Diesel and damper: Changes in seed use and mobility patterns following contact amongst the Martu of Western Australia

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ABSTRACT

Seed-reliant, hunting and gathering economies persisted in arid Australia until the mid-twentieth century when Aboriginal foragers dropped seeds from their diets. Explanations posed to account for this “de-intensification” of seed use mix functional rationales (such as dietary breadth contraction as predicted by the prey choice model) with proximate causes (substitution with milled flour). Martu people of the Western Desert used small seeds until relatively recently (ca. 1990) with a subsequent shift to a less “intensive” foraging economy. Here we examine contemporary Martu foraging practices to evaluate different explanations for the dietary shift and find evidence that it resulted from a more subtle interaction of technology, travel, burning practices, and handling costs than captured solely by the prey choice model. These results have implications for understanding the roles of mobility, aggregation behavior, sexual division of labor, and seed use in the broad-spectrum revolutions of arid Australia and the Western United States.

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1. Introduction

A hallmark of the “broad-spectrum revolution” (BSR) was the systematic adoption of wild seeds into forager diets, marking initial steps toward domestication of many cereals (Flannery, 1969). Investigating causes of this change (Bettinger et al., 2010; Fuller et al., 2011; Geib and Jolie, 2008; Piperno et al., in press; Rhode et al., 2006; Savard et al., 2006) is an ongoing subject of archaeological investigations worldwide, but proponents of human behavioral ecology (HBE) often see it as a broadening of diet to include resources requiring higher handling, but lower search costs, triggered by depression of higher ranked prey (Edwards and O’Connell, 1995; Simms, 1987; Stiner, 2001; but see Zeder, 2012 for an alternative view). Australia represents an important case because hunter–gatherers there relied on Acacia and grass seeds without domesticating them (Allen, 1974; Bliege Bird et al., 2008; Gould, 1969; Tindale, 1977; Walsh, 1990). Although prehistorians disagree when Aboriginal foragers first used seeds, most agree that use of seeds as staple foods was a consequence of intensification among broad-spectrum foragers.

The BSR in arid Australia appeared to reverse its course in the twentieth century when Aboriginal foragers ceased harvesting seeds, while still foraging for other foods. The proximate cause seemed obvious: foragers simply substituted commercial flour for seeds – why harvest and grind seeds when milled flour is free (Altman, 1987; Balme, 1983)? O’Connell and Hawkes (1981, 1984), posed an HBE explanation grounded in principles of the prey choice model (PCM) in their study of the foraging ecology of the Alyawara. They argued that availability of commercial foods discouraged foraging, easing depression of highly ranked foraged foods. Consequently whenever Alyawara women chose to forage their overall returns (E/T – kcal/search + handling-h) were sufficiently high that lower-ranked seeds fell out of the optimal diet. O’Connell and Hawkes speculated that had potatoes rather than wheat flour been the introduced staple, Alyawara would nonetheless have bypassed seeds while continuing to harvest native tubers because of the higher post-encounter return rates (e/h – kcal/handling-h) of the latter.

Like other Aboriginal groups, contemporary Martu of Western Australia rarely harvest seeds despite the facts that seeds were staples until relatively recently, foraged foods account for about half...
of all calories currently consumed, and Martu foragers frequently encounter seeds. Foraging returns in seed-bearing habitats are often low enough that the PCM predicts Martu would do better by taking seeds. Although Martu have substituted commercial flour for seeds, we argue that it is their use of 4-WD vehicles and diesel fuel that has made seed harvesting uneconomical by imposing an opportunity cost between time spent processing seeds and traveling to new patches.

2. Background on the issue

Alyawara foragers voluntarily harvested seeds of only one species of Acacia (Acacia coriaceae) during O’Connell’s year of observations in the mid-seventies. Taken while still green, their pods required no grinding so provided a much higher caloric return than feasible for milled seeds. Alyawara ground ripe acacia pods (A. aneura, A. coriaceae, and A. cowleana) only at O’Connell’s request, despite evidence that they had regularly collected these resources recently.

Similarly Devitt (1988) observed nearby Annmatyerre foragers harvest only the same green acacia, however they were willing to process seeds of woollybutt (Eragrostis eriopoda) grass and ripe A. coriaceae pods to show what women’s work had recently been like. Cane (1987) observed Pintupi foragers prepare dampers (a common term for wet-milled seed cakes and bread cooked on coals) from seeds of five different grasses and forbs to demonstrate their traditional lifeway, but found little evidence of ongoing seed usage in a survey of 35 outstation communities (Cane and Stanley, 1985). Nash (1993) found that Pintupi children learned of wild seeds as “olden time tucker,” then used for cultural, rather than subsistence purposes. Altman (1987) found that Gunwinggu women in Arnhem Land no longer made seed damper except to prove they retained necessary skills. Brokensha (1975) found that Pitjantjatjara in South Australia no longer made damper from Native Millet (Paniceum decompositum), but were willing to demonstrate traditional collecting and processing techniques. Palmer and Brady (1991) found that the Pitjantjatjara speaking Maralinga had stopped making damper from native seeds, even though they still occasionally ate the root of Pigweed (Portulacca oleracea), one of their traditionally important seed plants. Across and Australia, Aboriginal foragers ceased harvesting seeds even though they retained the necessary expertise and technology. Anthropologists saw the availability of flour and the work required to make damper as being the reasons contemporary Aboriginal foragers largely forsake seeds.

The situation in the 1980s was somewhat different for Martu people. One of the authors (PMV) documented Martu use of 17 different species of grass and Acacia seed as staple foods. Yet by 1990, Walsh (2008) recorded Martu use of only six seed species. Recording nearly 1200 foraging bouts from 2000 to 2005, two of the authors (DWB and RBB) recorded only ten instances of Acacia and grass seed harvesting (Bliege Bird and Bird, 2008). We have since observed Martu collect seeds on only three occasions. Martu almost completely dropped seeds from their diets between 1988 and 2000 with a documented shift from a seed-reliant to a less intensive foraging economy.

3. Post-colonial context

To put this transition in historical context, we concentrate on the Martu community of Parnngurr, located within Karlamiliyi (Rudall River) National Park and hosting a shifting population of about 80 people. Martu were among the last full-time hunter-gatherers in Western Australia. An autonomous band of Martu was first contacted near the modern location of Parnngurr in 1963 and relocated to join other Martu at Jigalong mission, 200 km away. While they continued to highly value bush foods, the Martu at Jigalong often found it difficult to forage and grew dependent on European food, especially flour. Tonnison (1997: 162) records Martu as saying, “we were captured by flour” during the mission period.

During their stay at Jigalong, Martu were no longer able to burn-off grasslands for various traditional economic and social purposes, causing the vegetation of Martu estates in the Great and Little Sandy Deserts to revert to relatively homogenous, mature, Spinifex (Triodia spp.) grasslands. This likely had detrimental effects on the abundance and distribution of seed bearing grasses that grow best in areas burned one to four years previously (Bliege Bird et al., 2012a).

Many Martu returned to their homeland to establish the community of Parnngurr in 1984 in a successful attempt to block uranium mining at a nearby sacred place. This early outstation lacked a reliable supply of commercial foods; the nearest regularly supplied stores were at Jigalong and Punnu (the neighboring Martu outstation) both requiring up to a full day to reach by 4-WD. Support from the Department of Aboriginal Affairs involved periodic but unreliable truck deliveries and airdrops of supplies that included flour. A “shop” (initially a freezer in a shed with a generator) was installed by 1988. Regular deliveries to the store were running by 1990, but shortages due to inclement weather and mishap remain common even today (Newman et al., 1993; Walsh, 2008).

Martu at Parnngurr resumed foraging, both out of necessity, and because they saw foraging as key to renewing social and religious ties to their homeland. It was during the early period following resettlement that anthropologists observed Martu using seeds most intensively. Although Martu also resumed traditional burning practices, it took years to re-establish the anthropogenic mosaic of vegetation communities that had existed previously (Bliege Bird et al., 2012a).

Commercial goods, especially flour, increased in availability in the late 1980s at the same time that Martu dropped seeds from their diets; paradoxically, simultaneous with the re-emergence of an anthropogenic fire mosaic conducive to seed growth. We will argue that this transition also corresponds with greater access to motor vehicle transport and diesel fuel and that this change in mobility and transport has not previously been given adequate attention.

4. Purchased and foraged foods: trade-offs in utilizing seeds and flour

Today, although many Martu engage in some wage labor and some sell painted and basketry art, opportunities for employment at outstations are limited and foraging remains the most productive occupation (Coddington, 2012; Coddington et al., in press). Parnngurr residents spend 25–30% of their days hunting or gathering, and rely on foraged food for 35–50% of their daily diet, depending on season (Bliege Bird et al., 2015). While they continue to collect a wide array of plant and insect resources (especially fruit from Solanum spp., nectar from Hakea suberea, and Endoxyla spp. cossid larvae), today both men and women, make up the bulk of the remainder (Bird et al., 2009, 2013).

Contemporary Martu foragers collect small-grained seeds only on rare occasions despite the retention of harvesting and processing skills. In 2002, two of the authors (DWB and RBB) observed
several Martu women harvesting and processing woollybutt grass seeds, one of the most prolific annual grasses in their homeland and a traditionally important staple. The process involved four stages: (First) women harvested ripe seeds and stripped the seeds from stalks directly into a container, (Second) large chaff was winnowed from husked seed, (Third) after a period of drying, seed was pounded and winnowed to separate edible seeds from husks and other debris, and (Fourth) the seed was wet-ground and cooked into a seed damper. Processing time and weight yields for this process are listed in Table 1. This was a laborious and time-consuming process; nearly 13 h of work yielded just 0.35 kg of ground seed. Assuming a caloric content of 3180 kcal/kg (Brand Miller et al., 1993), Martu earned less than 100 kcal/h for their effort.¹

In 2010 two of the authors (DWZ and BFC) observed a Martu informant grind and cook damper from a cache of panic grass (Yakirra australis) using her mother’s milling tools (Fig. 1). She earned about 1300 kcal for an hour of work, but not counting the time she had spent harvesting and winnowing the seed earlier in the year. We estimate the yield for the entire process to have been about 700 kcal/h using previously reported harvesting and winnowing times for the same species of seed (Walsh, 1990).

Table 2 combines these seed return rates with others reported in the literature to estimate the range of variability of seed returns. The highest yields are for green acacia pods that require no milling. Excluding that as well as the next highest and the lowest returns as unrepresentative, 300–1000 kcal/h provides a sound estimate of the range of post-encounter caloric return rates feasible for seeds requiring wet milling.

Handling costs for the set of representative seeds range from 3.9 to 9.1 h/kg. These are very high compared to handling costs necessary for other traditional resources that Martu continue to take (Table 3). Only cossid larvae are comparable to seeds, but the bulk of handling costs are in finding and extracting grubs from acacia roots. This differs from woollybutt (Table 2) in that only 12% of handling costs are in the collection of the resource, which is comparable to proportional contribution of harvesting to processing in the other reported seeds (Cane, 1987). Thus, Australian small seeds are “back-loaded” after harvest (cf. Bettinger, 2009) compared to other resources in which pursuit (frequently failed pursuits) makes up the bulk of handling costs (Bird et al., 2009).

A significant portion of the non-foraged diet comes from store-bought flour. Since Martu make damper from flour in a nearly identical manner as milled seeds (cf. Palmer and Brady, 1991), it is possible to compare the costs of buying wheat flour with harvesting, winnowing, and wet milling indigenous seeds. Martu can purchase 2 kg packages of flour at the community store for AU$5. With 3510 kcal/kg, flour offers the best caloric return per dollar spent of all the food items commonly for sale (Coddin, 2012). Unemployed Martu receive welfare payments of about AU$500 every two weeks but this is insufficient to feed a ‘forager’ and her dependents (Coddin, 2012), so it is misleading to consider flour as ‘free’: five dollars spent on flour (a commodity for which there is a local substitute) cannot be spent buying goods for which there is no local alternative. All Martu adults can supplement their income by working part-time for the Community Development and Education Program (CDEP) at a rate of about AU$15/h. Thus the caloric return for wheat flour can be assessed at 21,000 kcal/h. In other words a Martu can earn the money to buy enough flour for a kilogram of damper in about 10 min, while it takes 3–10 h to collect, winnow, and grind the same amount of seed damper. Clearly, milled white flour provides a much higher caloric return per unit of wage labor than do traditional seed resources per unit of foraging labor. While this may appear intuitive, the comparative yields of seeds and flour have rarely been quantified.

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<table>
<thead>
<tr>
<th>Processing stage</th>
<th>Date</th>
<th>Time cost (min)</th>
<th>Gross yield (kg)</th>
<th>Final yield of seed (kg)</th>
<th>Gross rate (min/kg)</th>
<th>Net (clean seed) rate (min/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collect</td>
<td>4/9/02</td>
<td>95</td>
<td>1.9</td>
<td>.35</td>
<td>50</td>
<td>271</td>
</tr>
<tr>
<td>Winnow</td>
<td>4/9/02</td>
<td>271</td>
<td>.825</td>
<td>.35</td>
<td>328</td>
<td>774</td>
</tr>
<tr>
<td>Dry/store</td>
<td>4/9/02</td>
<td>na</td>
<td>.75</td>
<td>.35</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Yandy</td>
<td>6/10/02</td>
<td>156</td>
<td>.35</td>
<td>.35</td>
<td>446</td>
<td>446</td>
</tr>
<tr>
<td>Grind¹</td>
<td>6/10/02</td>
<td>256</td>
<td>.35</td>
<td>.35</td>
<td>731</td>
<td>731</td>
</tr>
<tr>
<td>Cook</td>
<td>6/10/02</td>
<td>na</td>
<td>.18</td>
<td>.18</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>778</td>
<td></td>
</tr>
</tbody>
</table>

¹ Only half the yield of yandied seed (18 kg) was ground into damper on 6/10 2002. We have adjusted the time and yield estimates to reflect the time necessary to grind the entire load to maintain consistency with the other processing stages.
Table 2
Caloric return rates for various Australian seeds.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Type</th>
<th>kcal/handling-h</th>
<th>Handling time (h/kg)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia coriacea</td>
<td>Tree</td>
<td>4333</td>
<td>.6</td>
<td>O'Connell and Hawkes (1984)</td>
</tr>
<tr>
<td>Yakirra australiensis</td>
<td>Grass</td>
<td>1738</td>
<td>2.5</td>
<td>Cane (1987)</td>
</tr>
<tr>
<td>Fimbristylis oxytachya</td>
<td>Grass</td>
<td>965</td>
<td>3.9</td>
<td>Cane (1987)</td>
</tr>
<tr>
<td>Chenopodium rhadinostachyum</td>
<td>Forb</td>
<td>835</td>
<td>4.5</td>
<td>Cane (1987)</td>
</tr>
<tr>
<td>Panicum cymbiforme</td>
<td>Grass</td>
<td>809</td>
<td>5.1</td>
<td>Cane (1987)</td>
</tr>
<tr>
<td>Yakirra australiense</td>
<td>Grass</td>
<td>690</td>
<td>5.2</td>
<td>This paper/Walsh (1987)</td>
</tr>
<tr>
<td>Acacia coriacea</td>
<td>Tree</td>
<td>676</td>
<td>5.25</td>
<td>O’Connell and Hawkes (1984)</td>
</tr>
<tr>
<td>Acacia coriacea</td>
<td>Tree</td>
<td>622</td>
<td>5.7</td>
<td>Devitt (1988)</td>
</tr>
<tr>
<td>Acacia aneura</td>
<td>Tree</td>
<td>580</td>
<td>6.5</td>
<td>O’Connell and Hawkes (1984)</td>
</tr>
<tr>
<td>Acacia cowleana</td>
<td>Tree</td>
<td>552</td>
<td>6.5</td>
<td>O’Connell and Hawkes (1984)</td>
</tr>
<tr>
<td>Chenopodium rhadinostachyum</td>
<td>Forb</td>
<td>411</td>
<td>9.1</td>
<td>Nash (1993)</td>
</tr>
<tr>
<td>Eragrostis eriopoda</td>
<td>Grass</td>
<td>379</td>
<td>8.4</td>
<td>Devitt (1988)</td>
</tr>
<tr>
<td>Panicum decompositum</td>
<td>Grass</td>
<td>261</td>
<td>5.5</td>
<td>Brokensha (1975); O’Connell et al. (1983)</td>
</tr>
<tr>
<td>Eragrostis eriopoda</td>
<td>Grass</td>
<td>88</td>
<td>32.7</td>
<td>This paper</td>
</tr>
</tbody>
</table>

Table 3
Mean caloric return rates for various resources.

<table>
<thead>
<tr>
<th>Prey</th>
<th>Martu name</th>
<th>N (follows)</th>
<th>Return rate (kcal/handling-h)</th>
<th>Handling time (h/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skink: Tiliqua scincoides</td>
<td>Lunkurta</td>
<td>26</td>
<td>21,188 ± 11,733</td>
<td>.1 ± .2</td>
</tr>
<tr>
<td>Bustard: Ardeotis australis</td>
<td>Kipara</td>
<td>124</td>
<td>8079 ± 16,388</td>
<td>.2 ± .1</td>
</tr>
<tr>
<td>Cat; Felix silvestris</td>
<td>Cat</td>
<td>18</td>
<td>5179 ± 12,270</td>
<td>.3 ± .1</td>
</tr>
<tr>
<td>Sand monitor: Varanus gouldii</td>
<td>Parnajarpa</td>
<td>111</td>
<td>4931 ± 4780</td>
<td>.4 ± .4</td>
</tr>
<tr>
<td>Hill kangaroo: Macropus robustus</td>
<td>Kirti-kirti</td>
<td>53</td>
<td>3843 ± 9910</td>
<td>.4 ± .2</td>
</tr>
<tr>
<td>Perentie: Varanus giganteus</td>
<td>Nyintaka</td>
<td>23</td>
<td>3455 ± 4897</td>
<td>.6 ± .4</td>
</tr>
<tr>
<td>Python: Aspidites ramsayi</td>
<td>Kanati</td>
<td>16</td>
<td>1491 ± 1501</td>
<td>.7 ± .7</td>
</tr>
<tr>
<td>Cossid larvae: Endoxyla spp.</td>
<td>Lunki</td>
<td>64</td>
<td>887 ± 513</td>
<td>2.8 ± 4.8</td>
</tr>
</tbody>
</table>

Table 4
Comparative return rates for purchased and foraged foods of contemporary Martu (Coddling et al., in press).

<table>
<thead>
<tr>
<th>Purchased item</th>
<th>kcal/h wage labor</th>
<th>Foraged item</th>
<th>kcal/handling-h foraging labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>21,840</td>
<td>Skink: Tiliqua scincoides</td>
<td>20,403 ± 12,206</td>
</tr>
<tr>
<td>Canola oil</td>
<td>18,267</td>
<td>Bustard: Ardeotis australis</td>
<td>10,261 ± 21,166</td>
</tr>
<tr>
<td>Dry red lentils</td>
<td>10,131</td>
<td>Corkwood nectar: Hakea suberea</td>
<td>8482 ± 3350</td>
</tr>
<tr>
<td>Sausages</td>
<td>6750</td>
<td>Honey: Apis mellifera</td>
<td>5378 ± 30,821</td>
</tr>
<tr>
<td>Honey</td>
<td>6270</td>
<td>Cat; Felix silvestris</td>
<td>5179 ± 12,270</td>
</tr>
<tr>
<td>Rice</td>
<td>5265</td>
<td>Bush tomato: Solanum diversiflorum</td>
<td>5006 ± 2120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand monitor: Varanus gouldii</td>
<td>4931 ± 4781</td>
</tr>
<tr>
<td>Pearl barley</td>
<td>3717</td>
<td>Hill kangaroo: Macropus robustus</td>
<td>3844 ± 9910</td>
</tr>
<tr>
<td>Hamburger</td>
<td>3055</td>
<td>Perentie: Varanus giganteus</td>
<td>3455 ± 4897</td>
</tr>
<tr>
<td>Kangaroo tail</td>
<td>2505</td>
<td>Desert raisin: Solanum centrale</td>
<td>2459 ± 1377</td>
</tr>
<tr>
<td>Stew chops</td>
<td>1897</td>
<td>Nectar: Grevillea eriostachya</td>
<td>1491 ± 1501</td>
</tr>
<tr>
<td>Chick peas</td>
<td>1812</td>
<td>Python: Aspidites ramsayi</td>
<td>1462 ± 549</td>
</tr>
<tr>
<td>Spaghetti noodles</td>
<td>1456</td>
<td>Pencil yam: Vigna lanceolata</td>
<td>465 ± 292</td>
</tr>
<tr>
<td>Frey Bentos meat pies</td>
<td>1283</td>
<td>Bush onion: Cyperus bulbosus</td>
<td>454 ± 186</td>
</tr>
<tr>
<td>Beans in tomato sauce</td>
<td>1230</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instant noodles</td>
<td>888</td>
<td>Cossid larvae: Endoxyla spp.</td>
<td>887 ± 513</td>
</tr>
<tr>
<td>Canned vegetables</td>
<td>788</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken breasts</td>
<td>717</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports drink</td>
<td>600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato sauce</td>
<td>306</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diet cola</td>
<td>38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mean overall return rates for Martu foraging activities (Bird et al., 2009).

<table>
<thead>
<tr>
<th>Foraging activity</th>
<th>Return rate per bout (E/T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit collecting</td>
<td>2760 ± 1800</td>
</tr>
<tr>
<td>Cat hunting</td>
<td>915 ± 1185</td>
</tr>
<tr>
<td>Perentie hunting</td>
<td>705 ± 900</td>
</tr>
<tr>
<td>Sand monitor hunting</td>
<td>635 ± 515</td>
</tr>
<tr>
<td>Grub collecting</td>
<td>515 ± 215</td>
</tr>
</tbody>
</table>

Fig. 2. Kernel density plots of the overall return rate (E/T) for sand monitor bouts relative to the mean estimated return rates (E/h) for grass seeds (vertical lines). Note: the curve plotted includes unsuccessful sand monitor bouts with a return of zero (@10%). For the entire set of sand monitor bouts: Mean = 547 kcal/h; StDev. = 565 kcal/h; Median = 4434 kcal/h; Median Absolute Deviation = 439 kcal/h. For the set of successful bouts only: Mean = 663 kcal/h; StDev. = 557 kcal/h; Median = 508 kcal/h; Median Absolute Deviation = 357 kcal/h.

Some foraged foods, despite their costs, are often more reliable than commercial alternatives (Scelza et al., 2014). Foraging returns from hunting resources such as sand monitor lizard (goanna, Varanus gouldii) and feral camel (Camelus dromedarius) are dependable, and Martu hunt them more often when commercial foods are less accessible, either because of scarcity in the shop (for camels) or limited access to money (for sand monitor). In contrast, common and calorically important foraging types, such as hill kangaroo and bustard hunting, are not responsive to shortages either of cash or limited access to money (for sand monitor). In contrast, common and calorically important foraging types, such as hill kangaroo and bustard hunting, are not responsive to shortages either of cash or limited access to money (for sand monitor). Since they almost always use 4-WD vehicles to access sand monitor patches, there is no reason they cannot arrive pre-equipped to switch to seed collection when returns for hunting monitor are sufficiently poor.

Contemporary Martu foragers insist that seeds are highly reliable resources, so one would expect that occasional shortages in the community store should trigger a resumption of the extensive seed harvesting observed in the mid-1980s. Yet, Martu increase their hunting for camels, make long distance trips to the grocery store in Newman (@ 250 km), and/or temporarly move to other communities whenever the store has not been resupplied (Scelza et al., 2014; Walsh, 2008), rather than take seeds. All three options are made possible by motor vehicle transport.

Further, there have been at least two attempts by NGOs since 1990 to stimulate development of a commercial seed harvesting industry among Martu for the purpose of supplying seed for re-vegetating mine sites. One of the authors (PV) recalls a Martu man using trowels and sieves to collect seeds from an anthill during the course of an archaeological excavation for one of these efforts to make seed collection economically viable in the early 1990s. Nonetheless, Martu interest in seed collection has remained relatively unenthusiastic overall.

The PCM also fails to predict the choice by Martu not to take seeds even when considering only foraged foods under circumstances where all the assumptions of the PCM are met. Table 5 summarizes overall calorric return rates for different foraging activities (bouts consisting of all time spent searching for and handling a concurrent set of resources) that are often conducted during the same season and in the same settings where grass seeds occur (Bird et al., 2009; Bliege Bird and Bird, 2008). Enough foraging data have been tabulated to gauge variability, as well as mean returns of these foraging activities. All are sufficiently variable that the PCM predicts seeds should enter forager diets whenever the returns for these foraging activities that Martu continue to practice fall within one standard deviation below the mean return.

We selected a database of 166 foraging bouts recorded between 2000 and 2010 (Bird et al., 2009; Bliege Bird and Bird, 2008; Bliege Bird et al., 2008; Codding, 2012; Codding et al., 2011) that occurred between April and June—the prime window for grass seed exploitation in this part of the desert—and on sand plain landforms where seeds are found. These bouts targeted sand monitor, but foragers engaged in this activity can simultaneously search for an array of options to accommodate other resources they find (skinks, larvae and Desert Raisin, Solanum centrale).

The distribution of sand monitor and grass seeds within the Spinifex sand plain depends on the stage of vegetative succession following fire. Sand monitors are hunted on-foot in recently burned tracts of manguu and kunarka (Martu designation of late stages of vegetative succession) where the overburden of Spinifex has been cleared to expose tracks and burrows. As a consequence of Martu mosaic burning practices (Bliege Bird et al., 2012a, 2013), monitor hunters often come across seed-bearing grasses in patches that have revegetated from an earlier burn that Martu refer to as nyukura. Since they almost always use 4-WD vehicles to access sand monitor patches, there is no reason they cannot arrive pre-equipped to switch to seed collection when returns for hunting monitor are sufficiently poor.

Quantitative observational data was collected through a combination of focal-individual follows and continuous-camp scans (Altmann, 1974). Detailed methods on the context of data collection are reported elsewhere (Bird et al., 2009; Bliege Bird and Bird, 2008).
Fig. 2 plots kernel density of the overall return rate (E/T) for sand monitor hunting against the mean estimated post encounter return rates (e/h) for grass seeds (300 and 1000 kcal/h as indicated by the vertical dashed lines). Results indicate that sand monitor hunting returns commonly fall below the post-encounter return range expected for seeds, but more often than not, contemporary Martu bypass seeds altogether regardless of the overall foraging returns they gain from sand monitor hunting at the moment. Indeed, time spent by women in the Sand hunting “patch” is positively correlated with the probability of successfully acquiring small game and negatively correlated with variability in small prey returns (Bliege Bird and Bird, 2008) suggesting that women abandon sand monitor patches before allowing seeds to enter their diets.

5. Motor vehicles: the true revolution in the Western Desert

We suggest that the economic choice Martu foragers make when they bypass seeds results from Martu use of 4-WD vehicles to forage, which has dramatically lowered travel costs between patches. Shifts in the availability of vehicles correspond to the dropping of seeds from Martu diets ca. 1990. From 1984 until 1988, 44-gallon drums of diesel fuel were trucked into the community for free, but only irregularly. The only reliable vehicle available in Parnngurr was a flatbed army truck. A few early series Land Rovers were also donated to the community, but these were only occasionally operable; typically lacked radiator caps; often ran on steel tire treads; and had to be started by ramming one vehicle with another. As a consequence of the limited availability and unreliability of motor vehicles, travel to foraging locales was usually conducted on foot. Whenever Martu used a vehicle to access remote patches, it was not uncommon to see people walking home after the vehicle broke down in the field.

This situation began to change in 1988, when a large diesel tank was installed in the community. By 1990 there were usually four vehicles in Parnngurr, not counting school, staff, and anthropologist vehicles that were often used to transport foraging parties. Foraging was conducted on 65 of 85 (77%) vehicle trips Fiona Walsh (2008) observed from outstation communities over a 44-day period. Martu made maximum use of the vehicles available to access remote patches previously unavailable within a day by foot. Expeditions were occasionally single-sex taking parties of women to target vegetable foods like desert raisin, but no longer seeds.

Although pedestrian foraging bouts from the community still occur, almost all foraging trips observed since 2000 have been vehicle mounted. Vehicle borne foraging bouts often consist of around eight participants, but mixed-sex parties as large as 15–23 in a vehicle are not uncommon. Motorized foraging parties leave usually in the late morning, travel to a targeted foraging region, and upon arrival establish a “dinner-time camp” (DTC) to which foragers will return, prepare, share and eat the day’s harvest.

In 2010, there were eleven vehicles owned by Martu in the community (Coddington, 2012). Toyota 70s series Land Cruisers are the community’s favorite for foraging trips. Two weeks income is sufficient to purchase six to twelve round trip forays into the bush. Fig. 3 illustrates the distance from Parnngurr for a sample of DTC’s occurring only within the ‘seed season’ on the sand plain. Two weeks income is sufficient to purchase six to twelve round trip forays into the bush. Fig. 4 shows the distribution of seed season DTC’s relative to the location of Parnngurr. The camps are linearly arrayed along the 4-WD routes from the community demonstrating the impact of vehicle transport on contemporary foraging practices.

Fig. 3. Frequency of DTC by distance from Parnngurr. Only including camps in which people targeted sand plain resources during the ‘seed season’. Calculated as Euclidean distance using UTM locations (Mean and Median: 25.2 km; SD: 13.2; MAD: 15.4 km).

6. Martu foraging, 4-WD transport, and the Marginal Value Theorem

The availability of motor vehicles and diesel fuel has revolutionized the foraging economy by allowing Martu foragers access to remote resource patches from permanent outstation communities. The coincidence between the availability of transport and the near-disappearance of seeds from Martu foraging suggests that reduced travel cost played a role in the dietary shift. The Marginal Value Theorem (MVT) models the trade-off between foraging within a patch and traveling to a new patch (Charnov, 1974), but does not distinguish between in-patch handling and search time, which we have shown is a major difference between the costs of most of the resources that Martu still forage and seeds.
To monitor the effects of handling costs in the MVT, we follow Bettinger and Grote’s (2012) equation for calculating diminishing patch returns incorporating handling time as a variable:

\[ I_{jk} = S_j + P_{jk} + h_k \]

The time \( i_{jk} \) needed to produce resource \( k \) from patch \( j \) for resource \( k \) depends on:

1. the time required to fully search the patch \( j \) (proportional to patch size): \( s_j \)
2. quantity of resource \( k \) available in patch \( j \) (measured as an integer count \( \geq 0 \)): \( p_{jk} \)
3. the processing time once the resource is found: \( h_k \)

The curve is generated in a series of discrete iterations where the value of \( p_{jk} \) diminishes by one value after each repetition.

To model the marginal returns of sand monitor hunting, we envision a patch of recently burned manguu/kunarka that takes a forager 180 min to fully search (the average time spent on sand monitor bouts in the seed season sample). The daily energetic yield per forager during sand monitor bouts rarely exceeds 3300 kcals in the seed season (Mean = 1800 kcal, StDev. = 1414 kcal, Median = 1370 kcal, MAD = 866 kcal), so we set that as the maximum energetic yield of the patch. For purposes of generating a continuous curve, we assume the forager encounters prey in 33 increments (iterations) of 100 kcal apiece. The average post encounter foraging return for sand monitor is about 5000 kcal/h or 1.2 min per 100 kcals is the value for handling time (\( h_k \)).

Fig. 5 presents the resulting diminishing returns curve for the values. We have plotted the predicted travel threshold for a forager who achieves the average seed season return rate for monitor bouts (at 660 kcal/h). The simulation predicts that foragers should spend no more than about 173 min foraging in the tract of manguu/kunarka when the travel time to the next patch exceeds 85 min. The average distance between seed season DTC’s in Fig. 4 is 25 km. Assuming an average 4-WD driving speed of 20 km/h, the predicted travel threshold closely matches the distribution of sand monitor DTC’s.

There are, however, two unrealistic aspects of this simulation. First, the equation assumes prey move randomly within the patch, but Martu foragers search for stationary monitor dens during this

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6 We exclude sand monitor bouts that produced no energetic return (≥10% of the total) because these distort predictions of the MVT. In a dataset that perfectly followed the MVT, an energetic yield of zero should only be associated with zero foraging time (the origin) but extremely low values of \( E_{per T} \) should be associated with extreme lengths of time in patch. In this dataset of seed season sand monitor bouts, we expect that zero return bouts should reflect foraging times in the 400–600 min range, but a large proportion of the bouts are associated with patch foraging times of less than 100 min, whereas only a couple exceed 300 min. These likely were situations where the forager abandoned the patch before gaining a return because they judged better options to be available, but additional time spent foraging would probably have yielded a return. Thus, the arithmetic affect of the zero return bouts is to depress average foraging return rates and predict longer patch residence times (push the tangent point to the right of the graph) when most of the actual residence times are closer to the origin.

7 We do not include diesel or vehicle maintenance costs here because almost all travel time in contemporary Martu foraging is done using motor vehicles, so these costs are embedded evenly across all foraged resources. In addition, fuel and maintenance costs are cheap compared to the cost in time for processing seeds. For example, at a mileage of 8 km/l and fuel cost of AU$3/l, it costs a forager less than AU$10 to drive 25 km to a new sand monitor DTC. At a CDEP wage of AU$15/h, the forager can earn enough cash to recover this cost in only three quarters of an hour, a fraction of the time necessary to process seeds.
season (although Sand Monitor frequently attempt escape after the forager begins to dig out the den). Since this applies equally for all dens, we chose to ignore this complication for modeling purposes. More challenging is the assumption that foragers encounter monitor in fractional increments of 100 kcals when, in fact, sand monitor come in full packages of about 1000–1500 kcals apiece. However, we note that monitor hunters encounter and almost always take other resources including skink, snakes, cossid larvae, and desert raisin. Thus, we assume that the curve roughly approximates the average return curve a forager may experience.

To model the marginal value for seed patches of nyukura, adjacent to the sand monitor patch, we use the same search time (180 min) and energy yield (3300 kcal allocated in 100 kcal increments) used for the monitor patch. These are realistic parameters for seeds. Fig. 6 presents the marginal return curves for seeds garnered at the upper (1000 kcal/h or 6 min of handling time per 100 g) and lower (300 kcal/h or 20 min per 100 g) range of caloric return rates. The curve for Sand Monitor is included for comparison. The curve for the grass seeds (nyukura) diminishes less rapidly than that for sand monitor (manguu/kunarka) because of the relatively higher contribution of handling costs to grass seed procurement (Bettinger and Grote, 2012). Increasing the value of handling time flattens the curve for seeds, with the initial segment of each curve approaching a straight line. A parallel line, tangent to the sand monitor curve predicts the travel time threshold between curve approaching a straight line. A parallel line, tangent to the grass seeds. Foragers will find switching to the highest ranked seeds economical when travel time to the next monitor patch exceeds 52 min, but should only harvest the lowest ranked seeds when travel time to next patch approaches 370 min.

A pedestrian forager traveling 4 km/h on sand plains (Bird and Bleige Bird, 2005) could only access alternative sand monitor patches in less than a 4-km radius before they find it profitable to switch to the highest ranked seeds but a 24-km radius before they found taking the lowest ranked seeds profitable. However, 4-WD vehicle transport dramatically alters pedestrian thresholds. At 20-km/h, a motorized forager could access alternative sand monitor patches 120 km distant before the lowest ranked seeds (300 kcal/h) became economical. The driving distance from Parnngurr to the nearest neighboring Martu outstation (Punmu) is a little over 100 km, taking over 6 h to drive. Thus, a vehicle equipped Martu foraging party can journey to a different community with its own store and sand monitor patches before finding local, lowest ranked seeds worthwhile to harvest. Given these thresholds, it is unsurprising that contemporary Martu rarely harvest the lowest ranked seeds.

Yet the MVT does not fully explain why contemporary Martu do not take the highest ranked seeds more often. Martu foragers only achieve an average successful foraging return of 660 ± 560 kcal/h for bouts with an expected travel threshold of 85 min (Fig. 5). Yet the highest ranked seeds (1000 kcal/h) should be economical to harvest if travel time to the next monitor patch exceeds 52 min (or a little less than 20 km away at 20 km/h). The model predicts that contemporary Martu foragers should occasionally find it economical to exploit the highest ranked seeds, yet they rarely do so.

### 7. Opportunity costs for back-loaded resources

Because of the heavily back-loaded handling costs, a contemporary Martu forager who chooses to harvest seeds commits to spending 2–8 h winnowing and grinding after harvest to realize a yield. These hours impose a high opportunity cost. Social and cash-based economic opportunities (ritual activities, painting, gambling, wage labor, sports, etc.) at outstation communities present attractive alternatives to winnowing and grinding seeds at a DTC.

Of course a forager could defer these costs by transporting unprocessed seeds back to camp in the vehicle and processing them at a more convenient time. In fact, this seems to be what...
the Martu usually do on the rare occasions they take seeds. For example in the 2002 event previously described, after initial winnowing, Martu dried and cached the unhusked woollybutt seeds in a canvas bag. Yanding and grinding occurred several weeks later when the cache was transported to another location where suitable milling equipment was available. The Martu woman grinding in 2010 had harvested the seeds the previous summer and cached them in a fruit jar in her house over the intervening period. Note, however, that it is in this very circumstance that the availability of cheap flour at the store directly competes with the need to process flour at the shop? But this choice is only possible because of the ease of transport from field locations back to Parmgurr made possible by 4-WD vehicles.

A contemporary Martu forager who chooses to harvest and process seeds at a DTC also forgoes other foraging opportunities made possible by motor vehicles. For example, use of vehicles has dramatically improved pursuit success of hunting bustard (Bird et al., 2013; Bliege Bird and Bird, 2008). Pedestrian hunters have little chance of coming close enough to fire a shot because bustard readily perceive the threat and fly away. However, hunters in vehicles often drive close enough for several rifle shots because bustards do not perceive vehicles as anthropogenic. Bustard hunting is usually done by men (40% of men’s production), but often is embedded in mixed-sex foraging bouts while journeying to and from sand monitor DTCs, and women are alert for signs of bustard over the course of these trips, often hunting bustard on their own (Bliege Bird and Bird, 2008). Bustard hunting can exceed 30% of women’s total foraging time in the seed season (Bliege Bird, personal communication).

In effect, 4-WD transport has increased the reliability of bustard hunting and facilitated convergence of Martu sexual division of labor in the context of journeys to and from seed season DTCs (Bliege Bird, personal communication; Codding et al., 2011). Bustard hunting bouts during the seed season take an average of 130 min (Mean = 133 min, StDev. = 71 min, Median = 124 min, MAD = 77 min), about the same time necessary to process the highest ranked seeds after harvest. Vehicle-mounted, hunting bouts have a 45% chance of successfully bagging a bustard, but successful bouts average one bustard of 10,000 edible kcal apiece. The mean energetic yield of seed season bustard hunts is 4000 kcal (StDev. = 11,100 kcal; Median and MAD 0 kcors). Therefore, over the long term a woman choosing to process a kilogram of edible seeds at a DTC (@3000–4000 kcors) sacrifices her opportunity to encounter an equal or greater quantity of kilocalories of bustard. Time spent winnowing and grinding seeds cannot be spent in the vehicle searching for bustard.

8. Implications for arid land prehistory and the BSR

O’Connell and Hawkes (1981) proposed that the abandonment of small grass seeds by twentieth century Australian foragers was an expectable consequence of the prohibitively high effort required to collect and process them if more efficiently handled resources are sufficiently available. Their explanation carried implications for understanding the Australian BTS. They speculated that desiccation during the Last Glacial Maximum (LGM) depressed the abundance of higher-ranked resources compelling prehistoric foragers to broaden their breadth of prey, adding grass seeds to their diets (Edwards and O’Connell, 1995). An early corollary of this theory was that use of small seeds might have been necessary for successful occupation of arid Australian habitats (O’Connell and Hawkes, 1981, 1984). Proponents of this view find evidence sporadically as plant macrofossils and residues, and non-formal milling equipment (Field and Fullagar, 1998; Fullagar and Field, 1997; McConnell, 1998) in Ice Age deposits.

An alternative explanation holds that social intensification (David, 2002; Lourandos, 1997), possibly driven by population growth and subsequent circumscription of mobility (Smith and Ross, 2008) prompted the systematic use of small seeds. Advocates of this view find no convincing evidence that seeds were intensively used until the Late Holocene, when formalized wet-milling equipment becomes common in the archaeological record. They point to ethnographic accounts of women using seeds to feed groups of people gathered for social and ceremonial purposes, and suggest that milling seed damper was crucial for provisioning such events (David, 2002; Veth, 2006).

Many prehistorians believe that LGM foragers in arid Australia were generally more mobile than their Late Holocene and ethnographic successors (Veth, 2005). Our use of the MVT to analyze contemporary Martu sand monitor hunting demonstrates that seed usage is more likely when travel times and distances between foraging patches are long. If desiccation of the LGM increased distances between foraging patches, ceterus paribus, we agree with O’Connell and Hawkes that climate change should have triggered an intensification of seed usage. Yet evidence of Pleistocene seed grinding appears episodically and usually involves casually manufactured milling equipment, suggesting wet-milled seed processing played a major role in LGM adaptations (Smith, 2013).

Archaeological evidence is compelling that humans effectively abandoned the most arid portions of Australia, retreating to relatively well-watered “refugia” during the LGM (Veth, 1993; Williams et al., 2013). Local resource use and occupational intensity increases in at least some refugia sites suggesting constricted foraging ranges and prolonged residential occupations (Hiscock, 2005; Hiscock and Wallis, 2005). However, radiocarbon curves suggest population densities were quite low even within refuges (Williams, 2013; Williams et al., 2013), and most archaeological evidence suggests that LGM foragers maintained a high degree of residential mobility (Veth, 2005). Smith (2013: 123) argues that “point to point” mobility involving frequent residential moves between reliable water sources within refugia best accounts for the LGM pattern.

We suggest that LGM foragers faced the same conflict between the heavily back-loaded handling costs necessary for seeds and the opportunity for traveling to new patches that contemporary Martu face. A Pleistocene forager who chose to spend the day winnowing and grinding seeds sacrificed her opportunity to travel 15–30 km (assuming 3–4 km/h for 5–8 h) in the same time. If distances between foraging patches within refugia were sufficiently short, we expect that LGM foragers resisted including back-loaded seeds in their diets, even when immediate foraging circumstances made seed harvesting economical. A lack of milling equipment nearby would further motivate foragers to move-on rather than collect seeds.

A decision by women to process seeds would also restrict men’s opportunity to travel to fresh patches for hunting large game (Codding, 2012). This imposed a particularly significant opportunity cost if, as Coding has argued, returns for kangaroo hunting were more reliable during the Pleistocene than the case with modern Martu, particularly given that highly mobile populations should have had limited impact on kangaroo populations (Codding et al., 2014). Under circumstances where high-energy resources can be acquired with low risk of failure, men’s and women’s foraging strategies should converge, with women and men either procuring the same resources, or women providing the logistic support for residential mobility (Codding et al., 2011; Elston et al., 2014). We expect women to forgo opportunities for
taking lower energy, but highly reliable resources even if such resources would raise their overall foraging return rate, if it were necessary to maintain encounters with higher-energy prey. This is directly analogous to the modern circumstance where Martu women bypass seeds thereby lowering their overall foraging return rate, in order to search for bastard in 4-WD vehicles. Such opportunity conflicts between the back-loaded handling time of seeds and travel time to new hunting patches may explain why evidence of Pleistocene seed grinding is rare.

Australian foragers only fully switched to the intensive seed economy with attendant wet milling technology that characterizes the ethnographic record when the risks of traveling on, but failing to obtain high-energy resources, were too high. Such circumstances were most likely during the mid-late Holocene when rising population densities (Smith and Ross, 2008; Williams, 2013) filled the most productive habitats of the arid zone and imposed high travel costs on foragers seeking to transit from one hunting patch to another (cf. Bettinger and Grote, 2012). Declining residential mobility and contracted foraging territories triggered a sexual division of labor in which men targeted high-energy resources that occasionally provisioned all within the group, and women focused on low-energy resources to reliably provision offspring and consequently provide the bulk of the resources consumed by the foraging group.

Based on contemporary Martu foraging practices, we expect that women seeking to reliably provision offspring preferred small reptiles and marsupials (Bliege Bird et al., 2013; Codding, 2012). Their use of fire to hunt burrowed prey inadvertently created stands of seed grasses (Bliege Bird et al., 2008). Although this reduced travel distances between patches within each anthropogenic mosaic, population inflilling increased the distances a forager would have to travel to access new mosaics. Female pedestrian foragers faced with local game shortages, either because of drought or socially induced resource depression at temporary aggregation sites, turned to seed damper as the most reliable means of provisioning offspring and supplying social gatherings. If so, the Holocene efflorescence of formal wet-milling technology, in fact reflects the emergence of anthropogenic fire regimes (Bliege Bird et al., 2008).

Elsewhere, Elston et al. (2014) have proposed that a similar set of circumstances involving a reduction in the reliability of high-energy resource acquisition, and degree of residential mobility, triggered a divergence of sexual division of labor in the terminal Pleistocene/Early Holocene of the Great Basin in the Western United States. A shift toward intensive use of seeds accompanied by proliferation of ground stone milling technology was the hallmark of this transition. If so, parallels with arid Australia are striking, and we expect similar parallels in other arid regions witnessing the BSR. Although modern Martu use 4-WD vehicles and have access to commercially available flour, we argue that their contemporary foraging practices serve as a useful analogy for LGM subsistence-settlement patterns precisely because of the way modern factors affect mobility, opportunity costs and sexual division of labor.

9 Nineteenth century Great Basin foragers also dropped small seeds from their diets, while maintaining other aspects of their traditional subsistence. The transition coincided with increased availability of milled flour, commercial foods and wage labor, but preceded motor vehicle transport by many decades. The range of post-encounter returns offered by Great Basin seeds were similar to their Australian counterparts and were similarly sensitive to changes in abundance of higher ranked resources (Simms, 1987; Zeanah, 2004). Handling costs of Great Basin seeds are also heavily back-loaded after harvest, creating opportunity conflicts between seed processing and alternative activities. Analyses based on HBE have concluded that the change was consistent with a contraction of diet breadth as predicted by the PCM, with higher ranked flour displacing small seeds from the diet (Tucker et al., 1992; Wall, 2014). If so, the Great Basin case occurred without the conflict between transport and handling costs we argue was critical in Australia. However, storability appears to have been an important economic factor in Great Basin seed usage (Simms, 1987; Zeanah, 2004) that has not been demonstrated in arid Australia (Cane, 1987; Kimber, 1984), so the introduction of commercial foods and food containers may have played a larger role in displacing seeds in the Great Basin (Tiley, 2008) than in Australia. In addition, the Great Basin transition did coincide with the introduction of horse and rail transport, which likely lowered foraging travel and search costs. It seems plausible that nineteenth century Great Basin foragers did face opportunity costs between time spent processing seeds and traveling to new patches, much like those faced by twentieth century Australian foragers. Given recent investigations that have linked archaeological excavations with analyses of archival sources (Tiley, 2008; Tucker et al., 1992; Wall, 2014), further investigations of the effects transport technology had on the economic use of seeds in the 19th century Great Basin will likely prove informative.

9. Conclusion

The availability of 4-WD vehicles and diesel fuel have altered the cost-benefits of contemporary Martu foraging, making seed harvesting uneconomical by imposing a conflict between time spent processing seeds and travel time. This opportunity cost is incurred because of the back-loaded cost structure of seeds; today, a woman foraging in circumstances where harvesting seeds would improve her overall foraging return rate faces a choice between spending the rest of the day at a DTC processing seeds, or traveling by vehicle either back to Parnngurr (where there are opportunities for alternative social and economic activities), or traveling to a new resource patch (sand monitor or bustard). Use of motor vehicles has reconfigured the traditional, seed-reliant social landscape in that permanent outstation communities have replaced temporary aggregation sites (McDonald and Veth, 2012; Veth, 2006) as the locations where social events are held. Traditionally, seed damper fed the pedestrian foragers who attended such events as local resources were depleted. Now 4-WD transport, in addition to local stores, allows a more mobile foraging economy that is not dependent on seeds. We suggest that contemporary Martu foraging practices are logisitic approximations of the highly mobile foraging pattern that existed before the inception of intensive seed usage and formal wet-milling technology in arid Australia more than 1500 years ago. If so, episodic evidence of seed usage and milling technology predating the Late Holocene, and particularly during the LGM, should be associated with long travel distances between foraging patches. These predictions are archaeologically testable from a new generation of excavations of Pleistocene-aged occupation sites from the Australian arid zone (Veth et al., 2014).

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Further reading