007; Basgall and Giambastiani 1995; Bettinger 1989, 1999; Rosenthal et al. 2011).

RESULTS

Surface Survey

General tool classes recovered within each quadrat were somewhat evenly distributed across the wetland areas (Table 2), with each wetland habitat containing quadrats with only debitage, debitage and expedient flake tools, as well as debitage along with flaked and ground stone tools. The greatest tool density was encountered in the freshwater habitat (19.3/km.^{2}), while the saline habitat contained the least (6.3/km.^{2}), and brackish habitats fell in between (10.1/km.^{2}). One pattern of artifact distribution that was noted is that bifaces were over-represented in the saline wetlands. In addition, projectile points, handstones, and millingstones were significant constituents in the northern half of the basin, while projectile points were absent in the southern half, including the freshwater habitats (Brady 2009). The freshwater wetlands also contained the only bedrock mortars encountered in the study area, suggesting a certain emphasis on plant processing.

Toolstone Material Distributions

Stone materials represented in the Mono Lake wetlands show variability by artifact class as well as across wetland habitat. Table 3 illustrates the notable lack of MC among projectile points, yet the source supplied the majority of flake tools, cores, and debitage. Though overwhelmingly weighted toward MC obsidian, the latter class also exhibits the greatest amount of stone material variability. This indicates that curated tools, such as projectile points and bifaces, were most often fabricated on extra-local stone and were transported to the wetlands in finished form. By contrast, local material was more often used to fulfill needs related to flake production and use, as shown by the high percentage of MC among flake tools, debitage, and cores.

Segregated by wetland class, stone material is differentially distributed across the habitats (Table 4). Support for differences in toolstone diversity across the three habitats is illustrated with the complement of Simpson's Index. The values show a dramatic difference in source diversity between the freshwater (0.03),

Table 2

QUADRAT TOOL CONSTITUENTS

Wetland Class	Empty	DEB only	GST only	DEB & FTL	DEB & FTL	DEB & GST	DEB, FST & GST	TOTAL
Freshwater	–	2 (33%)	–	2 (33%)	–	1 (17%)	1 (17%)	**6**
Brackish	2 (13%)	2 (13%)	–	1 (7%)	2 (13%)	2 (13%)	6 (40%)	**15**
Saline	–	11 (58%)	1 (5%)	2 (11%)	–	2 (11%)	3 (16%)	**19**
Total	**2 (5%)**	**15 (38%)**	**1 (3%)**	**5 (13%)**	**2 (5%)**	**5 (13%)**	**10 (25%)**	**40**

Note: Number is count of quadrats containing each tool class group; DEB = debitage; GST = ground stone tool; FTL = flake tool (expedient); FST = flaked stone tool (formed).

Table 3

TOOLSTONE SOURCE BY ARTIFACT CLASS

Tool Class	CD	MC	BH	MH	MGM	TQ	CCS	BAS	TOTAL
Projectile Point	1 (14%)	–	3 (14%)	1 (14%)	1 (14%)	1 (14%)	–	–	**7**
Biface	3 (30%)	2 (20%)	2 (20%)	2 (20%)	1 (20%)	–	–	–	**10**
Flake Tool	2 (5%)	25 (63%)	2 (5%)	6 (15%)	–	1 (3%)	4 (10%)	–	**40**
Core	–	6 (100%)	–	–	–	–	–	–	**6**
Debitage	2 (1%)	144 (89%)	3 (2%)	3 (2%)	2 (1%)	1 (1%)	4 (2%)	2 (1%)	**161**
Total	**8 (4%)**	**177 (79%)**	**10 (5%)**	**12 (5%)**	**4 (2%)**	**3 (1%)**	**8 (4%)**	**2 (1%)**	224

CD = Casa Diablo; MC = Mono Craters; BH = Bodie Hills; MH = Mt. Hicks; MGM = Mono Glass Mountain; TQ = Truman-Queen; CCS = cryptocrystalline silicate; BAS = basalt.

Table 4

TOOLSTONE SOURCE BY WETLAND CLASS

Wetland Class	CD	MC	BH	MH	MGM	TQ	CCS	BAS	TOTAL
Freshwater									
Tools	–	16 (100%)	–	–	–	–	–	–	**16**
Debitage	–	50 (98%)	–	–	–	1 (2%)	–	–	**51**
Brackish									
Tools	3 (13%)	7 (30%)	5 (22%)	6 (26%)	–	1 (4%)	1 (4%)	–	**23**
Debitage	–	53 (95%)	1 (2%)	1 (2%)	–	–	–	1 (2%)	**56**
Saline									
Tools	3 (17%)	4 (22%)	2 (11%)	3 (17%)	2 (11%)	1 (6%)	3 (17%)	–	**18**
Debitage	2 (4%)	41 (76%)	2 (4%)	2 (4%)	2 (4%)	–	4 (7%)	1 (2%)	**54**
Total	**8 (4%)**	**177 (79%)**	**10 (5%)**	**12 (5%)**	**4 (2%)**	**3 (1%)**	**8 (4%)**	**2 (1%)**	224

CD = Casa Diablo; MC = Mono Craters; BH = Bodie Hills; MH = Mt. Hicks; MGM = Mono Glass Mountain; TQ = Truman-Queen; CCS = cryptocrystalline silicate; BAS = basalt.

brackish (0.41), and saline (0.59) wetlands. The similarity between the brackish and saline wetlands is at odds with the environmental characterization.

Similar patterns of source distribution are identified through source richness and evenness values across the three habitat types. Richness values (s) for toolstone material are 2 (freshwater), 7 (brackish), and 8 (saline), recognizing the greater number of sources/materials present in the brackish and saline habitats. Evenness measurements pose a slightly different order, with source variability becoming more uneven from the freshwater ($E = 0.52$), saline ($E = 0.30$), and brackish ($E = 0.24$) habitats. Low evenness values in the brackish habitat are affected by the higher incidence of MC obsidian relative to the other sources, while the saline habitat has slightly less MC and relatively greater amounts of the remaining sources/materials. Although a Mann-Whitney U test fails to demonstrate significant differences between the samples with $p < 0.05$, source diversity is made apparent by other means.

Considering toolstone diversity as an indicator of past mobility range, it appears that the saline habitat represents a more wide-ranging settlement pattern, whereas the overwhelming emphasis on local obsidian found in the freshwater region indicates a more localized occupation. Source diversity in the brackish wetlands is more similar to that of the saline habitat, and toolstone deposition reflects more varied or wide-ranging settlement strategies.

The dispersion of stone material shows some correspondence with what is expected in a linear distance-decay model (Table 4). The predominance of MC in the freshwater habitat is expected in the linear model, though its continued high presence in brackish and saline habitats is less expected, especially when considering patterns previously identified in the Mono Basin (Arkush 1995; Bettinger 1981; Carpenter 2001; Richman and Basgall 1998).

Separating tools and debitage, the percentage of tools by toolstone variety supports expectations of the linear model in the brackish habitat, with northern sources (BH and MH) showing the greatest presence after MC. The saline region presents greater divergence from expectations. The greater frequencies of CD and cryptocrystalline silicate (CCS) suggest, along with the higher diversity index, more wide-ranging land use when people were initially exploiting the saline wetlands.

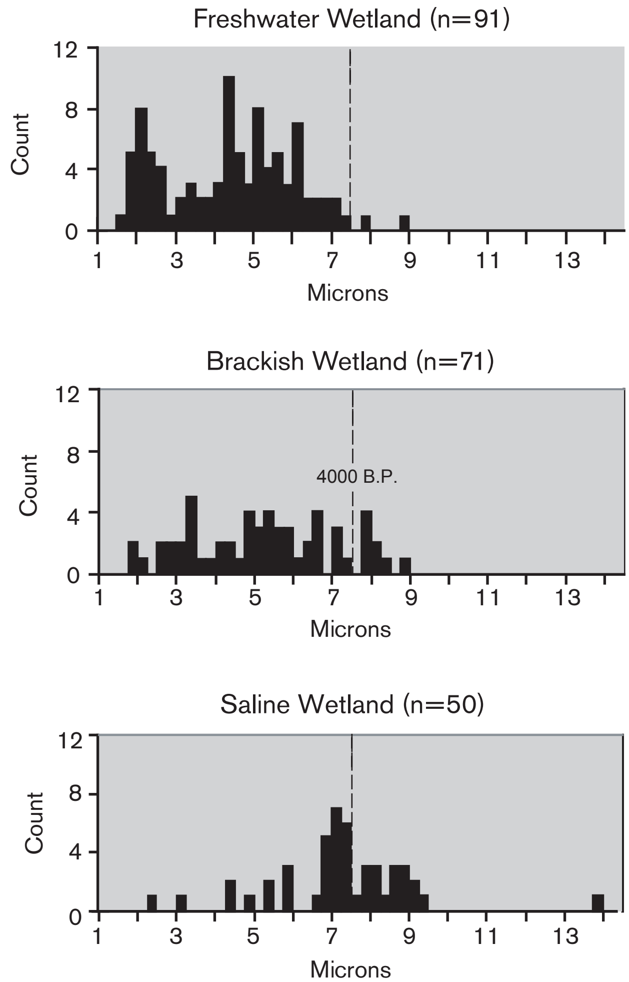


Figure 5. Histograms of Mono Craters obsidian hydration measurements from the MLWS.

OBSIDIAN HYDRATION ANALYSIS

MC hydration measurements from each wetland habitat are presented as histograms in Figure 5. Raw counts show the saline wetland to be more intensively used in early times, at around seven microns (ca. 3,300 B.P.) and older, while the freshwater region sees greatest use in more recent times. The brackish wetlands exhibit more continuous use from the early part of the sequence, but with a decrease in use in more recent times. T-tests comparing MC micron values across the three wetland habitats identify significant differences between the three samples (Freshwater-Brackish, $t=-2.69$, d.f. 162, $p<0.01$; Freshwater-Saline, $t=-6.03$, d.f. 160, $p<0.001$; Brackish-Saline, $t=-3.30$, d.f. 138, $p<0.001$).

Local versus Extra-local Obsidian Use

In considering the distribution of component-grouped hydration measurements, a first order of analysis is to compare the prevalence of MC to non-MC obsidian in the sample over time. Adjusted residuals illustrate that for time corrected values, it is apparent that non-MC obsidian is significantly overrepresented before 6,000 years ago (PN-IV), with MC becoming prominent more recently (Table 5). There is a weaker, fluctuating presence of local and extra-local sources between PN-III and NW-II times; however, non-MC obsidian is again significantly overrepresented in NW-I. Meeting expectations, the two most recent prehistoric periods are the only times that MC is significantly overrepresented relative to non-MC obsidians. The spike in non-MC obsidian during NW-I is also notable and deserves further discussion.

Two possible factors may account for the increased presence of non-MC obsidians during NW-I times: (1) increased artifact scavenging from older archaeological deposits; or (2) an expanded mobility range during the

Table 5

MC VS. NON-MC OBSIDIAN BY TEMPORAL COMPONENT*

	MR	HW	NW-I	NW-II	PN-I	PN-II	PN-III	PN-IV	TP/EH
COUNT									
MC	42	40	52	28	28	13	7	0	1
Non MC	5	5	13	4	5	3	2	2	6
Total	**47**	**45**	**65**	**32**	**33**	**16**	**9**	**2**	**7**
						$X^2 = 35.79$, df = 8; $p < 0.001$			
CORRECTED									
MC	458	343	337	182	210	78	42	0	1
Non MC	55	43	84	26	38	18	12	8	6
Total	**513**	**386**	**421**	**208**	**248**	**96**	**54**	**8**	**7**
						$X^2 = 97.38$, df = 8; $p < 0.001$			
RESIDUAL									
MC	3.13	2.34	–3.26	1.05	–0.18	–1.07	–1.52	–6.76	–5.26
Non MC	–3.13	–2.34	3.26	–1.05	0.18	1.07	1.52	6.76	5.26

*Temperature adjusted. MR = Marana (Historic [100] – 650 B.P.); HW = Haiwee (650 – 1,350 B.P.); NW-I = Newberry I (1,35014 – 2,275 B.P.); NW-II = Newberry II (2,275 – 3,200 B.P.); PN-I = pre-Newberry I (3,200 – 4,000 B.P.); PN-II = pre-Newberry II (4,000 – 5,000 B.P.); PN-III = pre-Newberry III (5,000 – 6,000 B.P.); PN-IV = pre-Newberry IV (6,000 – 7,500 B.P.); TP/EH = Terminal Pleistocene/Early Holocene (7,500–13,500 B.P.); MC = Mono Craters obsidian; Non MC = non Mono Craters obsidian. CORRECTED = values adjusted to 6,000 year time span for each component; RESIDUAL = adjusted residual.

time interval. The first proposition could account for an increased presence of non-local sources during the NW-I interval. Mono Lake underwent a lakeshore recession during this time period, making wetland productivity similar to what it was in PN-III and earlier times. This would have provided foragers access to obsidian tools and debitage associated with earlier archaeological deposits. Raw material scavenging is sometimes identified in items with multiple hydration bands. Evidence of stone material scavenging from older archaeological deposits has been identified in other Inyo-Mono contexts (though typically post-Newberry). In these contexts, raw material profiles often mirror those identified from earlier deposits (Basgall and Giambastiani 1995; Basgall and McGuire 1988; Delacorte 1999:256–258; Delacorte et al. 1995; Gilreath 1995:251, but see Eerkens et al. 2008a).

Late Newberry (NW-I) non-MC samples are from quadrats with more extensive earlier hydration values, along with greater source diversity.[6] Interestingly, the incidence of artifacts with multiple hydration bands accounts for 22% (n = 14) of the hydration measurements dating to this era, compared with only 16% (n = 32) for the remaining sample, which lends support to the idea that scavenging may have been somewhat more prevalent during this time. However, only 14% (n = 2) of the NW-I artifacts with multiple hydration bands are from non-MC obsidian, suggesting that the increased prevalence of non-MC obsidian at this time may be due to other factors, such as a more expansive mobility range.

A rise in logistical mobility leading up to NW-I times has been documented in the western Great Basin (Basgall and McGuire 1988; Basgall et al. 2003; Delacorte 1997, 1999; Delacorte et al. 1995; King et al. 2001; Zeanah and Leigh 2002), and more generally across much of western North America (Hildebrandt and McGuire 2002; McGuire and Hildebrandt 2005). This behavior would bring people into contact with a greater range of environments, and possibly stone material sources.

There is some debate as to why this change in settlement organization occurred; whether it was related to the sexual division of labor and differential foraging goals relative to environmental productivity (i.e., increased importance of women's foraging activities) (Zeanah 2004), or occurred as a result of heightened large game acquisition by logistically-organized hunting parties for prestige-related benefits (Hildebrandt and McGuire 2002; McGuire and Hildebrandt 2005). One important difference between the two views involves the question of whether the residential base camps from which the logistical parties traveled were sedentary/semi-sedentary villages (King et al. 2001; McGuire and Hildebrandt 2005:705), or were seasonally (winter) occupied localities (Basgall and McGuire 1988; Basgall et al. 2003:357; Zeanah and Leigh 2002:654–658).

Table 6

OBSIDIAN HYDRATION MEASUREMENTS BY TEMPORAL COMPONENT AND WETLAND CLASS*

	MR	HW	NW-I	NW-II	PN-I	PN-II	PN-III	PN-IV	TP/EH
COUNT									
Freshwater	27	23	26	13	4	0	1	0	0
Brackish	16	16	28	11	9	4	1	2	6
Saline	4	6	11	8	20	12	7	0	1
Total	**47**	**45**	**65**	**32**	**33**	**16**	**9**	**2**	**7**
						$\chi^2=83.98$, df=16; $p<0.001$			
CORRECTED									
Freshwater	294	197	169	84	30	0	6	0	0
Brackish	175	137	181	72	68	24	6	8	6
Saline	44	52	71	52	150	72	42	0	1
Total	**513**	**386**	**421**	**208**	**248**	**96**	**54**	**8**	**7**
						$\chi^2=563.14$, df=16; $p<0.001$			
RESIDUAL									
Freshwater	9.22	4.86	−0.02	0.06	−9.66	−8.24	−4.42	−2.32	−2.17
Brackish	−0.42	0.28	3.95	−0.08	−2.64	−2.08	−3.72	3.87	2.83
Saline	−9.98	−5.82	−4.33	0.02	13.85	11.63	9.10	−1.63	−0.65

*Temperature adjusted. MR=Marana (Historic [100]–650 B.P); HW=Haiwee (650–1,350 B.P.); NW-I=Newberry I (1,35015–2,275 B.P.); NW-II=Newberry II (2,275–3,200 B.P.); PN-I=pre-Newberry I (3,200–4,000 B.P.); PN-II=pre-Newberry II (4,000–5,000 B.P.); PN-III=pre-Newberry III (5,000–6,000 B.P.); PN-IV=pre-Newberry IV (6,000–7,500 B.P.); TP/EH=Terminal Pleistocene/Early Holocene (7,500–13,500 B.P.); MC=Mono Craters obsidian; Non MC=non Mono Craters obsidian. CORRECTED=values adjusted to 6,000 year time span for each component; RESIDUAL=adjusted residual.

The current data presented here can shed some light on this debate, as there appears to be increased access to more extra-local stone sources within the time frame in question. That five of the seven projectile points from the project have hydration measurements that correspond to the NW-I era suggests an increased importance of hunting, possibly from base camps situated adjacent to Mono Lake's wetlands. Moreover, bifaces, cores, and flake tools also provide hydration measurements dating to this era, suggesting that a variety of processing/retooling activities occurred around the fringe of the lakeshore. The suite of the four tool classes is not present together in the remaining components. Additionally, ground stone artifacts are present in 71% (n=5) of the quadrats with non-MC hydration readings dating to the NW-I interval, and 60% (n=3) of the quadrats with double-band hydration measurements.

A definitive temporal placement of the ground stone artifacts is hampered by the fact that they were surface finds, and quadrats with multiple hydration readings generally exhibit an extended temporal range. Nevertheless, the association of ground stone artifacts along with the NW-I hydration measurements on both non-MC and MC obsidian suggests that the lakeshore may have served as a locality for seasonal base camps. From the base camps, logistical forays could be made to the uplands while the remaining family unit stayed behind at lakeshore base camps to exploit wetland resources.

Temporal Changes in Wetland Use

While it appears that a linear distance-decay model does not fully account for the distribution of materials relative to Mono Lake's near-shore wetlands, a model that accounts for changing mobility strategies through time better explains the arrangement. When source specific hydration values are converted to temporal components and corrected for component time span, there is an apparent pattern of temporal change in wetland use that is also affected by geography and lake level fluctuation (Table 6). The earliest wetland use before 6,000 B.P. (EH, PN-IV) occurs mainly in the brackish habitats. The hydration readings come largely from artifacts in the northwestern basin and are associated with a time of rapidly decreasing lake levels. During the remaining portion of the pre-Newberry era, land use intensity was focused on the saline habitat. At this time, Mono Lake's elevation remained relatively low, increasing to a high stand during the PN-I period. Items pertaining to this era are primarily debitage and suggest short-term use.

During the Newberry era, there is a shift in emphasis from the saline to the brackish habitat. This appears to be a response to a lake-level decline that promoted wetland instability (especially in the saline habitat). As the lake level declined, geomorphic and hydrologic conditions indicate that wetlands in the saline area would not have been able to migrate downslope as the lake receded, but would instead have dried up. In contrast, conditions in the more well-watered western area allowed wetlands to re-establish on newly exposed lakebed.

Corresponding with this change, there was increased toolstone procurement from local quarry areas in the southwest. Toolstone acquisition is apparent at this time in southwestern freshwater and brackish quadrats where Mono Craters obsidian is present in the alluvium and there is abundant debitage and assayed cobbles.

Throughout the Haiwee (HW) and into the Marana (MR) periods, land use focused on the freshwater habitats at the expense of both the brackish and saline wetlands. That people increasingly spent more time in the area is demonstrated by the variety and greater density of discarded tools, along with the presence of bedrock mortar features. These imply recurring if not relatively more stable residence than found earlier. Being near permanent water sources, the freshwater habitats may have been preferable for occupations of greater duration. These latest time periods, dating from about 1,350 years ago, are associated with increased lake level oscillations. Rapid fluctuations have a more detrimental effect on the migration of wetlands or the revegetation of exposed playa in other areas around the lake.

DISCUSSION

Evidence presented here points to changes in the use of near-shore wetlands at Mono Lake throughout the Holocene. One avenue of exploration tested a linear distance-decay model of toolstone source prevalence from known obsidian sources in the vicinity of the Mono Basin. In contrast to expectations developed from excavated assemblages in the Mono Basin and in nearby areas, Mono Craters was the most prevalent source in all three habitats. When the focus was restricted to formal tools and expedient flake tools, a distance-decay model showed a somewhat better fit, accounting for the use of some alternative sources.

Source specific, temperature-corrected obsidian hydration data illustrate changing patterns of land use, with the earliest Holocene use of the basin found in the brackish wetlands. Middle to early-late Holocene times (PN-III to PN-I) had the most intensive obsidian deposition in the saline habitat. During NW-II, there appeared to be no preference for a given wetland habitat, possibly as a result of a continued lakeshore decline during this era. The late Newberry (NW-I) occupation again emphasized the brackish wetlands, while the latest Holocene use of the Mono Basin wetlands was strongly focused on the freshwater wetlands.

Recognizing temporal changes in land use better illuminates differences in obsidian source distributions than a linear distance-decay model. The earliest use of the basin involved a significant use of non-MC obsidian and was focused on the brackish habitat. Later (PN-III to PN-I) occupations shifted to the saline wetlands, where MC obsidian is prevalent; however, this habitat also contains the greatest toolstone diversity of the three wetlands, suggesting continued high levels of residential mobility with an array of sources represented in the toolkit. In late Newberry (NW-I) times, there was a shift to the brackish habitat and a renewed heightened presence of non-MC obsidian. This indicates an expanded mobility range, and possibly represents residential base camps within a logistically organized settlement system. Late Holocene (HW, MR) occupation of the study area was most intensive in the freshwater wetlands, and involved localized toolstone use.

As noted previously, tool densities were lowest in the saline habitat and highest in the freshwater habitat, suggesting that people were spending more time in the latter area and visiting the former on a more short-term basis. Additionally, the saline habitat is notable for the prevalence of bifaces and bifacial flaking debris, while the freshwater wetlands have a predominance of cores, core reduction debitage, and non-portable milling features (Brady 2007, 2009). The relationship between bifaces and mobility, along with associations of core reduction use and sedentism, is discussed in more depth elsewhere (Kelly 1988; Parry and Kelly 1987; but see Railey 2010), but is presented here as supporting evidence for greater residential stability in the late prehistoric use of the freshwater wetlands at Mono Lake.

Placing the current study within the greater context of wetland use in the Great Basin or other semi-arid environments, it appears that wetlands must be understood not only for what they have to offer relative to the surrounding environment; one must also consider the settlement strategy being practiced, the potential resources being targeted, and the paleoenvironmental history of a given wetland. The wetlands at Mono Lake do not indicate the presence of the same levels of intensive activity that are found at other Great Basin wetlands (cf. Janetski and Madsen 1990; Livingston 1986; Oetting 1989; Simms 1999; Zeanah 2004), yet this lakeshore habitat contains data relevant to changes in settlement and mobility throughout the Holocene that have not been previously addressed.

NOTES

[1] Recent research in the western Great Basin regarding temporal patterns of source diversity has identified instances of heightened source diversity in the latest prehistoric intervals (cf. Eerkens et al. 2008a; McGuire 2002; Smith 2010). In these contexts, source profiles are as variable, if not more so, than those of earlier components. The degree to which the scavenging of raw material from older archaeological deposits or more varied trade relations might have affected this pattern, rather than increased late prehistoric mobility, is unclear. The fact that studies from obsidian quarries in the Inyo-Mono region show a consistent, significant decline in late prehistoric obsidian acquisition (Gilreath and Hildebrandt 1997; Halford 2008; Ramos 2008; Singer and Ericson 1977) lends support to the scavenging hypothesis (cf. Delacorte 1999), with changing social relations potentially introducing new or previously underrepresented raw material (Basgall and Delacorte 2003; Eerkens and Spurling 2008; Zeanah and Leigh 2002:659).

[2] One confounding factor may be general patterns of lithic conveyance after acquisition from the sources. For example, Bodie Hills and Casa Diablo obsidians are common west of the Sierra Nevada (Bouey and Basgall 1984; Jones et al. 1996; King et al. 2011; Rosenthal and McGuire 2005), while Mt. Hicks and Truman-Queen obsidians are more commonly found at sites located to the east (Giambastiani 2004; Jones et al. 2003; Ramos 2008; Smith 2007).

[3] Survey methodology operated under a distributional (Ebert 1992) or non-site (Thomas 1975) approach, where the individual artifact is treated as the unit of analysis. Following this approach, artifacts identified on transect were recorded and collected. Tools encountered outside of the 5 m. transect area (for example, when recording a site) were not included in the sample. General transects within the quadrat were spaced at 25 m. intervals. A 100 x 100 m. debitage collection unit was situated in the southwest corner of each quadrat. Transect spacing was reduced to 10 m. intervals within the debitage collection units.

[4] Evenness is calculated as a modification of Simpson's D where $E_{1/D} = (1/D)/S$ (Magurran 2004:116)

[5] The method proposed by Rogers (2007) produces slightly elevated EHT measurements compared to an alternative method that uses Lee's (1969) temperature integration equation, following Basgall (1990, 1998; see also Origer 1982).

[6] One freshwater, four brackish, and two saline quadrats.

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