

What Explains Differences in Men's and Women's Production?

Determinants of Gendered Foraging Inequalities among Martu

Rebecca Bliege Bird · Brian F. Codding ·
Douglas W. Bird

Published online: 9 May 2009
© Springer Science + Business Media, LLC 2009

Abstract Researchers commonly use long-term average production inequalities to characterize cross-cultural patterns in foraging divisions of labor, but little is known about how the strategies of individuals shape such inequalities. Here, we explore the factors that lead to daily variation in how much men produce relative to women among Martu, contemporary foragers of the Western Desert of Australia. We analyze variation in foraging decisions on temporary foraging camps and find that the percentage of total camp production provided by each gender varies primarily as a function of men's average bout successes with large, mobile prey. When men target large prey, either their success leads to a large proportional contribution to the daily harvest, or their failure results in no contribution. When both men and women target small reliable prey, production inequalities by gender are minimized. These results suggest that production inequalities among Martu emerge from stochastic variation in men's foraging success on large prey measured against the backdrop of women's consistent production of small, low-variance resources.

Keywords Gender division of labor · Foraging risk · Human behavioral ecology · Australia

R. Bliege Bird (✉) · B. F. Codding · D. W. Bird
Department of Anthropology, Stanford University, 450 Serra Mall Bldg. 50,
Stanford, CA 94305, USA
e-mail: rbird@stanford.edu

B. F. Codding
e-mail: bcodding@stanford.edu

D. W. Bird
e-mail: dwbird@stanford.edu

Characterizations of traditional subsistence in Australia routinely emphasize the high production of women relative to men: plants and small game provided the mainstay, there was considerable overlap and flexibility in gendered foraging decisions, and the larger animals pursued by men were scarce and successes uncertain (Bell 1993; Berndt and Berndt 1988; Gould 1967, 1969, 1980; Kayberry 1939; Megitt 1957, 1962; Roheim 1974). However, contemporary data from the post-mission period provides a contradictory picture of gendered production. In 1974–1975, Alyawarre women in the Central Desert around McDonald Downs brought in only about 10% of all foraged foods; men focused almost exclusively on kangaroo hunting and women on tubers, fruit, and only some small game (O’Connell and Hawkes 1981, 1984). Devitt (1988) described Alyawarre women at Utopia (60 km west of McDonald Downs; Figure 1a) as hunters of small game who nevertheless contributed only 5% of the total foraged calories acquired outside of their cooperative efforts with men. Meehan’s study of coastal subsistence at Kopanga on the Blyth River prompted her to conclude that women of the tropical north coast were no more productive than men (Meehan 1982). Likewise, on the basis of quantitative analysis of subsistence production in the early 1980s, Altman (1987) concluded that Kunwinjku women near Momeka, 50 km from the Blyth River, produced 20 to 30% of all foraged foods. He noted that although it was likely that men’s production had increased with access to guns, vehicles, and feral water

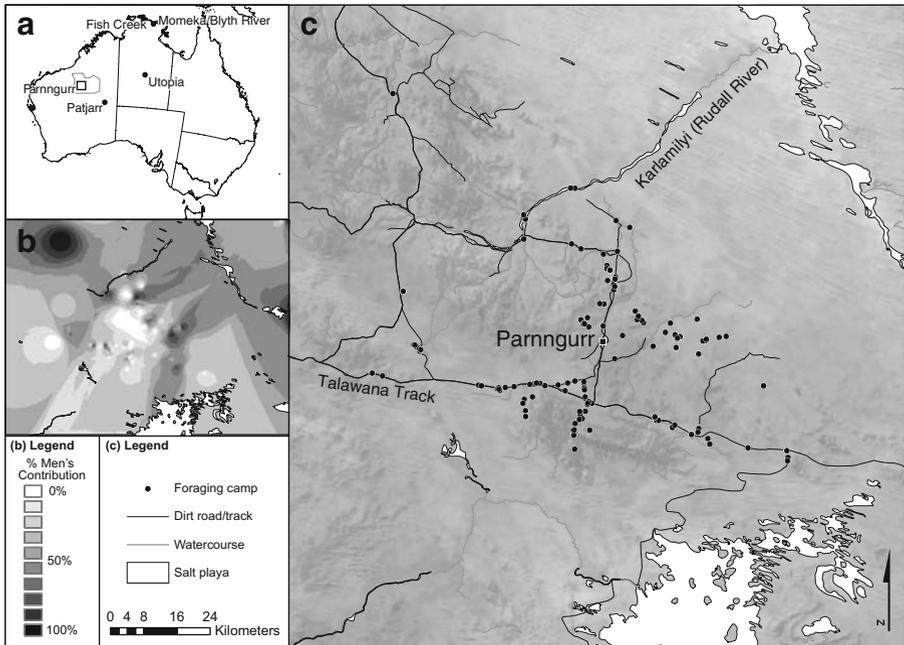


Fig 1 Map indicating (a) locations mentioned in the text and a box situating frames b and c within an outline of the Martu Native Title (gray polygon); (b) an interpolated surface showing spatial variation in the percent men contribute to the daily harvest across all foraging camps, with dark areas indicating a high male relative contribution and light areas indicating a high female relative contribution; and (c) the foraging camp locations on which the Martu foraging data are based

buffalo, and women's decreased with the introduction of market carbohydrates, it was unlikely that women had achieved anything more than parity in the pre-contact era. By far the majority of foraged calories produced and consumed by each contemporary study population came from larger animals hunted by men: plains kangaroo, bustard, hill kangaroo, emu, and feral (or not-so-feral) ruminants.

It is tempting to characterize these differences in men's and women's relative contribution to foraging production across study sites as reflecting a secular temporal trend toward increasing gender inequities brought on by colonialism (Leacock 1978, 1983). Introduced technology, the emergence of a welfare economy, market integration, deliberate policies of assimilation or "capture by flour," changes in the local environment as a result of altered fire regimes, pastoral incursion, invasive species, and policies that disenfranchised Aboriginal land-owners have all played a role in changing the nature of contemporary foraging and production. However, the effects of European incursion and market involvement are not entirely spatially homogenous, suggesting that other socioecological processes may be equally important. For example, a report by McCarthy and McArthur (1960)¹ from Fish Creek near Oenpelli in northern Arnhem Land show women contributing about the same to total foraging production (30%) in 1948 as in the late 1970s (Altman 1987; Meehan 1982). An exception such as this begs questions about what variables might contribute to aggregate measures of relative production, and what assumptions underlie the consideration of such a ratio as a meaningful explanatory entity.

In the past, production inequalities were perceived and measured as long-term averages, with the implicit assumption that such inequities served some functional purpose. Julian Steward's work is a classic example, arguing that the gender division of labor and extensive food sharing among Great Basin hunter-gatherers were core adaptations designed to more efficiently provide food for a local group (1938:230–237). With similar logic, Richard Gould (1991) argued that highly flexible gender-linked socioeconomic strategies among Australian Aborigines around Patjarr in the Western Desert were adaptations to minimize risks across highly unpredictable environments. More recently, production inequalities have been used to describe variation in the proportion of the diet contributed by each gender or variation in men's and women's time allocation decisions (e.g., Kaplan et al. 2000; Marlowe 2007; Bliege Bird and Bird 2008). There are, however, difficulties in interpreting such a measure, especially when it averages over extensive temporal and spatial variability. Such a ratio is the structural result of an aggregate pattern of behavior observed over a period of time: that is, it is the product of individual decision-making by both men and women. Similar structural outcomes may be the product of a host of alternative

¹ These data refer to the time McCarthy and McArthur (1960) spent at Fish Creek. Their detailed narrative covers observations on subsistence activities for fourteen days from October seventh to October twentieth. Men's and women's relative contributions were calculated by extracting the time each forager spent searching, pursuing, and transporting resources and the weight of resources acquired. When two or more individuals participated, the total was divided by the number of foragers. Weight was converted to kilocalories following Brand-Miller et al. (1993). Complete information was available for a total of 30 bouts (12 women-only, 14 men-only, and 4 mixed-gender groups). The results show that men's foraging time accounted for 55% of the total foraging time for that period, during which they contributed 72% of the total kilocalories acquired.

processes: 50% average production by men could result either from consistently providing half of the production or from providing all or nothing half of the time. Examining the outcome alone tells us very little about the process that formed it.

Most human behavioral ecologists examine differences in the relative proportion of foraged foods contributed by men and women as a function of patterned individual decisions about time allocation, differences in the efficiency of resource types compatible with childcare, and/or differences in resource variance (e.g., Bliege Bird 2007; Bliege Bird and Bird 2008; Bliege Bird and Smith 2005; Bliege Bird et al. 2001; Gould 1967; Gurven 2004; Gurven and Kaplan 2006; Hawkes 1991, 1993; Hill and Hurtado 1996; Hill et al. 1987; Hurtado et al. 1992; Lee 1968, 1979; Marlowe 2003; Sahlins 1972). Much of the focus on gendered production inequalities has been on explaining men's overproduction relative to women as a function of childcare and efficiency trade-offs: women underproduce (and men overproduce) when they benefit from spending less time foraging and more time caring for children, and when resources offer trade-offs between childcare compatibility and efficiency (Kaplan et al. 2000). Alternatively, men's overproduction relative to women has been modeled more as a function of gender-biased costs and benefits of acquiring resources associated with large harvest bonanzas (Hawkes 1991). This hypothesis suggests that men produce more than women when they are drawn into competitions for social status that rely on producing or sharing with many others—competitions in which women often find it too costly to engage. Such resources that provide competitive benefits are usually those associated with large-bodied animals: these offer high variation in harvest sizes and the potential for occasional large harvest bonanzas (with big risks of complete failure). Thus, men's overproduction is a function of how successful they are in acquiring a large animal.

These models suggest that inequalities in total production by one gender relative to another over time should be a function of several components: differences in the number of men and women choosing to allocate time to foraging, the total amount of time they allocate to foraging, the mean rate of return across all foraging activities, and the probability of a successful harvest (or of actually reaching the mean rate of return). It should also be a function of resource choice: that is, to which sets of resources or activities men and women allocate their foraging time. Both models suggest that gendered time allocation tends to fall into two major types of activities: those that are generally assumed to be associated with high mean rates of return, high childcare incompatibility, and lower success probabilities (larger, more mobile animals) and those that are generally assumed to be associated with lower mean rates of return, lower childcare incompatibility, and higher success probabilities (less mobile animals and vegetal resources). Cross-culturally, men tend to allocate more time to the former, and women more time to the latter, although men often spend considerable time acquiring small game and collected resources (Marlowe 2007). This in turn suggests the following specific hypotheses about how these components of variation work to affect production inequalities: (1) *The number component*: if variation in the relative production of men and women is a function of the number of men and women out foraging, then men should contribute significantly more when there are more men in a mixed-sex foraging group. (2) *The time component*: if daily production is merely a function of time spent foraging, then when men spend significantly more time foraging per day than women, they should contribute

relatively more than women to the total harvest (e.g., Gould 1969; Sahlins 1972). (3) *The efficiency component*: the average daily harvest size of men and women may be a function of the rate at which they harvest resources while foraging, such that when men are able to forage more efficiently per day than women, they should outproduce them (e.g., Gurven 2004; Gurven and Kaplan 2006; Lee 1979:261–262). (4) *The variance component*: the average daily harvest of men and women may be associated with different probabilities of success. When men have a higher probability of a successful harvest than women, they should outproduce them (e.g., Bliege Bird 2007; Bliege Bird and Bird 2008; Lee 1968:33, 40). (5) *The choice component*: do men outproduce women when they have higher rates of return or success probabilities on larger prey, or on smaller prey/collected resources? Although our main focus in this paper is on describing how these components lead to patterned variation in production inequalities, our analytical question is geared toward explaining why measures of production inequalities in “traditional” Australia favor women, while more contemporary ones favor men. Do men overproduce as a function of unpredictable variation in successes on large-bodied animals, or is overproduction a function of men spending more time foraging, or choosing resources that provide higher rates of return? If the former, production inequalities across Australia may be linked to environmental variation in encounter rates with large-bodied prey. If the latter, changes in social or economic constraints that disenfranchise women’s foraging production may be more likely to be at work, reducing the time they can spend foraging or limiting their foraging choices to low-return activities.

To examine how these components covary with production inequalities, we use fine-grained data on the relative daily foraging camp production of Martu men and women in the Western Desert of Australia. Our focus in this paper is on exploring how daily variation in the number of men and women foraging, their time allocation, return rates, success probabilities, and resource choice predicts the daily percentage of total production acquired by men relative to women in temporary foraging camps. We have previously shown that Martu men’s and women’s relative production in foraging camps varies extensively across space (Fig. 1b) and over time (Fig. 2); there is often considerable overlap in the kinds of resources men and women choose to acquire, particularly with respect to hunting. Although Martu men rarely acquire collected resources, they do sometimes hunt small animals. Small-animal hunting is a specialty of women;² they occasionally hunt larger, highly mobile prey but show clear preferences for low-variance foraging activities (often at the expense of harvest size), whereas men show clear preferences for larger-harvest-size foraging activities

² One reviewer of this paper asked whether Martu women’s hunting might be better considered collecting, given that sand monitor hunting frequently involves digging prey from subsurface dens. We have dealt with this issue extensively elsewhere (Bliege Bird and Bird 2005, 2008; Bird et al. 2009). Martu women’s small game hunting is *hunting* because it involves a non-zero probability of pursuit failure owing to the prey’s mobility, and furthermore, it is emically defined as such (*wartilpa*, hunting, as opposed to *nganyimpa*, collecting). Even though sand goanna are seasonally burrowed, they do not become the animal equivalent of an underground plant storage organ: tubers don’t dig and move to elude capture, nor can they escape the hunter from a “pop hole.” When summer arrives, sand monitors must be tracked on the surface like any other mobile prey, and they are faster than humans over short distances (see Bird et al. 2009 for detailed description and analysis).

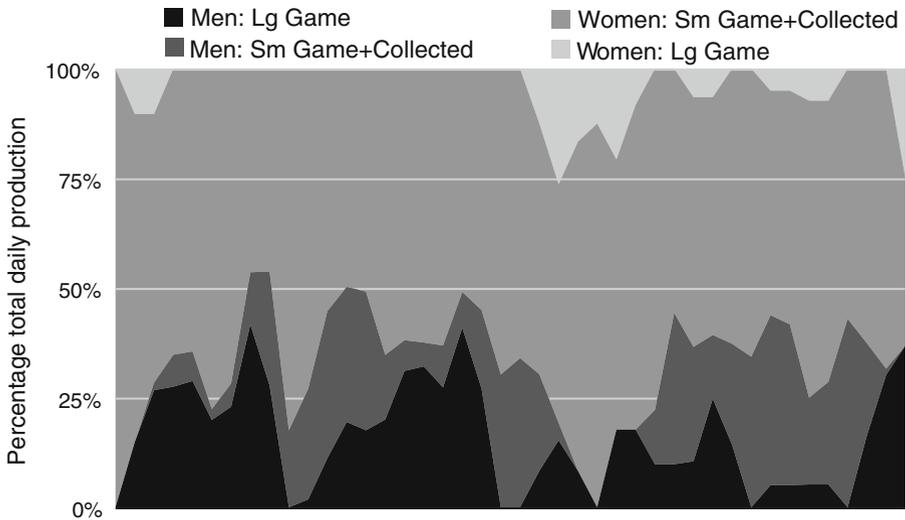


Fig. 2 Five-day moving average calculating the percentage of the total daily harvest acquired by men and women

(often at the expense of taking on high variance and risks of bout failure). Gender differences among Western Desert Martu can be predicted by the inter-bout coefficient of variation in mean returns and the probability of bout failure, which is a function of resource size and mobility (Bird et al. 2009; Bliege Bird and Bird 2008), suggesting that gender differences in resource choice are a function of differential variance sensitivity. This leads to considerable variation in production over time and space that may enable us to more easily tease apart the components of production inequalities and predict how relative production should vary in response to changes in the number of men and women, time spent foraging, the efficiency of foraging, average harvest size, the chances of a successful harvest, or the differences between men's and women's preferred foraging activities.

Ethnographic Background

Martu (aka Mardu or Mardujarra) is a term of self-reference commonly used by about 1,000 indigenous Australians from a number of dialect-named groups who live in and have Native Title over a large portion of the northwest section of Australia's Western Desert around Lake Disappointment and the Percival lakes (Fig. 1c). Two main Aboriginal outstation communities, Parngurr and Punmu, were founded in the heart of this homeland in the 1980s when Martu returned to the desert after the last bands were drawn into missions and pastoral stations in the mid 1960s. A third outstation, Kunawarritji, was founded along the Canning Stock Route at Well 33 (see Davenport et al. 2005; Tonkinson 1991; Scelza and Bliege Bird 2008). Typically each outstation has between 50 and 200 people, with populations constantly redistributing between each outstation, temporary remote camps, and the towns of Newman in the Pilbara or Port Hedland on the northwest coast. In

fluctuating between these central places, Martu maintain a high level of residential mobility and are often away for extended periods of time, traveling throughout the Western Desert and Pilbara regions to fulfill traditional religious and social obligations. More detailed ethnographic information may be found in a number of sources (Bird and Bliege Bird 2005, *in press*; Bird et al. 2005; Bliege Bird and Bird 2005, 2008; Scelza and Bliege Bird 2008; Davenport et al. 2005; Tonkinson 1974, 1978, 1988a, 1988b, 1990, 1991, 2007; Tonkinson and Tonkinson 2001; Veth 1987, 1989, 1995, 2000, 2005; Veth and Walsh 1988; Walsh 1990). Our remaining description is focused on the context of daily foraging.

For most Martu in the outstations, foraging is a primary occupation. Depending on the season, location, and personal or ritual obligations, foraged foods make up 25–50% of total daily food calories per capita and more than 80% of total daily meat calories per capita, with the remainder consisting of processed foods purchased in town or at a government-run shop. The context of contemporary Martu foraging centers around the formation of a “dinner-time camp” (hereinafter referred to as “camp”): a foraging party leaves the community by vehicle to establish a temporary camp usually <50 km from the community. Individuals set out on foot from the camp except when bustard hunting, in which case a vehicle is generally used. Men and women sometimes forage together, but more frequently they travel out from the camp in single-gender groups or alone, returning to process, cook, and share foraged foods.

While foraging, Martu generally engage in one of some 15 emically defined activities (or hunt types), each of which occurs in one of four primary habitats (dunefield, watercourse margin, rocky range, acacia woodland). Although each hunting activity involves a particular set of prey types, the hunt types are referred to by the dominant (though not exclusive) prey type. The five most common hunting activities are (1) bustard (*Ardiotis australis*), (2) hill kangaroo (*Macropus robustus*), (3) sand monitor (*Varanus gouldii*), (4) perentie (*Varanus giganteus*), and (5) cat (*Felis silvestris*; see Bird et al. 2009; Bliege Bird and Bird 2008 for details and analysis). Martu also make trips to resource patches to collect plant and insect foods, including (6) bush tomato (*Solanum diversiflorum*), (7) bush raisin (*Solanum centrale*), (8) cossid moth larvae (*Endoxyla* spp.), and (9) geophytes (especially *Vigna lanceolata* and *Cyperus bulbosus*). For short periods during the spring, foragers also allocate significant effort toward collecting (10) nectar from flowering groves of *Hakea suberea* and *Grevillea eriostachya* trees. Recently, (11) honey collected from the hives of feral European bees has become increasingly important. Children typically hunt for ridge-tail monitors (*Veranus acanthurus*) in rocky outcrops, but they also often collect *Solanum* fruit and cossid larvae (Bird and Bliege Bird 2005). Although traditionally important, grass and tree seed harvesting for milling purposes has declined dramatically with increased reliance on commercial flour. Sand monitor, bustard, and cat hunting, along with bush tomato, raisin, and moth larvae collecting, all occur in dunefields, whereas hill kangaroo hunting is restricted to rocky ranges and perentie hunting and geophyte collecting to the sandy margins of watercourses. Women devote 93% of their foraging time to small/medium-sized prey and collected resources (activities 3–11); men allocate 62% of their foraging time to large, mobile prey (activities 1 and 2; see Bliege Bird and Bird 2008 for more details on the foraging division of labor and its determinants).

The decision to engage in one hunt type over another is typically made prior to departure from the camp, and since people are more or less technologically and ecologically limited to one or a few of these hunt types after departure, each one can be treated analytically as a patch and the trade-offs modeled accordingly (Smith 1991).

Methods

The foraging data reported here were collected from 2000 to 2007 by following a single foraging party daily that left the community (usually by vehicle) to establish a temporary camp from which to travel on foot to acquire bush foods. We could not randomize our choice of parties to follow each day since their formation was spontaneous: one or two individuals would plan to go out using a vehicle (ours, theirs, or someone else's) and would drive around the community picking up anyone else who wished to go along. Parties were thus composed of members (and guests) from multiple extended-family households in the community, as described in Bliege Bird and Bird 2008; parties averaged eight participants per camp but always varied in size and composition. Some parties were composed entirely of adult females, some of adult males, but the majority were composed of a mix of individuals of both sexes and all ages. During each foraging trip, we recorded the coded identity of each participant, the time spent traveling to foraging locales, the route taken, the foraging location chosen, and foraging bout details of all party participants. Here, a foraging bout is operationally defined as the time each participant in the party spent searching for and handling wild food resources while away from a central place, usually the temporary camp. During each trip, at least one researcher present asked permission to conduct a focal individual foraging follow, in which they accompanied a forager for the duration of a bout, recording all time allocated to search and the different components of handling: pursuit, capture, transport, and processing. On many follows, foraging paths were also recorded using a handheld GPS unit. As with all bouts, all the resources acquired were weighed and counted at the end of the follow. Martu most often forage separately, but occasionally people cooperate (see Bliege Bird and Bird 2008). During these episodes we divided the returns by the number of individuals who foraged together.

Field notes were compiled to create a foraging-bout-and-follow database in which each row represents an individual's time and production on that bout. Raw weights from the field were converted to edible kilocalories following Brand Miller et al. (1993), Latz (1996), and O'Connell and Marshall (1989; see details in Bliege Bird and Bird 2008; Bird et al. 2009). The dataset used in this analysis aggregates the individual bout data by date and foraging location (Universal Transverse Mercator [UTM] easting and northing points), resulting in a dataset of 221 foraging camp-days in which each row sums total daily production and time allocation by foraging activity and gender. Mixed-gender camps accounted for 75.6% of all foraging production: all-female and all-male camps produced 12.5 and 11.9%, respectively (Table 1). Since this analysis is focused on the question of what factors influence daily variation in how much food men produce relative to women at temporary camps, we use only those camps at which men and women were present and at least

Table 1 Summary of the foraging camp database

	Women's Camps	Men's Camps	Mixed-Sex Camps	
			Men	Women
All Resources (days attempted, total number of bouts observed)	<i>n</i> =34 days, 164 bouts	<i>n</i> =32 days, 78 bouts	<i>n</i> =155 days, 416 bouts	<i>n</i> =155 days, 683 bouts
Mean <i>N</i> foragers observed/day (95%CI)	4.8 (4.1–5.5)	2.4 (1.9–3.0)	2.7 (2.4–2.9)	4.4 (4.1–4.7)
Mean daily per capita harvest (95%CI)	2340 (1363–2781)	6633 (4539–8908)	3302 (2268–4336)	2323 (1865–3317)
Mean daily summed harvest (95%CI)	12445 (5426–19464)	12531 (5693–19369)	7753 (5850–9657)	8716 (7618–9815)
Percent Sum production	12.50%	11.90%	35.60%	40%
Large Prey (days attempted)	<i>n</i> =4 days	<i>n</i> =31 days	<i>n</i> =110 days	<i>n</i> =24 days
Mean daily per capita harvest (95%CI)	4536 (2269–11342)	5100 (2782–7418)	3384 (2153–4614)	3700 (922–6479)
Mean daily summed harvest (95%CI)	12781 (1529–24034)	10570 (5403–15738)	6859 (4116–9602)	6178 (1585–10772)
Mean daily success probability (95%CI)	0.75 (0.25–1.24)	0.36 (0.21–0.52)	0.39 (0.31–0.47)	0.42 (0.22–0.62)
Small Prey (days attempted)	<i>n</i> =30 days	<i>n</i> =2 days	<i>n</i> =94 days	<i>n</i> =147 days
Mean daily per capita harvest (95%CI)	2047 (1450–2644)	7195 (2583–11808)	2848 (2175–3521)	1982 (1712–2251)
Mean daily summed harvest (95%CI)	12400 (8699–16102)	9684 (2941–16427)	4759 (3776–5743)	8182 (6510–9855)
Mean daily success probability (95%CI)	0.92 (0.85–0.99)	1	0.86 (0.81–0.91)	0.92 (0.88–0.95)

one member of each sex was actively foraging. This is appropriate because we are not modeling long-term summed production at the community level, and because we are interested only in modeling the factors that influence how much one gender will produce relative to the other at foraging camps. Our question is not what the average Martu man's or woman's production effort is but, rather, what the average production effort of male vs. female producers is. We are interested here in differences in men's and women's choices to forage and to forage for different things, which leads to differences in daily summed production at foraging camps. Indeed, we do not know the long-term summed production at the community level: although we know the full production of all members of the foraging party that we recorded, other foraging parties who left the community on the same day were not accounted for. Our measures of production are thus specific to one party, but since our methods of party formation were identical to those used by Martu who left the community without us, we are confident that they are representative of gendered production in the community as a whole. A summary of the dataset is presented in Table 1.

Our dependent variable, *percent men's contribution*, measures the daily proportion that was contributed by men of the total harvest acquired at each camp. We first use four difference measures as independent predictors in four separate univariate

regression models: (1) *number of men minus number of women* represents the daily difference in the number of men and women foraging; (2) *men's foraging time minus women's* represents the daily difference between the per-capita average amount of time men and women spend foraging; (3) *men's return rate minus women's* indicates the difference of men's and women's mean E/T (or in-patch return rates; kcal/hr/person); and (4) *men's average proportional success minus women's* shows the difference between men's and women's average daily proportion of bouts that were successful. For the two most significant independent predictors (based on R^2_L values, see below) we broke out the difference measure by gender and type of resource acquired (large prey vs. small prey/collected resource) in eight separate univariate regression models in order to determine whether relative production was best predicted by small-prey return rates for (5) women or (6) men, large-prey return rates for (7) women or (8) men, average success probabilities on small prey for (9) women or (10) men, and average success probabilities on large prey for (11) women or (12) men. The significant variables from this set were then run in a multivariate model (13).

Because the nature of the dependent variable (a binomially distributed proportion that is constrained to vary between 0 and 1) violates several assumptions of ordinary least squares (OLS) regression models, we used a Generalized Linear Model (GLM) with a binomial distribution and a logit (or logistic) link function to model the relationship between the independent variables as described above and the daily mean percent men's contribution (Kieschnick and McCullough 2003). Analysis was run in JMP 7.0.1 (SAS 2007) and/or R 2.6.2 (R Development Core Team 2008). Following Menard (2002), we calculated likelihood ratios (R^2_L) for each model. R^2_L values are measured as the $-2 \log$ -likelihood ($-2LL$) value of the null model (D_0), which includes only the intercept, divided by the $-2LL$ value for the difference (G_M) between D_0 and the $-2LL$ of the full model (D_M), which includes the intercept plus the independent variable(s). In other words, $R^2_L = (G_M/D_0)$, or the reduction in unexplained deviance resulting from the inclusion of the independent variable(s). R^2_L values are to be interpreted as analogous to R^2 values in OLS regression analysis and can be interpreted as representing how well the model fits the data.

Results

There is considerable daily variability in the relative contribution to subsistence by each gender. Men's average daily production ranges from 0 to 100% of all foraged calories (IQR: 5–58%). Although men's summed production over all camp days is 46%, their average daily production is much lower. The cumulative probability distribution of men's contribution shows that men contribute less than 50% of all caloric production on 69.5% of camp days, with an average daily production of $35\% \pm 4\%$ (Fig. 3).

Model 1: The Number Component

If differences in men's and women's relative production are a product of the number of men and women foraging, then when men outnumber women, they should out-produce them. Indeed, the difference between the number of men and the number of women significantly predicts men's proportional daily production ($\chi^2=6.15$, $p=$

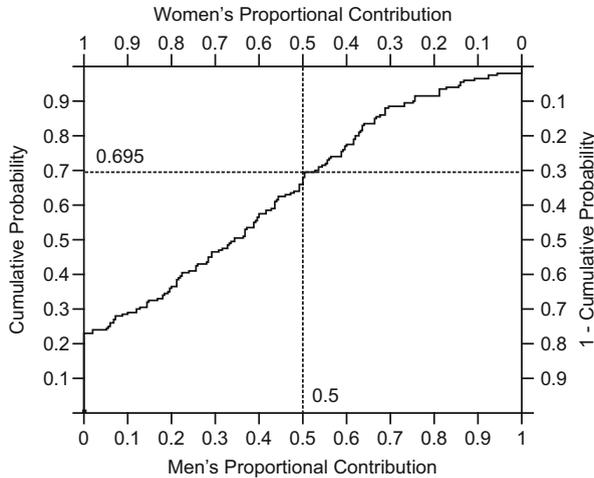


Fig. 3 Cumulative probability distribution of the proportion of all daily calories contributed by men (bottom, left axis) and its complement showing the proportion contributed by women (top, right axis). The dotted crosshairs show the probability (0.695) that men will contribute 50% or less to total daily production, or that women will contribute 50% or more

0.0132; Table 2, Fig. 4a). However, in order for men to produce as much as women, they need to outnumber them substantially. According to this model, when there are equal numbers of men and women, men's relative production centers around 41.9%, ranging from 32.6% to 51.8%. Two more men than women are required to bring men's production up to 50%; four more brings production to 59% (38.3–76.9%). Since there were never more than four more men than women in the dataset, the model is undefined for production levels higher than 59%. Thus, while the number of men and women is important for negative production inequalities (women producing more than men), it is not able to explain positive production inequalities (men producing more than women).

Model 2: The Time Component

If variability in daily production is merely a function of time spent foraging, then when men spend significantly more time foraging per day than women, they should contribute relatively more than women to the total harvest. Here, however, production does not appear to be a simple function of per-capita time spent foraging. Differences between men's and women's mean per-capita foraging time do not significantly predict relative production ($\chi^2 < 0.006$, $p = 0.9350$, $df = 1$; Table 2, Fig. 4b). Regardless of how much time per capita men spend foraging relative to women, their contribution remains the same (about 35%). The probability that men and women spend equal time foraging per day is about 0.45 (Fig. 4f).

Model 3: The Efficiency Component

If there are no differences in time spent foraging, the average daily harvest size of men and women may be a function of the rate at which they harvest resources while

Table 2 Summary of results

Model No.	Model Name	N	df	$\chi^2(G_M)$	D_b	Estimate	R^2_L	p	R^2_L rank
Men's & Women's Relative Variation									
1	Number Component	150	1	6.15	194.10	0.1727	0.0317	0.0132	6
2	Time Component	150	1	0.02	194.10	0.0003	0.0001	0.8757	12
3	Return Rate Component	150	1	23.20	194.10	0.0005	0.1195	<0.0001	5
4	Success Component	150	1	28.47	194.10	2.6440	0.1467	<0.0001	3
Men's & Women's Independent Variation by Prey Type									
5	Returns: Women's Small Prey	142	1	0.03	183.17	<0.0001	0.0002	0.8550	11
6	Returns: Men's Small Prey	94	1	0.72	128.45	<0.0001	0.0056	0.3961	9
7	Returns: Women's Large Prey	22	1	0.40	27.49	-0.0001	0.0147	0.5249	7
8	Returns: Men's Large Prey	105	1	17.02	134.22	0.0003	0.1268	<0.0001	4
9	Success: Women's Small Prey	143	1	0.48	185.20	-0.7130	0.0026	0.4868	10
10	Success: Men's Small Prey	94	1	1.06	128.45	0.7844	0.0083	0.3021	8
11	Success: Women's Large Prey	22	1	0.00	27.49	-0.0249	0.0000	0.9793	13
12	Success: Men's Large Prey	105	1	20.59	134.22	2.2337	0.1534	<0.0001	2
Multi Model									
13	Men's Large Prey	102	2	23.85	134.22		0.1777	<0.0001	1
	Returns	-		3.25	-	0.0002		0.0712	
	Success	-		6.82	-	1.6340		0.0090	

Generalized linear models of the binomial family and logit link function showing the effect of various independent predictors on the proportion of daily production supplied by men. The first block (models 1–4) measures the difference (men-women) in the number of men and women (the number component), their per-capita average time spent foraging (the time component), their mean daily return rates (the return rate component), and the mean average daily frequency of successful bouts, across all foragers (success component). The second block (models 5–12) breaks out the effect of men's and women's return rates and success averages to examine their separate effects on the proportion of daily production supplied by men. The third block (multi model) examines the interaction between returns and average successes on men's relative production. All models are ranked by their R^2_L values (see text). Values in bold are significant at $p < 0.05$

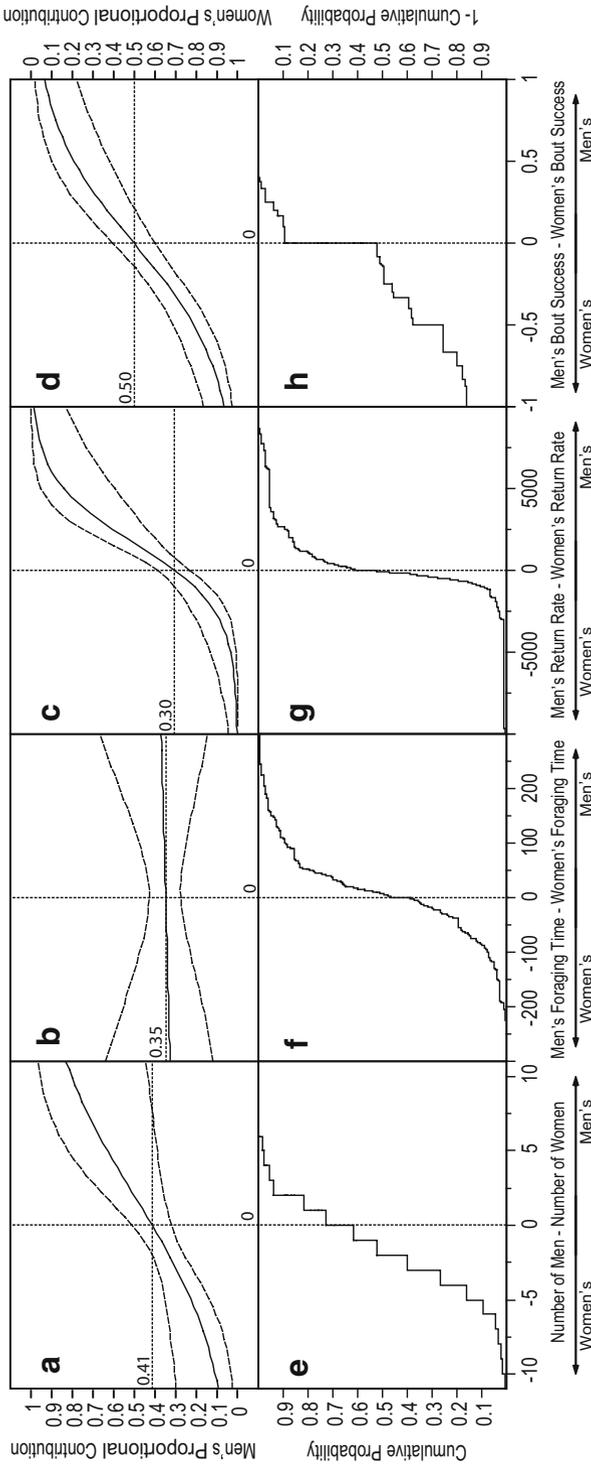


Fig. 4 Prediction profile plots showing the results of the first four models, and associated cumulative probability distributions. The top panels (a–d) show the predicted relative contribution (\pm 95% confidence intervals, dotted lines) derived from binomial logit regressions of the difference between (a) the number of men and women, (b) men's and women's mean foraging time, (c) return rate, and (d) daily average bout success probabilities. The crosshairs show the predicted relative contribution at a mean difference of zero for each variable. The bottom panels (e–h) show the associated cumulative probability distributions for each difference measure. The probability that men's values will at least equal women's is shown with each dotted line. See text for details

foraging, such that when men are able to forage at a higher mean rate than women, they should out-produce them. To test this hypothesis, we examined the effect of *men's return rate minus women's return rate* on relative production, which produced a highly significant model ($\chi^2=21.42$, $p<0.0001$, $df=1$; Table 2, Fig. 4c). But the effect of daily mean foraging return rate is not symmetric: if men's and women's mean returns are equal, men contribute 31% (and women 69%) of total production (Fig. 4c). Men must forage with a rate more than 1,900 kcal/hour/day higher than women in order to acquire more than 50% of the calories for any given day; this has a 0.14 probability of occurring on any day that men and women forage from the same camp (Fig. 4g). Even if they achieve this rate, the uncertainty in proportional contribution is quite high: the 95% confidence interval for men's contribution at this point ranges from 0.38 to 0.63.

Model 4: The Variance Component

The fact that foraging efficiency has asymmetric effects on production inequalities suggests that the relationship between relative production and foraging returns may be more affected by the probability of men getting daily mean foraging returns more than 1900 kcal/hr higher than women's. If the average daily harvest sizes of men and women are associated with different probabilities of success, when men have a higher probability of success than women, they should out-produce them. Differences between men's and women's daily mean probability of success is a significant predictor of relative production ($\chi^2=28.96$, $p<0.0001$, $df=1$; Table 2). As Fig. 4d shows, when men's and women's proportional bout success averages are equal, men's and women's proportional contribution is roughly 0.50; however, men will have a mean success probability equal to or higher than women's on only 11% of all days (Fig. 4h).

Models 5–13: The Choice Component

Models 1–4 identify men's and women's relative return rate and relative mean daily success probabilities as the two most salient variables in explaining their relative contribution to the daily harvest. But this leaves us uncertain as to whether this result is a product of men's or women's foraging decisions and whether or not these outcomes are due to variation in returns or successes in large- or small-game hunting/collecting. To further understand these patterns, the next eight models (Table 2: models 5–12) disaggregate the independent predictors to examine how men's and women's individual foraging returns and hunting success with small and large prey covary with relative production. As shown in Table 2, only men's return rates with large prey (Model 8; $\chi^2=17.02$, $p<0.0001$) and their daily mean success probabilities with large prey (Model 12; $\chi^2=20.59$, $p<0.0001$) significantly predict relative contribution. Variance in women's hunting returns and in success with large or small prey does not significantly explain relative contribution, nor do men's returns and successes on small prey.

When men's hunting return rates and success probabilities with large prey are both combined in a single model (13), only men's hunting success remains significant, suggesting that whether or not men succeed when pursuing large game has the single greatest effect on men's and women's relative contribution. These

results show that just by being successful when pursuing larger prey, men can raise their contribution above 0.50, with only a marginal (but not significant) increase thereafter as a function of increasing return rates (see Fig. 5).

As shown in Table 2, when all the models are ranked by their R^2_L values, Model 13 provides the best fit to the data (Table 2). The next best fit is Model 12, which includes men's success rates with large prey, followed by Model 4, which includes men's and women's relative mean success. All of these models have in common the centrality of men's mean bout success probabilities, suggesting this variable is the most significant in predicting men's and women's relative contribution.

Discussion

The chance of successfully acquiring large, highly mobile prey, rather than the number of men and women, the time spent foraging, or foraging return rates, seems to best predict inequities in gendered food production at temporary foraging camps. Since men generally target such resources, they tend to contribute a disproportionate amount of the daily total harvest when they are successful. However, these items tend to have higher bout and pursuit failures (see Bird et al. 2009); thus success is relatively rare (e.g., Bliege Bird 2007; Bliege Bird and Bird 2008; Hawkes 1991, 1993; Hill et al. 1987). As such, Martu men's preferences for pursuing large mobile prey prevents them from dominating production relative to women because daily successes are few and far between. Martu men may choose to increase the reliability of their contribution by targeting smaller prey, as they might when women's foraging returns are constrained by investments in offspring (e.g., Marlowe 2003), but these data show that (all else being equal) such investments do not predict foraging inequalities. At foraging camps, production inequalities are the function of stochastic variation in the probability of a successful hunt of kangaroo, emu, or bustard, and they depend little on women's production or the production of lower-variance resources. Women predictably provide about 60–70% of caloric production, with

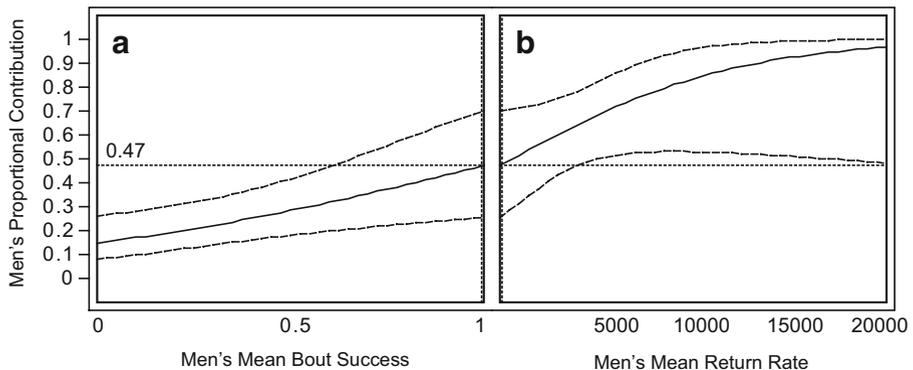


Fig. 5 Prediction profile plot showing the results of model 13. Frame a shows the effect of men's mean bout success with large prey and frame b shows the effect of men's mean large prey return rates on the proportion of daily calories contributed by men. With men's mean bout success set to 1, men can be expected to contribute 47% of total daily production; the effect of return rate is not significant (see Table 2)

men producing more than women only when intermittently successful in capturing larger prey. While this analysis answers questions about what drives variation in gendered production inequities, other questions remain as to why these patterns exist. Below, we explore additional data that might shed some light on what structures this patterning in gendered preferences, and how individuals might benefit from the occasional success that provides a large proportion of the total harvest for that day.

Where Do Gendered Preferences Come From?

As Hawkes (1990, 1991) proposed for Ache and Hadza foragers, foraging decisions may be gender-biased on Martu foraging camps because men and women have different foraging goals that lead them to perceive the costs and benefits of risk differently. Differences in production are thus a function of differences in individual foraging goals that lead to preferences for different types of prey—for women, a preference for resources that increase the chances of a *successful daily harvest* (low-variance resources); for men, often a preference for resources that increase the chances of a *larger-than-average harvest* (high-variance resources).

In a companion piece (Bliege Bird and Bird 2008), we show that Martu camp “divisions of labor” emerge as a result of gendered patterns in variance sensitivity. Men are more variance-prone not because they are specializing in high mean returns owing to women’s foraging constraints, but because they seek the rewards of big harvests, discounting the costs of uncertainty in the process. Men are more likely than women to fail to acquire a harvest on any foraging day, but they are also more likely to get more than two adults can consume, whereas women are more likely to acquire a harvest within the maintenance range (500–4000 kcal). There is no negative covariance between men’s and women’s foraging time, indicating that for the most part, men and women tend to allocate time to foraging activities independent of each other’s choices. Ninety-three percent of the variability in women’s relative contribution to any foraging activity is explained by the chance of harvest success (see Table 3); men show significantly higher variance than women at all mean return rates; and women respond dynamically to temporal and spatial variability in the reliability of hunting returns, spending more time hunting for small game when returns were more reliable. Although men allocate most of their time to the pursuit of larger, mobile prey, they do spend more time on small game when the

Table 3 Correlations between characteristics of foraging activities and percentage male contribution

Characteristic of Activity	Correlation with %Male contribution	<i>p</i>
Probability of successful bout	-0.924	0.0001
CV in harvest size	0.833	0.0009
CV in return rate	0.950	0.0001
Harvest size range	0.871	0.0003
Mean harvest size	0.679	0.0128
Mean return rate	0.114	0.3207

Values in bold are significant at $p \leq 0.05$

chances of acquiring a very large harvest are higher (see Table 4). The fact that men and women are sensitive to different characteristics of resources is best illustrated with the data in Table 4, which shows how correlations between men's and women's time allocation to small prey hunting at dinner-time camps are predicted by very different aspects of variation in risk and returns. Women's time allocation to small prey by camp shows negative correlations with maximum harvest size of collected resources and coefficient of variation in small prey returns and positive correlations with small prey bout success; men's time allocation to small prey tends to covary positively with small prey maximum harvest size and negatively with average successes for larger prey.

When men are successful in acquiring high-variance prey, their relative production is much higher, but the benefits of this high production are distributed as "public goods." Bird and Bliege Bird (in press) have shown that the consumption costs of acquiring high-variance prey lie not only in the greater uncertainty of success, but also in the lower consumption return after all hunters had shared their catch. Men who hunted kangaroo did not keep proportionately more for themselves to repay the costs of extra variance. Nor were they paid back by receiving more meat than non-hunters from others. Small-game hunters, however, did end up with more for their own consumption, keeping more of what they acquired while still receiving shares from the small-game production of others. Most of the low-variance prey women acquired went to feed other women and children.

Table 4 Correlations between risk variables, return rates, and men's and women's proportional time allocation to small game hunting

	% Total Foraging Time on Goanna			
	Men		Women	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Small prey return rates	-0.199	0.3504	0.083	0.6983
Large prey return rates	-0.094	0.6608	0.089	0.6799
Collecting return rates	0.292	0.1663	-0.225	0.2912
Small prey max harvest size	0.555	0.0059	0.398	0.0602
Collecting max harvest size	-0.385	0.0634	-0.461	0.0233
Small prey CV in returns	-0.122	0.5981	-0.509	0.0184
Large prey bout success	-0.414	0.0441	-0.287	0.1746
Small prey bout success	0.297	0.1913	0.715	0.0003

Correlations showing positive or negative relationships between goanna-hunting time allocation and return rates, maximum possible harvest sizes, bout success percentages, and the coefficient of variation in returns (Bliege Bird and Bird 2008). Women spend more time goanna hunting when bout successes are more likely, and less time when returns are more variable and collecting can potentially provide a big harvest. Men spend more time goanna hunting when harvest sizes are potentially larger and less time when kangaroo or bustard success is more likely. A multivariate regression model incorporating both collection harvest size maximum and goanna success rate explains 59.7% of the variance in women's goanna hunting time allocation ($p=0.0003$), while 37.7% of the variability in men's goanna hunting time allocation is explained by both goanna size range and the success rate of bustard and kangaroo hunting ($p=0.0088$).

Values in bold are significant at $p \leq 0.05$

These differences are shaped by gendered patterns in foraging goals. Martu men's foraging goals more often involve political strategies, in which men use hunting for high-variance prey (here, mainly kangaroo) as a way to rise in the ritual hierarchy. Because the acquisition and distribution of high-variance prey ends up being costly, it can serve as an honest signal of a hunter's absolute generosity, and of his or her motivation to work for the public good (Bliege Bird et al. 2001; Boone 1998; Gurven et al. 2000; Sackett 1979; Smith and Bliege Bird 2005; Wiessner 2002). For Martu, this magnanimity demonstrates an honest disengagement with property, conceptualized as *mirtilya*—not only one who is a skilled producer, but one who frequently produces public goods (Bird and Bliege Bird *in press*). For Martu, inequalities develop as a function not of who keeps more, but of who produces more, which leads to a sort of competitive magnanimity that provides the basis for both secular and religious hierarchy (Bird and Bliege Bird *in press*). Rises in the ritual hierarchy are important not only for a man's ability to build relationships and impress potential in-laws who may provide him with their daughters (for wives), but also for one's ability to invest in one's current children. An active father who participates in meetings leading up to his son's initiation can influence the timing of initiation, and early initiation for boys leads to earlier age at first marriage and higher age-specific fertility (Brooke Scelza, personal communication 2008).

Martu women's foraging goals more often center around feeding a smaller network of kin and maintaining their cooperative relationships with other women: daughters, sisters, and cowives. Rather than focusing on cooperative production within the nuclear family, women more frequently form cooperative production groups with other women, both coresidents and non-coresidents (Bliege Bird and Bird 2008). This seems to reflect a long history of reliance on forming partnerships between mothers and daughters, sisters and cowives; the historic patterns of residential group composition echo the importance of these relationships (Scelza and Bliege Bird 2008). The sharing of low-variance prey is primarily directed among women in these partnerships, particularly those formed between older women, who tend to do more goanna hunting, and younger women, who tend to do more collecting of fruit, roots, and grubs (Bliege Bird and Bird 2008). Most importantly, the formation of production groups among Martu cross-cuts nuclear family associations, and indeed, one is expected to remain within one's production group until cooking, distribution, and consumption are complete, even when one's own nuclear family arrives and establishes a hearth nearby. Rather than a division of labor that is the result of cooperative specialization and reciprocal sharing between men and women, we suggest that cooperation and sharing is more commonly occurring between women, whose foraging decisions differ across their lifespans. Because women's production is frequently high relative to men's, and men's overproduction so unpredictable, both gain *mirtilya* status, albeit usually through different avenues.

Implications for Production and Social Inequalities

In light of these findings, inequalities in gendered production are seen to emerge less out of colonial fallout (*sensu* Leacock 1978, 1983) and more from a process of competitive magnanimity interacting with local ecological variability. This research suggests that men's and women's production inequalities develop out of a complex

set of individual goals that articulate with social and environmental ecologies. Typical gender differences in resource choice in Australia involve men spending most of their time searching for larger animal prey (kangaroo, emu, bustard) and women on smaller animal prey and collected foods (lizards, cats, insect larvae; see Gould 1969; Kayberry 1939; McCarthy and McArthur 1960). These goals appear to be relatively consistent along gendered lines: women seem to hold a preference for reliability in prey acquisition while men seem to hold a preference for large harvest size. Although flexible, these goals seem to vary less than the availability of the prey that satisfy them. If changes in social, technological, and ecological factors alter the mode of prey acquisition and both encounter and success rates as a consequence, these could then be reflected in the aggregate totals of men's and women's relative production.

Researchers have previously noted the relationship between encounter rates with larger prey items and variation in men's contribution (Hill and Hawkes 1983; Kaplan et al. 1990; Winterhalder 1981). When both encounter rates and pursuit successes are low, a failed pursuit may mean a failed daily bout, as another encounter might be unlikely. Given the same low pursuit success, a higher encounter rate means a higher probability of coming home with at least one successful pursuit. Encounter rates could fluctuate as a result of seasonal or climatic variation (Hawkes et al. 1991; O'Connell et al. 1988), changes in the method of capture (e.g., O'Connell et al. 1988), or changes in acquisition technology (e.g., Hill and Hawkes 1983; Winterhalder 1981).³ The latter seems characteristic of Australia's Central Desert, where increased hunter mobility with the incorporation of vehicles leads to an increase in men's success rates, making large mobile prey more reliable (O'Connell and Hawkes 1984; see also Altman 1987). O'Connell and Marshall (1989:394) note that when Alywarre men set out on foot to hunt red kangaroo (*Macropus rufus*) with firearms, they had a bout success of about 70% and seldom took more than one animal per trip; however, when they set out in vehicles they traversed more country, frequently took more than one animal, and had daily bout success probabilities that neared 100%. This increase in men's bout success rates results in an increase in both men's overall foraging efficiency and their certainty of success; it is possible that these changes could have also articulated with women's goals in such a way as to lead to a reduction in women's investment in collecting and processing wild seeds (O'Connell and Hawkes 1981) since men's and women's goals may have been simultaneously met by the reliable acquisition of large prey.

Our models predict that if Martu men succeeded any day they searched for larger-bodied prey, as mean daily harvest sizes exceeded about 6 kg of edible meat, they

³ The adoption of technology that increases encounter rates may have a more profound effect on men's relative contribution than changes in projectile technology. McCarthy and McArthur (1960) provide detailed data for 7 kangaroo hunting bouts around Fish Creek. These data show that men hunting kangaroo (*M. rufus*) on foot and with spear throwers had an average pursuit success rate of 0.25 and an average bout success rate of 0.86 (failing on only one of the seven bouts for which "focal follow" data was available). Martu men hunting kangaroo (*M. robustus*) on foot but with .22 gauge rifles have a similar pursuit success rate per focal follow (0.31) but a lower bout success rate (0.22; see Bird et al. 2009). Although the difference in bout success rates may be due to interspecies or ecological variation leading to differences in prey abundance, the similarity in pursuit success rates suggests that using rifles over spear throwers does not significantly increase pursuit success. When asked, Martu men even go so far as to suggest that more encounters end in success when a skilled hunter uses a spear thrower.

would produce more than 70% of total calories. There are other factors at work here as well: high male production may be a function both of increases in men's encounter rates with large-bodied prey and of changes to local environments that severely decrease women's encounter rates with smaller-bodied prey. The efficiency of hunting small prey like lizards declines by more than half in habitats that are not managed with anthropogenic fire, where foragers are unable to make fires in order to hunt (Bliege Bird et al. 2008). This was the case in Australia's Central Desert around McDonnell Downs in the 1970s, where the expansion of pastoralism led to restrictions on Aboriginal burning, which had largely ceased by the 1970s (James O'Connell, personal communication 2008).

These articulations between gendered production inequities and social, technological, and ecological variables also have salient implications for recent archaeological research aimed at addressing the prehistoric gender division of foraging labor (see Codding and Jones 2007; Elston and Zeanah 2002; Hildebrandt and McGuire 2002; Jochim 1988; Jones 1996; Jones et al. 2008; Kuhn and Stiner 2006; McGuire and Hildebrandt 1994, 2005; McGuire et al. 2007; Waguespack 2005; Zeanah 1996, 2004). If archaeologically visible changes in (1) social organization, (2) prey acquisition technology, or (3) proxy measures of prey abundance are correlated with changes in the relative frequencies of larger taxa, this may be indicative of an increase in men's hunting success rates, which in turn may have altered production inequalities between men and women. Assuming that food is shared widely, evidence for such changes in the costs of prey acquisition may also provide evidence for variation in the benefits accorded to successful hunters since higher success rates may lead to a dispersal of benefits, with more individuals receiving a portion of social prestige. The inverse may also be the case for diachronic trends in the opposite direction.

Understanding such trends through time may also inform more theoretical notions surrounding the emergence of enduring social inequality. Hawkes (2000) outlined how a system of prestige hunting with extreme variance could ultimately erode rigid gerontocracies, as the basis of prestige (hunting success) is a gamble outside the immediate control of the hunter; while all hunters must continue to focus on high-variance resources just to maintain themselves on a positional treadmill, stochasticity allows young upstarts to undercut the dominance of their elders. This same logic holds for emergent inequality along gendered lines: men's successes, and thus their contributions, are typically stochastic relative to women's production, thereby undercutting the possibility of long-term deficits by one gender. However, if uncertainty in large-game hunting success declines, persistent gendered production inequalities could emerge. Such persistent production inequalities by one gender may also affect broader social organization, leading to more rigid inequities.

This possibility is echoed by discussions of variability in gender hierarchy in Australia: both Hamilton (1980) and Tonkinson (1988a) suggest that Western Desert peoples had considerably less gender hierarchy than in other regions of Australia, particularly Arnhem Land. For example, Altman and Peterson (1988) describe the normative "first tier" distributional rules following successful kangaroo hunts among the Kunwinjku as specifying only male recipients: the hunter, his companions, his mother's brother's son, and so on. In the Western Desert, as typified by Martu,

macropod first-tier distributional norms specify that women with appropriate kinship relationships to the hunter have rights to claim some of the largest portions: the rump (or the hunter's mother-in-law's portion) and hind limbs (or the hunter's elder married sister's portion). The recipients of first-tier distributions are thus given the right to distribute these portions to others, and only in the Western Desert do women often participate in giving away portions of large game. In addition, while many Aboriginal women occasionally hunt kangaroo, Martu women claim that they are among the only women allowed "by Law" to handle one after its death (albeit only in very particular circumstances)—in preparing a kangaroo for cooking and consumption certain ritualized butchery sequences must be carried out precisely. In the context of preparing kangaroo, one woman remarked that she could only do this here, "on our side" of the desert. Elsewhere she would be speared, or worse. It is certainly possible that the enhanced autonomy women enjoy may be, at least in part, a function of the stochastic nature of men's overproduction.

Conclusion

Our tests of models of production difference on Martu foraging camps suggest that production inequalities are probabilistically determined by the chances men will acquire large mobile prey. Thus, the "structural" division of foraging labor is an emergent property reflecting (and in turn influencing) the aggregate outcomes of fine-grained individual decisions made by men and women in the daily business of foraging. Martu men's and women's camp production varies primarily as a result of men's bout success with large prey. Thus, against the backdrop of women's consistent production, men's stochastic contributions produce significant fluctuations in men's and women's relative production. This patterning in gendered production has implications for understanding variation in gendered political inequalities across Australia, suggesting that where men's encounter rates with large-bodied prey are higher, variance in their returns is lower and they more consistently overproduce relative to women. Although Martu women increase time spent on acquiring small game when it is more reliable, this analysis suggests that more predictable large-game acquisition seems to lead not to greater female participation in acquiring these prey but to greater inequality of production, both within and across various Australian populations. We suggest a plausible (and testable) hypothesis to explain this discrepancy: within a population, the lower variance in acquisition of large game by men allows women to satisfy their foraging goals by working less and relying more on men's contributions. This reliance on men's consistent overproduction creates inequalities in bargaining power between men and women that may lead to the institutionalization of gender roles and the exclusion of women from the acquisition of political status through sharing of large game.

Acknowledgments We owe an immense debt of gratitude to all Martu out at Punmu, Kunawarrtji, and Parngurr and the surrounding deserts, and especially to the Taylor and Morgan families. This paper benefited tremendously by suggestions and comments from James Holland Jones, Ian Robertson, Sarah Robinson, Eric Alden Smith, and two anonymous reviewers. Funding for this research was provided by the National Science Foundation, the Leakey Foundation, the Stanford Archaeology Center, and Stanford's Department of Anthropology. Any mistakes in fact or judgment are the sole responsibility of the authors.

References

- Altman, J. C. (1987). *Hunter-gatherers today: An aboriginal economy in north Australia*. Canberra: Australian Institute of Aboriginal Studies.
- Altman, J., & Peterson, N. (1988). Rights to game and rights to cash among contemporary Australian hunter-gatherers. In T. Ingold, D. Riches & J. Woodburn (Eds.), *Hunters and gatherers: Property, power and ideology*, pp. 75–94. Oxford: Berg.
- Bell, D. (1993). *Daughters of the dreaming*. Minneapolis: University of Minnesota Press.
- Berndt, R. M., & Berndt, C. H. (1988). *World of the first Australians: Aboriginal traditional life—past and present*. Canberra: Aboriginal Studies Press.
- Bird, D. W., & Bliege Bird, R. (2005). Mardu children's hunting strategies in the Western Desert, Australia: Foraging and the evolution of human life histories. In B. S. Hewlett & M. E. Lamb (Eds.), *Hunter-gatherer childhoods*, pp. 129–146. New York: Aldine de Gruyter.
- Bird, D. W., & Bliege Bird, R. (in press). Competing to be leaderless: Food sharing and magnanimity among Martu aborigines. In J. Kantner, K. Vaughn & J. Eerkins (Eds.), *The emergence of leadership: Transitions in decision-making from small-scale to middle-range societies*. Santa Fe: SAR Press.
- Bird, D. W., Bliege Bird, R., & Parker, C. (2005). Aboriginal burning regimes and hunting strategies in Australia's Western Desert. *Human Ecology*, 33, 443–464.
- Bird, D. W., Bliege Bird, R., & Codding, B. F. (2009). In pursuit of mobile prey: Martu hunting strategies and archaeofaunal interpretation. *American Antiquity*, 74, 3–29.
- Bliege Bird, R. (2007). Fishing and the sexual division of labor among the Meriam. *American Anthropologist*, 109, 442–451.
- Bliege Bird, R., & Bird, D. W. (2005). Human hunting seasonality. In D. Brockman & C. van Schaik (Eds.), *Primate seasonality*, pp. 243–266. Cambridge: Cambridge University Press.
- Bliege Bird, R., & Bird, D. W. (2008). Why women hunt: Risk and contemporary foraging in a Western Desert Aboriginal community. *Current Anthropology*, 49, 655–693.
- Bliege Bird, R., & Smith, E. A. (2005). Signaling theory, strategic interaction, and symbolic capital. *Current Anthropology*, 46, 221–248.
- Bliege Bird, R., Smith, E. A., & Bird, D. W. (2001). The hunting handicap: Costly signaling in male foraging strategies. *Behavioral Ecology and Sociobiology*, 50, 9–19.
- Bliege Bird, R., Bird, D. W., Codding, B., Parker, C., & Jones, J. H. (2008). The fire stick farming hypothesis: Anthropogenic fire mosaics, biodiversity and Australian aboriginal foraging strategies. *Proceedings of the National Academy of Sciences (USA)*, 105(39), 14796–14801.
- Boone, J. L. (1998). The evolution of magnanimity: When is it better to give than to receive? *Human Nature*, 9, 1–21.
- Brand Miller, J., James, K. W., & Maggiore, P. M. A. (1993). *Tables of composition of Australian Aboriginal foods*. Canberra: Aboriginal Studies Press.
- Codding, B. F., & Jones, T. L. (2007). Man the show-off? Or the ascendance of a just-so-story: A comment on recent applications of costly signaling theory in American archaeology. *American Antiquity*, 72, 349–357.
- Davenport, S., Johnson, P., & Yuwali. (2005). *Cleared out: First contact in the Western Desert*. Canberra: Aboriginal Studies Press.
- Devitt, J. (1988). *Contemporary Aboriginal women and subsistence in remote, arid Australia*. Ph.D. dissertation, University of Queensland.
- Elston, R. G., & Zeanah, D. W. (2002). Thinking outside the box: A new perspective on diet breadth and sexual division of labor in the prearchaic Great Basin. *World Archaeology*, 34, 103–130.
- Gould, R. A. (1967). Notes on hunting, butchering, and sharing of game among the Ngatajara and their neighbors in the west Australian desert. *Kroeber Anthropological Society Papers*, 36, 41–66.
- Gould, R. A. (1969). *Yiwara: Foragers of the Australian Desert*. New York: Charles Scribner's Sons.
- Gould, R. A. (1980). *Living archaeology*. Cambridge: Cambridge University Press.
- Gould, R. A. (1991). Arid land foraging as seen from Australia: Adaptive models and behavioral realities. *Oceania*, 62, 12–33.
- Curven, M. (2004). To give or to give not: An evolutionary ecology of human food transfers. *Behavioral and Brain Sciences*, 27, 543–583.
- Curven, M., & Kaplan, H. (2006). Determinants of time allocation across the lifespan: A theoretical model and an application to the Machiguenga and Piro of Peru. *Human Nature*, 17, 1–49.

- Curven, M., Allen-Arave, W., Hill, K., & Hurtado, A. M. (2000). "It's a wonderful life": Signaling generosity among the Ache of Paraguay. *Evolution and Human Behavior*, 21, 263–282.
- Hamilton, A. (1980). Dual social systems: Technology, labour and women's secret rites in the eastern Western Desert. *Oceania*, 51, 4–20.
- Hawkes, K. (1990). Why do men hunt? Some benefits for risky strategies. In E. Cashdan (Ed.), *Risk and uncertainty in tribal and peasant economies*, pp. 145–166. Boulder: Westview.
- Hawkes, K. (1991). Showing off: Tests of an hypothesis about men's foraging goals. *Ethology and Sociobiology*, 12, 29–54.
- Hawkes, K. (1993). Why hunter-gatherers work: An ancient version of the problem of public goods. *Current Anthropology*, 34, 341–361.
- Hawkes, K. (2000). Big game hunting and the evolution of egalitarian societies: Lessons from the Hadza. In M. Diehl (Ed.), *Hierarchies in action: Cui bono? Center for Archaeological Investigations, Occasional Paper 27*, pp. 59–83. Carbondale: Southern Illinois University Press.
- Hawkes, K., O'Connell, J. F., & Blurton Jones, N. (1991). Hunting income patterns among the Hadza: Big game, common goods, foraging goals and the evolution of the human diet. *Philosophical Transactions: Biological Sciences*, 334, 243–251.
- Hildebrandt, W. R., & McGuire, K. R. (2002). The ascendance of hunting during the California Middle Archaic: An evolutionary perspective. *American Antiquity*, 67, 231–256.
- Hill, K., & Hawkes, K. (1983). Neotropical hunting among the Ache of eastern Paraguay. In R. Hames & W. Vickers (Eds.), *Adaptive responses of native Amazonians*, pp. 139–188. New York: Academic Press.
- Hill, K., & Hurtado, A. M. (1996). *Ache life history*. New York: Aldine de Gruyter.
- Hill, K., Kaplan, H., Hawkes, K., & Hurtado, A. M. (1987). Foraging decisions among Aché hunter-gatherers: New data and implications for optimal foraging models. *Ethology and Sociobiology*, 8, 1–36.
- Hurtado, A. M., Hill, K., Kaplan, H., & Hurtado, A. M. (1992). Trade-offs between female food acquisition and child care among Hiwi and Ache foragers. *Human Nature*, 3, 185–216.
- Jochim, M. A. (1988). Optimal foraging and the division of labor. *American Anthropologist*, 90, 130–136.
- Jones, T. L. (1996). Mortars, pestles, and division of labor in prehistoric California: A view from Big Sur. *American Antiquity*, 61, 243–264.
- Jones, T. L., Porcasi, J., Gaeta, J., & Coddling, B. F. (2008). The Diablo Canyon fauna: A coarse-grained record of trans-Holocene foraging from the central California mainland coast. *American Antiquity*, 73, 289–316.
- Kaplan, H., Hill, K., & Hurtado, A. M. (1990). Risk, foraging, and food sharing among the Ache. In E. Cashden (Ed.), *Risk and uncertainty in tribal and peasant economies*, pp. 107–144. Boulder: Westview.
- Kaplan, H., Hill, K., Lancaster, J., & Hurtado, A. M. (2000). A theory of human life history evolution: Diet, intelligence and longevity. *Evolutionary Anthropology*, 9, 156–185.
- Kayberry, P. (1939). *Aboriginal woman: Sacred and profane*. London: Routledge.
- Kieschnick, R., & McCullough, B. D. (2003). Regression analysis of variates observed on (0, 1): Percentages, proportions and fractions. *Statistical Modeling*, 3, 193–213.
- Kuhn, S., & Stiner, M. C. (2006). What's a mother to do? The division of labor among Neanderthals and modern humans in Eurasia. *Current Anthropology*, 47, 953–980.
- Latz, P. (1996). *Bushfires and bushucker: Aboriginal plant use in Central Australia*. Alice Springs: IAD.
- Leacock, E. (1978). Women's status in egalitarian society: Implications for social evolution. *Current Anthropology*, 19, 247–275.
- Leacock, E. (1983). Interpreting the origins of gender inequality: Conceptual and historical problems. *Dialectical Anthropology*, 7, 263–284.
- Lee, R. B. (1968). What hunters do for a living: Or, how to make out on scarce resources. In R. B. Lee & I. Devore (Eds.), *Man the hunter*, pp. 30–55. New York: Aldine de Gruyter.
- Lee, R. B. (1979). *The !Kung San: Men, women and work in a foraging society*. Cambridge: Cambridge University Press.
- Marlowe, F. W. (2003). A critical period for provisioning by Hadza men: Implications for pair bonding. *Evolution and Human Behavior*, 24, 217–229.
- Marlowe, F. (2007). Hunting and gathering: The human sexual division of foraging labor. *Cross-cultural Research*, 41, 170–195.
- McCarthy, F. D., & McArthur, M. (1960). The food quest and the time factor in Aboriginal economic life. In C. P. Mountford (Ed.), *Records of the American-Australian Scientific Expedition to Arnhem Land, 2: Anthropology and nutrition*, pp. 145–194. Melbourne: Melbourne University Press.

- McGuire, K., & Hildebrandt, W. R. (1994). The possibilities of women and men: Gender and the California Milling Stone horizon. *Journal of California and Great Basin Anthropology*, 16, 41–59.
- McGuire, K., & Hildebrandt, W. R. (2005). Rethinking Great Basin foragers: Prestige hunting and costly signaling during the Middle Archaic period. *American Antiquity*, 70, 695–712.
- McGuire, K. R., Hildebrandt, W. R., & Carpenter, K. L. (2007). Costly signaling and the ascendance of no-can-do archaeology: A reply to Codding and Jones. *American Antiquity*, 72, 358–365.
- Meehan, B. (1982). *Shellbed to shell midden*. Canberra: Aboriginal Studies Press.
- Megitt, M. (1957). Notes on the vegetable foods of the Walpiri. *Oceania*, 28, 143–145.
- Megitt, M. (1962). *Desert people: A study of the Walbiri Aborigines of Central Australia*. Sydney: Angus and Robertson.
- Menard, S. (2002). *Applied logistic regression analysis* (second ed.). Thousand Oaks, CA: Sage.
- O’Connell, J. F., & Hawkes, K. (1981). Alyawara plant use and optimal foraging theory. In B. Winterhalder & E. A. Smith (Eds.), *Hunter-gatherer foraging strategies: Ethnographic and archaeological analyses*, pp. 99–125. Chicago: University of Chicago Press.
- O’Connell, J. F., & Hawkes, K. (1984). Food choice and foraging sites among the Alyawara. *Journal of Anthropological Research*, 40, 504–535.
- O’Connell, J. F., & Marshall, B. (1989). Analysis of kangaroo body part transport among the Alyawara of Central Australia. *Journal of Archaeological Science*, 16, 393–405.
- O’Connell, J. F., Hawkes, K., & Blurton Jones, N. (1988). Hadza hunting, butchering, and bone transport and their archaeological implications. *Journal of Anthropological Research*, 44, 113–161.
- R Development Core Team. (2008). *R: A language and environment for statistical computing*. Vienna, Austria: Foundation for Statistical Computing.
- Roheim, G. (1974). *The children of the desert: The western tribes of Central Australia*. New York: Basic Books.
- Sackett, L. (1979). The pursuit of prominence: Hunting in an Australian Aboriginal community. *Anthropologica*, 21, 223–246.
- Sahlins, M. (1972). *Stone Age economics*. Chicago: Aldine.
- SAS Institute. (2007). *JMP, version 7*. Cary, NC: SAS Institute, Inc.
- Scelza, B., & Bliege Bird, R. (2008). Group structure and female cooperative networks in Australia’s Western Desert. *Human Nature*, 19, 231–248.
- Smith, E. A. (1991). *Inujjamiut foraging strategies: Evolutionary ecology of an Arctic hunting economy*. New York: Aldine de Gruyter.
- Smith, E. A., & Bliege Bird, R. (2005). Costly signaling and cooperative behavior. In H. Gintis, S. Bowles, R. Boyd & E. Fehr (Eds.), *Moral sentiments and material interests: On the foundations of cooperation in economic life*, pp. 115–148. Cambridge, MA: MIT.
- Steward, J. H. (1938). *Great Basin–Plateau aboriginal sociopolitical groups*. Smithsonian Institution Bureau of American Ethnology, Bulletin 120. Washington D.C.
- Tonkinson, R. (1974). *The Jigalong mob: Aboriginal victors of the desert crusade*. Menlo Park: Cummings.
- Tonkinson, R. (1978). Semen vs spirit child in a Western Desert culture. In L. R. Hiatt (Ed.), *Australian Aboriginal concepts*, pp. 81–92. Canberra: Aboriginal Studies Press.
- Tonkinson, R. (1988a). Egalitarianism and inequality in a Western Desert culture. *Anthropological Forum*, 5, 545–558.
- Tonkinson, R. (1988b). Ideology and dominations in Aboriginal Australia: A Western Desert test case. In T. Ingold, D. Riches & J. Woodburn (Eds.), *Hunters and gatherers, 2: Property, power and ideology*, pp. 150–164. Oxford: Berg.
- Tonkinson, R. (1990). The changing status of Aboriginal women: “Free agent” at Jigalong. In R. Tonkinson & M. Howard (Eds.), *Going it alone? Prospects for Aboriginal autonomy*, pp. 125–148. Canberra: Aboriginal Studies Press.
- Tonkinson, R. (1991). *The Mardu Aborigines: Living the dream in Australia’s Desert*. New York: Holt, Rinehart & Winston.
- Tonkinson, R. (2007). Aboriginal “difference” and “autonomy” then and now: Four decades of change in a Western Desert society. *Anthropological Forum*, 17, 41–60.
- Tonkinson, R., & Tonkinson, M. (2001). “Knowing” and “being” in place in the Western Desert. In A. Anderson, I. Lilley & S. O’Connor (Eds.), *Histories of old ages: Essays in honour of Rhys Jones*, pp. 133–140. Canberra: Pandanus Books.
- Veth, P. M. (1987). Martujarra prehistory: Variation in arid zone adaptations. *Australian Archaeology*, 25, 102–111.
- Veth, P. M. (1989). Islands in the interior: A model for the colonisation of Australia’s arid zone. *Archaeology in Oceania*, 24, 81–92.

- Veth, P. M. (1995). Aridity and settlement in North West Australia. *Antiquity*, 69, 733–746.
- Veth, P. M. (2000). Origins of the Western Desert language: Convergence in linguistic and archaeological space and time models. *Archaeology in Oceania*, 35, 11–19.
- Veth, P. M. (2005). Cycles of aridity and human mobility: Risk-minimization amongst late Pleistocene foragers of the Western Desert, Australia. In P. Veth, M. A. Smith & P. Hiscock (Eds.), *Desert peoples: Archaeological perspectives*, pp. 100–115. Oxford: Blackwell.
- Veth, P. M., & Walsh, F. (1988). The concept of “staple” plant foods in the Western Desert region of Western Australia. *Australian Aboriginal Studies*, 2, 19–25.
- Waguespack, N. M. (2005). The organization of male and female labor in foraging societies: Implications for early Paleoindian archaeology. *American Anthropologist*, 107, 666–676.
- Walsh, F. (1990). An ecological study of traditional Aboriginal use of “country”: Martu in the Great and Little Sandy Deserts, Western Australia. *Proceedings of the Ecological Society of Australia*, 16, 23–37.
- Wiessner, P. (2002). Hunting, healing and hxaro exchange: A long-term perspective on !Kung (Ju/'hoansi) large game hunting. *Evolution and Human Behavior*, 23, 407–436.
- Winterhalder, B. (1981). Foraging strategies in the boreal forest: An analysis of Cree hunting and gathering. In B. Winterhalder & E. A. Smith (Eds.), *Hunter-gatherer foraging strategies: Ethnographic and archaeological analyses*, pp. 66–98. Chicago: University of Chicago Press.
- Zeanah, D. W. (1996). *Predicting settlement patterns and mobility strategies: An optimal foraging analysis of hunter-gatherer use of mountain, desert, and wetland habitats in the Carson Desert*. Ph.D. dissertation, Department of Anthropology, University of Utah, Salt Lake City.
- Zeanah, D. W. (2004). Sexual division of labor and central place foraging: A model for the Carson Desert of western Nevada. *Journal of Anthropological Archaeology*, 23, 1–32.

Rebecca Bliege Bird received her Ph.D. from UC Davis in 1996. She is interested in gendered strategies of social and economic production, especially as they relate to altruism and public goods provisioning in prestige competitions. In pursuit of these and other questions related to the socioecology of subsistence, she has worked in Torres Strait among the Meriam and is currently working with Martu in Australia's Western Desert.

Brian F. Coddling received his B.S. from California Polytechnic State University, San Luis Obispo in 2005 and his M.A. in 2008 from Stanford University, where he is currently a Ph.D. student in the Department of Anthropology. His current research examines the social ecology of gender-specific foraging in archaeological and ethnographic contexts in California and Western Australia.

Douglas W. Bird received his Ph.D. from UC Davis in 1996. His interest in ethnoarchaeology led him to explore the processes of shellmidden formation among Meriam of the Torres Strait. He is currently investigating the politics of hunting among Martu and the way that sharing can, paradoxically, create social hierarchy.