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It has long been thought that the only means by which the American Southwest’s extensive pinyon-juniper woodlands, with their inherently low primary productivity, could have supported indigenous populations during prehispanic times was with the transformative consequences associated with the widespread cultivation of low-moisture-intolerant domesticated plants, principally maize (Zea mays L.). In this paper we present an alternative to this orthodox view which posits that anthropogenic fire was a vegetation-community management technology that was used to create disturbance patches and to propagate abundant, edible seed-rich ruderals in them. This perspective allows us, as well, to introduce and illustrate the interpretive possibilities of a conceptual scheme that focuses on three resource production types—cultivated wild plants, gathered wild plants, and domesticated plants—with multi-contextual macrobotanical data from a partially burned and rapidly abandoned multi-room settlement (occupied between AD 1070–1080) located south of the Grand Canyon in northern Arizona. By integrating these data with previous archaeobotanical, pollen, and sedimentary micro-charcoal studies, we propose that the systematic cultivation of wild plants in pyrogenic resource patches was a sustainable practice that enhanced food-supply security by insulating populations from the effects of short-term environmental variability and long-term climate change that challenge maize farmers. Importantly, these investigations indicate that low-intensity burning did not involve widespread deforestation, as some models of Holocene climate change suggest, and that prehistoric depopulation and modern fire suppression have altered fundamentally the composition and economic potential of contemporary pinyon-juniper ecosystems.

Keywords: fire, pinyon-juniper woodlands, ruderal production, archaeobotanical analysis

Despite its romantic appeal as a time of renewal, springtime in America can be a wicked season marked by floods, drought, and devastating wildfires, particularly in the arid West. As predictable as the appearance of tornadoes and dandelions, warnings are issued routinely for residents in wildfire-prone areas to brace themselves for yet another active fire season (e.g., Banks and Noel 2014). Although anthropogenic climate change is commonly invoked as one cause of the increasing frequency and severity of these dangerous conditions (e.g., Schwinning et al. 2008), it is worth remembering that humans have been coping with blazing landscapes for millennia (Pyne 2012). In fact, the “early anthropogenic” hypothesis of William F. Ruddiman (2003) posits that the expansion of farming and the clearing of forests by burning may have increased atmospheric levels of methane and carbon dioxide well before the Industrial Age (Smith and Zeder 2013). Although one could quibble with Ruddiman’s terminology (e.g.,
“simple peasant agriculture”) and scale of analysis (e.g., the entire environmentally and culturally diverse American Southwest is one case), his proposition has exposed the extent of our embryonic knowledge about the role of anthropogenic fire in ancient economies and vegetation management (Glikson 2013).

For instance, despite the attention fire receives in modern life, considerations of its effects have rarely figured in archaeologists’ accounts of North American indigenous subsistence practices (e.g., Barton 2014:313; Minnis 2000:279; Smith 2011a:597–598; Sullivan 1982)—fire ecologists, environmental historians, geographers, and cultural anthropologists have assumed the bulk of that responsibility (e.g., Allen 2002; Lewis and Anderson 2002; Myers and Doolittle 2014; Parker 2002; Pyne 1982; Steward 2002; Williams 2002:182–185). Historically, Southwest archaeologists, in contrast to their European counterparts (e.g., Mason 2000; Mellars 1976; Rösch et al. 2002), have developed a host of creative non-fire-based models to understand the economies that sustained the ancient societies that once occupied the region’s extensive pinyon-juniper woodlands, such as those that cloak the uplands of the Colorado Plateau (e.g., Euler et al. 1979), where archaeological sites are thickly concentrated (Ortman et al. 2012; Tainter 1984). These models, however, invariably focus almost exclusively on the environmental conditions that affect the production of low-moisture-intolerant domesticated plants, principally maize (Zea mays L.) (e.g., Benson et al. 2013; Spielmann et al. 2011). In fact, it has long been suggested that, because of their comparatively low natural primary productivity (Haberl et al. 2007), pinyon-juniper woodlands could support aboriginal occupation only after maize agriculture had been adapted to the variable growing conditions that prevail in these widespread, heterogeneous ecosystems (Ford 1984; Matson 1991; Peeples et al. 2006).

The core tenets of these understandings about maize-centric societies have become so deeply ingrained in Southwest archaeological theory and method (e.g., Benson 2011; Gumerman et al. 2003) that they have assumed paradigmatic status in view of their pervasiveness and ostensible unassailability (e.g., Kohler et al. 2012). Consequently, the frequently attributed riskiness of maize farming in pinyon-juniper ecosystems, regionally (e.g., Dean et al. 1994) or locally (e.g., Bellorado and Anderson 2013), is the inspiration for inferences regarding, for example, the variable expression (temporally and spatially) of trade and exchange networks (e.g., Nelson 1996), settlement relocation (e.g., Kohler et al. 2000), ecological impacts (e.g., Dickson 1993; Minnis 2000), and ultimately occupational curtailment (e.g., Axtell et al. 2002; Betancourt and VanDevender 1981). Nonetheless, despite widespread theoretical commitment to the centrality of maize farming in ancient Southwest societies, maize production itself has rarely been substantiated empirically with archaeological data (in contrast to evidence for maize consumption; see Fish and Donaldson [1991] in regards to this important distinction). In fact, as Gleichman and Gleichman (1992:30) candidly report: “Exactly where they farmed is therefore left open to question.” Such lacunae in our knowledge about the basic aspects of food supply systems (Schroeder 2013; Wills and Dorshow 2012), however, has not prevented Southwest archaeologists from simulating the locations and extent of maize farming and projecting their demographic and socio-ecological consequences (e.g., Barton 2014; Johnson et al. 2005; Pool 2013).
With these considerations in mind, we intend to nudge the archaeological study of ancient subsistence economies in pinyon-juniper ecosystems in a direction that is unconstrained by the assumptions of the “maize paradigm,” as sketched above (for additional details see Sullivan in press). First, we introduce and explore the interpretive advantages of a conceptual scheme for thinking about variation in pinyon-juniper subsistence economies based on differences among three resource production types: 1) cultivated wild plants; 2) gathered wild plants; and 3) domesticated plants (cf. Diehl 2005:78–79; Harris 2007:28–30; Smith 2011b:839, 841). We illustrate the effectiveness of conceptualizing plant-use patterns in these terms with new multi-contextual macrobotanical data from a partially burned, multi-room masonry ruin (occupied AD 1070–1080) located in a dense pinyon-juniper woodland south of the Grand Canyon in northern Arizona (Berkebile 2014). Second, we discuss the economic implications of a food-supply model for the ancient occupants of pinyon-juniper ecosystems that features the productive advantages of anthropogenic, indigenous fire ecology (Fowler 2013). By focusing on the effects of human-controlled ignitions of surface/understory fuels in pinyon-juniper woodlands, we show how our archaeobotanical data align with the production of ruderals—plants that thrive in pyrogenic disturbances (Grime 2001) and whose productive capacities are largely unaffected by variation in factors, such as soil nutrients, temperature, and precipitation patterning, that bedevil maize farming (Benson et al. 2013; Toll 1995). Finally, we conclude with some thoughts about the necessity of incorporating archaeological data for understanding pinyon-juniper ecosystem histories, particularly for those periods that predate fire-scar chronologies, and for appreciating the profound compositional differences between prehistoric and modern vegetation communities (cf. Briggs et al. 2006).

The Upper Basin and Its Pinyon-Juniper Woodland

Our study area is the Upper Basin, a down-faulted and tilted portion of the Coconino Plateau in north-central Arizona that is approximately 251.3 km² in area (Figure 1) (Morales 2003; Strahler 1944a). The northern terminus of this graben is the South Rim of the Grand Canyon with an elevation of 2286 m at Desert View; from there, the Upper Basin slopes south to the base of the Coconino Rim (the lowest elevation is 1860 m at Lee Canyon; Sullivan and Ruter 2006:182–183).

Precipitation Patterns

For tens of millions of years, the Upper Basin has been capped by fossiliferous Kaibab Limestone, which is the uppermost member of the Grand Canyon sequence (Hopkins and Thompson 2003). Kaibab Limestone is heavily fractured and, consequently, does not retain precipitation; hence, today, the Upper Basin has no streams, seeps, springs, or other sources of surface water (Metzger 1961; Rand 1965:210). However, during the period when the Upper Basin was occupied, principally between the tenth and twelfth centuries AD (Euler 1988), its residents built a variety of strategically-placed catchments to capture rainwater and snowmelt (Norr 1997). Nonetheless, an analysis of the
area’s historic precipitation record reveals that two periods of low rainfall can be expected yearly: one develops in late spring and another in the fall, precisely bracketing the traditional growing season for maize (Sullivan and Forste 2014:141–142). Paleo-dendroclimatological research indicates that this pattern was in place when the area was occupied prehistorically (Dean 1996). In addition, tree-ring reconstructed precipitation values for this area of the Coconino Plateau suggest that Upper Basin maize farmers would have been challenged profoundly to successfully produce harvests annually (Sullivan and Ruter 2006:185–188), which helps explain why direct evidence of maize from well-dated archaeological contexts is scarce in the region (Sullivan 1996, in press).

Vegetation Patterns

The Upper Basin is covered by a dense woodland, dominated by pinyon (Pinus edulis Engelm.) and juniper (Juniperus sp.) (Brown 1994), that thins to a savanna-like grassland in its southern and southeastern reaches, and merges with ponderosa pine (Pinus ponderosa Lawson & C. Lawson) and Gambel oak (Quercus gambelii Nutt.) in its western stretches as the forest ascends the slopes of the Coconino Rim (Figure 1) (Huffman et al. 2008). Paleoecolological analysis of pack-rat middens in the eastern Grand Canyon has determined that these
vegetation communities (woodlands and grasslands) have been around at least since the terminal Middle Holocene to Late Holocene (ca. 5000–4000 yrs BP [Cole 1982, 1990]), although abundances of pinyon and juniper trees have varied considerably within the community through time (Cole and Cannella 2005).

The composition and dynamics of modern pinyon-juniper woodlands in the Grand Canyon area have been intensively studied for nearly a century (e.g., Darling 1967; Merkle 1952; Miller 1921; Rand 1965; Strahler 1944b; Vankat 2013). Even though the factors that influence the spatial extent and boundaries between grassland/savannas and woodlands are fairly well understood, specific local effects that are attributable to complicated interactions among “drivers” such as climate, ungulate population dynamics, lightning-caused fires, anthropogenic fires, fire exclusion, and grazing, are differentially expressed (Romme et al. 2009). Informed by these considerations, the pinyon-juniper woodland of the Upper Basin has been classified as a persistent type (Vankat 2013:272; see also Huffman et al. 2013) in view of its variable stand structure (e.g., heterogeneous densities of pinyon and juniper trees of various sizes), discontinuous (patchy) surface distributions of fine-fuels, and inconstant understory “litter” accumulation depths (Darling 1967)—factors that consequentially affect the ability of forests to carry fires (Rand 1965; Tausch and Hood 2007; Wright and Bailey 1982).

The Hidden Legacy of Economic Fire

From the perspective of fire history, Fule et al. (2002) posit that the strong synergistic effects between fire exclusion and grazing during the twentieth century have so thoroughly influenced fuel loads that it is fair to assume that widespread lethal “stand killing” fires in these ecosystems were infrequent during historic times, although there is less than unanimous agreement on the subject (Baker and Shinneman 2004). One point of common agreement among these and other studies that focus on fire in the pinyon-juniper ecosystems of the eastern Grand Canyon, however, is that they are constrained by time depth, particularly for “pre-Euro-American” periods of occupation that date half a millennium or more before the present (Fule et al. 2003; Romme et al. 2009:211; Williams and Baker 2013).

We contend, however, that archaeology can contribute to an understanding of fire and its use by humans in these forests during prehispanic times, well before they were dramatically transformed during the last century and, furthermore, that anthropogenic fire, rather than maize agriculture, made pinyon-juniper woodlands suitable for sustained habitation (cf. Gillson and Marchant 2014:321). For instance, pollen assemblages recovered from tenth to twelfth century AD prehistoric fire-cracked-rock piles (Sullivan et al. 2001), rock alignments (Bozarth 1992; Sullivan 2000), and buried alluvial surfaces (Sullivan and Ruter 2006) are dominated by cheno-ams and grasses whereas maize pollen accounts for less than 1% of all economic species (Jelinek 1966; Sullivan 1996). Also, macrobotanical samples recovered from ceramic vessels and hearths in one-room structures (Becher 1992; Huckell 1992) and a multi-structure site (Site 17 [Sullivan 1987]) reveal the same pattern—maize remains (cobs, kernels) are significantly less frequent and ubiquitous (when they occur) than chenopods, amaranths, pinyon nuts, and various grass seeds, which are common and omnipresent (Sullivan and Forste 2014). Thus, decades of archaeobotanical
research conducted by different specialists involving samples excavated from a wide variety of contexts by different teams of archaeologists, support the inference that the prehistoric occupants of the Upper Basin relied on disturbance-responsive wild plants—ruderals—and not on low-moisture-intolerant domesticated plants (Sullivan in press). From an economic perspective, importantly, the effects of fire on the phenology and productivity of ruderals are well known: “Ruderals are highly adapted to disturbance because of their copious and rapid seed production” (Kramp et al. 1983:2; see also Adams and Bohrer 1998; Wright et al. 1979). To enhance the robustness of these understandings, we present the results of recent archaeobotanical analyses that confirm the pervasiveness of ruderals, and other wild plants, in the subsistence economies of people who populated pinyon-juniper ecosystems in the past (Bayman and Sullivan 2008; Berkebile 2014).

**Sampling for Subsistence at MU 125**

Nestled at the base of a low mesa in the Upper Basin, and sporting an unobstructed view of the San Francisco Peaks 96 km to the south near Flagstaff, AZ, archaeological site MU 125 was excavated with the express purpose of acquiring archaeo-economic data to test the reliability of interpretations based on the samples recovered from the aforementioned sites. Upon excavation, MU 125, which produced tree-ring cutting dates of AD 1070 and 1080, disclosed the remains of six architectural spaces (Figure 2) (Fugate 2003). However, in sharp contrast to nearby Site 17, which produced the region’s most robust “Pompeii” assemblage of archaeobotanical remains (Sullivan 1987), MU 125 had a different formation history. First, unlike Site 17, where four structures were destroyed by fire simultaneously (Sullivan 1986), MU 125 was not consumed entirely by fire—only Room 2 burned catastrophically; Room 3 was partially burned but was repaired and reused prior to abandonment; all the other rooms were unburned. Second, with the exception of Room 2, rooms at MU 125 lack assemblages of floor-contact artifacts (in contrast, three of four structures at Site 17 had extensive floor-contact artifact arrays [Sullivan 2008a]). Third, MU 125 failed to disclose a single whole ceramic vessel, unlike Site 17 (Sullivan 2008b). And fourth, in contrast to Site 17, MU 125 lacks conventional “cooking” hearths; only the remains of two shallow ash-filled basins (which probably represent repositories of once-hot coals for heating and seed-parching) were discovered in Room 2, and Room 3 disclosed a small, asymmetric thermal feature.

In view of these differences, and to enable synthetic inference building regarding plant-use patterns in the Upper Basin, the 28 sediment samples from MU 125 that form the core of this study were selected and analyzed with respect to four context types (Figure 2): (1) Thermal Processing Contexts (which include samples from one thermal feature, one roasting pit, three ash-filled basins, and two fire-cracked-rock piles); (2) Metate Grinding Surfaces (n = two metates); (3) Post-Hole and Floor-Contact Contexts (which include samples from six post-holes, two post-hole trenches, four floor-contact “areal” [featureless and artifact-free] zones, and sediments from beneath two metates); and (4) Other Contexts (which include samples from an anthropogenic “limestone ledge” in Room 2, a
bowl sherd associated with a burial in Room 1, a bowl sherd in Room 2, and the contents of two unburned pits in Room 6).

This contextually heterogeneous sample was designed specifically to disclose aspects of plant use that may not have been revealed in the analysis of samples recovered from the de facto Pompeii situation at Site 17 (Sullivan 1987), as well as of samples recovered from three non-Pompeii single-room sites in the region (Becher 1992; Cummings and Puseman 2010; Huckell 1992). Furthermore, adopting a time perspectivism view of the different behavioral clocks registered by the MU 125 samples enables a determination of the extent to which plant-use patterns inferred for the other sites and contexts mentioned above may have been misinterpreted (Sullivan 2008a). For example, these “clocks” chronicle the by-products of activities that range from routine (multiple, daily plant-grinding events) to exceptional (single disposal episode of disarticulated human remains), from early construction (roof-support post-holes) to last-minute domestic events (shallow ash-filled basins), from casual long-term deposition (floor sediment accumulations) to intentional short-term discard (rock-filled unburned pit). If, however, the same picture emerges from these contexts—the samples are dominated by cultivated and gathered wild plants—it clearly would go a long way toward alleviating doubts about the prevalence of non-maize-based foodways in the Upper Basin (Sullivan in press).

Measures of Archaeobotanical Assemblage Variability

To ensure comparability with previous analyses (Sullivan and Ruter 2006), relative frequency and ubiquity values were calculated to assess compositional
similarities and differences among the four context types. Relative frequency is the percentage of the remains of a specific taxon within a context type (Miksíček 1987). However, relative frequency values should be supplemented with another, independent measure to ensure they have not been unduly influenced by uncontrollable preservation or inadvertent recovery biases (Minnis 1986). Ubiquity analysis (Popper 1988:61) serves this function and is a measure of the frequency (expressed as a percentage) with which a particular taxon appears among samples within a context type. It is important to bear in mind that whereas “ubiquity controls for spatial variation among macrofloral samples, it exaggerates differences in content diversity by inflating the importance of uncommon types” (Sullivan 1987:145). In determining assemblage variability, therefore, both measures need to be employed in a complementary fashion to avoid privileging preservation or sampling.

Finally, to develop fine-grained interpretations about the relations between plant-use patterns inferred from processing and domestic contexts and those that may typify production contexts, three resource production types were defined (Berkebile 2014; these categories are broadly similar to Diehl’s [2005:78–79] Plant Resource Group concept; Table 1). First, cultivated wild plants are those whose growth patterns, distribution, density, and yields can be influenced by humans (e.g., Geib 2011:10). Second, gathered wild plants are those whose growth patterns, distribution, density, and yields can rarely, if ever, be influenced by humans (Winter and Hogan 1986). Finally, domesticated plants are those genetically-modified plants whose establishment, growth, and yields are dependent upon humans (Smith 2001).

**Results**

Figures 3 and 4 show that cultivated and gathered wild-plant remains are both far more numerous and widespread than domesticated-plant remains among all context types at MU 125, which is the typical Upper Basin plant-use pattern (Sullivan and Forste 2014). What is particularly noteworthy about these results is that they include material from archaeological contexts that previously

<table>
<thead>
<tr>
<th>Cultivated wild plants</th>
<th>Gathered wild plants</th>
<th>Domesticated plants</th>
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<tbody>
<tr>
<td>Chenopod (<em>Chenopodium</em> sp.)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Pinyon (<em>Pinus</em> sp.)</td>
<td>Maize (<em>Zea mays</em>)&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Amaranth (<em>Amaranthus</em> sp.)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Juniper (<em>Juniperus</em> sp.)</td>
<td>Bean (<em>Phaseolus</em> sp.)&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tansy mustard (<em>Descurainia pinnata</em>)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Cactus (<em>Cactaceae</em>)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Cotton (<em>Gossypium</em> sp.)&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Purslane (<em>Portulaca</em> sp.)&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Cattail (<em>Typha</em> sp.)</td>
<td></td>
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<tr>
<td>Bugseed (<em>Corispermum</em> sp.)&lt;sup&gt;4,a&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Globemallow (<em>Sphaeralcea</em> sp.)&lt;sup&gt;4&lt;/sup&gt;</td>
<td></td>
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</tr>
<tr>
<td>Sunflower family (<em>Asteraceae</em>)&lt;sup&gt;4,a&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Panicoid and other small-seed grasses (<em>Panicum</em> sp. and <em>Poaceae</em>)&lt;sup&gt;4&lt;/sup&gt;</td>
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</table>

<sup>1-5</sup> These plants correspond to Diehl’s (2005:78–79) First through Fifth Resource Groups, respectively; note that plants in his Third Resource Group are considered “high-density crop weeds” whereas those in his Fourth Resource Group are categorized as “low-density crop weeds.”

<sup>a</sup> According to Bohrer (1983:122), “burned patches of vegetation would foster an increased abundance of game and annual plants like sunflower (*Helianthus*) and bugseed (*Corispermum*) whose seeds were consumed directly.”
have not been investigated—burials, post-hole trenches, and metate grinding surfaces. With these new results from MU 125, it is reasonable to claim that, based on the abundance and ubiquity of cultivated and gathered wild-plant macrobotanical remains recovered from consumption, processing, storage, and discard contexts at a multi-structure “Pompeii” site (Sullivan 1987), non-Pompeii single-structure sites (Becher 1992; Cummings and Puseman 2010; Huckell 1992), and extramural processing localities (Sullivan et al. 2001), domesticated plants (maize in particular) were not the principal foods by which prehistoric groups in the Upper Basin sustained themselves. To argue otherwise would entail claiming that the least common and least ubiquitous plant remains represent the primary resources upon which the subsistence economies of these pinyon-juniper woodland-dwelling populations depended, which would constitute an epistemologically precarious position (Lucas 2012).

Pyrogenic Resource Production: Theory and Socio-ecological Consequences

We return to a central question: Where would these plants have been produced? Even if domesticated plants were grown exclusively on all the “agricultural” features that have been discovered in the Upper Basin (Figure 5), they would have accounted for an extremely low amount of the per capita food supply, in view of their small aggregate production area (639 m² combined from 110 terraces). Considering that the majority of the cultivated and gathered wild plants recovered from archaeological contexts are drought-tolerant and fire-responsive (Sullivan and Forste 2014:138), their production is not limited by the
two principal uncontrollable or ecologically “bound” variables (stipulated by an obligate ecological theoretical framework; Sullivan in press) that affect domesticated plant production—suitable soil (in terms of depth, moisture, nutrient availability, and extent; Homburg and Sandor 2011) and sufficient rainfall (that must be available within a specific growing window; Doolittle 2000:219–234; Muenchrath and Salvador 1995:309–318). Hence, we propose that food-supply systems in pinyon-juniper ecosystems, such as the Upper Basin, involved the creation by fire of anthropogenic micro-habitats, or disturbance niches (Smith 2011b), in places and at times selected by humans, which is a strategy that would have enabled people to control the factors that affect edible resource production. In this facultative ecological theoretical framework, pyrogenic disturbances in pinyon-juniper woodlands encouraged the production of ruderal species (Adams and Dockter 2013), such as those cultivated wild plants identified in the archaeological samples from MU 125 and other archaeological phenomena in the Upper Basin, anywhere sufficient surface fuel loads could be ignited (Roos et al. 2010). In support of our pyrogenic-disturbance model, the results of controlled studies have shown that low-intensity surface fires release nutrients, such as phosphorous, potassium, and nitrogen, that are essential to plant growth (DeBano et al. 1998; Rösch et al. 2002; Viro 1974), particularly in early successional stages (Smith 2011a:598; West 1984). Also, low-intensity fire may enhance the productivity of gathered wild resources (Winter and Hogan 1986), such as nut-bearing pinyon trees, by reducing competition for nutrients (Ford 2000; Smith 2011b:841–842).
Figure 5. Spatial distribution of 110 rock alignments and associated terraces, often implicated in models of maize production, which have been discovered in the intensively surveyed polygons of the Upper Basin.
Overall, the body of archaeobotanical, pollen, and sedimentary micro-charcoal evidence recovered from prehistoric consumption and production contexts in the Upper Basin supports the idea that ruderal agriculture unbinds economic resource production from the environmental constraints that affect maize farming, thereby increasing the predictability, productivity, and security of the local food-supply system (Smith 2011b:845). Moreover, our estimates (Table 2) indicate that the yields and nutritional qualities of ruderals, which are available throughout the year (Berkebile 2014; Bohrer 1975, 1983; Doebley 1984), are comparable to or exceed those of maize.

These considerations create epistemological space to contemplate the possibility that, despite their continuing use in Southwest archaeology (e.g., Freeman 2012), terms such as forager (wild-plant gatherer) and farmer (domesticated-plant grower) may actually muddle our thinking about ancient subsistence economies (Harris 2007:28–29; Iriarte 2007:176). If agriculture is broadly considered the systematic and intentional manipulation of vegetation communities (Hunt and Rabett 2013; Mabry 2005; Smith 2001)—the creation of alien (anthropogenic) niches in otherwise natural ecosystems (Smith 2011a:596)—then these pinyon-juniper forest-dwellers indeed were farmers who focused on wild-plant production by the application of fire (Smith 2011b:844). Moreover, it is fair to say that the remains of ruderals recovered in these upland conifer archaeological contexts should no longer be considered “weeds” or the unintended consequences of maize farming (Geib 2011:369). Again, to make the case that ruderals are weeds, and hence economically inconsequential, necessitates claiming that the most common and ubiquitous remains of cultivated and gathered wild plants actually register dependence on maize agriculture. Only an uncritical commitment to the “corn paradigm” can explain why ruderals are not considered the objects of food production and the keystone plant species of prehistoric subsistence economies in upland coniferous woodlands (Sullivan in press).

Summary and Conclusions

It is little wonder that many archaeologists might think that pinyon-juniper woodlands are comparatively unproductive and somewhat inhospitable places to live—formerly cultivated wild plants are no longer observable on the modern landscape. In fact, a comparison of species compositions determined by a modern ecosystem survey (Brewer et al. 1991), a hazardous-fuels-reduction experimental burn (Huffman et al. 2013), a multi-site review of archaeological findings (involving macrobotanicals, pollen, and micro-charcoal; Sullivan and Forste 2014), and results of the multi-contextual analysis of macrobotanical samples from MU 125 reported here, reveals the degree to which the pinyon-juniper woodlands in the Grand Canyon area have changed since they were abandoned as locations of permanent habitation in the late twelfth century AD (Table 3). As these data show, the economically important ruderals that populate our archaeological samples do not occur or rarely occur in today’s pinyon-juniper woodlands, except as a consequence of burning. Such species diversity attenuation is attributable not only to the discontinuance of anthropogenic
Table 2. Nutritional values of some economic resources broken down by Resource Production Type (CWP = cultivated wild plant, GWP = gathered wild plant, and DP = domesticated plant).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Resource production type</th>
<th>Part</th>
<th>Kcal/kg</th>
<th>Kcal/m²</th>
<th>Nutrient content (g/100 g)</th>
<th>Notable nutrients</th>
<th>Source</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>CWP</td>
<td>green</td>
<td>210–330</td>
<td>33–82.5</td>
<td>Carbohydrate: 4.11 Fat: 0.18 Protein: 2.11 Fiber: 1.31</td>
<td>Ca</td>
<td></td>
</tr>
<tr>
<td><em>Chenopodium</em> sp.</td>
<td>CWP</td>
<td>seed</td>
<td>3726–4140</td>
<td>-</td>
<td>Carbohydrate: 42.40 Fat: 5.23 Protein: 16.80 Fiber: 15.60</td>
<td>Ca, Fe, K, Vitamins A &amp; C</td>
<td>Cummings 1995, Fowler and Rhode 2011</td>
</tr>
<tr>
<td></td>
<td>CWP</td>
<td>green</td>
<td>320–340</td>
<td>-</td>
<td>Carbohydrate: 5.00 Fat: 5.00 Protein: 3.20 Fiber: 1.80</td>
<td>Ca</td>
<td></td>
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<tr>
<td><em>Juniperus</em> sp.</td>
<td>GWP</td>
<td>berry</td>
<td>4800</td>
<td>-</td>
<td>-</td>
<td>Ca, Fe, Mg</td>
<td>Darling 1967, Lentz 1984</td>
</tr>
<tr>
<td><em>Zea mays</em></td>
<td>DP</td>
<td>kernel</td>
<td>1080</td>
<td>30.51</td>
<td>Carbohydrate: 25.11 Fat: 1.28 Protein: 3.32 Fiber: 0.60</td>
<td>Vitamin A, Fe, K, Zn</td>
<td>Cummings 1995, Hegmon 1996</td>
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surface fires in late prehistory, when populations withdrew from the area, but to the suppression of all fires in the twentieth century and to the introduction of domesticated animals (principally cattle and sheep), whose palates preferred the same suite of cultivated wild plants as did the Upper Basin’s prehistoric inhabitants, and whose grazing habits eventually led to the local extinction of many of these economically important species (Bohrer 1978; Bond and Keeley 2005:389; see also Bird et al. 2008).

Table 3. Differences in pinyon-juniper woodland species composition recorded among a modern vegetation survey (Brewer et al. 1991), a hazardous-fuel control burn (Huffman et al. 2013), and two archaeological studies (Berkebile [2014] and Sullivan and Forste [2014]): CWP = cultivated wild plant, GWP = gathered wild plant, and DP = domesticated plant.

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<td>Herbs and forbs</td>
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With regard to the "early anthropogenic" hypothesis, it seems reasonable to posit that, although humans indeed could have been responsible for introducing elevated amounts of methane and carbon dioxide to the atmosphere by systematic burning, such burning, particularly for agricultural purposes, need not have entailed deforestation of the landscape (Barton 2014; Kohler 1992; Minnis 2000:279–280). Actually, cutting down pinyon trees—the sources of nutritious and tasty pinyon nuts—to clear land for intensive farming does not make much sense when the fine fuels and litter around them can be ignited without damaging the trees themselves (see Power et al. 2008). More likely, in prehistoric times, upland conifer woodlands in the American Southwest were arguably pyrogenic ecosystems created and managed by human-controlled ignitions of understory vegetation (Roos et al. 2010); such biomass burning may have affected the black carbon content of the atmosphere that, in turn, influenced regional temperature (Cadzow 2012:213–214). Whatever the atmospheric consequences, the important point is that these were "fire woods" whose occupants sustained themselves on ruderals and other wild plants, which have long use-histories in Southwest prehistory (e.g., Doby 1972; Dobbly 1984; Huckell 1996; Lentz 1984; Morrow 2006).

In essence, twenty-first century pinyon-juniper ecosystems are a complex and imperfectly understood historical precipitate of vegetation communities whose origin and structure are ultimately anthropogenic (Williams and Baker 2013:299). Based on comparisons with the returns of paleoecological data recovered by archaeological investigations in the Upper Basin, today’s pinyon-juniper woodlands are indeed characterized by low net primary productivity—thanks to grazing and fire suppression—and, without artificial supplies of water, are completely unsuitable for permanent human habitation. In addition, for at least 700 years before the twentieth century, the structure of the forest was determined by neither grazing nor fire suppression but by fuel loads that materialized as a consequence of the absence of humans and that presumably were ignited by lightning exclusively (Allen 2002). During the tenth to twelfth centuries, however, these forests were alive with people and their fires, and were punctuated with pyrogenic disturbances, which were the sources of food that sustained these ancient societies without, evidently, much call for maize.

Notes

1 Rand observes (1965:210) that runoff “is carried swiftly down the wash and permanent streams or standing water are absent, most of the water simply sinking into the soil at the conclusion of the rain.” Her observation pertains equally to snowmelt. Hence, any form of precipitation in the Upper Basin gets absorbed rapidly and, save for small exposures of unfractured bedrock that have been modified to disrupt and capture runoff, such as the features described by Norr (1997), is unavailable for harvesting.

2 Huffman et al. (2013:480) report mean annual precipitation was 408 mm for 1976–2012, which agrees with our previously reported value of 16.06 inches for 1904–1983 (Sullivan and Ruter 2006:185).

3 The Upper Basin pinyon-juniper ecosystem is currently experiencing extreme fragmentation and degradation that is attributable to differences in land-use policies between the
two federal agencies that authorize (USDA Forest Service) or prohibit (USDI National Park Service) "recreational" activities, such as unrestricted camping, wood cutting, and hunting, within their jurisdictions (Balsom et al. 2005; Uphus et al. 2006; Vankat 2013:291–292; Washam 2014).

4 The terrace area (639 m$^2$ or .000639 km$^2$) is .00027% of the area (23.8 km$^2$) intensively surveyed in the Upper Basin. Applying this percentage to the unsurveyed terrain in the Upper Basin yields a potential terrace area there of .0614 km$^2$; combining these two values yields a total potential terrace area of the Upper Basin of .062 km$^2$, or 6.2 ha, or 15.32 acres.

References Cited


Arizona, edited by M. W. Diehl, pp. 73–90. Anthropological Papers No. 34. Center for Desert Archaeology, Tucson, AZ.


Geib, P. R. 2011. Foragers and Farmers of the Northern Kayenta Region: Excavations along the Navajo Mountain Road. University of Utah Press, Salt Lake City, UT.


