



Megafauna in a continent of small game: Archaeological implications of Martu Camel hunting in Australia's Western Desert

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ABSTRACT

Archaeologists often assume that large ungulates are inherently highly ranked prey because of their size, especially attractive to hunters using sophisticated capture technologies common after the late Pleistocene. Between 1840 and 1907, over 10,000 dromedary camels were imported to Australia, and today feral populations number well over a million. Although contemporary Aboriginal hunters in Australia's Western and Central Deserts regularly encounter camels, they rarely pursue them. We present data on camel encounter and pursuit rates, with comparisons of energetic search and handling efficiency relative to other foraging options among Martu, the Traditional Owners of a large region of the Western Desert. We then explore some hypotheses concerning the determinants of prey rank and the technological and social contexts that influence resource value. In some respects the case runs counter to common expectations about hunting large ungulates, and highlights the special kinds of opportunity costs that large game acquisition might entail in many contexts. The data should therefore provide insight into the socio-ecological contexts of large ungulate hunting and its archaeological signatures.

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1. Introduction

In the classic hypothesis of Early Pleistocene human evolution, the genus *Homo* embarked upon a subsistence niche that included hunting large ungulates, from which co-evolved all the distinctive features of a human life-history (extended juvenility and long life), morphology (large brains, small teeth, and simple guts), and social behavior (cooperation and family organization) (Washburn and Lancaster, 1968; Isaac, 1978; Hill, 1982; Aiello and Wheeler, 1995; Lewin, 1998; Kaplan et al., 2000; Stanford and Bunn, 2001; Hill and Hurtado, 2003). This hypothesis, however, is somewhat at odds with the Pleistocene record, which shows no clear archaeological signatures of a distinct reliance on hunting until after 500,000 years ago, more than a million years after the emergence of our genus (O'Connell et al., 2002; cf. Dominguez-Rodrigo and Barba, 2006; Klein, 2009). Likewise, complex technology (including compound weaponry, drives, and traps) in association with abundant archaeofaunal evidence of large game hunting is limited mostly to modern humans and Neanderthals (Stiner, 2002; Schmitt et al., 2003; Kuhn and Stiner, 2006; Klein, 2009; Morin, 2012).

A common interpretation of such archaeofaunal evidence is that large ungulates were preferred prey, hunted mainly by men, and acquired to support a household. It seems reasonable to assume that because of the potential harvest size, large game (or small game acquired en masse through coordinated communal hunts) would be a highly ranked resource, well suited for supplying family based production. The payoffs from this strategy are thought to have shaped the nature of human socio-political, economic, and technological integration: a lot of meat translates into a highly effective way to provision yourself and family, especially when labor is specialized and complemented by plant resources and reciprocal sharing to smooth out acquisition variance (for discussion see Gurven et al., 2000; Gurven and Hill, 2009 for discussion). This would subsidize subsistence strategies constrained by rearing offspring with long juvenility, and favor the evolution of complex organizational abilities related to the acquisition, storage, and distribution of large amounts of food, as well as sophisticated technologies common in human societies since the Late Pleistocene.

However, there has been a good deal of research calling into question the notion that specialized large game acquisition or communal hunts serve primarily as a reliable provisioning strategy among ethnographically or archaeologically known foragers (let alone our more poorly equipped hominin ancestors)

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(e.g. Hawkes, 1991, 1993; Bliege Bird et al., 2001; Hildebrandt and McGuire, 2002, 2003; Lupo and Schmitt, 2002; O'Connell et al., 2002; McGuire and Hildebrandt, 2005; Alemseged and Bobe, 2009; Speth, 2010; Speth et al., 2013). Prey that utilize effective escape or defensive behaviors make themselves costly to pursue; costs that in some cases make capture virtually impossible without highly specialized technology and coordinated communal hunting strategies. These costs are compounded for an individual forager if, after distributing the meat to those who paid none of the cost hunting the animal, he/she receives less meat (either directly or reciprocally) per hour hunting than would have been possible by foraging for other prey (e.g. Lupo and Schmitt, 2002; Bliege Bird et al., 2002; see Alvard and Nolin, 2002 for institutionalized rules required to capitalize on potential benefits of communal acquisition of risky prey). However, if hunters do bear such costs, hunting becomes an especially attractive option (beyond its provisioning value) for securing social and political relationships that involve inherent conflicts of interest (Bliege Bird and Smith, 2005; Smith and Bliege Bird, 2005). While the returns from hunting efforts probably always serve many purposes, there remains considerable debate about whether risky game acquisition is commonly maintained primarily in support of family provisioning goals (Hawkes et al., 2010). A rehearsal of the lively argument – and its implications for models of human evolution – is well beyond the scope of this article, but the above summary situates a few of the questions we address here.

In what follows we explore three specific questions, framed by patch and prey choice models in behavioral ecology (see Stephens and Krebs, 1986; Bird and O'Connell, 2006; Bettinger, 2009 for review). These questions are intrinsic to many of the debates about the function of large ungulate hunting among human foraging populations, past and present:

- 1) Is large ungulate hunting an efficient foraging activity relative to other foraging options dominated by smaller prey or plant resources?
- 2) Would overall hunting efficiency increase if large ungulates were pursued on encounter relative to other smaller prey options?
- 3) If searching for large ungulates (to the exclusion of other options) is a relatively efficient foraging activity, and if foragers expect to increase their hunting efficiency by pursuing large ungulates on encounter (to the exclusion of other prey), do the decisions that hunters make with regard to searching for and pursuing large prey match our expectations about increasing foraging efficiency?

We stress that the answers to these questions are context specific, but exploring the ecological and social contexts that shape “efficiency” and decision-making can have broad implications for a range of hypotheses commonly utilized in archaeofaunal analysis (O'Connell, 1995). Here we investigate these questions with a large foraging dataset collected between 2000 and 2010 during our work with Martu Traditional Owners in Australia's Western Desert. Previously we have shown that the return rate from hunting medium sized prey – mostly hill kangaroo (*Macropus robustus*) and bustard (*Ardeotis australis*) which are primarily, although not exclusively, the focus of Martu men – is on average higher than hunting small game – mostly monitor lizard (*Varanus gouldii*) which is primarily, but not exclusively, the purveyance of Martu women (Bliege Bird and Bird, 2005, 2008; Bliege Bird et al., 2009; Bird et al., 2009; Codding, 2011). However, the differences in return rate are not significant because of the high variance associated with hunting medium sized game: over 50% of all kangaroo and bustard hunts fail outright, while small game hunts are almost always successful

(Bliege Bird et al., 2009, 2012a; Codding et al., 2011; Codding, 2011). The source of the failures is linked to the probability that a pursuit will fail: when pursued, the capture rates of prey decline dramatically with prey escape velocity (Bird et al., 2009). Acquiring such prey is also costly for the hunter: nearly 90% of the whole weight of a kangaroo is shared to other families, dropping a hunter's return below what they could achieve hunting monitor lizards, and hunters are not favored recipients of other prey in future distributions (Bliege Bird and Bird, 2008; Bliege Bird et al., 2009; Bird and Bliege Bird, 2010). Moreover, cooperation during hunts can reduce, rather than improve, per capita efficiency (Bliege Bird et al., 2012a). This then raises questions about why high-risk prey would be searched for in the first place, and why hunting is often cooperative: among Martu, if the goal of hunting and sharing is to provision yourself and a local residential group with meat, efforts should focus on solitary acquisition of small game.

The Martu situation also offers a unique opportunity to investigate how the contexts of such decisions interact with historic changes in foraging options. Prior to European invasion, there were no populations of megafauna (prey over 150 kg) in Martu country, at least not since the Late Pleistocene extinctions. Hill kangaroo were the largest (maximum mass of about 60 kg) commonly encountered game, although plains kangaroo (*Macropus rufus*, which can reach 90 kg) and emu (*Dromaius novaehollandiae*, which can reach 60 kg) were – and are – present but rare. This situation has changed dramatically over the last century with the explosion of invasive feral dromedary camel (*Camelus dromedaries*) populations. During our work with Martu, camels have been, by far, the most commonly encountered of all medium to large sized prey taxa. Relative to the traditional resources that remain critical in daily subsistence, what are the costs and benefits that hunters experience in searching for and pursuing these megafauna in Martu country?

2. Prey size, behavior, and rank

This is an important question especially in light of recent arguments about the relationship between prey body size and the rankings archaeologist use to estimate prey value (e.g. Bird et al., 2012; Ugan and Simms, 2012). Archaeologists have often used the size of potential prey as proxy for the return rate a hunter might expect from handling (e.g. energetic yield per unit time pursuing, capturing and processing) (Bayham, 1979; see Ugan, 2005; Broughton et al., 2011 for discussion). The assumption is that body size will generally be the most influential determinant of post-encounter return rate in a ranking of potential prey items. This assumption is likely to be valid under conditions where we can hold constant across taxa the probability that prey will escape if pursued. However, potential prey differ widely in response to pursuit, which can have a big impact on post-encounter returns, especially when larger prey have very high escape speeds or are highly aggressive. If larger prey are especially likely to evade or discourage a hunter, the post encounter return rate from pursuit may be quite low, despite the potentially high yield (Winterhalder, 1981: 95–96; Hawkes et al., 1982: 391; Hill et al., 1987; O'Connell et al., 1988; Hawkes, 1991; Smith, 1991: 230–236; Bird et al., 2009).

Morin (2012: 27–37) has recently presented an instructive meta-analysis of how maximal velocity varies taxonomically for terrestrial mammals and, importantly, whether it scales with body size. Two linear patterns are obvious: escape velocity scales positively with body mass across taxa up to ~150 kg, but negatively at larger sizes. For most mammals smaller than 150 kg (especially non-artiodactyls), if a hunter's goal is to increase yield per unit time spent foraging, the decision to pursue a prey type should thus reflect a trade-off between an increase in yield and a decrease in the

probability of capturing faster prey. The Martu data clearly illustrate this trade-off, showing that prey speed is often more important than body size for predicting the return rates of small-medium sized prey that differ widely in antipredator behaviors (Bird et al., 2009).

In contrast to the trend in small-medium sized taxa, for terrestrial mammals larger than ~150 kg, maximum escape velocity tends to decrease with body size. We might then expect that the largest animals, given that they are relatively slow, would be especially attractive to human hunters. This, however, is not necessarily the case: most weapons are progressively less effective at killing the largest prey – almost all of the largest terrestrial mammals (those with maximum body size >500 kg), while relatively slow, have aggressive defenses that make capture very difficult. Relative to this group, one species of ungulate clearly stands out: dromedary camels.

Dromedaries are huge (adult males can weigh up to 1000 kg), but are relatively slow (maximum speed is 32 km/h) (Köhler-Rollefson, 1991). Moreover, among the slower-moving terrestrial megafauna that exceed 500 kg, they are the only taxa without highly aggressive defenses (see Morin, 2012; table 3.1): male dromedaries are notoriously grumpy, but unlike elephants, hippos, rhinoceros, brown and polar bears, and wild bovids, when wounded, dromedaries pose no serious threat to hunters with effective weaponry. Among modern hunters with highly efficient pursuit and capture technologies, we would thus expect dromedaries to have especially high post-encounter return rates, and if introduced into a region dominated by smaller and faster prey, subsistence hunters should quickly incorporate them into their repertoire.

Here, we evaluate these expectations with data on the search, pursuit, and handling costs of camel hunting in comparison with other foraging activities routinely practiced among Martu hunters.

3. Ethnographic setting and methods

Martu are the Traditional Owners of 136,000 km² of Australia's Western Desert (<http://www.wdlac.com.au/>). Their homelands are comprised of an expansive network of traditional estates in the Percival Lakes, Karlamilyi (Rudall River), and Lake Disappointment regions. While members of some western Martu bands had been engaged with government depots, pastoral stations, and missions such as Jigalong since the 1930's, many Manyjilyjarra and Warnman speaking Martu remained completely autonomous of colonial economic intrusion until the 1960s. A number of bands were first contacted in the mid-1960s when government patrols met up with them in the Percival Lakes and Karlamilyi regions, mostly in preparation for the Blue Streak nuclear missile testing range (Davenport et al., 2005). Many Martu that were cleared out from the desert experienced the brunt of trauma associated with colonial upheavals, and in the 1980s they returned to their desert homelands to establish three settlements, Punmu, Parnngurr and Kunawarritji (see Tonkinson, 1993, 2007a, b, 2008; 2011; Tonkinson and Tonkinson, 2010). We live and work mainly from Parnngurr, which has a fluid residential population, usually varying between 40 and 100 people (Coddling, 2011). Many Martu keep a permanent residence in one of the settlements, but remain highly mobile between the communities and on extended trips throughout the Western Desert in the maintenance of ritual, social, and economic obligations.

3.1. Contemporary foraging among Martu

The return by Martu to their homelands was an intentional response to concerns about caring for their country and their sacred obligations in maintaining their Law, their rituals, and initiations.

Today these obligations are integrated into a modified foraging economy, one fundamentally embedded in concerns about autonomy and social obligation – as Martu often say, “we hunt to share”, and they share to maintain the ritual and social bonds underwritten by high residential mobility and pervasive material egalitarianism.

Foraging has changed since their exodus and return to the desert, but today many Martu hunt and/or gather on a daily basis (Walsh, 1988, 1990, 2009; Bird et al., 2005, 2009; Bliege Bird and Bird, 2005, 2008; Bliege Bird et al., 2009, 2012a, 2012b; Coddling, 2011). In Parnngurr, food from foraging accounts for 37% of all calories per capita, and about 80% of the meat calories. On average, individuals spend one out of every three to four days foraging (Coddling, 2011; Scelza et al., *in press*). Most of the daily hunting and gathering is logistically organized from the settlements, where usually at least one party, but often more, leaves in a vehicle to access general foraging locales. On reaching the area where they will forage, the party typically establishes a “dinner-time camp”, a central locale to which people will return after foraging, and most foraging is conducted on foot out from a dinner-time camp. Plant foods are important, but women spend most of their foraging time in sand monitor hunting, while men often focus on hill kangaroo and bustards. Bustards and camels differ from most other foraging in that they are usually hunted from vehicles. Although bustard hunts are often conducted from dinner-time camps (often on the drive to and from the camp), camel hunts typically originate from and finish at one of the three communities. Martu foraging parties average 8.1 ± 3.4 participants (3.7 ± 0.8 women, 2.3 ± 1.1 men, 2.2 ± 1.4 children; all errors are given as standard deviation). Foraging bouts average 2.5 ± 1.4 h in duration (this is time an individual spent in search, pursuit, capture, transport and processing per day, not including travel to and from the foraging locale).

For camel acquisition in particular, a hunting party is usually organized within the community on the day of the hunt (often at the request of senior men and women), with hunters departing in one or two vehicles in the general direction of a recent sighting. On average, parties consist of 3.9 ± 1.3 hunters (mostly young men, but older men occasionally participate), although groups of up to 9 hunters have occurred during our residence. Hunts are highly co-ordinated: search is cooperative and begins in the vehicle immediately after leaving the community. When encountered, the targeted animal is approached and shot from the vehicle, and then pursued in fast chase using the vehicle to cull the individual from the herd as it slows. For accuracy, and out of convention, small caliber rifles are always used: while some pursuits cost much ammunition (up to 20 shells), half of all kills are made with three or fewer hits, and 20% are brought down with a single shot. Younger camels are usually the stated preference, but during our study, adults were taken more often. Unlike all other prey, which are routinely transported whole to a temporary dinner-time camp and cooked before distribution, camels are butchered immediately at the kill site, and cuts are then returned in the vehicle and distributed uncooked to various residential camps in the community. This appears to result from the sheer size of camels relative to traditional prey; camels are simply too large to be fully consumed by the number of people present at a dinner-time camp.

3.2. Camels in the Western Desert

The world's only population of dromedary camels exhibiting wild behavior is the large introduced feral population in the Central and Western Deserts of Australia. Between 1840 and 1907, thousands of dromedaries (mostly from Pakistan and India) were shipped via Tenerife to Adelaide to aid in expanding the pastoral frontier (McKnight, 1969). The first camels in the remote parts of the Western Desert probably went feral during the establishment

of the Canning Stock Route between 1906 and 1910, where they were used in attempts to survey a route to drive cattle over 1800 km through the desert. Later, camel breeding stations were established at settlements such as Jigalong on the western margin of the desert proper. Over a million feral dromedaries now live in the Central and Western deserts, and despite culling efforts, populations continue to expand (Edwards et al., 2010; Saalfeld and Edwards, 2010). In Martu country there have been a number of government sponsored projects to curb the population, but prior to 2011, these had little noticeable effect. As we show in the results below, camels (often in large herds) are almost always encountered during Martu foraging trips.

3.3. Data collection

The foraging data presented here are derived from 385 foraging trips that we participated in between 2000 and 2010. During foraging trips, we recorded party composition, route, locale, and time that each participant devoted to travel, search, pursuit, capture, transport, and processing. Resources acquired were counted and weighed before processing, usually at the temporary dinner-time camp, where foragers gathered to prepare, share, and eat before returning to the settlement. Edible masses were converted into caloric measures using Brand Miller et al. (1993). These records comprise a dataset of 1831 individual adult foraging bouts, consisting of all time each forager spent in search, pursuit, capture, and processing of resources per day. In Table 1, data from all of the bouts are summarized by the foraging activity performed according to Martu definitions: these correspond to mutually exclusive tasks associated with acquiring particular suites of resources (although a given resource may be available in a number of different foraging activities). Further details on methods and definitions are provided in Bliege Bird and Bird (2008), Bird et al. (2009), Bliege Bird et al. (2009, 2012a), and Codding (2011).

The camel hunting data presented here were collected in the same manner as described above. However, due to the sheer size of camels, field records of whole and edible masses are only available from three carcasses. As such, in the analysis here we use published data to estimate the edible yield from each kill (Yousif and Babiker, 1989). Accordingly, we estimated the whole live mass of large adult prime males at 600 kg, medium-sized prime adult females at 400 kg, large juveniles at 150 kg, and smaller juveniles at 100 kg. The whole dressed carcass mass is estimated as 56.6% of whole live, and dressed mass without bone (edible meat and fat) is 81% of whole dressed mass. Mean kcal available from edible meat and fat is 1.6 times the edible dressed mass without bone.

4. Results

4.1. Camel hunting and other foraging activities

Table 1 presents a summary of all of the returns and time allocation from foraging bouts, categorized by foraging activity. Despite their abundance and overall hunting efficiency, Martu rarely hunt camels, and rarely pursue them when encountered during other hunting activities (see Figs. 1a and 2). Over the course of all 385 foraging trips, Martu killed only 22 camels (15 prime adults and 7 juveniles). This is despite the fact that 73% of the 385 foraging trips included technology (firearms, butchery knives, vehicles) and habitats well suited for camel hunting. Twenty of the 22 camels acquired were taken on designated camel hunts ($n = 19$, comprising 89 individual forager bouts), which involved coordinated groups of hunters using one or two vehicles in search and pursuit in the manner discussed above in Section 3.1.

Table 1
Martu foraging activities (listed in order of percent foraging time allocation).

Foraging activity	Primary resource type	Secondary resource types	Seasonality ^a	Habitat ^b	n (bouts ^c)	Return rate/ bout (kcal/hr) ^d		% total foraging time			% success/bout
						Mean	SD	All	Women	Men	
Sand monitor hunting	Sand monitor: <i>Varanus gouldii</i>	Skink, python, cat, grub, solanum fruit, nectar	All, peak May–Oct	S	752	644	595	0.51	0.71	0.27	0.88
Bustard hunting	Bustard: <i>Ardeotis australis</i>	Sand monitor, skink, hill kangaroo, perentie, grub, nectar	May–Feb	S, M	370	1792	4736	0.18	0.05	0.40	0.46
Kangaroo hunting	Hill kangaroo: <i>Macropus robustus</i>	Bustard, sand monitor	All	R	141	1119	3826	0.09	0.02	0.20	0.14
Perentie hunting	Perentie monitor: <i>Varanus giganteus</i>	Argus monitor: V. panoptes, cat	Nov–April	W	98	765	1109	0.06	0.06	0.07	0.62
Camel hunting	Dromedary: <i>Camelus dromedaries</i>	Bustard, sand monitor	All	S, M, W	61	21079	26732	0.04	0	0.02	0.78
Cat hunting	Feral cat: <i>Felis silvestris</i>	Sand monitor, skink, python, perentie	All	S, W	26	1087	1363	0.02	0.03	0.01	0.92
Desert raisin collecting	Fruit: <i>Solanum centrale</i>	–	Variable, usual peak April–June, Oct–Nov	S	58	1115	983	0.02	0.03	<0.01	0.86
Grub collecting	Cossid larvae: <i>Endoxyla</i> spp.	–	Variable	S, M, W	76	440	307	0.02	0.03	<0.01	0.87
Bulb collecting	Bush onion: <i>Cyperus bulbosus</i>	–	Variable, usual peak May–Aug, Oct–Nov	W	32	381	240	0.02	0.04	<0.01	0.94
Bush tomato collecting	Fruit: <i>Solanum diversiflorum</i>	–	Variable, usual peak April–June, Oct–Nov	S	52	2718	2015	0.01	0.01	<0.01	0.96
Root collecting	Pencil yam: <i>Vigna lanceolata</i>	–	Variable, usual peak May–Aug	W	29	418	260	0.01	0.01	0	1
Nectar collecting	Flower: <i>Hakea suberea</i>	Flower: <i>Grevillea erostachya</i>	Aug–Sept	S	24	6409	4090	0.01	0.01	0.01	1

Honey collecting ^e	Honeybee: <i>Apis mellifera</i>	—	Variable	W	19	5378	3081	<0.01	<0.01	0.01	0.89	
	Grass seed collecting	Grass seeds: <i>Eragrostis eriopoda</i>	—	Variable, peak April–June	S, M	4	476	27	<0.01	<0.01	0	1
	Tree seed collecting	Tree seeds: <i>Acacia aneura</i>	—	Nov–Jan	M	6	NA	—	<0.01	<0.01	0	1
	Other	Emu, plains kangaroo, ridge tail monitor, grass seed, medicinal plants, feral cattle	—	—	—	28	NA	—	<0.01	<0.01	<0.01	—

Sample covers 102 individual foragers, over 1831 adult foraging bouts, on 385 foraging trips in June–July 2000, June–August 2001, January–August 2002, March–September 2004, August–November 2005, June–August 2007, June–August 2009, and April–September 2010.

^a Availability of many resource types depends on season, variable rains and mosaic burning.

^b S = Spinifex dunefields, M = Mulga woodland, R = Rocky range, W = Watercourse margin.

^c A foraging bout is defined as the total time a given forager spends in search, pursuit, capture, and processing per day.

^d Foraging return rate is calculated as the mean kcal/foraging-hr/bout. Foraging consists of all time an individual spent in search, pursuit, capture, and processing on a given day.

^e Feral honey bees first established hives in the region in 2002. Since then, during years of good rain, honey collecting has become a common activity.

^f Nectar from *Hakea* flowers is only available for only about a month in August or September depending on rains. In a given patch, the flowers will produce nectar only for about a week.

Camel hunting is truly an outlier in the repertoire of Martu forging. Fig. 1b shows the log-scaled energetic returns for time spent foraging (kcal/foraging-hr/forager) across all activities. The return rate from choosing to search for camel is $21,079 \pm 26,732$ kcal/h, more than an order of magnitude greater than bustard hunting ($t = 1.96, p < 0.0001$) the next highest ranked hunting activity (see Table 1). This raises an important question relative to the time allocation data shown in Fig. 1a: why do Martu hunters not allocate more time to camel hunting?

Activities such as nectar and honey collecting, while highly efficient (Fig. 1b), are only available in highly seasonal patches (which explains why there is so little time devoted to their collection), but bustard and camel hunting are for the most part always an option (see Table 1). These two hunting activities could often be conducted at the same time: while in the vehicle, searching for camels does not preclude searching for bustards, and both hunt types involve the same technology, similar search and pursuit strategies, and include prey encountered across the same range of habitats. For camel hunts, the hunters frequently gear-up with specialized equipment, including the vehicles themselves, very large and recently sharpened butchering knives, axes, and sometimes even a trailer for carrying the meat if one happens to be operational in the community. Thus, it may be that Martu occasionally bypass opportunities to hunt camels on encounter simply because they are not equipped to conveniently do so. However, we stress that Martu can take camel on an encounter basis during almost all bustard hunts (for example, by strapping the meat on the roof of the vehicle and using the cutting tools commonly stashed in any vehicle commonly used in foraging), and that there is no reason why hunters should not regularly forage well prepared to take camels given the returns they potentially could receive. As Fig. 1c and d show, the notable bias toward bustard hunting is not because camel hunts are more likely to fail, rather the opposite is the case: camel hunts are less variable and twice as often more successful than bustard hunts.

4.2. Prey choice: camels vs. bustards

This question about camels is put into even starker relief when we look at prey choice while bustard hunting. During bustard hunts there is the possibility of encountering a wide assortment of prey types: by using a vehicle, hunters generally search across multiple habitats. As shown in Fig. 2, some prey types are rarely encountered during these hunts, others are quite common: during bustard hunts, camels are encountered more often than any other prey type, even more often than bustard: 78% of bustard hunts ($n = 199$ hunts, comprising 370 individual forager-bouts) included at least one encounter with a camel (but usually many more) well within pursuit range. As further illustrated in Fig. 2, if camels were pursued on-encounter during bustard hunts, a hunter would expect to earn on average $122,944 \pm 511,397$ kcal/pursuit + processing-hr/forager, nearly two orders of magnitude greater than what the hunter expects by passing over a camel to continue searching for bustard. The conundrum, then, is summed up well in Fig. 3: during bustard hunts, only 4% of encounters with camels resulted in pursuit – the hunter shown here is not shooting at the camel, but at the bustard. We might imagine that this is due to the risks of pursuit failure, but this is not the case. As shown in Fig. 2, less than a quarter of camel pursuits fail, while pursuits of bustard fail nearly 70% of the time.

5. Discussion

Why do Martu not search for and pursue camel more often? Despite many informal discussions with hunters about this over many years, and despite the fact that one of us (C. Taylor) is an

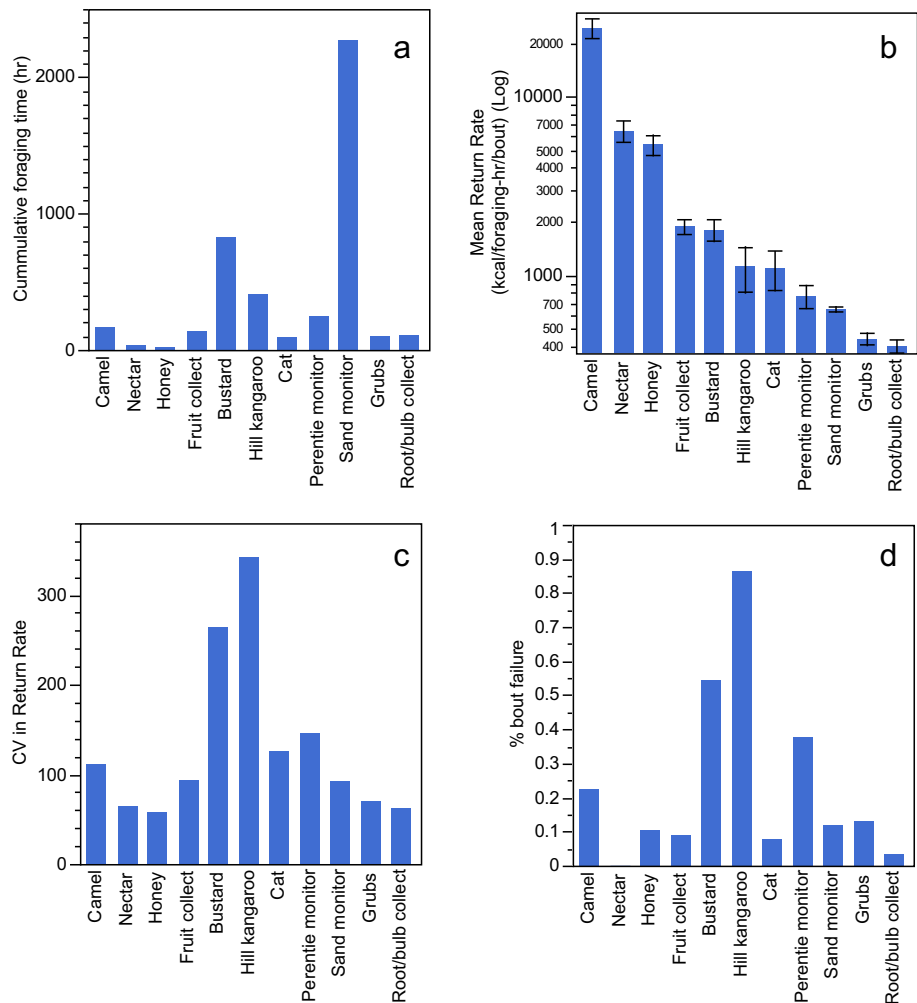


Fig. 1. Martu foraging activities: return rates, time allocation, and risks. Data are compiled from 385 foraging trips between 2000 and 2010, comprising 1831 individual foraging bouts. A foraging bout is the total time a given forager spent in search, pursuit, capture, and processing per day (see text). 1a provides the total cumulative foraging time (search, pursuit, capture, and processing) allocated to each activity; 1b shows the mean overall foraging return rate (kcal/foraging-hr/bout) for each activity, error bars are one standard error; 1c gives the coefficient of variation associated with the foraging return rate of each activity; and 1d provides the bout failure rate for each activity.

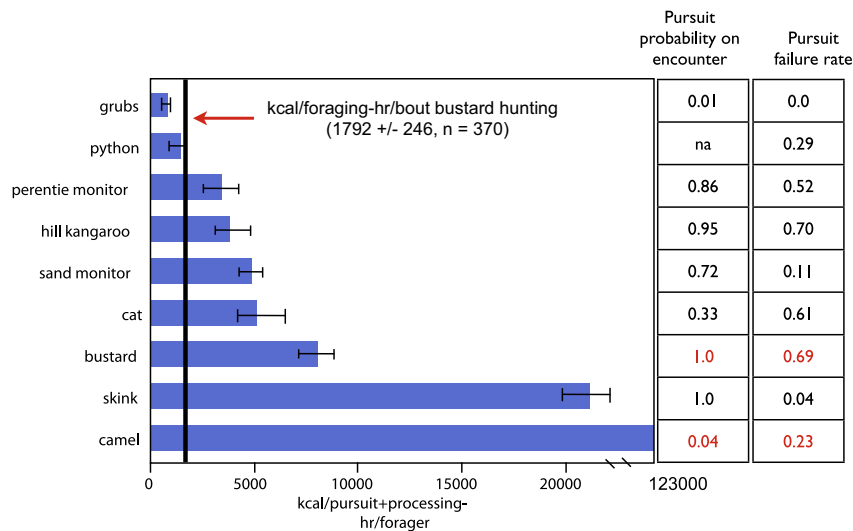


Fig. 2. Post-encounter return rate of Martu prey types. The post-encounter return rate is calculated as kcal/pursuit + processing-hr/bout (see text). Post-encounter return rates are presented relative to the overall foraging return rate (kcal/foraging-hr/bout) from bustard (*Ardeotis australis*) hunting, and the post-encounter pursuit probabilities and the pursuit failure rates during bustard hunts.



Fig. 3. A Martu hunter sights in a wounded bustard in the foreground, with a camel resting behind. The camel has little reason to be concerned: camels were encountered on 78% of all bustard hunts ($n = 199$), while only 4% of those encounters resulted in pursuit. Photograph by Brian Coddington.

accomplished Martu hunter himself, we have no definitive answers. However, Martu have suggested a range of potential hypotheses, some of which have implications for thinking about large game hunting in archaeological contexts.

When discussing the conundrum with Martu, it is not uncommon for people to respond by questioning themselves and each other about why they did not (and now do not) hunt camel more often. When Martu were full time foragers, hunters avoided pursuing camels. If camels wandered near a camp or were chanced upon during other activities, they were chased away, rather than pursued. Martu report that for the most part, camels have always been treated as non-prey. Even though camels were not as common as they are now, remote bands had become well familiar with them before they went into the missions in the 1960s. Martu that we work closely with in Parnngurr and Punmu recall a single kill when they were full-time foragers: despite favorable reviews of the meat and fat, tears were shed over the death.

In contrast, prior to contact it would have been very unusual to pass over a good opportunity to pursue, for example, a kangaroo when armed with a spear thrower, and today hunters very rarely disregard a possible kangaroo pursuit. The contrast with camels is striking: camels are so much larger and slower than kangaroos, and camels certainly could have been brought down in orchestrated hunts involving coordinated pursuit by multiple hunters after delivering well placed spears. Some older Martu do not like camel meat, but most do, and when camels are acquired, all of the meat is used up very quickly, always within just a few days. As discussed in Section 5.1, large portions of camel are used up immediately to feed both people and camp dogs. We have observed small portions of camel being stored in individually owned refrigerators, but this is rare, and the meat never lasts for more than a day or two.

There have been a number of camel culling projects conducted over the last ten years. These have mostly been carried out by the military using high powered firearms and helicopters. The most recent program was conducted in 2011, in coordination with Kanyirninpa Jukurrpa, the Martu Cultural Knowledge Project, and appears to have noticeably reduced the numbers camels in Martu country, although there are no analyzed data yet published. Sometimes when discussing the issue, or upon seeing an unused camel carcass culled during the government sponsored population

reduction programs, older folks respond with sympathy toward camels, given that they organize themselves in families “just like Martu”. This accords with anthropomorphizing of other domesticates that Martu explain is related to their time spent in pastoral stations and missions. But this fails to explain why, in our experience, other feral domesticates in Martu country are of great interest to hunters, but camels are not.

We want to stress that we would be remiss if we gave the reader the impression that the tendency to pass over camels means that hunters are not concerned with the efficiency of provisioning food. Coddington's (2011: 37–77) recent analysis of time allocation in Parnngurr Community demonstrates the fundamental economic role that foraging plays among remote Martu: it remains vital to individual income, as well as the health and success of their communities, culture, and country (see also Bliege Bird et al., 2008, 2012b; Bird, 2009). Providing food is very difficult in these remote communities, whether it comes from foraging or other sources (such as the community shop), and people are keenly concerned with the associated constraints and material costs. Our point (Section 5.1) is simply that the costs of foraging are set in a rich context of dynamic social, material, and ecological trade-offs.

It is certainly probable that our analysis does not reflect all the time and technological costs experienced by hunters. For example, during our informal discussions about why they often avoid searching for camel, hunters have sometimes (although not often) mentioned prohibitive fuel and ammunition costs. In comparison with bustard hunting, fuel and ammunition costs might be higher during some camel hunts. Our data, however, suggest that on average less time is spent using the vehicle for search and pursuit during camel hunts relative to bustard hunts (respectively, 113 ± 58 vs. 134 ± 82 min, $t = 1.96$, $p = 0.02$). And even if camel hunting sometimes costs more fuel and ammunition, it is difficult to imagine that a hunter could not recuperate these costs many times over given the high energetic efficiency of camel hunting (for example, a hunter could store the meat in the community freezer at the shop, thus freeing up time to allocate otherwise). However, for hunters to be able to recuperate these costs, they need to exert some level of control to coordinate hunting labor and distribute the meat thereafter. Many Martu (especially younger men) are reluctant to exert such control.

Hunters also mention that after sharing out camel parts, they sometimes end up with little meat for themselves. The return rates presented here are calculated per hunter, prior to post-acquisition distribution. We have not yet analyzed the data on camel meat sharing, and it may be that a hunter could, after all distributions, increase overall foraging efficiency by forgoing camel hunting when certain other high-return activities are an option. However, it is important to note that widespread sharing after acquisition is the pattern for almost all resources, and hunters often end up with the smallest shares, especially for larger game like kangaroo (see Bird and Bliege Bird, 2010). The point we make here is that, in terms of simple measures of foraging efficiency, the opportunity costs of not hunting camel are very steep relative to other options.

While the costs of avoiding camel may be high, the value of camel may also be low relative to the value of purchased foods. Given that Martu are not full time foragers, one possibility is that they refrain from hunting camels because prey choice is affected by the availability of food in the community shop, which might sometimes be a high-return patch. While the availability of money to purchase food (economic scarcity) and the availability of food to purchase (store patch quality) do not affect foraging time to most activities, people do acquire more monitor lizards as monetary scarcity increases, and there are more hunts for camel as meat available for purchase decreases (Scelza et al., in press). However,

monetary scarcity does not predict camel hunting, and meat scarcity does not predict lizard hunting. Scelza et al. interpret this result to suggest that women, who are primarily hunting monitor lizards, are likely to fall back on monitor lizards for daily subsistence when they cannot purchase flour and other staple non-meat foods. Men, who are the primary camel hunters, are hunting camel not because they are low on money to purchase household staples, but rather because no one in the community can purchase meat; meat hunger is thus high, increasing the social and nutritional value of a camel portion shared. In other words, monitor lizards are hunted to eat, camel are hunted to share (with both people and camp dogs, see Section 5.1). Hunters may thus frequently pass over camels because the value of a portion transferred is usually low, either because others are able to purchase their own meat, or they have already hunted monitor lizard or other prey. The question, then, remains: why would foragers have already chosen prey associated with hunt types that are far less efficient than camel hunting? And why, if hunters come across a camel while searching for other prey, would they not dispatch and process it quickly, thus freeing time to devote to something else?

The intense reactions of sympathy that we have observed when Martu come across a culled camel carcass may speak to the low value attached to hunting and distributing such large animals – camels that are killed but go unused are “poor things, they died for no good reason”. This may help explain a general ambivalence among Martu for camel culling programs, despite the fact that many recognize camels as a serious ecological nuisance. We have often heard it explained this way: food that is unused or distributed unequally means that someone did not receive an appropriate share, and those people that wasted that opportunity to share appropriately are to blame. For most resources, hunters avoid these problems by ensuring that someone else distributes prepared portions of game (see Section 5.1 below). When this is done at a dinner-time camp, those not present do not get a share, but cannot blame either the hunter or the distributor: the hunter made no special claim and all present received an equal share (Bird and Bliege Bird, 2010; Bliege Bird et al., 2012a). As we explain below, this is simply not logistically possible for camel because they are too large to be consumed at a dinner-time camp, and the meat, invariably, goes back directly to the community at large. A common refrain, especially among those that do hunt camels, concerns the social consequences and trade-offs that they face when they acquire these megafauna and distribute parts throughout the community. As one hunter remarked, “Why waste the whole day getting a camel? Everyone just growls me when I get back to camp.” Below, we focus on attempting to understand camel hunting relative to the socially embedded costs and benefits that their acquisition might engage.

5.1. Foraging and socio-political organization

As Coddington (2011) illustrates, economic decisions involved in foraging are never merely economic. Food choices are always made relative to whom you are feeding and with whom you are eating. It is important to keep in mind, that among Martu this is rarely a “nuclear family”. If Martu hunters were concerned only (or primarily) with provisioning a nuclear family, perhaps camel hunting, given its especially high return rate, would be an important foraging activity. However, nuclear families – as units of economic production – are essentially non-existent in remote Martu communities. The compositions of dinner-time camps, where most foraged foods are prepared, shared, and consumed, never resemble a nuclear family, and provisions are not preferentially directed toward consanguines or co-residents (Bliege Bird and Bird, 2008; Bliege Bird et al., 2012a). Children are provisioned most often by

a range of mothers, aunts, and grandmothers (although self-provisioning, along with food from grandfathers, uncles, and fathers, is not inconsequential) (Bird and Bliege Bird, 2005; Scelza and Bliege Bird, 2008). The point is that provisioning decisions, even when people are very hungry, can never be made outside of a socio-political context, a context into which many Martu find it quite difficult to integrate camel hunting.

We think that one possible (certainly not exclusive) explanation for the rarity of camel hunting speaks directly the integrated nature of subsistence, ritual, and social obligation. It is difficult to overstate the importance of material dispossession in Martu economic and religious life. The long road to ritual status involves a lifetime of disregarding personal material accumulation along with dedicated high residential mobility: the pervasive egalitarian economy is underwritten by commitments to maintain ritual and social networks throughout the Western Desert and Pilbara regions (Myers, 1988; Tonkinson, 2008; Bird and Bliege Bird, 2010; Bliege Bird et al., 2012a).

Among Martu, commonly acquired bush foods are treated in a highly formalized way that ensures mostly equal distributions to all present (although, as we said above, especially with kangaroo, the hunter often gets a smaller share than others, Bliege Bird et al., 2009, 2012a; Bird and Bliege Bird, 2010). The common unit of economic production is the foraging party and dinner-time camp (whose composition changes daily), not a nuclear family or residential unit (which is also very fluid, Coddington, 2011: 23–77). Resources acquired during foraging are returned to the dinner-time camp where everything is prepared, shared, and consumed. Cuts of larger game are not usually distributed by the hunter, but by the most senior member of the foraging party, generally someone with high ritual status. After eating, the party then returns to their respective residential camps within the community.

Treating camel this way would be very difficult: transporting the large carcass requires butchery at the kill site, which is generally well beyond walking distance to a locale where distribution can take place. Portions of unequal size and quality are thus transported in the hunting vehicle and distributed by the hunters (generally without a high status ritual elder present) to different residential camps within the community. This exposes the hunters to accusations of unfairness that they find difficult to deal with, and we have often heard camel hunters complain (or complained ourselves) about the social dilemmas this involves.

Attempting to store large cuts of camel for future consumption only exacerbates the problem, both for hunters and the recipients of shares: everyone in the community knows who has what parts, and hoarding for the future will likely bring accusations of stinginess, certainly not helpful to a hunter who is very mindful of his ritual status in the community. Moreover, attempting to store large portions of meat makes little sense under the pressures of ever-present travel duties: as stressed above, Martu residential patterns are highly fluid both within and between remote communities, with shifting residential travel throughout the region. While individuals do attempt to transport (and sometimes hide) meat in vehicles on trips throughout the desert, the results are rarely successful.

As we indicated, we have yet to analyze data collected on camel meat distribution, but camp dogs are always recipients of big portions. The fact that more than an insignificant share of camel meat goes to the dogs not only speaks of Martu love for their dogs (feeding the dogs sometimes seems to be an important motive for a camel hunt), but we think also reflects a penchant to quickly use up a resource in the face of social problems surrounding its acquisition and distribution. This is why Martu will simply burn a vehicle when disputes arise regarding differential use access: it is a clear demonstration of the priority that individuals place on social

relationships, and their asserted disregard for the material wealth accumulation, both of which are key to ritual status (Myers, 1988).

The difficulty of integrating camels may also be linked to the fact that camels are a relatively new potential resource. As one thoughtful reviewer of a previous version of this paper pointed out, we may be observing a lag between changing subsistence patterns and aspects of socio-political organization that can temporarily constrain them. Camel populations throughout the desert have significantly increased since Martu returned to their homelands in the 1980s (Edwards et al., 2005), and it is possible that there exists some degree of lag between the threshold at which increasing abundance pays for the costs of shifting socio-political organization. Given that so few individuals hunt camel, and that hunters sometimes experience technological constraints, it may not be possible to get everyone to change socio-political strategies at once. When we have asked Martu, they agree that this might be the case: continuous hunting records are not available since camels were introduced, but the rate of camel hunting in remote communities may have increased in the last few years. But we hypothesize that a sustained and notable increase in camel hunting will not occur without fairly substantial socio-political changes.

An alternative explanation is that people simply take time to learn that novel species are high ranked foraging choices. However, this seems very unlikely: other introduced species were quickly and seamlessly integrated into Martu subsistence. One wonders why cats, European bees, rabbits, and novel technology to acquire them were so readily adopted and modified into Aboriginal foraging strategies as soon as they were available. European bees arrived into Martu country from the south following big rains in 2000–2001, and foragers were waiting in advance for the honey. Harvesting strategies were passed along social networks and practiced during travel on social and ritual business in the south, and within the space of a few short months after the bees first established hives near Parnngurr, many people were effectively acquiring large amounts of honey. This is not surprising given the high rate of return available from honey collecting (see Table 1) – technological and subsistence organization adjusted seamlessly with a changing effective environment. This puts the question about camels into especially stark relief: because of their slow escape speed and lack of aggressive defense behavior, one might expect that camels would have been adopted very rapidly by Martu equipped with firearms and vehicles.

We suspect that acquiring camel engages a series of problems that, due in part to their size, are difficult to handle when your social status hinges on the autonomy that you can afford to others, your lack of concern about your own material accumulation, and your ability to pull up stakes at a moment's notice for ritual and social duties. Solving the coordination problems of organizing a successful camel hunt and the responsibilities of sharing such a massive package of meat are no small things – they require marshaling control over others' labor and directing distribution in a manner that may be antithetical to the extreme material egalitarianism and autonomy of everyday Martu life. Social asymmetries are ever present, but these are religiously constituted and ritually constrained: the path to ritual power, where you have tremendous authority over others, is paved by your ability to disengage with material property. We suspect that camels present a series of real collective action problems that arise when suddenly someone has to take responsibility for – and is tagged with the “ownership” of – such an unwieldy bonanza. The acquisition of traditional resources such as monitor lizards, cossid larvae, kangaroo, and bustards (as well as “non-traditional” ones that can be treated in similar fashion, such as feral cats and honey from feral bees) may be woven so tightly into the egalitarian and mobile priorities of Martu life, that hunters find it difficult to integrate cumbersome camels.

6. Conclusion

As anticipated by foraging models commonly used in archaeology (see Bird and O'Connell, 2006), the Martu data support the hypothesis that slow-moving, large ungulates without particularly aggressive defenses, such as camels, are highly ranked (kcal/pursuit + processing-hr) prey options, and that if pursued when encountered by well-armed hunters, will likely improve hunting efficiency. Our analysis also shows that with a high probability of encounter, choosing to search for camels will increase a hunter's overall foraging return rate (kcal/foraging-hr). However, as the Martu data clearly show, this does not necessarily mean that the decisions that hunters make will match those expectations. Despite their abundance, Martu hunters only occasionally organize hunts to search for camels, and rarely pursue camels on encounter when engaged in other routine hunting activities. We argue that organizing camel hunts and distributing the meat present series of social dilemmas that are difficult to manage for hunters with high residential mobility, egalitarian material relationships, and “households” that are not the units of economic production.

6.1. Foraging models

It is important to stress here that we feel strongly that these results do not undercut “optimal foraging theory”; rather, they illustrate a mature theoretical framework in human behavioral ecology in general, and the utility of models from foraging theory specifically. The models used here provide the necessary heuristics to formalize the problem, test predictions of theoretically framed hypotheses, evaluate mismatches between predictions and observations, and compare the results with data collected in other contexts.

Searching for the “ultimate currency” (energy, protein, fat, fitness, reproductive success, social status, etc.) that determines foraging decisions within the contexts of real-time, real-world, trade-offs is a fool's errand. Ultimately, of course, the only things that “matter” for biological organisms are energy and fitness. But within the experienced social and ecological contexts of decision-making, while calories always matter, they only matter relative to the opportunity costs of their acquisition. The real value of foraging models lies in how their application elucidates the opportunity costs involved in decisions about acquiring and using vital resources. The fact that some simple models in foraging theory begin by assuming a goal of energetic rate maximization is a research tactic, not an assertion that we would expect organisms to behave “optimally” (see Stephens and Krebs, 1986; cf.; Zeanah and Simms, 2000). Measures of energetic yield and time-based opportunity costs provide a systematic foundation to begin to explore the trade-offs that shape foraging patterns. The quantitative results are then potentially comparable across a wide range of contexts. We hope that the results and discussion above demonstrate that the common critique of foraging theory – that it is too reductive to inform more holistic, and uniquely human problems – misses the mark. What we need is more systematic attention to the social and ecological contexts that shape patterns in subsistence decisions and their archaeological consequences. This is precisely what foraging models allow us to do (Bird and O'Connell, 2012).

6.2. Archaeological implications

Many archaeologists, paleoanthropologists, and ethnographers (ourselves included) have assumed that once the cognitive and technological problems were solved, the benefits to scale of coordinated hunting were simply there for the taking – that as long as we have the smarts and the tools, cooperative large game hunting

would be readily adopted, often to the detriment of megafaunal populations (e.g. Martin, 1967; cf.; Speth et al., 2011). The underlying notion is that we would expect megafaunal hunting when there are increasing returns to scale: when coordinated action increases individual hunting success, prey encounter rates, or harvest size; or reduces the costs of search and pursuit leading to increased per capita foraging return rates. Such benefits can be achieved through reciprocal sharing rules to ensure that each member of a cooperative hunting group contributes labor and receives a fair share of the harvest (e.g. Gurven and Hill, 2009). In this case, cooperation becomes a form of synergistic mutualism, with immediate economic benefits to participants either in the form of increased consumption return rates per capita, or increased chances of harvest success (e.g. Alvard and Nolin, 2002).

However, if we assume that cooperation is, perforce, a form of mutualism, we may fail to recognize the pervasive collective action problems that coordinated subsistence strategies entail. Conflicts of interest, free riding, and heterogeneity among individual foragers in goals and access to group production can produce differential benefits to cooperation, raising questions about how collective action in group hunting and other forms of production is sustained (see Smith, 1985; Hawkes, 1993; Bliege Bird et al., 2012a). These collective action problems are amplified when,

- 1) Any potential returns require extensive planning to coordinate the installation and maintenance of requisite capture technology and facilities,
- 2) There are large asynchronies and variance in acquisition (failures are common but success yields a massive harvest),
- 3) The costs of possible success are disproportionately front-loaded with long delays between planning and ultimate acquisition, and,
- 4) Distributions tend to flow from producers to non-producers.

Some of these conditions may have characterized a good deal of large ungulate hunting in the past, especially for communal drives. Among Martu, conditions 1) and 4) seem to characterize camel hunting: camels tend to be hunted on special purpose forays at the instigation of seniors within the community; hunting involves some specialized technology, and hunters seem to find it difficult to direct shares in ways that would compensate their labor. This may contribute to the reluctance among the younger male Martu hunters to devote much effort to camels. Their reluctance may be exacerbated given that camel hunting is somewhat inconsistent with conditions 2) and 3): possibly because of the high success rate, camel hunting may not offer clear opportunities for the hunters to distinguish their skills and the attention to ritual that characterizes other hunting options, thus reducing the incentives to pay the front-loaded costs of organizing a hunt.

We suggest, as have others, that archaeological evidence indicating heavy investment in capturing a lot of large game may indicate circumstances where it pays foragers to bear the costs associated with conditions 1)–4) above. Such evidence, especially involving the maintenance of facilities to acquire a lot of large game, would not necessarily demonstrate that the hunters relied on those resources for regular provisioning purposes (see Bird and O'Connell, 2006; Speth, 2010 for review). Some of the social costs and unpredictability of acquiring large game for provisioning can be ameliorated through reciprocal sharing. But investing a share in someone else to reduce long-term acquisition variability – without a means to guarantee reciprocity – can make acquiring more reliable but lower-return resources a better provisioning strategy (e.g. Bliege Bird and Bird, 2008). When the composition of foraging and sharing groups is highly fluid, it becomes very difficult to balance the accounts from shares previously given. Storing, of course, can

also reduce temporal and spatial variability in income, but as we argued above, this often proves difficult in egalitarian circumstances coupled with high residential mobility. These circumstances may often make camel hunting an unattractive option for Martu. Exploring other contexts in which this may (and may not) have been the case archaeologically should prove especially fruitful (e.g. Speth et al., 2011).

We suspect that where people have highly fluid residential mobility embedded in an immediate-return equalitarian economy, and where the unit of economic production is not a nuclear family, the social dilemmas discussed above would be common features of large mammal hunting. We are not suggesting that hunting big game was not (or is not) an important source of food, simply that social circumstances can reduce its value as a means of provisioning to individual hunters who bear hunting costs if there are no social mechanisms for resolving collective action problems. This would be especially the case when hunting involves coordinated drives and communal mass procurement, such as well-documented Great Basin *bandungos* (see Hockett, 2005). Our data are thus generally consistent with the hypothesis that communal hunting strategies in the Great Basin – with substantial labor investments in building and maintaining antelope drives and corrals – coincide with socio-political organizations capable of resolving the social dilemmas that should arise from cooperative hunting. If communal hunting developed during the Middle Holocene to Late Holocene transition (5000–3500 BP) in the Great Basin, then it was likely accompanied by concomitant socio-political shifts driven by factors other than concerns about family provisioning (Hildebrandt and McGuire, 2003; Hockett, 2005).

While we share Hildebrandt and McGuire's (2002, 2003) doubts that such hunting could be maintained for provisioning purposes alone, we would not be surprised if some less formal cooperative ungulate hunting occurred (or occurs) in conjunction with the support of more autonomous family based economic units – especially if the variance inherent in acquisition can be ameliorated through reciprocity, and if guaranteeing reciprocity is not too costly. This is often a big “if”: investing shares in others to reduce acquisition variance often engages a second order of collective action problems emerging from the costs of ensuring that shares given will be returned when needed. This is hard to do with high mobility, fluid group composition, and an emphasis on equal resource distributions and individual autonomy. As Hawkes (1992) illustrated, if you share equally to all, without regard for differences in labor contributed (the common pattern for Martu), your work becomes a public good. Some Martu consistently find it worthwhile to provide those public goods relative to social capital that traditional prey can engender (Bliege Bird and Bird, 2008; Bird and Bliege Bird, 2010; Bliege Bird et al., 2012a). However, as others have shown, it is not uncommon for hunters to reduce the amount of time that they work due to concerns about sharing without contingent reciprocity (Sahlins, 1972; Wiessner, 1982).

We suspect that is one reason why Martu routinely choose to not work at camel hunting; despite the high potential efficiency, they often find the social costs of controlling labor and distribution prohibitive. Where conditions exist that favor the ability of some to control the labor of others, in conjunction with the ability to control (re)distribution of resources, a good deal of social capital can be secured by those that can organize and conduct formalized large game hunts. We might then hypothesize that common archaeological signatures of coordinated hunting of large ungulates indicate circumstances that favor large gatherings of people, institutional or situational leadership, and hierarchies of power where individuals have strong incentives to bear the burden of the social costs involved in coordinating such hunts and distributing the proceeds.

This has implications for the use of megafauna by Pleistocene foragers in North American and Australia. The assumption that hunters would have preferred megafauna as prey lies at the heart of arguments that overhunting played a role in extinction. The underutilization of camels by contemporary Martu gives good reason to be skeptical of that assumption, and the conspicuous absence of megafaunal kill sites in Pleistocene Australia (Field et al., 2013), as well as parts of North America such as the Great Basin (Grayson, 2011), appear consistent with such an analogy. However, taphonomic factors may contribute to the lack of direct archaeological evidence for hunting megafauna, so the possibility of human predation cannot be dismissed (Surovell and Grund, 2012). This study provides direct evidence that relatively slow and non-aggressive megafauna would have ranked very high compared to other prey, but demonstrates that Pleistocene foragers would have had to be organized in appropriate social contexts to realize those returns. The value of the behavioral ecology research tack followed in this study is that it allows us to anticipate the socio-ecological circumstances in which Pleistocene foragers should or should not have targeted large prey.

If we take the record at face value, Pleistocene groups in Australia and the Great Basin were highly mobile, dispersed, relatively small, preferentially targeted high return resource patches, and lacked a pronounced sexual division of labor (O'Connell and Allen, 2012; Elston et al., n.d.). We surmise that hierarchical, redistributive social organization is unlikely in such settings, but caution that we know of no appropriate ethnographic analogs. If Pleistocene residential patterns were highly fluid, perhaps to facilitate socio-political advantages in a far-flung population, opportunities for nuclear family provisioning based on a sexual division of labor would have been limited and megafauna unlikely to be attractive targets for hunting. Alternatively, if Pleistocene residential patterns were based on nuclear families, the benefits of hunting megafauna could have gone directly to the hunters and closely related kin. If the inherent risks associated with these benefits could be buffered by guaranteed reciprocity, megafaunal hunters may have been able to avoid the collective action problems faced by contemporary Martu. However, Martu reluctance to hunt camels from traditional dinner-time camps suggest that Pleistocene foraging groups would have had to be significantly larger than the 5–12 individuals typical of contemporary Martu foraging parties, at least while hunting megafauna, to capitalize on the potential large quantities of meat yielded. Otherwise the cost-benefits of hunting extremely large prey may have fallen short of that obtainable from smaller more reliable fauna. In either circumstance, the argument that megafauna would have been more than an occasional provisioning resource seems tenuous at best. Far more attention is now in order to develop operational hypotheses that evaluate links between large game hunting, demographic patterns, and socio-political organization as expressed archaeologically.

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