Resilience at the Edge: Strategies of Small-Scale Societies for Long-Term Sustainable Living in Dryland Environments

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Abstract Modern Western communities have much to learn from the ways in which small-scale societies have survived and even thrived while cycling through phases of profoundly shifting moist to dry environmental conditions. In doing so, these small communities display a resilience developed from thousands of years of being rooted in what Western Society considers 'marginal' environments. The most important of the solutions they developed are sustainably rooted in deep-time and identifiable in archaeological records. The ability to live sustainably in these kinds of challenging environments emerges from a profound and long-term reservoir of 'Traditional Ecological Knowledge' that includes a keen awareness of the interface between human needs and natural processes. Although these traditional solutions may not apply to massive complex systems that drive the survival of large cities as a whole, we can benefit a great deal from the study of these past societies to help generate ideas for smaller segments and sub-systems of larger cities, such as neighborhood collectives, urban gardening, water conservation methods, and others that will lead us towards a more sustainable existence on our planet through the use ground-up solutions.

Keywords Wetland exploitation · Foraging societies · Pastoralists · Resource storage · Diversification

Introduction

Complex societies have the potential to provide members with resilience to climate change through numerous interconnected social institutions and advanced technological innovations. Small-scale societies lack this overarching umbrella effect of a vast social and economic network and infrastructure. These smaller, more localized groups must rely on a number of "ground-up" mechanisms for resilience and ultimate survival when abruptly changing climates lead to shifts in environments that affect

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the plant and animal resources these groups rely on for subsistence and materials critical for maintaining their lifeways. This is especially true in semi-arid environments with plant and animal distributions that are highly sensitive to variations in rainfall and droughts. Our current situation of a steadily warming planet with the accompanying increase of drought years, fires, and decrease in rangelands across the globe, have led numerous geographers, anthropologists, and archaeologists to investigate the impacts of these adverse climatic changes on societies through time. Many have studied the ways in which small-scale societies living in present-day dryland environments use their deeply rooted systems of Traditional Ecological Knowledge (TEK) to exist in these challenging settings.

Modern Western communities have much to learn from the ways in which small-scale societies have survived and even thrived while cycling through phases of dramatic environmental changes from moist to dry conditions, and in doing so, display a resilience that can only come from thousands of years of being rooted in these environments considered marginal by more complex agricultural societies. Although our present-day technological societies are far more able to apply innovative scientific and engineering solutions to immediate situations of drought, decreasing crop yields, and increasing vulnerability to fires, what they lack are solutions for long-term sustainable maintenance of the landscape and agricultural resources. Adaptations to dryland environments by past societies can help provide insights to future sustainability in an ever-challenging environment of global warming. This may be especially true for some of the smaller, more independent social subsets within the larger more complex modern social systems, such as smallhold farmers, and urban gardeners. To gain insights into some of the challenges and innovations of adaptations by prehistoric small-scale societies to climate change and droughts in drylands, I will explore some of the commonalities of strategies for maximizing the predictability of critical resources in two dryland regions. One is the semi-arid zones of the Southern Levant, and the other is the Gobi Desert of southern Mongolia.

Modern researchers studying contemporary and ethnohistorical accounts of foragers in areas such as Australia and the Great Basin in the Western United States have identified the ways in which these groups respond to abrupt adverse climate change in the present and recent past. Archaeologists have built on these ethnographic observations using evidence from archaeological sites. Together these data can contribute a deep time perspective that shows there are patterns of adaptive strategies, which foragers implement in response to cycles of climatic degradation and amelioration over the course of thousands of years. These patterns suggest there are long-term memories of methods by which these small-scale societies respond to adverse environmental changes. These methods and solutions to survival pass down through the generations as TEK through mechanisms such as generational memory, stories of the recent past, and finally myths and legends with this information embedded within. These memory-messages may include the ways of exploiting plants and animals that thrive in harsh environments, including some poisonous plants and not-so-palatable animals, ways of finding sources of sub-surface water, and rituals that promote social bonding and resilient social institutions such as traditions of sharing. Some of this Traditional Knowledge and lifeways for thriving under adverse climatic conditions are recognizable in the archaeological record and can help us understand the longevity of a forager and early pastoral lifestyle in these very harsh and unpredictable dryland regions. More importantly, they contain methods for the long-term sustainable use of resources. Some of the most important of the strategies that are identifiable in the archaeological record include the following four factors:

(1) *Water Resources*, including knowledge of the range of variability of unmanaged water sources, and/or the technology to manage these sources at varying levels of engineering skills.
(2) *Strategies for diversification* of resources, diet, social institutions, and toolkits.
(3) *Some form of low-level storage*, either a natural characteristic of a particular plant food, or technologies for caching or preserving food items in times of abundance.
(4) *"Niche Construction"*—the ability to alter habitats for improved reliability of resource acquisition, at some level of action.

All four of these strategies rely heavily on a society's Traditional Ecological Knowledge, which can shift, or increase through time. For hunter-gatherers living in dryland regions, these four important elements of dryland survival are all facilitated by proximity to wetland environments. The wetlands are a key focal point, providing water and food resources, but also provide for increased diversity, natural storage, and a fertile environment for niche construction at varying levels of technology.

(1) Water and desert adaptations

Watery places in desert environments typically become "landscape anchors" (Hammer 2014) and "persistent places" (Schlanger 1992; Olszewski and al-Nahar 2016; Maher 2019) which attract human groups over the course of millennia or throughout the lifespan of these water sources. These can be lakes, rivers, springs, marshy wetlands, ephemeral playa lakes, and human-made cisterns and wells. Water is a limiting factor in semi-arid environments and arguably one of the most critical resources for human settlement and subsistence. Settled agricultural societies deal with the negative effects of too little or too much water on the landscape in the form of droughts and floods respectively which destroy crops, agricultural infrastructures and lead to famine and human suffering. But the advantage for settled societies is their long-term experience and profound knowledge of their immediate environs. They have had time to adapt to and learn about the variability of the rainfall patterns leading to droughts or floods, assess risks, and respond accordingly. If cycles of droughts and floods impact these societies with relative regularity, then agricultural societies can prepare for such situations through technological and social planning. If drought or flood inflection points are unpredictable and severe occurrences, they can enhance the inherent weaknesses within a social and political system of organization. This contrasts with small-scale mobile populations which tend to have more resilient strategies of mobility, social flexibility for altering group size, and knowledge of a broader range of environmental zones across the landscape.

The control of water resources in dryland environments is an area of much research, discussion and debate among anthropological archaeologists concerned with developing agricultural societies and the rise of complex social systems (Mithen 2010; Hammer 2018). These debates go back to the 1930 and 1950s with Childe (1936), and Wittfogel (1957), including the proposition that the very process of building irrigation systems was the single most important factor leading to the rise of elite managers and eventually to stratified societies. Of course, this proposition led to much debate and eventual rejection of the idea in its simple and basic form (Adams 1960; Butzer 1996; Mithen 2010). This focus on the core area of settled agricultural societies and their relationships to water resources in prehistory has vastly overshadowed the adaptations of smaller societies living on the peripheries of complex societies, and indeed their forager predecessors who ultimately developed resilient adaptations to water scarcity in their home ranges.

These seemingly diverse human social/ecological systems, early complex societies, marginal small-scale societies (foragers, pastoralists, and subsistence farmers living on the peripheries of contemporaneous complex societies), and preceding generations of bands of foragers, are closely related, either in the vertical trajectory of deep time with learned experiences of a landscape—or horizontally across a social/economic system where peripheral small-scale societies are tightly woven into a more complex core. Yet the use, exploitation, limitations, and impact of water sources in these small-scale societies thriving in dryland regions have received much less attention from archaeologists (Fuller and Qin 2009; Hammer 2018).

Another challenge to consider in the study of adaptations by small-scale societies to water resources in drylands is that water availability is a moving target at all temporal scales. Water sources vary seasonally with fluctuations in the amount and timing of rainfall events. Yearly averages rise and fall dramatically around a statistical mean, and total amounts can shift greatly over the course of decades and millennia in a secular or stochastic manner (Butzer 1982). A key element to consider then, is the “predictability” of rainfall and water sources. Human social/ecological systems are innovative and can adapt to the driest deserts on the planet if these environments are predictably dry. It is the series of unpredictable and unexpected weather events, causing sudden droughts and floods that throw social/economic systems off balance and subsequently exacerbate inherent weaknesses in the social and economic systems. This is true of both small-scale and complex societies.

Archaeological and ethnohistorical evidence points to various patterns of movement and exploitation of water resources among mobile foragers in dryland environments. Two of the most important are basin-centered wetlands, and linear valleys containing spring-fed perennial flow.

Basin Wetlands

It is well-known that wetlands are a key ecological zone for foragers (Janetski and Madsen 1990; Kelly 1990; Nicholas 1998; Ramsey 2016; Ramsey and Rosen 2016). In regions with broad basins, the wetlands form from the emergence of underground springs yielding perennial marshes, catchment basins with no outlet that accumulate standing water and form seasonal playa lakes which collect water in rainy seasons but have no outlet, or more permanent saline lakes. They also can occur around the margins of permanent lakes with perennial outlets.

Wetlands are replete with essential resources that provide materials for shelters, basketry, matting, and protein in the form of birds, fish, eggs, mammals, and reptiles that are attracted to the water sources. One of the most important nutrients provided by wetlands are the calories from starches derived from the roots rhizomes and shoots of cattails (*Typha* sp) and sedges (Cyperaceae), for example *Cyperus* sp. and *Scirpus* sp. (Hillman et al. 1989; Wollstonecroft et al. 2008). The contribution of roots and rhizomes supplied by wetland plants is a critical resource for foragers living in general dryland habitats. There are few other sources of these essential nutrients in semi-arid environments, especially in the interfluves. However, in contrast, protein from small mammals and reptiles is more readily available in the uplands and interfluves of these zones.

The water, food, and materials from wetlands provide a key focal point for foragers living in semi-arid regions especially in times of drought. Ramsey and Rosen (2016) have focused on these ecozones as an essential part of forager adaptations to dryland environments in the Southern Levant, describing these societies as being tethered to the wetlands, since they are often a vital component of their seasonal migrations. The tethering effect of the wetlands might lead to a radial pattern of movements among mobile foragers as they would be free to radiate out from the wetland focal points to hunt and collect other important resources. In years of abundant rainfall, migrations can extend further from the wetlands, in years of more sparse rainfall, populations would be restricted in the distances they could travel away from the water and its embedded resource base. Pastoralists had the added concern of pasturage for their flocks (Hammer 2018).

The configuration of basin centric wetlands existed for millennia in both the Southern Levant, and the Gobi Desert of southern Mongolia during the late Pleistocene through the middle Holocene. The Levantine corridor has been a conduit for hominins and *Homo sapiens* for close to two million years (Goren-Inbar and Saragusti 1996; Gaudzinski 2004). It is a narrow strip of land flanked by the Mediterranean Sea to the west, and the harsh deserts of the Arabian Plateau to the east. Throughout these time periods there have been many dramatic shifts in climate and water availability. In the Levant, wetlands have been geobotanical foci which attracted numerous groups of foragers through time. Wetlands around Lake Kineret (Sea of Galilee) in present-day Israel were home to the Kebaran Period foragers at the site of Ohalo II around 23,000 cal BP. These peoples lived in a semi-sedentary village on the lake shore during the coldest-driest episode of the Late Pleistocene, known by climatologists as the Last Glacial Maximum (LGM) (Nadel et al. 2004; Ramsey et al. 2017). This time period was marked by the contraction of the oak/pistachio forest, expansion of the grassland vegetation and frequent droughts (Rosen 2007).

The unique situation of Ohalo II as a waterlogged site, has led to phenomenal preservation of organic remains, giving archaeologist a full picture of how these Kebaran Period foragers not only existed, but thrived on the shores of these wetlands, exploiting fish, birds, small-grained grasses, wild cereals, and the rhizomes of sedges (Weiss et al. 2004a, b). Ohalo II demonstrates that the presence of the lake shore and accompanying wetland surrounding it was a key focal point contributing to the resilience of these foragers during a long phase of otherwise unpredictable resource distribution and availability.

Likewise, at the Natufian settlement at Eynan/Ain Mallaha, foragers were able to live year/round by the marshland of the Hula Lake and wetlands in modern-day northern Israel, while in other localities further south, Natufian foragers had to increase their mobility to satisfy their subsistence requirements (Goring-Morris, Hovers et al. 2009). During the Younger Dryas cool-dry climatic episode (ca. 12,900–11,700 BP) of the terminal Pleistocene, the Late Natufian foragers adapted to the dry conditions by broadening their use of multiple species of plants and animals including small-grained grasses, and a wide variety of small and medium-sized mammals (Stiner 2004; Weiss, Wetterstrom et al. 2004a, b; Munro and Atici 2009; Rosen and Rivera-Collazo 2012), compared with the Early Natufians of the preceding Bølling–Allerød warm-moist episode (ca. 14,700–12,900 BP). The Late Natufians increased their mobility and organized into smaller, more highly mobile groupings. They frequently visited springs spots, lake shores, seasonal playa lakes and wetlands (Ramsey et al. 2015, 2016; Maher et al. 2016), exploiting much the same types of resources as were targeted by the Kebaran Period peoples who lived on the shores of Lake Kineret (Galilee) during the very cold-dry Last Glacial Maximum (LGM), at 23,000 BP at the site of Ohalo II. Evidence from the Kebaran Period archaeological site of Ohalo II, show heavy exploitation of a wide range of wetland resources including fish, birds, reeds, rushes, and importantly both small-seeded grasses as well as wild cereals. The Late Natufian populations living through similar cold-dry conditions at sites such as Eynan/Mallaha on the shores of Lake Hula in modern-day northern Israel relied on a similar broad resource base of small/medium-sized mammals, fish, and small-seeded grasses as well as wild cereals.

It is worth noting the that the Early Natufian (ca. 15,100–13,000 cal BP) populations who lived during the warmer/wetter Bølling/Allerød Period may have differed from both the preceding Kebaran (ca. 23,000 BP) and the subsequent Late Natufians (13,000–11,700 cal BP) in their plant resource selection. This was a period when the oak woodlands were expanding, and the phytolith data suggests an increased reliance on woodland resources, including acorns and perhaps pistachios, and less on grass seeds, indicating a movement away from the broader, more diverse plant resource base.

Archaeologists have shown a similar pattern of reliance on basin wetlands in the Azraq Basin of northern Jordan (Ramsey et al. 2015). Here again, the seasonal expansion of the playa lake formed a key draw for Late Pleistocene Epipaleolithic foragers, allowing the exploitation of critical protein and starch resources throughout the late and terminal Pleistocene (Janz 2012).

In the desert-steppe zones of the southern Mongolian Gobi, Lisa Janz's research has shown that early Holocene foragers began intensive exploitation of a broader range of plant resources such as the 'underground storage organs' (UGS) of sedges, wild grass seeds, and small-fast "*r*-selected species" with high reproductive rates, as the large mammal populations diminished at the end of the Pleistocene. She attributes this to a more specialized intensification of land-use potential (Janz et al. 2017). This went together with increasing warmth and humidity, and the early development of wetlands, as they began to appear within swales of eroded Pleistocene lake beds, and other localities in the Gobi dryland regions (Feng et al. 2005; Janz et al. 2021; Rosen et al. n.d.). In her research, Janz defined three phases of terminal Pleistocene through late Holocene occupation, which are distinctly focused on the intensive use of wetlands and their resources in the semi-arid desert-steppe region (Janz 2012). Janz's terminology is outlined as:

(1) Oasis 1/Mesolithic (13,500–8000 cal BP), defined by sites showing the earliest use of the wetland environments and their adjacent ecozones in the vicinity of rivers or lakes

(2) Oasis 2/Neolithic (8000–5000 cal BP) with sites indicating the intensive exploitation of wetland oases, characterized by camp sites within dune-fields and marshlands, and notably a common occurrence of grinding stones, suggesting the exploitation of small-seeded grasses and other steppe plants, along with a wider range of microlithic tool types, also suggesting the possibility of composite tools for hunting small-fast prey, harpooning fish, and possible reaping activities associated with these wetlands.

(3) Oasis 3/Bronze Age or Eneolithic (5000–3000 cal BP) with evidence for even more intensive use of wetland habitats including larger numbers and types of ceramics, and bifacial flaking of projectile points, knives, and other small tools (Janz 2012).

The subsistence activities of the desert-steppe inhabitants during these three periods are distinctly different from the Big-Game hunting specialists which preceded the terminal Pleistocene, and the later Bronze Age pastoralists which succeeded these populations in the later Holocene. It is useful to think of the unique adaptations of the middle Holocene foragers in terms of 'Push' and 'Pull' factors. The distinction of the resilient adaptations of mid-Holocene foragers from the terminal Pleistocene Big Game hunters can be attributed to the Push of declining populations of large game animals due to the increasing trends of the Pleistocene Extinctions of the large mammals in Eurasia, which undoubtedly undermined the advantage of this strategy. The Pull factor would have been the increased rainfall from the strengthening of the East Asian Monsoons, raising ground water tables and forming ponds and small lakes across the landscape of the eastern Gobi. In southern Mongolia, the region would have been at the very northernmost edge of the East Asian Monsoonal systems, and thus still a semi-arid zone. Thus, these newly formed wetlands would have been an attractive draw to the hunters and foragers living in this region.

These middle Holocene foragers would have employed adaptive strategies that were not available to the later Holocene inhabitants who were presented with an ever increasingly dry environment. In the later Holocene the Gobi Desert experienced weakened East Asian Monsoons, which led to the disappearance of the lakes, marshlands, and small perennial streams in this region. It is also a period in which the inhabitants of the eastern Gobi adopted animal husbandry and a nomadic pastoral lifestyle (Honeychurch and Makarewicz 2016; Honeychurch 2017; Wright et al. 2019).

Linear Valleys

In addition to the basin-centric wetland focus of mid-Holocene adaptation, the Gobi Desert of southern Mongolia presents another configuration of wetland adaptation. This is a mobile movement along "hydrological corridors". These are a series of valleys, many trending north/south, that form belts of springs leading from the lusher steppe zones north towards central Mongolia, to the wetlands and marsh zones fringing the former Paleolake beds of the Mongolian Gobi Desert. Examples of sites along these kinds of corridors were studied by Holguin and Sternberg (2018), Holguín (2019) in the region of Ulaan Nuur, and by Rosen and others at the Ikh Nart Nature Reserve (Schneider et al. 2016; Rosen et al. 2019). The foragers living in these regions reduced their subsistence risk by taking advantage of the mosaic of micro-environments associated with these extensive linear palaeohydrological systems. These geomorphological features accommodated both the resource needs of these foragers and later hunter/pastoralists. They also facilitated mobility and movement throughout the Gobi in both east/west and north/south directions.

A second critical factor for survival in drylands, and especially in situations of increasing desertification is the capacity for diversification. This applies to resilient strategies for subsistence diversity, as well as the flexibility to alter social patterns and institutions.

(2) *Diversification*

The ability to diversify our diet, material culture, and social institutions is one of the most powerful implements in the survival toolkits of our genus *Homo*. We are a species that can consume a wide variety of foods, withstand many types of climatic conditions and ecological zones, move easily from habitat to habitat, and adapt our material and non-material culture accordingly.

When climatic conditions are favorable and rainfall and other resources are abundant, people living in dryland environments are free to target the foods that most appeal to them. They have the option to narrow their resource selection to high yield, highly nutritious, or large packets of foods, and specialize in the collection, hunting, and processing of a narrower range of resources. Examples of this are big game hunting, and heavy reliance on collection of nuts from groves of nut-bearing trees (Mason 1995; Abrams and Nowacki 2008). With a non-mobile food source, this can lead to increasing sedentary residential patterns as well as specialization in the use of that resource (Rosen and Rivera-Collazo 2012). These populations can afford to engage in high-risk, high profit endeavors. Some societies may choose to increase their risk and select for more "costly" resources, others may choose not to do so, but the option is there.

In periods of increasing drought, climatic degradation, and especially in situations when rainfall events become more stochastic and unpredictable over the long term, the most resilient strategy would be to diversity subsistence resources. This diversity is a approach referred to by many archaeologists as a "Broad Spectrum" strategy (Stiner and Munro 2002; Weiss et al. 2004a, b; Stutz et al. 2009; Janz 2016). It may take the form of exploiting more animal food sources that are small, fast, difficult to catch, and have less palatable meat with little fat content such as rabbits and other small mammals (Stiner and Munro 2002). Plant exploitation may take the form of concentrating more on small-seeded grasses (Weiss et al. 2004a, b; Rosen 2010), or plants that require more intensive labor in collection, processing, and cooking. Diversification of plant resources may also include plants which are rich in nutrients but require extensive processing to remove toxins which would otherwise be harmful to humans if consumed directly.

In the Near East, Rosen and Rivera-Collazo (2012) point to a cyclicity of narrow to broad spectrum targeting of plant resources depending upon the expansion or contraction of forest and grassland zones with changes in climate from cold/dry to warm/wet conditions. They suggest that the resilience of the adaptation lies in the ability of hunter-gatherer groups to switch their plant exploitation strategies from the narrower focus of gathering tree foods (including acorns, pistachios, almonds and carob) in times of warn/moist climatic amelioration, to the more broad spectrum exploitation of diverse resources (including small-grained grasses and wild cereals), and more intensive use of wetlands in the periods of harsher cool/dry climates when grassland zones expanded. But rather than a linear trajectory from one type of plant collection strategy to the other, Rosen and Rivera-Collazo (2012) suggest that the resilience lies in the ability of foragers to switch from one to the other (narrow to broad) and back again, in harmony with the distribution of plant communities in a cyclical fashion. This pattern only ceases when populations of foragers begin to increase in the Southern Levant during the early Holocene. This led to the inception of growing settlements of sedentary foragers, decreasing size of home ranges, and impeded mobility. It is only then, under the lower-risk and more predictable warm/wet conditions that the foragers narrowed their focus even further in the middle Holocene to the cultivation and domestication of wheat and barley. Interestingly, the cyclicity in plant collection strategies is not mirrored by species selection in hunting. Animal species targeted seem to follow a more linear pattern of narrow to broad throughout the late Pleistocene into the early Holocene (Rosen and Rivera-Collazo 2012).

In the Gobi, Holguin applies the work of Australian researchers who have robust theoretical perspectives on the use of desert landscapes as foragers arrive in these regions and begin to understand the cycles of abundance and fluctuations of resource microenvironments (Holguin 2019: 29–31). Holguin cites cases from Australian research, which refer to a sequence of the first foragers arriving in the desert during times of moister climate giving them the opportunity of developing a sophisticated ecological knowledge of the behavior of the plant and animal resources. With drying climate, these populations use this ecological understanding to broaden the types of resources they are able to exploit (Veth 1989; Hiscock and Wallis 2005; Smith et al. 2005).

Again, wetland environments are a source of high biodiversity, and attracts mobile foragers for its diversity in food resources, lending a large measure of increased resilience to droughts and otherwise drying climatic conditions and/or unpredictable rainfall events. The site of Ohalo II is a poster child for this kind of wetland contribution to a highly diverse diet in times of climatic degradation in the Levant at the LGM (Nadel et al. 2004; Weiss et al. 2004a, b).

(3) *Storage and Caching*

Storage of resources is a key part of resilience in unpredictable environments. Storage technologies are critical for agricultural societies and will allow farmers to recover from at least one year of severe drought, and often two or even three years of persistent rainfall shortages and crop failures. Mobile foragers and early pastoralists will also use systems of storage and caching of food and other resources which can accommodate the group for recovery from unproductive drought years in their home ranges (Rowley-Conwy and Zvelebil 1989; Gerber et al. 2004; Bettinger 2009; Morgan 2012; Tushingham and Bettinger 2013). Tushingham and Bettinger (2013) have explored the concept of "Front-Loaded" and "Back-Loaded" storability of resources from the perspective of Optimal Foraging Theory, to explain the selection of food items from the view of energy output for collecting, storing, processing, and planning future return. "Front-loaded" resources are costly to acquire and store, but preparation for consumption is easy. "Back-loaded" resources are easy to acquire and store, but energy intensive to prepare. They note that back-loaded resources involve less risk because the energy expenditure needed to acquire and store them is lower, and therefore if the cache is lost or not needed, then there was little wasted effort. We can explore this concept from the perspective of wetland exploitation as well.

One great advantage of wetland localities in dryland environments is their high potential as natural caches for the storage of important high-value year-round resources (Ramsey and Rosen 2016). Some of the most important of these are the underground storage organs (USOs) of sedges such as club rush (*Bolboschoenus maritimus*), yellow nutsedge (*Cyperus esculentus*), and purple nutsedge (*Cyperus rotundus*) (Hillman et al. 1989; Wollstonecroft et al. 2008). These resources are available for collection as needed for most of the year, thus exploitable at a comparable level with low-risk "back-loaded" stored resources. Additionally, they are rich in caloric value, being the starch repository for the plants. As mentioned above, calories are hard to come by in dryland regions such as the Southern Levant and the Gobi where the animal foods are lean, and there is less access to other forms of calorie-rich plants such as nuts, cereals, or an abundance of small-grained grasses. Some desertic environments provide high-caloric succulents such as cactus and Agavaceae species as in the American Southwest, but in the Gobi and Levantine deserts these foodstuffs are less prevalent.

(4) *Niche Construction*

The success of our *Homo sapiens* species, and indeed our genus *Homo* lies in our ability to innovate and survive in in a multitude of environments far from the tropical grasslands where we evolved. A substantial element of our survival is based on our propensity to shape our habitats to fit our subsistence and other needs. These abilities have allowed our species to inhabit the entire planet and thrive in niches well beyond our African homeland (Potts 2012). One essential requirement for all human societies is an understanding of how to predict and control water availability. This is especially true for dryland regions. Water can be a limiting factor inhibiting settlement and subsistence, and at times—in the cases of massive floods and severe droughts—"nature" may have the upper hand. But water is also a resource that human societies have controlled to a certain extent through varying degrees of technology and TEK.

The study of how societies have manipulated water resources for irrigation farming has a long history of investigation, with many authors drawing links to increasing social complexity and the political ecology of water management back to the earliest Neolithic farming communities. But small-scale mobile societies also manipulate water resources to intensify and secure food resources. Research into the ways mobile communities manage water can be challenging due to transitory evidence left on the landscape by these societies which leave behind only a faint environmental footprint. Yet such evidence does exit, and examples are also surmised by auxiliary data (Harrower 2016).

Reaching back to the more distant past, Harrower's (2016) excellent comprehensive study makes a strong case for water management and manipulation on the part of foragers and other small-scale societies worldwide. Fuller and Qin (2009) surmise that pre-agricultural foragers collecting the wild ancestral *Oryza sativa japonica* rice along the Yangtze River in China, would have needed to enhance the supplies of water to the wetland microenvironments in order to increase the productivity of that ancestral rice sub-species. They suggest that this took the form of burning and weeding out undesirable species to clear the waterways and allow more water to flow to the stands of wild rice and directing drainage so selected areas were flooded during the rainy season, but dry out when the rice grains had ripened. A more recent example of the enhancement of water resources among foraging societies comes from Australia. Lourandos (2010) writes about substantial water manipulation systems in southwestern Victoria which native Australian peoples excavated for the purpose of fishing for eels. Here the hunter-gatherer groups dug channels that extended hundreds of meters in length for the expansion of water courses and the intensification of fishing. Likewise, Campbell (1965) and Tindale (1977) discuss cases in which foragers in Australia manipulated water flowing in and out of wetlands to increase the extent of wild plant foods.

Mobile pastoralists are also adept at enhancing water supplies in their dryland home ranges, which is an adaptive strategy that extends far into antiquity and predates the advent of farming communities (Mithen 2010; Hammer 2018). Pokrandt (2014) maintains that in Jordan's south-eastern desert there is substantial evidence for water source enhancement among mobile pastoralists that dates back to the middle Holocene. This evidence includes well-building, channel-type watering systems, and rainwater harvesting techniques of capturing ponded water in depressions with small-stone dams.

Conclusions

This paper briefly touched on some of the effective and resilient strategies employed by small-scale societies in the past for thriving in dryland environments through sustainable use of their environments. I argue that the ability to live sustainably in these kinds of challenging environments emerges from a profound and long-term reservoir of Traditional Ecological Knowledge. These strategies are based in part on (1) the knowledge of the range of variability of unmanaged water sources, and/or the technology to manage these sources at varying levels of engineering skills, (2) Strategies for diversification of resources, diet, social institutions, and toolkits, (3) A system of storage, either a natural characteristic of a particular plant food, or technologies for caching or preserving food items in times of abundance. This is also enhanced by sharing and the accumulation of “social capital”. Finally, (4) “Niche Construction” and the management of local environments for sustainable production of essential resources. For small-scale, mobile societies living in dryland regions in the past and present, these highly successful strategies are markedly enhanced by living near and exploiting wetland environments.

In our modern world consisting of highly technical and sometimes over-engineered solutions to environmental problems, it might seem that small-scale and mobile societies of the past have little to offer us in terms of solutions to global issues of abruptly changing climates, increasing desertification, and the politics of decreasing water resources. However, there is much to learn from such societies and their “ground-up” solutions which operated effectively and sustainably for generations and sometimes millennia. These adaptations, based in Traditional Ecological Knowledge and environmental understanding over deep time may translate well as modern-day small-scale community-based solutions. We can benefit a great deal from the study of these past societies to help generate ideas about neighborhood collectives, urban gardening, water conservation methods, and others that will lead us towards a more sustainable existence on our planet.

References

Abrams MD, Nowacki GJ (2008) Native Americans as active and passive promoters of mast and fruit trees in the eastern USA. Holocene 18(7):1123–1137

Adams RM (1960) Early civilizations, subsistence, and environment. In: Kraeling CH, Adams RM (eds) City invicible: a symposium on urbanization and cultural development in the ancient near East. University of Chicago Press, Chicago, pp 269–295

Bettinger RL (2009) Hunter-gatherer foraging: five simple models. Eliot Werner Publications Inc., Clinton Corners, NY

Butzer KW (1996) Irrigation, raised fields and state management: Wittfogel Redux? (book review). Antiquity 70:200–204

Butzer KW (1982) Archaeology as human ecology: method and theory for a contextual approach. Cambridge: Cambridge University Press

Campbell AH (1965) Elementary food production by the australian aborigines. Mankind 6(5):206–211

Childe VG (1936) Man makes himself. Oxford University Press, Oxford

Feng ZD, Wang WG, Guo LL, Khosbayar P, Narantsetseg T, Jull AJT, An CB, Li XQ, Zhang HC, Ma YZ (2005) Lacustrine and eolian records of Holocene climate changes in the Mongolian Plateau: preliminary results. Quatern Int 136(1):25–32

Fuller DQ, Qin L (2009) Water management and labour in the origins and dispersal of Asian rice. World Archaeol 41(1):88–111

Gaudzinski S (2004) Subsistence patterns of early Pleistocene hominids in the Levant—taphonomic evidence from the 'Ubeidiya Formation (Israel).' J Archaeol Sci 31(1):65–75

Gerber LR, Reichman OJ, Roughgarden J (2004) Food hoarding: future value in optimal foraging decisions. Ecol Model 175(1):77–85

Goren-Inbar N, Saragusti I (1996) An Acheulian biface assemblage from Gesher Benot Ya'aqov, Israel: indications of African affinities. J Field Archaeol 23(1):15–30

Goring-Morris N, Hovers E, Belfer-Cohen A (2009) The dynamics of Pleistocene and early Holocene settlement patterns and human adaptations in the Levant: an overview. In: Shea JJ, Lieberman DE (eds) Transitions in prehistory: essays in honor of Ofer Bar-Yosef. Oxbow Books, London

Hammer E (2014) Local landscape organization of mobile pastoralists in southeastern Turkey. J Anthropol Archaeol 35:269–288

Hammer E (2018) Water management by mobile pastoralists in the middle East. In: Holt E (eds) Water and power in past societies, vol 7. State University of New York Press, New York, pp 63–88

Harrower MJ (2016) Water histories of ancient Yemen in global comparative perspective. In: Harrower MJ (ed) Water histories and spatial archaeology: ancient Yemen and the American West. Cambridge University Press, Cambridge, pp 51–83

Hillman GC, Madeyska E, Hather JG (1989). Wild plant foods and diet at Late Palaeolithic Wadi Kubbaniya (Upper Egypt): evidence from charred remains. In: Wendorf F, Schild R, Close A (eds) The prehistory of Wadi Kubbaniyavol: stratigraphy, subsistence and environment, vol 2. Southern Methodist University, Dallas, pp 162–242

Hiscock P, Wallis LA (2005) Pleistocene settlement of deserts from an Australian perspective. In: Veth P, Smith M, Hiscock P (eds) Desert peoples: archaeological perspectives. Blackwell, Oxford, pp 34–57

Holguín LR (2019) The changing Neolithic landscape of Ulaan Nuur: Modelling hydro-social dynamics in the Mongolian Gobi Desert. Ph.D. dissertation, University of Southampton

Holguín LR, Sternberg T (2018) A GIS based approach to Holocene hydrology and social connectivity in the Gobi Desert, Mongolia. Archaeol Res Asia 15:137–145

Honeychurch W (2017) The development of cultural and social complexity in Mongolia. In: Habu J, Lape PV, Olsen JW (eds) Handbook of East and Southeast Asian archaeology. Springer, New York, pp 513–532

Honeychurch W, Makarewicz CA (2016) The archaeology of pastoral nomadism. Ann Rev Anthropol 45(1):341–359

Janetski JC, Madsen DB (eds) (1990) Wetland adaptations in the Great Basin. Brigham Young University Museum of Peoples and Cultures Occasional Papers 1. University of Utah Press, Salt Lake City

Janz L (2012) Chronology of Post-glacial hunter-gatherers in the Gobi Desert and the neolithization of arid Mongolia and China. Unpublished Ph.D. dissertation, University of Arizona
Janz L (2016) Fragmented Landscapes and economies of abundance: the broad spectrum revolution in Arid East Asia. Curr Anthropol 57(5):537–564
Janz L, Odsuren D, Bukhchuluun D (2017) Transitions in palaeoecology and technology: hunter-gatherers and early herders in the Gobi Desert. J World Prehist 30(1):1–80
Janz L, Rosen AM, Bukhchuluun D, Odsuren D (2021) Zaraa Uul: an archaeological record of Pleistocene-Holocene palaeoecology in the Gobi Desert. PLoS One 16(4):e0249848
Kelly RL (1990) Marshes and mobility in the western Great Basin. In: Janetski JC, Madsen DB (eds) Wetland adaptations in the Great Basin. University of Utah Press, Salt Lake City, pp 259–276
Lourandos H (2010) Change or stability?: hydraulics, hunter-gatherers and population in temperate Australia. World Archaeol 11(3):245–264
Maher LA (2019) Persistent place-making in prehistory: the creation, maintenance, and transformation of an Epipalaeolithic landscape. J Archaeol Method Theory 26(3):998–1083
Maher LA, Macdonald DA, Allentuck A, Martin L, Spyrou A, Jones MD (2016) Occupying wide open spaces? Late Pleistocene hunter–gatherer activities in the Eastern Levant. Quatern Int 396:79–94
Mason SLR (1995) Acornutopia? Determining the role of acrons in past human subsistence. In: Wilkins J, Harvey D, Dobson M (eds) Food in antiquity. Exeter University Press, Exeter, pp 12–14
Mithen S (2010) The domestication of water: water management in the ancient world and its prehistoric origins in the Jordan Valley. Philos Trans A Math Phys Eng Sci 368(1931):5249–5274
Morgan C (2012) Modeling modes of hunter-gatherer food storage. Am Antiq 77(4):714–736
Munro ND, Atici L (2009) Human subsistence change in the Late Pleistocene Mediterranean Basin: the status of research on faunal intensification, diversification and specialisation. Before Farming 1:1–6
Nadel D, Tsatskin A, Belmaker M, Boaretto E, Kislev ME, Mienis H, Rabinovich R, Simchoni O, Simmons T, Weiss E, Zohar I (2004) On the shore of a fluctuating lake: environmental evidence from Ohalo II (19,500 B.P.). Israel J Earth Sci 53:207–223
Nicholas GP (1998) Wetlands and hunter-gatherers: a global perspective. Curr Anthropol 39(5):720–731
Olszewski DI, Al-Nahar M (2016) Persistent and ephemeral places in the Early Epipaleolithic in the Wadi al-Hasa region of the western highlands of Jordan. Quatern Int 396:20–30
Pokrandt J (2014) Water management of a Late Chalcolithic pastoral culture in Jordan's south-eastern desert: case study of Qulban Beni Murra. Levant 46(2):268–284
Potts R (2012) Evolution and environmental change in early human prehistory. Ann Rev Anthropol 41(1):151–167
Ramsey MN, Jones M, Richter T, Rosen AM (2015) Modifying the marsh: evaluating early epipaleolithic hunter-gatherer impacts in the Azraq wetland, Jordan. Holocene 25(10):1553–1564
Ramsey MN, Maher LA, Macdonald DA, Rosen A (2016) Risk, reliability and resilience: phytolith evidence for alternative 'Neolithization' pathways at Kharaneh IV in the Azraq Basin, Jordan. PLoS One 11(10):e0164081
Ramsey MN, Rosen AM (2016) Wedded to wetlands: exploring Late Pleistocene plant-use in the Eastern Levant. Quatern Int 396(7):5–19
Ramsey MN, Rosen AM, Nadel D (2017) Centered on the Wetlands: integrating new Phytolith evidence of plant-use from the 23,000-year-old site of Ohalo Ii, Israel. Am Antiquity 1–21
Rosen AM (2007) Civilizing climate: social responses to climate change in the ancient near East. Altamira, Lanham, MD
Rosen AM (2010) Natufian plant exploitation: managing risk and stability in an environment of change. Eurasian Prehist 7(1):117–131
Rosen AM, Rivera-Collazo I (2012) Climate change, adaptive cycles, and the persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant. PNAS 109(10):3640–3645

Rosen AM, Hart TC, Farquhar J, Schneider JS, Yadmaa T (2019) Holocene vegetation cycles, land-use, and human adaptations to desertification in the Gobi Desert of Mongolia. Veg Hist Archaeobotany 28(3):295–309

Rosen AM, Odsuren D, Bukhchuluun D, Janz L (n.d.) Holocene desertification and human resilience in the Eastern Gobi Desert. Manuscript in Preparation

Rowley-Conwy P, Zvelebil M (1989) Saving it for later: storage by prehistoric hunter–gatherers in Europe. In: O'Shea J, Halstead P (eds) Bad Year economics: cultural responses to risk and uncertainty. Cambridge University Press, Cambridge, pp 40–56

Schlanger SH (1992) Recognizing persistent places in Anasazi settlement systems. In: Rossignol J, Wandsnider L (eds) Space, time, and archaeological landscapes. Springer US, Boston, MA, pp 91–112

Schneider JS, Tserendagva Y, Hart TC, Rosen AM, Spiro A (2016) Mongolian 'Neolithic' and early bronze age ground stone tools from the northern edge of the Gobi Desert. J Lithic Stud 3(3):479–497

Smith M, Veth P, Hiscock P, Wallis LA (2005) Global deserts in perspective. In: Veth P, Smith M, Hiscock P (eds) Desert peoples: archaeological perspectives. Blackwell, Oxford, pp 1–13

Stiner MC (2004) Small game use and expanding diet breadth in the Eastern Mediterranean basin during the Palaeolithic. In: Brugal JP, Desse J (eds) Petits Animaux et Sociétés Humains: du Complément Alimentaire Aux Ressources Utlitaires: XXIVe Recontres Internationales d'Archéologie et d'histoire d'Antibes. Antibes, APDCA, pp 499–513

Stiner MC, Munro ND (2002) Approaches to prehistoric diet breadth, demography, and prey ranking systems in time and space. J Archaeol Method Theory 9(2):181–214

Stutz AJ, Munro ND, Bar-Oz G (2009) Increasing the resolution of the broad spectrum revolution in the Southern Levantine Epipaleolithic. J Hum Evol 56(3):294–306

Tindale NB (1977) Adaptive significance of the Panara grass seed culture of Australia. Stone tools as cultural markers. R. V. S. wright. Australian Institute of Aboriginal Studies, Canberra, Australia, pp 345–350

Tushingham S, Bettinger RL (2013) Why foragers choose acorns before salmon: storage, mobility, and risk in aboriginal California. J Anthropol Archaeol 32(4):527–537

Veth P (1989) Islands in the Interior: a model for the colonization of Australia's arid zone. Archaeol Ocean 24(3):81–92

Weiss E, Kislev ME, Simchoni O, Nadel D (2004a) Small-grained wild grasses as staple food at the 23,000-year-old site of Ohalo II, Israel. Econ Botany 58(Supplement):SI25–S134

Weiss E, Wetterstrom W, Nadel D, Bar-Yosef O (2004b) The broad spectrum revisited: evidence from plant remains. Proc Natl Acad Sci USA 101(26):9551–9555

Wittfogel KA (1957) Oriental despotism: a comparative study of total power. Yale University Press, New Haven, CT

Wollstonecroft MM, Ellis PR, Hillman GC, Fuller DQ (2008) Advances in plant food processing in the Near Eastern Epipalaeolithic and implications for improved edibility and nutrient bioaccessibility: an experimental assessment of *Bolboschoenus maritimus* (L.) Palla (sea club-rush). Veg Hist Archaeobotany 17:19–27

Wright J, Ganbaatar G, Honeychurch W, Byambatseren B, Rosen A (2019) The earliest Bronze Age culture of the South-Eastern Gobi Desert, Mongolia. Antiquity 1–19

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