A Landscape Architecture of Fire

Cultural Emergence and Ecological Pyrodiversity in Australia's Western Desert

by Douglas W. Bird, Rebecca Bliege Bird, Brian F. Codding, and Nyalangka Taylor

Aboriginal foraging systems in Australia's Western Desert have been structured around landscape-burning practices for millennia. These systems are mediated at one end by factors that influence an immediate-return economy and at the other by the way that burning transforms vegetative succession and habitat heterogeneity (pyrodiversity). The distinctive pyrodiversity of anthropogenic landscapes are where Martu insist that they and their estates are conceived. These estates are transgenerational storehouses of relational wealth that operate in a delayed-return ritual economy. These storehouses were ransacked by colonialism in the mid-twentieth century, precipitating a collapse in the anthropogenic fire regime and a decline and extinction of many endemic species. Since returning to their homelands in the 1980s, Martu have reestablished a tight patchwork of vegetative succession and rescaled the landscape mosaic. Previous work has shown how the emergent ecological consequences of foraging and burning interact to create greater local diversity, increase landscape patchiness at massive spatial scales, and buffer against climate-driven ecosystem disturbance. In this paper we explore how the rescaling of patch diversity through anthropogenic fire operates as a form of dynamic cultural and ecological niche construction shaping systems of sociality among people and their interactions with other species.

A call to demolish the two-story edifice of dualism constructed to separate humans from nonhumans is nothing new. It should be demolished not only because our natural worlds are culturally constructed but because our cultural worlds are wholly natural. Cultural niches and social intuitions are constructed in the interactions of decisions, bodies, materials, values, and intentions of organic beings designed by natural selection. The barriers that we build between natural and artificial phenomena are constructs specific to very particular contexts. In many other worlds, no such dichotomy exists, or it exists in radically different forms (see Elkin 1969 for an Australian example). An important goal, then, in developing a reintegrated anthropology—one that combines rigorous empirical analysis with an appreciation of diverse epistemologies and institutions fashioned in complex interactions between people, other species, and physical space—is to

> render intelligible the way in which organisms of a particular kind find a place in the world, acquire a stable representation of it, and contribute to its transformation by forging with it and between one another links either constant or occasional and of remarkable but not infinite diversity. . . . For although it is commonly said, these days, that worlds are constructed, it is not known who are their architects and we still have very little idea about what materials are used in building them. (Descola 2013:xvii)

Reintegrating anthropology as imagined by Wiessner (2016) and Fuentes (2016) will involve just that: figuring out (1) who the architects of niches are and (2) what construction materials they are using. We suggest this will require building a science that fully embraces an understanding of people in ecosystemic relationships. This will involve deliberate acts of both analytical reductionism and holism to identify scaled links between processes that shape decision making in resource use and vehicles through which they emerge as com-

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plex systems.[1] We see the contributions to this special issue of *Current Anthropology* as an honest attempt to continue the job. All of the contributors to the Wenner-Gren conference from which this volume grew were intent on seeking explanations of diverse human worlds, including peoples' complex and divergent representational models and perceptions of life, by teasing apart processes and materials that shape the ways through which our habitats (or niches) are constructed, experienced, and made meaningful.

In what follows we set out to investigate some of the players, interactions, and materials used in constructing aspects of Martu worlds in a remote part of Australia's Western Desert (fig. 1). We are especially concerned with measuring factors that influence contemporary Martu hunting decisions, the expressions of which are mediated in social practices and the application of landscape fire, that feed back through ecological mechanisms to transform social-environmental relationships.[2]

We agree with recent theorists such as Descola (2013) and others (e.g., Cormier 2003; Hartigan 2014; Kohn 2013) in calling into question notions that we, because of culture, exist buffered from the natural environment. While this is old hat in anthropology, "a dichotomy between the material and the mental, between ecological interactions in nature and cultural constructions of nature" (Ingold 1996:144) continues to dominate the policy and science of global environmental change, where "human dimensions" are cast principally in terms of how people affect the "natural" system (Castree et al. 2014). In this paper we hope to further dissolve such dichotomies, but we do so from a reductionist stance. In the heart of the analysis presented here, we intend to show how reducing complex phenomena to measurements of key interactions gives critical insight into the processes involved in making dynamic and complex social-ecological systems. This provides an ecological and quantitative perspective into how Aboriginal people often characterize themselves and their lands. Thus, we argue that distinctive Martu selves do not exist independently of the ecological relationships that make and signify family and homelands (Tonkinson 2011). Their notions of homeland and family are inherently relational, similar to notions captured in *oikos*, the Greek for home and the root for ecology.

It is important to note at the outset that the relationships many Martu have with their country, framed in *Jukurrpa* (the Dreaming, as discussed below), do not reflect a "conservation ethic," or what Sponsel (2012) refers to as "spiritual ecology." As Martu often explain it, the Dreaming is more than just a spiritual relationship between them and the natural world. Many traditionally oriented Martu believe that the proper taking and use of resources—not their conservation—is the key to a healthy country and healthy selves. To conserve resources is akin to hoarding and requires managing the labor and consumption of others through dictatorial action. Moreover, they do not perceive of themselves as having a spiritual connection that makes them "closer to the land" and thus natural conservationists; they insist that they *are* their country in the sense that humans are a critical component of ecological relationships. For many Martu, country and self are foraged in work (spiritual, ritual, mundane) that consumes and regenerates, especially in the application of fire to the landscape. There are sacred geographies, but they are diverse in scale and arbitrated in the intensity of living interactions and exchange between people, other species, and place. The key, as Tonkinson (2005) and Myers (1988) have suggested, is in how a lived world of material transfers between and among people and other species is interwoven with a world of religiously/spiritually constituted ownership (Bird and Bliege Bird 2010; Bliege Bird et al. 2012*a*). At the core of these relationships are practices associated with landscape burning and the way it is situated in the function of ecological systems.

Following a summary of contemporary Martu economies and ecological organization, we illustrate how many Martu express the architecture of their country and how they conceive of themselves and their land-based estates especially in relation to fire. We then provide a rough framework to situate humans in general as niche constructors, especially in the emergence of distinctively pyrodiverse habitats. We argue that such a framework requires investigating the effects of existential trade-offs people face in decisions about resource use. We thus describe the ways that Martu hunting decisions transform their lands into homelands in a series of analyses based on Martu accounts and quantitative records of over a decade of participant observation in Martu foraging, and we combine this with remote sensing and spatial analyses of anthropogenic and nonanthropogenic landscapes. We argue

1. Our use of "emergence" follows a common definition in evolutionary ecology, focusing on the synergistic processes shaping system organization that feed back on the fitness-related trade-offs of the organisms that compose complex systems. "In evolutionary processes, causation is iterative; effects are also causes. And this is equally true of the synergistic effects produced by emergent systems. In other words, emergence itself . . . has been the underlying cause of the evolution of emergent phenomena in biological evolution; it is the synergies produced by organized systems that are the key" (Corning 2002). This is not a call to a return of the old systems ecology of the 1960s and 1970s but instead to a new ecology that fully embraces agency and a science of individual decision making while recognizing the emergent properties of larger-scale social and ecological systems that interact with individual decisions.

2. Much has been written about how Western Desert Aboriginal selves and identities are conceived in relation to country and landesque capital: Aboriginal "country" is constituted within sets of social practices, dynamic rights, and contested values that link people to land (e.g., Dussart 2000; Myers 1988; Tonkinson 2007, 2011; Tonkinson and Tonkinson 2010). As Tonkinson (2011) and Myers (2002) so clearly explain for Western Desert Martu and Pintupi, respectively, their *ngurra*—their homelands—come into being not only through the lived experience of hunting and gathering (the concrete labor entangled in an environment of direct experience, sensu Ingold 1996, 2008) but also through processes of previous and lived experience shaped at all points by tiers of social interaction. "People do not simply 'experience' the world; they are taught—indeed, disciplined—to signify their experiences in distinctive ways" (Myers 2002:103).

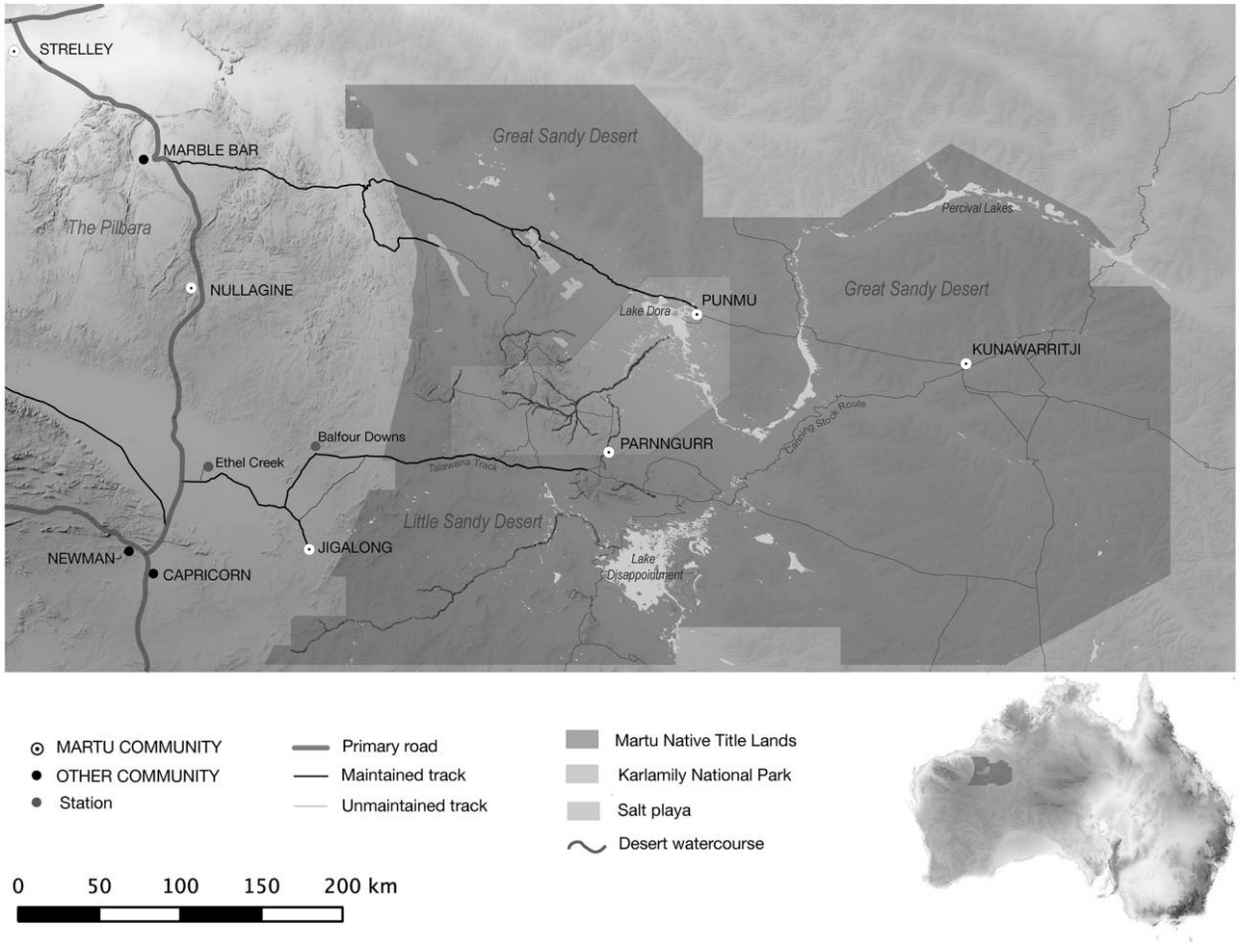

Figure 1. Map of the Martu homelands showing the Martu Native Title (darkest gray), Karlamilyi National Park (light gray within the Native Title), and the location of the three remote Martu communities within the Native Title (Parnngurr, Punmu, and Kunawarritji).

that these distinctively measurable landscapes emerge from the daily business of hunting and make up the owned ritual estates that form the basis of Martu-conceived heritage.

Martu Economic and Ecological Organization

The contemporary economy in remote Martu communities is a hybrid of customary, state, and market sectors (sensu Altman, Biddle, and Buchanan 2012). In Parnngurr (fig. 1), the community where we are based, this includes hunting, gathering, some wage labor in mining and related industry, arts and crafts production through Martumili Artists (supported by the East Pilbara Shire), a new ranger program for Karlamiliyi National Park and Martu Native Title Lands (facilitated by the Martu-based NGO Karnyirninpa Jukurrpa), as well as government benefit payments, some money from the Martu Lands trust, and work in the Community Development Employment Program. The links are dynamic, and labor within each sector is interwoven with commercial, subsistence, social, and religious values (Bird et al., forthcoming). Since the early 1990s Parnngurr has also had a community-run primary school staffed by a Martu advisory council and mostly non-Aboriginal teachers. Based on a series of observational time-allocation surveys conducted in 2006 (Scelza, Bird, and Bliege Bird 2014) and 2009–2010 (Codding 2012; Codding et al. 2016), our research team recorded that adults and children five and over in Parnngurr spend an average of 23% of their days foraging, producing bush foods that make up 29%–49% of daily caloric intake for a person (man, woman, or child). Today this often involves the use of vehicles to access temporary foraging camps from which most hunting and gathering then proceeds on foot. Foraging—modified with the incorporation of new technologies, entanglements with markets and governments, and changing mobility and settlement patterns—remains fundamental to ecological and social organization.

Contemporary Foraging

Between 2000 and 2010, members of our research team participated in 368 foraging trips with Martu. During foraging trips (averaging just over eight foragers per trip), we recorded

party composition, route, locale, and time that each participant devoted to active foraging. Resources acquired were counted and weighed before processing, usually at *mirrka ngurra* (see below), a locale where foragers gathered to prepare, share, and eat before returning to the settlement. Edible masses were converted into caloric measures using Brand-Miller, James, and Maggiore (1993). These records make up a data set of 1,831 individual adult foraging bouts consisting of all the time each forager spent in search, pursuit, capture, and processing of resources per day.

Men, women, and children are active hunters. Men tend to concentrate more of their effort on larger game (especially kangaroo and bustard hunting, which together make up 61% of men's foraging time), and women focus much of their foraging in pedestrian sandplain hunting, targeting sand monitor lizards (which makes up 72% of women's foraging time). However, there is a high degree of fluidity in gendered differences of labor, and there are times when men and women cooperate in hunting, especially during the summer in long-distance pursuits of large monitor lizards (Bird, Bliege Bird, and Codding 2009; Bliege Bird and Bird 2005, 2008; Codding, Bliege Bird, and Bird 2011).

Today, mutually exclusive foraging activities (made so by differences in habitat, technology, seasonality, and search strategy; see Bird et al. 2009, 2013 for details) are usually organized around the search for five staple animal prey: hill kangaroo (*kirti-kirti* [*Macropus robustus*], 24.7% of total production by whole weight), bustard (*kipara* [*Ardeotis australis*], 24.1%), sand monitor (*parnajarlpa* [*Varanus gouldii*], 19.1%), larger monitors (*maruntu* and *yalapara* [*Varanus giganteus* and *Varanus panoptes*], 2.7%), and feral house cats (1.5%). The remaining bush food comes mostly from solanum fruit, nectar, geophytes, and feral camel. When they choose to go out, a forager typically acquires about 3,000 kcal per day.

While kangaroo and bustard hunting produce occasional bonanzas, much of daily bush food comes from pedestrian hunting in spinifex (*Triodia* spp.)–dominated grasslands. The activity targets sand monitor but also includes the on-encounter pursuit of skinks, snakes, fruit, feral cats, and larger monitors. As shorthand we will refer to this as "sandplain hunting." Martu refer to the activity as *parnajarlpa wartilpa*, or sand monitor hunting, because sand monitors are the principal resource acquired. Overall, Martu in Parnngurr allocate more time to sandplain hunting than any other type of foraging activity. While this type of hunting is an important economic activity for all, it is especially so for older women and when money is short (Bird et al., forthcoming; Bliege Bird and Bird 2008; Scelza et al. 2014).

Contemporary Burning

Because monitor lizards are denned in the cool-dry season, sandplain hunting is constrained by den visibility, so foragers either target patches characterized by early-successional vegetation or set a broadcast fire to clear off a large patch of older growth vegetation to expose a searchable area. Hunters work alone or in small cooperative groups, searching for dens and tracks and probing the area around an encountered den with a long, narrow digging stick to locate the resting chamber, which lies 10–20 cm belowground.

In the winter, if foragers do not burn a patch of late-successional-age vegetation, they gain only 25 ± 407 (SE) kcal per hour of search and pursuit. Older-growth vegetation inhibits search, and at that rate (given energy expended while foraging), on average hunters would work at energetic deficit. However, if they burn those patches, their returns increase dramatically to 1,552 ± 326 kcal per hour (Bliege Bird et al. 2013). Then, over the course of an average foraging bout (just under 3 hours), a single forager can very reliably supply daily food requirements for two to three people. There is a clear linear relationship between time invested and harvest size, so unlike less reliable activities such as kangaroo and bustard hunting, foragers can predictably adjust harvest sizes with more search if there are more consumers at camp (Codding, Bird, and Bliege Bird 2010). Both men and women conduct broadcast burns while sandplain hunting, but women do so more often (Bird, Bliege Bird, and Parker 2005; Bliege Bird et al. 2008).

In the summer, when fire behavior is often unpredictable and monitors are active on the surface and pursued by tracking, burning is uncommon. Access to ground that was burned earlier in the year is then critical in the warmer months. Summer returns per hour hunting in late-successional patches are significantly lower (76 ± 771) than those in early-successional patches (1,838 ± 446). With ready access to patches burned earlier in the year, there is little need to burn extensively in order to pursue lizards in the summertime (Bliege Bird et al. 2013).

The main fuel burned in hunting fires is the highly flammable spinifex hummock grass, mainly *Triodia schinzii* and *Triodia basedowii*, which dominates much of the arid interior of Australia. Patches regenerating after fire are associated with different community composition, referred to as seral stages (Latz and Green 1995; Pianka and Goodyear 2012). Martu use a five-tiered seral classification of spinifex grasslands to characterize their landscapes. *Nyurnma* is the stage immediately following a burn, when there is no surface vegetation except surviving shrubs and trees. *Waru-waru* characterizes a community of new green shoots from the seed bank of diverse forbs and grasses, usually following a *nyurnma* within a few months, depending on precipitation. *Nyukura* is a community where fruiting plants have matured, and there is an abundance of resources for people and other herbivores. Herbs such as *Solanum diversiflorum* and other bush tomatoes, along with seed grasses such as woolybutt (*Eragrostis eriopoda*), are most abundant in *nyukura*, usually 1–4 years postfire. *Manguu* characterizes patches where spinifex has started to crowd out other grasses and forbs, a process that usually takes 5–10 years following a burn. *Manguu* has spinifex hummocks close enough to carry a fire. *Kunarka* is the final stage of spinifex growth, in

which large hummocks of grass completely dominate the patch, and the hummocks are so old that they begin to die in the middle and form circular rings several meters across, a process that can take up to 20 years.

Animals, too, show differential fire responses. Bustards (*Ardeotis australis*) come into *nyurnma* to feed and also to enjoy the desert raisin (*Solanum centrale*) so abundant in *nyukura*. Hill kangaroo prefer *waru-waru*, where newly emerging green shoots offer more nutritious browse, and *nyukura*, where solanum fruit is more abundant (Codding et al. 2014). Sand monitors are omnivorous edge lovers: they often den in "islands" of older growth *manguu* or even *kunarka* adjacent to younger *nyukura* patches for foraging. As such their populations increase with edge density in the finer-grained anthropogenic mosaics Martu create (Bliege Bird et al. 2012*b*, 2013).[3] Having many different patches at different regrowth stages (a tight mosaic of seral stages) is a good indicator of both animal and plant species diversity at the landscape scale (Bliege Bird et al. 2008).

Contact History and Ecological Changes

Many remote Western Desert people who walked west at European contact are referred to as Martu,[4] while those who went east are called Pintupi. Some bands from a number of dialect-named groups, mostly Manyjiljarra and Warnman, remained fully autonomous in the Karlamilyi and Percival Lakes regions until the mid-1960s, when they went west, mostly to Jigalong (Davenport, Johnson, and Yuwali 2005; Tonkinson 1991). In the 1980s many of these people began a process of reoccupying their homelands, establishing three remote communities at Parnngurr, Punmu, and Kunawarritji in the Little and Great Sandy Deserts (fig. 1). Unlike other parts of Australia, the Sandy deserts have been spared the ecological degradation of pastoralism, agriculture, and development: in the absence of Martu, the desert had been silent, the only visitors being mining exploration teams intent on gold and uranium. Even so, when Martu returned to their homelands, they confronted an ecosystem far different from the one they had left. Paradoxically, their hiatus coincided with the local extinction of numerous species of endemic mammals and the decline of many more. Gone were several small marsupials that had been common prey: the rufous hare wallaby (*mala* [*Lagorchestes hirsutus*]), the brush-tail possum (*wayuta* [*Trichosurus caninus*]), the burrowing bettong (*jamparn* [*Bettongia lesuer*]), and the golden bandicoot (*minkajurru* [*Isodon auratus*]), and in their place were feral house cats, camels, and foxes. These new landscapes were dominated by extensive lightning fires that burned 10 to 100 times larger than the fires Martu were used to (Bliege Bird, Codding, and Bird 2016). Nyalangka Tayor recounted that in 2004,

> when the first lot of folks came to Parnngurr after being gone for 20 years, they burned the area first before they made their *ngurra*. When they went out hunting, they burned in every direction to keep lightning fires from coming close to camp. Martu like to make sure that they burn areas in all directions from camp and keep the *waru* [fire] small, controlled, so that it doesn't burn places that it shouldn't.

Between 1986 and 1990, ethnobotanist Fiona Walsh made several visits to Parnngurr to document customary foraging and land use and found that fires were becoming smaller and the country more diverse. Yet people were still concerned that not enough habitat had been burned, and there was a perception of food scarcity—not just the decline of marsupials but the disappearance of fruiting trees (e.g., *Santalum lanceolatum*) and the limited distribution of fruiting forbs, including staples such as solanum fruit. Martu in 1986 "attributed the scarcity of bush food species to factors other then hunting. In their view, the converse was true, traditionally oriented people believed hunting, gathering, and the manipulation of country and resources to be critical to their perpetuation" (Walsh 2008:170). That hunting, gathering, and burning is not the cause of resource scarcity but the critical support for resource persistence seems paradoxical, and to many, evidence of a logic that has little to do with ecological reality. Many Martu insist rather that the continued performance of these activities is critical to the integrity of both the ecological and socioritual landscapes.

Fire, Food, Family, Home: "We Are [Kin]. . . . We Are Painters. . . . We Hunt. . . . We Burn."

The painting shown in figure 2 is titled *Yarrkalpa* (hunting ground). Its accompanying caption, composed in Martu Wangka by the artists, begins with a rehearsal of the seral stages of vegetative succession that follow the application of fire to the landscape (*nyurnma*, *waru-waru*, *nyukura*, *manguu*, *kunarka*) and then transitions to a verse translated here by Nyalangka Tayor, who is also one of the artists.

> We are sisters, mothers, daughters, granddaughters, aunties, nieces.
> We are painters, we are Martu women, caring for our country.
> We hunt in this country to look after it.
> We burn it, then gather bush fruit.
> We burn it, and the animals eat the *waru-waru*,

3. Termite specialists such as *Ctenophorus nuchalis*, the netted dragon, a 50–100-g slow-moving lizard, are more prevalent in the recent burns of *nyrunma*, while *Ctenophorus isolepis*, which requires long-unburned spinifex for refuge and thermoregulation, is more abundant in long-unburned areas (Letnic et al. 2004; Masters 1996; Pianka and Goodyear 2012).

4. "Martu," meaning "people" (indigenous people), is commonly used as a term of self-reference for members of different linguistic dialect groups that migrated to Jigalong in the 1950s and 1960s. It is not a culturally, linguistically, or relationally self-contained ethnic unit, and thus some of the beliefs and practices we describe for our mainly Manyjiljarra and Warnman interlocutors in Parnngurr and Punmu will differ from those described by Tonkinson, who worked mainly with Kartujarra speakers in Jigalong.

Figure 2. Kumpaya Girgirba walking in front of a section of the large canvas *Yarrkalpa* painted by women whose estates make up contiguous country across the Martu homelands. *Yarrkalpa* (hunting ground), 2013, 300 cm × 500 cm, by Kumpaya Girgirba, Yikartu Bumba, Karnu Taylor, Ngamaru Bidu, Yuwali Nixon, Reena Rogers, Thelma Judson, and Nyalangka Taylor. Photo by Gabrielle Sullivan. Used with permission from Martumili Artists. A color version of this figure is available online.

Then they get fat, and we hunt and eat the animals:
Goanna, hill-kangaroo, bustard, cat.
We are telling lots of little stories about hunting in the Parnngurr area
All of the women putting their stories together on a big canvas.
It is special to teach others—Martu and non-Martu—how we live now
And always have
In this country.
This country is us.
We need to share it, and talk about it, and protect it . . . keep it strong.

Each of the eight artists (and their apprentices) has painted her own estate. An estate is a co-owned body of "little stories": sets of owned and heritable responsibilities for maintaining the ceremony and totemic geography depicted in the painting as patches and paths forming mosaics from a bird's-eye view of the landscape. Each estate contains a core group of custodians who are most closely tied to one of the regions associated with the principal Martu dialect-named groups (mostly Putijarra, Kartujarra, Kiyajarra, Warnman, and Manyjilyjarra; Tonkinson 1991). While owned corporately, the estates are not necessarily clearly bounded units in space or held to the exclusion of all others by a discrete group of people—each estate contains individuals who claim the most responsibility to a core set of sacred sites and ceremonies, but each of those individuals will also have ties to other estates through negotiations about initiation, decent, spirit travel, totemic conception place, and residence (Tonkinson 2011). Both men and women can be estate holders (such that siblings are often co-owners), but within an estate there are gender-specific segments of knowledge and ceremonial performance (see Dussart 2000). However, even the most sacred "men's business" usually requires participation of senior co-owning women (Tonkinson 1991). Below we suggest that Martu estates are constituted by social ties of relational wealth (Borgerhoff Mulder et al. 2009) facilitated in part through trust bound in foraging, burning, and food sharing.

Taken together, the whole of the patches, points, and tracks in figure 2 represent the ancestral estates that make up much of the Martu homelands ("All of the women putting their stories together on a big canvas"). Note that the artists begin by drawing attention to the ties that define their social relationships and the means—both on country and on canvas—used to represent how those relationships are expressed. The forms used show vegetative mosaics, dunes, watercourses, rock holes, clay pans, playas, Dreaming tracks, and roads. The shapes and colors represent both the terraforming activities of ancestral beings and different patches of seral stage regrowth.

Martu often use the patchwork of seral stages (both on the ground and in painting) as an index of devotion to one's estate: the efforts of those that hunt to share enough to support

large networks of people are signified in landscapes that Martu refer to as *ngurra juri*, or sweet country, that have a tight mosaic of seral stages. In order to share, one must burn the land (*waruku ngurra*) to produce food (*waruku mirrka*). Burning both destroys and creates, but it is necessary for sharing. And sharing for Martu is simultaneously virtuous and political (Bird and Bliege Bird 2010; Bliege Bird et al. 2012*a*; Bliege Bird and Power 2015).

The act of painting *ngurra juri*, or maintaining it through burning, is as much an asserted claim to an estate as it is an ecological, commercial, and spiritual representation of home. Only those artists whose claims are recognized as legitimate by an audience of fully initiated owners would dare to assert representation of an estate through painting (Carty 2010), and only those who know the sacred geography would dare to burn within an estate. The legitimacy is forged in part through a reputation built by hunting and sharing. In turn, the cumulative existential processes of foraging and burning on country are a rehearsal of the terraforming acts of ancestral beings that brought homelands into existence in the Jukurr, the Dreaming.

Jukurrpa, described by Martu and others variously as "Law" or "Business" and by anthropologists as "The Everywhen" (Stanner 1979 [1953]), is cosmology, religion, philosophy, politics, and natural history. *Jukurrpa* encompasses the creative epoch of Dreamtime ancestors and the contemporary practice/knowledge required to sustain a homeland. It is the totemic geography, epistemology, and body of knowledge and ceremony concerning the terraforming performance of ancestral beings that left their life force across the landscape, the sacred and mundane activities that maintain the world, and prescriptions concerning the nature of the relationships between humans and other species and how those relationships are sustained (Tonkinson 2011). It "provides an explanation of nature, establishes a social code, creates a basis for prestige and political status within the community, acts as a religious philosophy and forms a psychological basis for life" (Cane 2002). Critical to the perpetuation of life is the proper adherence to the Law contained in *Jukurrpa*, which for many Martu frames the importance of hunting and sharing within the notion that "country must be used and appropriately burned" if life is to continue. As one elder put it, to stop using up resources, to stop hunting and burning, would mean "the end of the world."

Jones (1969) and others (e.g., Gould 1971) have noted a clear link between Aboriginal fire ecology, harvestable food resources, water sources, and religious practice in *Jukurrpa*. Gammage (2011) has recently expanded the argument, suggesting that at the time of European invasion, the "landesque capital" of Aboriginal Australia existed as a set of contiguous estates held together by systems of land management facilitated by anthropogenic fire. Whether or not these systems were designed as long-term land management strategies (which for Martu, we argue, they are not), most acknowledge a profound role for landscape-burning practices in the function of many Australian societies and ecosystems (Bowman et al. 2011).

For Martu, following the Law set out in *Jukurrpa* requires that one burn in particular ways: holding (*kanyini*) the country, not managing in top-down fashion, but holding it as part of a larger set of caretaking responsibilities over people. To burn outside of the context of permission from estate owners, or at times or in areas where a fire will threaten sacred sites, will bring consternation at the least and likely severe punishment. However, any designed "management" of land is an epiphenomenon of *kanyininpa*, the treatment of people and resources that Martu insist is based on encouraging individual autonomy (sensu Folds 2001). *Kanyini* means literally to carry something, but it is often used in the context of nursing: to nurse a child, or to nurse a fire stick and keep it from going out. When one *kanyininpa ngurrara*, carries the country, one is looking after country like one would look after a child, nurturing, feeding, giving it room to grow according to its own inevitable processes, fostering its autonomy and self-direction, and not controlling and managing it.

Traditional Martu beliefs emphasize that holding the country involves reenacting the creative forces first established by the Dreaming ancestors who brought the landforms into existence. Burning is a requisite reenactment of this creation given expression by the mundane business of everyday work. This, they say, ensures the fruitful reproduction of Martu, of species that sustain Martu, and the animals and plants that sustain those species. Thus, they claim that the estates represented in figure 2 exist only as a result of the terraforming activities of the Dreamtime ancestors sustained in *kanyininpa* by emulating their landscaping through burning.

Nurturing sentiments in *kanyininpa* are most often expressed through food sharing, especially unconditional sharing (*yankupayi*) with family (*walytja-marri*, defined as those of us who share, whether it be a home, country, birthplace, food). *Kanyininpa* creates both *walytja* and *ngurra*, a camp. *Ngurra* is a profoundly complex term incorporating notions of place, belonging, home, country, habitat, and generosity (Tonkinson 2005). Elsewhere in Australia there may be more clearly defined differences between the spatial notions of *ngurra* and the social notions of *walytja*, but many remote-living Manyjilyijarra- and Warnman-speaking Martu insist the distinction is blurry and that *ngurra* exists only within *walytja*. There is no home without family, and *walytja* share *ngurra* by definition. *Ngurra* is not bound in space or time; it can be formed and transformed at any spatial or temporal scale, with any group of people that come together as family, especially to share food.[5]

5. Within a *ngurra*, kinship always affects how individuals interact, but kinship does not, in a direct sense, determine the outcome of food sharing. For example, outside of a highly constrained and specific religious context, two *yumuri* (a mother-in-law and son-in-law of orthogonal alternate merged generational groups; Tonkinson 1991) would never address each other, sit near each other, or make eye contact, let alone hunt together or directly transfer food between each other. But

Out from the settlement foragers often establish a central locale to which they return in the evening to prepare, cook, share, and consume the day's take. Martu call this a *mirrka ngurra*, a dinner camp, and the location of that camp, as well as the individuals in the foraging party, will usually shift from day to day. Regardless of how ephemeral, at a *mirrka ngurra*, Martu assert they have an obligation to share evenly with everyone at the camp—if the day's take was meager, everyone will be equally hungry (Bliege Bird and Bird 2008).[6] Our data confirm that this is largely the case in practice, but any biases that emerge materially disfavor the more consistent large producers (Bird and Bliege Bird 2010; Bliege Bird et al. 2012*a*; Bliege Bird and Power 2015). For a producer to bias the consumption away from others based on kinship would be offensive.[7] How shares are nominally identified, as well as who hands what shares to whom and how one can address someone regarding a share, are of course matters of kinship (think of the closest grandparental relationships, which are same or parallel sections, vs. the most restrained in-law relationships, which are orthogonal sections; Tonkinson 1991). But this does not structure the composition of people present at *ngurra*—where food is delivered, prepared, distributed, and consumed—nor does it bias the amount and quality of who consumes what (Bird and Bliege Bird 2010; Bird et al. 2013). Martu claim that tiers of distribution ensure that all adults present ultimately get an equal share, and it is the obligation of the producer to act modestly—and the distributor compassionately—toward those with less (Bliege Bird and Power 2015).

The obligations to ensure consumption equality emerge through the way social status is maintained, which is mediated through the maintenance of social networks of sharing and cooperation. We have argued elsewhere that individuals are motivated to return as much food as possible to the *ngurra* because they gain respect and some measure of prestige from distributing a greater percentage of their harvest, as in kangaroo hunting (Bird and Bliege Bird 2010; Bliege Bird 2012*a*) or, as in sand monitor hunting, that they gain social capital from the costly support of extensive social networks and an honest display of pecuniary disinterest, of not benefitting from one's own overproduction (Bliege Bird and Power 2015). The benefits of costly sharing thus condition the return of all foraged foods to the dinner camp.

Martu are thus strict central place provisioners with respect to the formation of the *ngurra*. Hunters very rarely eat while searching for and pursuing prey and do not cook prey except at the hearth in the *ngurra*. Even children return all prey back to the *ngurra* for cooking before consumption. The only exception is the consumption of small amounts of fruit or nectar while collecting or occasionally a snack if gutting larger game at a kill site. This is not conditioned by the constraints of tools, cooking pots, or other items left back at the central place: nearly all foraged food Martu acquire is either eaten raw or roasted whole over coals or in roasting pits. Ironically, the formation of the *ngurra* trumps residential patterns in the community at large. Martu are not strict central place provisioners with respect to the settlement; only what is not consumed at the *ngurra* is brought back to the settlement. Most of the small prey is thus consumed by the *ngurra*, while only leftover portions of larger prey are brought back to the community and redistributed. The formation of a *ngurra* is determined simply by coresidence around a cooking hearth. Those who share a cooking fire are "at table" together regardless of their kinship relationships or residency in other contexts (Bliege Bird et al. 2012*a*). They are made family.[8]

Martu family making includes the sharing of a multiplicity of ties created through consubstantiality and rituals of unconditional economic exchange (Tonkinson 2011). "Consub-

there are often *yumuri* sharing a camp and sharing food that they or others produce—they simply separate themselves in space. For example, if out on a temporary camp, *yumari* will often separate themselves by at least a few tens of meters, backs to each other and a brush divider or vehicle between them. Yet *yumuri* are fundamentally family and fundamental to family in part, say Martu, because they share food at camp.

6. While for Martu, social interactions—including food sharing—never exist independent of concerns about kinship relationships (in fact, parcels of game are often referred to in terms of a kinship relationship between a hunter and an idealized recipient of the share, e.g., a kangaroo rump is often called the in-law share), kinship relationships do not diametrically regulate the everyday flows and amounts of food distributed from producers to consumers. Martu that we live with insist that all of the adults present when food is distributed at a *ngurra* should receive equal shares of food (or defer shares as they wish) regardless of the kinship relationship between the producer and the consumer.

7. This is so even under broad obligations young men have to hunt for their in-laws or other older men, especially a mother's brother. Younger Martu men often declare that affinal obligations influence their decisions to go hunting and that they have responsibilities to work for old men and affinal kin, but a young hunter almost never takes the lead in cooking, butchering, or distributing large game. Distributions are conducted by the most senior person present, and they do not bias portions such that larger shares go toward affinal kin or mother's brother of the hunter (Bird and Bliege Bird 2010). This does not mean, however, that younger men do not have special responsibilities to their in-laws or older men.

8. This does not mean that all family are equal or that everyone who is considered family gets an equal share. It is simply that those present when food is prepared, distributed, and eaten are made family and get an equal share (or have the right to refuse an equal share). Those not present get nothing, or only what is not consumed immediately. In the context of most foraging today, someone not present in a foraging party (the group that makes a *mirrka ngurra*) cannot expect to get much of anything that was acquired that day. They may be upset about that and may address their concerns according to kinship ("I am your auntie, you went foraging; why did you not bring me anything?"), but neither the producers nor distributors control distribution in a way that would ensure shares at a foraging camp are biased in order to return portions to specific individuals in the settlement. One could defer consumption of a share received at distribution and then deliver it to someone in the settlement, but that is likely to raise questions from others in the settlement about perceived bias (see Bird et al. 2013).

stantiality" refers to the possession of a common substance as the basis of a social tie between two individuals. In some societies, this is primarily the substance of genetic decent, but in others, it also includes the shared intake of many different substances. For Martu, family (*walytja*) is generated through the sharing of one mother's milk, the consumption of the same hunted animal, or sharing souls or spirits that have emerged from the same *yinta*, a spring with life-giving water. Families are said to be established through sharing the love of the same mother(s) who raised them as her own children, sharing the same or parallel section (merged alternate generational groups: *Karimarra and Panaka* or *Milangka and Purungu*; Tonkinson 1991) or sharing material without the expectation of return (*yankupayi*). It is not that consanguinity is unimportant; it is that one can buffer questions about descent by creating social bonds through shared experience and "substance," and these bonds can be given just as much weight as those characterized by clearly defined ancestry (Tonkinson and Tonkinson 2004). Being *walytja-marri* (those of us from the same spring, *yinta*) is about sharing, and it can be as much about sharing the same country, meat, fire, water, or mother's milk as it is about sharing an ancestor.

For Martu, decisions about foraging are thus shaped by decisions about sharing. Martu often say they hunt to share: hunting is always embedded in a context of social exchange. When hunters leave *ngurra* thinking about *yunkupayi* (sharing without expectation of return), they are said to bring back more meat, and in bringing back more, the goal is not to eat more but to share more to other members of the *ngurra*. Sharing unconditionally is partly a manifestation of one of the central emotions of Martu existence: sympathy, or sorrow (*nyarru*). One shares with those less successful because one feels sorry for them. Yet there is also a motivation to share to receive the rewards of being *mirtilya*, a good hunter. *Mirtilya* are skilled hunters who broker their excess production into social capital. A hunter who produces more than anyone else should eat as little as possible from his or her own production and share the surplus widely and unconditionally, especially to those with whom she has little obligation to share—those who are not genealogical kin. A *mirtilya* has that status because she builds kinship ties with those to whom she is not necessarily closely related. A productive hunter's reward is not the meat but the *pukurrpa* (happiness) that comes from binding people together in a family through the meat they have provided. This binding of family is *kanyininpa*, holding, and it is simultaneously economic, parental, and ritual.

Among Martu, holding country requires that you feed and nurture others without restricting their autonomy in any way: shares are thus distributed in ways that defuse the "power of the gift" (Mauss 1954). The power of the gift is muted in several ways typical of "immediate return economies" that disassociate the hunter with ownership of the food he or she has acquired, create egalitarian distributions of economic goods, promote tolerance of free riding, encourage cooperation, and discourage contingency in the sharing of food. Those who acquire more do not benefit in consumption from their overproduction: better hunters share a larger proportion of their harvest and do so routinely without contingent reciprocity in food (Bliege Bird and Power 2015). However, the better hunter who eats little, shares most, and cooperates extensively with poor hunters does benefit, and although we cannot measure *pukurrpa*, we can measure the social networks of interaction that are created through sharing. The benefits of sharing lie in the construction of social relationships of trust and cooperation that build family ties. Those who are more generous on average have higher centrality scores in the cooperative hunting network, meaning they cooperate more with others who are also cooperative (Bliege Bird and Power 2015). More generous sharers are thus able to create a social network of strong ties between connected individuals. Where "generosity is the main measure of a man's goodness" (Hiatt 1982:14), building and maintaining a reputation for virtue generates trust in many different dimensions of Martu social life. Foragers share a greater percentage of their harvest the larger it is, feeding and holding those who cannot or will not forage for themselves. For this is how Martu gain a measure of social prestige and become respected as those strong in the law: through disengaging with material property (Tonkinson 1988) and fostering egalitarian material relationships in the holding of *ngurra* and *walytja* (Bird and Bliege Bird 2010).

Emergent Pyrodiversity: "We Hunt in This Country to Look After It. The Animals Get Fat, and We Hunt and Eat Them."

As expressed in the poem above, the notion that people are critical for the perpetuation of life in the desert has parallels with nonequilibrium theory in ecology, which recognizes the importance of disturbance and the positive effects it can generate. When organisms disturb ecological communities, some species experience population reductions, but others may do better. If in influencing local population declines among a few species an organism provides positive effects such as enhancing food or shelter for other species, they are referred to as "ecosystem engineers" (Jones, Lawton, and Shachak 1996) or "niche constructors" (Odling-Smee, Laland, and Feldman 2003). The classic example is that of beavers constructing dams. Dams flood creeks, which causes localized mortality to some plants but increases wetland habitat and produces greater environmental heterogeneity, in turn supporting larger populations of a wider range of species at a landscape scale (Wright, Jones, and Flecker 2002). Ecosystem engineers can have positive effects through a variety of different mechanisms. They can affect landscape heterogeneity, which may stabilize species interactions and provide a variety of habitats for shelter and feeding (Holt 1984; Roff 1974; Roxburgh, Shea, and Wilson 2004); they may also increase food web stability simply by being a predatory generalist who hunts prey at different trophic levels (Gross et al. 2009). Organisms that play a key role in holding

communities together are often referred to as "keystone species" or "foundational facilitators." Remove that species and you may precipitate a wave of extinctions that ripples through an entire food web (Terborgh et al. 2001).

Like species, physical processes can act as keystone facilitators. Fire shapes global ecosystem patterns and is often a keystone process, a form of disturbance that causes mortality at local scales but may have positive effects at the scale of the community or landscape (Bowman et al. 2009). At the scale of a burned patch, fire immediately removes vegetation and reduces local animal populations, but it may increase in-patch species diversity (alpha diversity) by interrupting the process of plant succession that results in domination by a few competitive species. Communities associated with different time since last fire may have a very different set of plants and animals associated with them, and species diversity may actually be highest not at the endpoint of recovery from fire but at some point in the middle. Across a landscape, fire may increase diversity by increasing the heterogeneity of community types across the landscape (beta diversity).

Across a vast landscape of nearly 500,000 hectares, Martu set approximately 360 fires per year, averaging around 100 hectares in area. These hunting fires are very different from lightning fires: they are ten times smaller on average and 10 times closer to each other (Bliege Bird et al. 2012). Fires are smaller for a number of reasons. Martu light fires mostly under conditions when fire size can be more easily controlled. Under conditions unfavorable to control of fire, hunting fires tend to be larger. Lightning fires are large regardless of conditions because they tend to be lit mainly when temperatures are high and winds are unpredictable. The size of lightning fires is limited mainly by the contiguity and amount of fuels, which is measured by antecedent cumulative rainfall (Bliege Bird et al. 2012). When the grass is thick, Martu simply light more small fires, because thick grass reduces sandplain hunting search efficiency. The small, patchy fires scattered throughout the landscape by Martu hunters have the incidental effect of creating firebreaks that prevent the spread of lightning fire during seasons when large fires threaten.

To explore the interactive effects of over 4,500 observed foraging hours on the structure of the landscape and its interaction with resources, we stratified the entire study area by different levels of human use, ranging from more than two forager days per square kilometer to practically zero, and then overlaid land-use intensity on a composite seral stage (vegetation age since fire) classification map (fig. 3). The patchy landscapes created through several years of wintertime hunting shown in figure 3 have significant effects on the distribution of both plant and animal species. Sand monitor density is increased in regions where there is greater environmental heterogeneity: the higher the density of habitat edges—contrasts between new burns, regrowing vegetation, and old growth—the higher the density of monitor lizards. In fact, lizards are more abundant in landscapes where they are more intensively hunted (Bliege Bird et al. 2013).

This increase in game, in turn, doubles Martu hunting efficiency and increases success rates six times over in more heavily hunted regions compared with regions that are rarely visited (Bliege Bird et al. 2013). As a result, foraging return rates across all different hunting and gathering activities are highest in areas under intermediate human use, where the negative effects of human predation are dominated by the positive effects of anthropogenic fire (fig. 4). Even in high-use regions, foragers do significantly better than they do in more remote regions less affected by anthropogenic fire.

Martu hunting fires also shape population distributions of other desert species that benefit from access to a more diverse successional mosaic, such as hill kangaroo, which are more abundant in regions associated with higher patch diversity (Codding et al. 2014). Characteristics of many of the animal species that disappeared or are in decline also suggest that they, too, may have been advantaged by Martu fire mosaics. Hare wallabies are browsers that rely on plants in many different successional stages as well as mature spinifex hummocks for nesting and predator predation. Before the 1960s, they were abundant and widespread throughout the spinifex sandplains and were hunted frequently. The continued persistence of the population has been argued to be dependent on continued patch mosaic burning to maintain access to early-successional habitat adjacent to mature spinifex (Lundie-Jenkins 1993; Lundie-Jenkins, Corbett, and Phillips 1993; Lundie-Jenkins, Phillips, and Jarman 1993; see Kerle et al. 1992 for similar effects in other endemic mammals).

Landscapes where hunting is most intense also have more patches of midsuccessional grassland, which has a significantly greater density of high-ranked seed grasses such as *Eragrostis* and fruits such as *Solanum*. Anthropogenic landscapes reduce the cost of accessing such patches by rescaling habitat structure. Foragers in an anthropogenic landscape have a 96% chance of being able to find a patch within 3 km; in regions far from Martu influence, the chances of finding such patches nearby drop to 82% (Zeanah et al. 2015). Essentially, an anthropogenic landscape rescales resource patch density to reduce the cost of accessing a wider range of resources.

Ecological Emergence of Homelands: "This Country Is Us."

In a very real sense, Martu foragers and their resources (especially sand monitor lizards) are locked in coevolutionary dependence with deep temporal roots, one that is akin to farming but on a spatial scale that requires more expansive mobility than most systems of horticulture. This is so in spite of (and in part because of) the fact that contemporary foraging and mobility are entangled in and modified by extrinsic markets and settler colonial constraints and opportunities. The customary sector of a Martu economy thrives because of the social value that Martu place in sharing: sandplain hunting is fundamental to sustaining relationships whose value is defined by pecuniary disinterest (Bliege Bird and Power

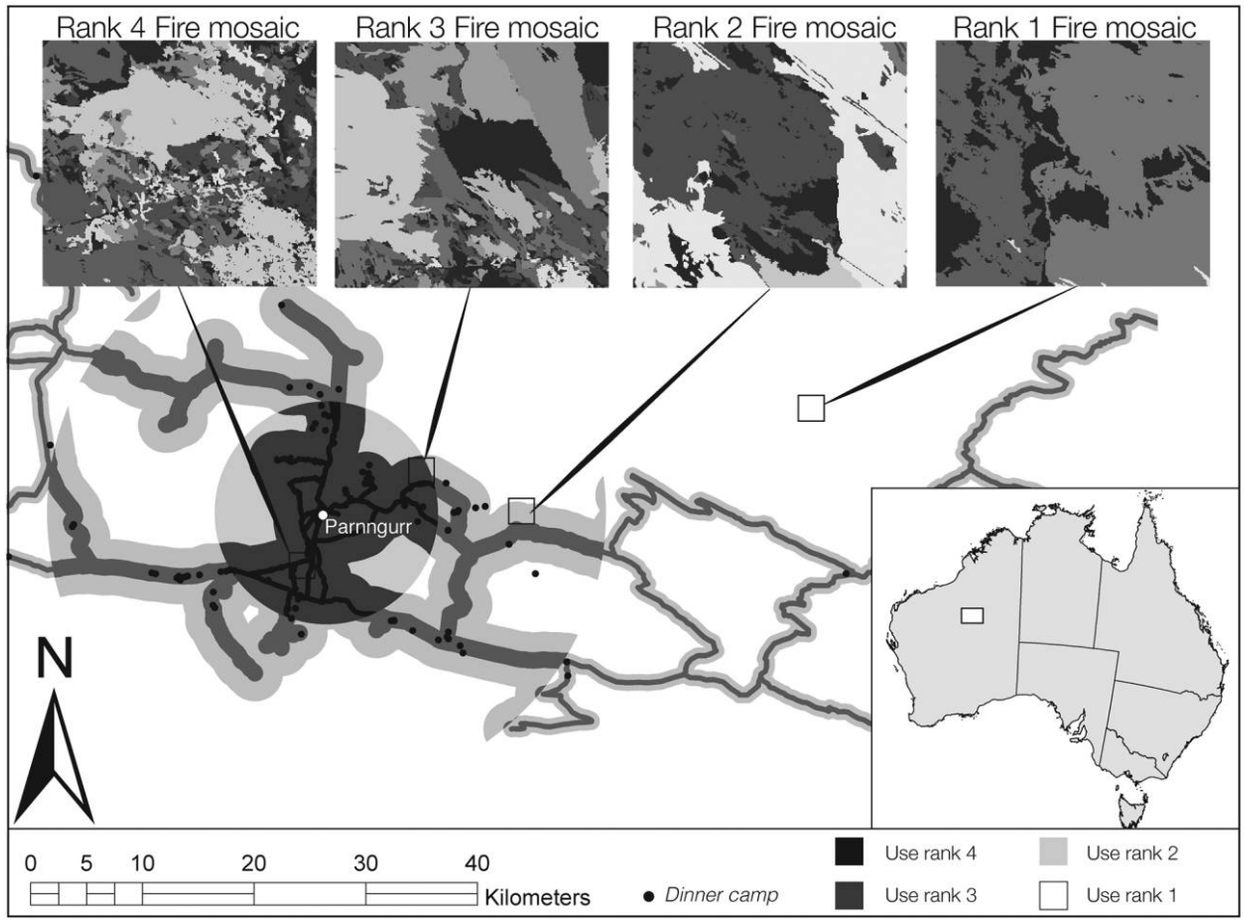

Figure 3. Study region within the Martu homelands stratified by different levels of land-use intensity from more than 4,621 observed forager hours between 2000 and 2010. As illustrated in the lower graphic, the highest-use areas (category 4, black) include those regions within a 25-km radius of Parnngurr with >2 forager days recorded per square kilometer. Moderately high-use areas (category 3, dark gray) include those regions within a 50-km radius with between 0.26 and 2 forager days recorded per square kilometer. Moderately low-use areas (category 2, light gray) include all regions with between 0.06 and 0.25 forager days per square kilometer. Low-use areas (white) include those regions with <0.05 forager days recorded per square kilometer. The mosaics (shown to scale in location in the lower graphic) are composite satellite images creating a cumulative 10-year fire-history map (Bliege Bird et al. 2012*b*) to illustrate patchiness of seral stage (earlier succession is shown in lighter shades) according to use rank.

2015). For Martu this is fundamentally tied to pedestrian hunting in the sandplains and the burning that supports it.

High predictability and density of lizards is a necessary precondition to produce desert livelihoods characterized by reductions in residential mobility, the mid-Holocene hallmark of broad spectrum foraging economies in arid Australia (Smith 2013). Even today, with vehicles and metal digging sticks, hunters cannot be efficient enough to support themselves or others without burning (see "Fire, Food, Family, Home"; Bliege Bird, Codding, and Bird 2016; Zeanah et al. 2015). Such livelihoods can only be sustained through the creation of a fine-grained mosaic of diverse vegetative succession produced by the cumulative effects of anthropogenic burning (Bliege Bird et al. 2008, 2012*b*). These anthropogenic landscapes, however, are emergent phenomena: they are maintained through attempts to increase the immediate efficiency of searching for small prey. The immediate benefits of burning to hunt offset the costs of collective action required for intentionally designed systems of management (policing, in effect) that characterize more intensified farming: Martu "farm" lizards with "fire sticks" (Jones 1969), but on a requisite spatial scale (supported by expansive logistical mobility out from a residential base) that would make maintaining long-term exclusive rites of producer control over a "cultivated" plot inordinately expensive. Ownership of land-based estates is maintained in a delayed-return ritual economy (Sutton 2003) in which the exclusivity of an estate is defined by the accumulation, performance, and inheritance of esoteric knowledge, not directly through the maintenance of long-term rites to exclude access to a spatially bound set of resources cultivated through burning. The route to sustaining a claim to an estate is indirectly linked to the maintenance of a

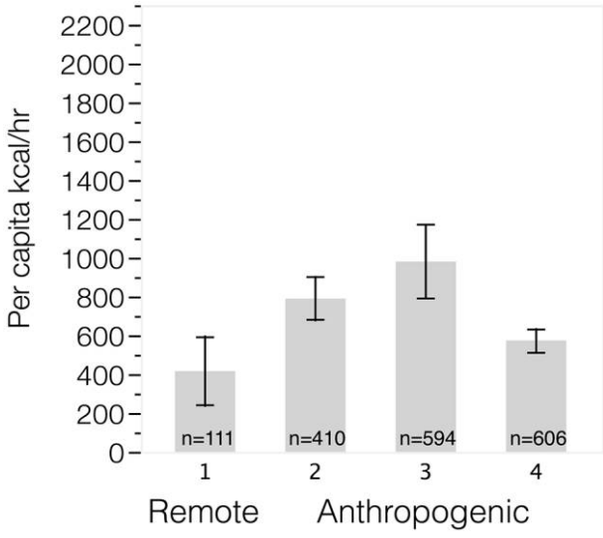

Figure 4. Relationship between foraging efficiency (kcal per forager hour, $N = 1{,}831$ foraging bouts) and intensity of land use (see fig. 3). Landscape heterogeneity increases as a result of higher levels of anthropogenic burning in more intensively used area (Bliege Bird et al. 2008, 2012*b*). This feeds back to increase subsistence returns for pedestrian foraging in intermediate-use regions. Even in the most intensively used areas (category 4), the positive effects of an established mosaic of anthropogenic burning outweigh the costs of localized resource depression from more intensive extraction. Return rates from foraging bouts in categories 2, 3, and 4 are all significantly higher than return rates in category 1 ($P < .05$).

distinctive anthropogenic landscape through the way that skill and generosity in hunting forge the rights of ritual performance and ownership (Bird and Bliege Bird 2010). These systems of social exchange thus emerge from the distribution of resources across the landscape, which is fundamentally shaped by anthropogenic fire.[9]

Implicit within the *Jukurrpa* is the notion that the desert supports a network of interactions between all species, what ecologists refer to as a food web, in which humans are an important keystone species and fire is a keystone process. The ritual significance of burning is that Martu fulfill their role within the food web by burning to acquire food and distributing it to the younger generation, holding them and in so doing, holding the country for inheritance.[10] Holding country emerges naturally out of the holding of *walytja*, a group who at the most local scale share ownership of "a little story" (see "Emergent Pyrodiversity"), often a single *yinta*, or waterhole. The patterning of fires on the landscape is not designed toward some optimal management goal, it is simply meant to be. If the mundane and ritual practices of life were not integrated, the land would not reproduce, and it would be the end of the world.

Conclusions

Many Martu emphasize that the social, ecological, and metaphysical landscape exist simultaneously, inextricably intertwined in a complex web of interaction. Hunting in the sandplain grasslands is integral to the maintenance of this web and ultimately sustains important networks of cooperation (Bliege Bird and Power 2015; Bliege Bird et al. 2012*a*). Such hunting is possible only within an environment where small animals flourish, which requires the intervention of human fire sticks (Bliege Bird et al. 2013). Fire makes possible high foraging production, increasing both predictability and return rates in hunting small animals. The foraging benefits supplied by fire-maintained habitats are invested into social relationships via food sharing. Fire sustains the generosity of the *mirtilya* (hunters with a lifetime of reputations based on skill and generosity) and supports a moral economy that emerges from generosity, which fosters stronger social ties between individuals by generating trust and facilitating cooperation.

Anthropogenic fire sustains a web of interaction that links the realms of the economic, the social, and the ecological. Fire is the shaping of country, the reenactment of creation, and the holding of *Jukurrpa* (the Dreaming), and it sustains the ties that bind people together. In binding networks together through sharing, Martu also serve as ecosystem engineers, creating small-scale habitats that prevent the spread of very large fires and buffer small, ground-dwelling mammals from both the effects of climate-driven fire and from the heavy predation that ensues when animals are exposed in burned areas.

The logic behind the Dreaming places humans within the web of ecological relationships critical to the coexistence of a wide range of desert species, predicted the trophic collapse that occurred during the Martu hiatus, and explains why Martu understood species extinctions to be linked to the loss, not the intensity, of human hunting. Once Martu began the

9. The status of being *mirtilya* (a skilled and generous hunter) is dependent on a lifetime of holding others and building relational wealth (sensu Mulder et al. 2009). This holding of others (*kanyininpa*), which are bonds of trust, requires honest displays of asceticism, of devotion to dispossession (Bird and Bliege Bird 2010; Bliege Bird and Power 2015; Bliege Bird et al. 2012*a*). Paradoxically, it is through this dispossession that a claim to possess an estate is maintained. The means of estate inheritance are complex and vary geographically across desert societies (Cane 2002; Dussart 2000; Myers 1986). For remote-living Martu, rights to stake and maintain a claim to an estate and negotiate its performance in ritual and artistic expression are in part based on respect generated by how well you can bind together networks of co-owners (sensu Myers 1988). Hunting to share requires immediate returns that can only be realized in landscape burning, the long-term ("emergent") effects of which are the distinctly anthropogenic landscapes that Martu call home. That becomes the landesque capital of a delayed-return economy of ritual inheritance.

10. Similar themes are expressed in the burning of a vehicle to forge trust in co-ownership: if there is a dispute over a vehicle, Martu will burn the vehicle (e.g., Myers 1988). It is a display of commitments to hold together networks of people and country made honest in your ability to bear the burden of subjecting an object to destruction.

mid-twentieth-century process of migration onto missions, pastoral stations, and European settlements and stopped hunting and burning on the landscape, fire mosaics began to break down, large fires swept through, both invasive and endemic predators spread and increased in population, and many species of both plants and animals went extinct (Bliege Bird, Codding, and Bird 2016; Bliege Bird et al. 2012*b*). The world, as Martu knew it, did come to an end, as the Dreaming had predicted it would. The homelands came back to life as Martu returned in the 1980s to hunt and burn. Dreaming logic is thus revealed as a deep understanding of the social-ecological relationships between human foragers and their environments.

Rather than viewing Martu conceptions of "looking after country" as management, we show here that what many Martu mean when they talk about caring is that the long-term benefits of anthropogenic habitat modification are an emergent property of a coevolved social-ecological system maintained by the short-term benefits to small game hunting returns. Positive environmental effects emerge not from designed or institutionalized management schemes but from the cumulative patterning of individual decision making across a landscape of social, residential, ritual, and economically driven land-use patterns. People, and other species, then capitalize on the ecological properties that emerge.

Our hope is that the analysis illustrates one way by which anthropological disciplines can be reintegrated through questioning the mutual exclusivity of reductionist versus holistic and emic versus etic perspectives. Our approach attempts to isolate and break down some of the processes shaping emergent properties of complex social-ecological systems while at the same time contextualizing the transcendent worlds that people construct from their relationships with each other, other species, and materials. Many Martu insist that they are their country through their "holding" of people and land. One way to interpret this is in how their practices construct networks of relationships from which an ecological niche emerges. Things in the niche are thus constituted not in delineated forms but in the weave of interactions (Hodder 2012). "The environment, then, comprises not the surroundings of the organism but a zone of entanglement" (Ingold 2008:1796). We argue that measuring the interactions and the way they are recorded in habitat heterogeneity, including patterns of decision making about food acquisition and the application of fire to the landscape, gives critical insight into the processes that hold together people and their entanglements with country.

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References Cited

Altman, Jon, Nicholas Biddle, and Geoff Buchanan. 2012. The indigenous hybrid economy: can the NATSISS adequately recognise difference? In *Survey analysis for indigenous policy in Australia: social science perspectives*. Boyd Hunter and Nicholas Biddle, eds. Pp. 163–191. Canberra: ANU.

Bird, Douglas W., and Rebecca Bliege Bird. 2010. Competing to be leaderless: food sharing and magnanimity among Martu Aborigines. In *The evolution of leadership: transitions in decision making from small-scale to middle-range societies*. John Kantner, Kevin Vaughn, and Jelmer Earkins, eds. Pp. 21–49. Santa Fe, NM: SAR.

Bird, Douglas W., Rebecca Bliege Bird, and Brian F. Codding. 2009. In pursuit of mobile prey: Martu hunting strategies and archaeofaunal interpretation. *American Antiquity* 74:3–29.

Bird, Douglas W., Rebecca Bliege Bird, Brian F. Codding, and Brooke A. Scelza. Forthcoming. The dynamics of indigenous livelihoods and ecologies in the Western Desert: economic, social, and environmental values of foraging in a remote Martu community. *Journal of Rural Studies*.

Bird, Douglas W., Rebecca Bliege Bird, and Christopher H. Parker. 2005. Aboriginal burning regimes and hunting strategies in Australia's Western Desert. *Human Ecology* 33:443–464.

Bird, Douglas W., Brian F. Codding, Rebecca Bliege Bird, David W. Zeanah, and Curtis J. Taylor. 2013. Megafauna in a continent of small game: archaeological implications of Martu camel hunting in Australia's Western Desert. *Quaternary International* 297:155–166.

Bliege Bird, Rebecca, and Douglas W. Bird. 2005. Human hunting seasonality. In *Primate seasonality: studies of living and extinct human and nonhuman primates*. D. Brockman and Carl van Shaik, eds. Pp. 243–266. Cambridge: Cambridge University Press.

———. 2008. Why women hunt: risk and contemporary foraging in a Western Desert Aboriginal community. *Current Anthropology* 49(4):655–693.

Bliege Bird, Rebecca, Douglas W. Bird, Brian F. Codding, Christopher H. Parker, and James H. Jones. 2008. The "fire stick farming" hypothesis: Australian Aboriginal foraging strategies, biodiversity, and anthropogenic fire mosaics. *Proceedings of the National Academy of Sciences of the USA* 105(39):14796–14801.

Bliege Bird, Rebecca, Brian F. Codding, and Douglas W. Bird. 2016. Holding the dreaming: economic, social and ecological benefits of hunting, sharing and fire in the Western Desert of Australia. In *Why forage? hunters and gatherers in the twenty-first century*. Brian F. Codding and Karen Kramer, eds. Pp. 213–230. Albuquerque and Santa Fe: University of New Mexico Press with School for Advanced Research Press.

Bliege Bird, Rebecca, Brian Codding, Peter G. Kauhanen, and Douglas Bird. 2012*a*. Aboriginal hunting buffers climate-driven fire-size variability in Australia's spinifex grasslands. *Proceedings of the National Academy of Sciences USA* 109(26):10287–10292.

Bliege Bird, Rebecca, and Eleanor A. Power. 2015. Prosocial signaling and cooperation among Martu hunters. *Evolution and Human Behavior* 36:389–397.

Bliege Bird, Rebecca, Brooke A. Scelza, Douglas W. Bird, and Eric A. Smith. 2012*b*. The hierarchy of virtue: mutualism, altruism and signaling in Martu women's cooperative hunting. *Evolution and Human Behavior* 33 (1):64–78.

Borgerhoff Mulder, Monique, Samuel Bowles, Tom Hertz, Adrian Bell, Jan Beise, Greg Clark, Ila Fazzio, et al. 2009. Intergenerational wealth trans-

mission and the dynamics of inequality in small-scale societies. *Science* 326(5953):682–688.
Bowman, David M. J. S., Jennifer K. Balch, Paulo Artaxo, William J. Bond, Jean M. Carlson, Mark A. Cochrane, Carla M. D'Antonio, et al. 2009. Fire in the earth system. *Science* 324(5926):481–484.
Bowman, David M. J. S., Jennifer Balch, Paulo Artaxo, William J. Bond, Mark A. Cochrane, Carla M. D'Antonio, Ruth DeFries, et al. 2011. The human dimension of fire regimes on earth. *Journal of Biogeography* 38 (12):2223–2236.
Brand Miller, Janette, Keith W. James, and Patricia Maggiore. 1993. *Tables of composition of Australian Aboriginal foods*. Canberra: Australian Aboriginal Studies.
Cane, Scott. 2002. *Pila Nguru: the spinifex people*. Freemantle, Western Australia: Fremantle Arts Center.
Carty, John. 2010. Drawing a line in the sand: the canning stock route and contemporary art. In *Yiwarra Kuju: the canning stock route*. John Carty, C. Davenport, and M. La Fontaine, eds. Pp. 23–77. Canberra: National Museum of Australia.
Castree, Noel, William M. Adams, John Barry, Daniel Brockington, Bram Büscher, Esteve Corbera, David Demeritt, et al. 2014. Changing the intellectual climate. *Nature Climate Change* 4(9):763–768.
Codding, Brian F. 2012. "Any kangaroo?" on the ecology, ethnography and archaeology of foraging in Australia's arid west. PhD dissertation, Stanford University, Stanford, CA.
Codding, Brian F., Douglas W. Bird, and Rebecca Bliege Bird. 2010. Interpreting abundance indices: some zooarchaeological implications of Martu foraging. *Journal of Archaeological Science* 37:3200–3210.
Codding, Brian F., Rebecca Bliege Bird, and Douglas W. Bird. 2011. Provisioning offspring and others: risk-energy trade-offs and gender differences in hunter-gatherer foraging strategies. *Proceedings of the Royal Society B* 278:2502–2509.
Codding, Brian F., Rebecca Bliege Bird, Douglas W. Bird, and David W. Zeanah. 2016. Alternative Aboriginal economies: Martu livelihoods in the 21st century. In *Why forage? hunters and gatherers in the twenty-first century*. Brian F. Codding and Karen L. Kramer, eds. Pp. 185–211. Albuquerque and Santa Fe: University of New Mexico Press with School for Advanced Research Press.
Codding, Brian F., Rebecca Bliege Bird, Peter G. Kauhanen, and Douglas W. Bird. 2014. Conservation or co-evolution? intermediate levels of Aboriginal burning and hunting have positive effects on kangaroo populations in Western Australia. *Human Ecology* 42:659–669.
Cormier, Loretta A. 2003. *Kinship with monkeys: the Guajá foragers of Eastern Amazonia*. New York: Columbia University Press.
Corning, Peter A. 2002. The re-emergence of emergence: a venerable concept in search of a theory. *Complexity* 7(6):18–30.
Davenport, Sue, Peter Johnson, and Yuwali. 2005. *Cleared out: first contact in the Western Desert*. Canberra: Aboriginal Studies.
Descola, Philippe. 2013. *Beyond nature and culture*. Chicago: University of Chicago Press.
Dussart, Françoise. 2000. *The politics of ritual in an Aboriginal settlement: kinship, gender, and the currency of knowledge*. Washington, DC: Smithsonian Institution.
Elkin, Adolphus P. 1969. Elements of Australian Aboriginal philosophy. *Oceania* 40(2):85–98.
Folds, Ralph. 2001. *Crossed purposes: the Pintupi and Australia's indigenous policy*. Sydney: University of New South Wales Press.
Fuentes, Augustin. 2016. The extended evolutionary synthesis, ethnography, and the human niche: toward an integrated anthropology. *Current Anthropology* 57(suppl. 13):S13–S26.
Gammage, Bill. 2011. *The biggest estate on earth: how Aborigines made Australia*. Sydney: Allen & Unwin.
Gould, Richard A. 1971. Uses and effects of fire among the Western Desert Aborigines of Australia. *Mankind* 8(1):14–24.
Gross, Thilo, Lars Rudolf, Simon A. Levin, and Ulf Dieckmann. 2009. Generalized models reveal stabilizing factors in food webs. *Science* 325 (5941):747–750.
Hartigan, John. 2014. *Aesop's anthropology: a multispecies approach*. Minneapolis: University of Minnesota Press.
Hiatt, Lester. 1982. Traditional attitudes to land resources. In *Aboriginal sites: rites and resource development*. Ronald M. Berndt, ed. Pp. 47–53. Perth: University of Western Australia Press.
Hodder, Ian. 2012. *Entangled: an archaeology of the relationships between humans and things*. Malden, MA: Wiley-Blackwell.
Holt, Robert D. 1984. Spatial heterogeneity, indirect interactions, and the coexistence of prey species. *American Naturalist* 124(3):377–406.
Ingold, Tim. 1996. Hunting and gathering as ways of perceiving the environment. In *Redefining nature: ecology, culture, and domestication*. R. F. Ellen and Katsuyoshi Fukui, eds. Pp. 117–155. Oxford: Berg.
———. 2008. Bindings against boundaries: entanglements of life in an open world. *Environment and Planning* 40(8):1796.
Jones, Clive G., John H. Lawton, and Moshe Shachak. 1996. Organisms as ecosystem engineers. *Oikos* 69:373–386.
Jones, Rys. 1969. Fire-stick farming. *Australian Natural History* 16(7):224–228.
Kerle, J. A., J. N. Foulkes, R. G. Kimber, and D. Papenfus. 1992. The decline of the brushtail possum, *Trichosurus vulpecula* (Kerr 1798), in arid Australia. *Rangelands Journal* 14(2):107–127.
Kohn, Eduardo. 2013. *How forests think: toward an anthropology beyond the human*. Berkeley: University of California Press.
Latz, Peter K. 1995. *Bushfires and bushtucker: Aboriginal plant use in Central Australia*. Alice Springs, Northern Territory: Iad.
Letnic, M., C. R. Dickman, M. K. Tischler, B. Tamayo, and C. L. Beh. 2004. The responses of small mammals and lizards to post-fire succession and rainfall in arid Australia. *Journal of Arid Environments* 59(1):85–114.
Lundie-Jenkins, G. 1993. Ecology of the rufous hare-wallaby, *Lagorchestes hirsutus* Gould (Marsupialia: Macropodidae) in the Tanami Desert, Northern Territory. 1. Patterns of habitat use. *Wildlife Research* 20(4):457–475.
Lundie-Jenkins, G., L. K. Corbett, and C. M. Phillips. 1993. Ecology of the rufous hare-wallaby, *Lagorchestes hirsutus* Gould (Marsupialia: Macropodidae) in the Tanami Desert, Northern Territory. 3. Interactions with introduced mammal species. *Wildlife Research* 20(4):495–511.
Lundie-Jenkins, G., C. M. Phillips, and P. J. Jarman. 1993. Ecology of the rufous hare-wallaby, *Lagorchestes hirsutus* Gould (Marsupialia: Macropodidae) in the Tanami Desert, Northern Territory. 2. Diet and feeding strategy. *Wildlife Research* 20(4):477–493.
Masters, P. 1996. The effects of fire-driven succession on reptiles in spinifex grasslands at Uluru National Park, Northern Territory. *Wildlife Research* 23(1):39–47.
Mauss, Marcel. 1954. *The gift*. New York: Norton.
Myers, Fred R. 1988. Burning the truck and holding the country: property, time and the negotiation of identity among Pintupi Aborigines. *Hunters and Gatherers* 2:52–74.
———. 1986. *Pintupi country, Pintupi self: sentiment, place, and politics among Western Desert Aborigines*. Berkeley: University of California Press.
———. 2002. Ways of place-making. *La Ricerca Folklorica* 2002:101–119.
Odling-Smee, F. John, Kevin N. Laland, and Marcus W. Feldman. 2003. *Niche construction: the neglected process in evolution*. Princeton, NJ: Princeton University Press.
Pianka, Eric R., and Stephen E. Goodyear. 2012. Lizard responses to wildfire in arid interior Australia: long-term experimental data and commonalities with other studies. *Austral Ecology* 37(1):1–11.
Roff, D. A. 1974. Spatial heterogeneity and the persistence of populations. *Oecologia* 15(3):245–258.
Roxburgh, Stephen H., Katriona Shea, and J. Bastow Wilson. 2004. The intermediate disturbance hypothesis: patch dynamics and mechanisms of species coexistence. *Ecology* 85(2):359–371.
Scelza, Brooke A., Douglas W. Bird, and Rebecca Bliege Bird. 2014. Bush tucker, shop tucker: production, consumption, and diet at an Aboriginal outstation. *Ecology of Food and Nutrition* 53(1):98–117.
Sponsel, Leslie E. 2012. *Spiritual ecology: a quiet revolution*. Santa Barbara, CA: ABC-CLIO.
Stanner, William E. H. 1979 (1953). *White man got no dreaming: essays, 1938–1973*. Canberra: ANU Research School of Social Sciences.
Sutton, Peter. 2003. *Native title in Australia*. Cambridge: Cambridge University Press.
Terborgh, John, Lawrence Lopez, Percy Nunez, Madhu Rao, Ghazala Shahabuddin, Gabriela Orihuela, Mailen Riveros, Rafael Ascanio, Greg H. Adler, and Thomas D. Lambert. 2001. Ecological meltdown in predator-free forest fragments. *Science* 294(5548):1923–1926.
Tonkinson, Robert. 1988. Ideology and domination in Aboriginal Australia: a Western Desert test case. In *Property, power, and ideology*, vol. 2 of *Hunters and gatherers*. Tim Ingold, D. Riches, and J. Woodburn, eds. Pp. 150–164. New York: Berg.
———. 1991. *The Mardu Aborigines: living the dream in Australia's Desert*. New York: Holt, Rinehart & Winston.
———. 2005. Individual creativity and property-power disjunction in an Australian desert society. *Property and Equality* 1(2005):32–46.

———. 2007. Aboriginal difference and autonomy then and now: four decades of change in a Western Desert society. *Anthropological Forum* 17:41–60.

———. 2011. Landscape, transformations, and immutability in an Aboriginal Australian culture. In *Cultural memories*. Peter Meusburger, Michael Heffernan, and Edgar Wunder, eds. Pp. 329–345. Dordrecht: Springer.

Tonkinson, Myrna, and Robert Tonkinson. 2010. The cultural dynamics of adaptation in remote Aboriginal communities: policy, values and the state's unmet expectations. *Anthropologica* 2010:67–75.

Tonkinson, Robert, and Myrna Tonkinson. 2007. Mardu. In *Encyclopedia of sex and gender*. Pp. 625–634. Detroit: Macmillan Reference.

Walsh, Fiona. 2008. To hunt and to hold: Martu Aboriginal people's uses and knowledge of their country, with implications for co-management in Karlamilyi (Rudall River) National Park and the Great Sandy Desert, Western Australia. PhD dissertation, University of Western Australia, Perth.

Wiessner, Polly. 2016. The rift between science and humanism: what's data got to do with it? *Current Anthropology* 57(suppl. 13):S154–S166.

Wright, Justin P., Clive G. Jones, and Alexander S. Flecker. 2002. An ecosystem engineer, the beaver, increases species richness at the landscape scale. *Oecologia* 132(1):96–101.

Zeanah, David W., Brian F. Codding, Douglas W. Bird, Rebecca Bliege Bird, and Peter M. Veth. 2015. Diesel and damper: changes in seed use and mobility patterns following contact amongst the Martu of Western Australia. *Journal of Anthropological Archaeology* 39:51–62.