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Authors: Bonta, Mark, Gosford, Robert, Eussen, Dick, Ferguson, Nathan, Loveless, Erana, et al.

Source: Journal of Ethnobiology, 37(4) : 700-718

Published By: Society of Ethnobiology

URL: https://doi.org/10.2993/0278-0771-37.4.700

Journal of Ethnobiology 37(4): 700–718 2017

INTENTIONAL FIRE-SPREADING BY "FIREHAWK" RAPTORS IN NORTHERN AUSTRALIA

Mark Bonta[1], Robert Gosford[2*], Dick Eussen[3], Nathan Ferguson[4], Erana Loveless[5], and Maxwell Witwer[6]

*We document Indigenous Ecological Knowledge and non-Indigenous observations of intentional fire-spreading by the fire-foraging raptors Black Kite (*Milvus migrans*), Whistling Kite (*Haliastur sphenurus*), and Brown Falcon (*Falco berigora*) in tropical Australian savannas. Observers report both solo and cooperative attempts, often successful, to spread wildfires intentionally via single-occasion or repeated transport of burning sticks in talons or beaks. This behavior, often represented in sacred ceremonies, is widely known to local people in the Northern Territory, where we carried out ethno-ornithological research from 2011 to 2017; it was also reported to us from Western Australia and Queensland. Though Aboriginal rangers and others who deal with bushfires take into account the risks posed by raptors that cause controlled burns to jump across firebreaks, official skepticism about the reality of avian fire-spreading hampers effective planning for landscape management and restoration. Via ethno-ornithological workshops and controlled field experiments with land managers, our collaborative research aims to situate fire-spreading as an important factor in fire management and fire ecology. In a broader sense, better understanding of avian fire-spreading, both in Australia and, potentially, elsewhere, can contribute to theories about the evolution of tropical savannas and the origins of human fire use.*

Keywords: *avian fire-foraging, avian fire-spreading, Black Kite, Brown Falcon, Whistling Kite*

Introduction

Overview of Australian Bushfire Management

Australian Aboriginal people possess fine-grained understandings of fire, utilizing it as a landscape and ecosystem management tool and to maintain cultural traditions (Gould 1971; Jones 1969, 1980; Kimber 1983; Tindale 1974). The value of their traditional ecological knowledge (henceforth "IEK," Indigenous Ecological Knowledge) of fire is widely accepted in collaborative (Aboriginal and non-Aboriginal) projects to restore pre-European fire regimes and attendant biodiversity to Aboriginal-owned landscapes (Bird et al. 2008; Bowman et al. 2004; Valentine et al. 2007). Though full and respectful incorporation of Aboriginal IEK in fire management remains elusive (Fache and Moizo 2015; Petty et al. 2015), such collaboration has been recognized as exemplary at the global level (Russell-Smith et al. 2013).

[1]Division of Mathematics and Natural Sciences, Pennsylvania State University-Altoona
[2]Central Land Council, 27 Stuart Hwy, Alice Springs, 0870, Northern Territory, Australia
[3]Tropical Australia Media, Mareeba, Queensland, Australia
[4]Northern Territory Fire and Rescue Service, Tennant Creek, Northern Territory, Australia
[5]School of Anthropology, University of Arizona, Tucson, AZ
[6]Environmental Resource Management Program, Pennsylvania State University
*Corresponding author (bgosford@gmail.com)

Throughout the northern Australian tropical savanna zone (parts of Queensland, Northern Territory, and Western Australia—henceforth "QLD," "NT," and "WA"), Indigenous, as well as non-Indigenous, people manage fire for community safety, range management (principally for cattle), wild and domestic food production, and a variety of ecosystem values. The term "fire-stick farming" (Jones 1969) accurately represents human food-producing strategies that, while not involving domestication, created intricate vegetation mosaics over tens of thousands of years. For example, people used fire to favor grass that attracted prey, such as kangaroos, and to stimulate the growth of plants used for human food or as food for hunted species, such as the Emu. Following their arrival in the late 1700s, European settlers seized Aboriginal land and cattle displaced native species while occupying enormous areas of habitat. But by the late twentieth century, owing to a series of legal decisions, restoration of Aboriginal land was proceeding apace and an overall focus on careful management of Aboriginal and non-Aboriginal land, including ecological restoration using fire, has become common.

Decisions for all fire managers—fundamentally, when, where, and how to burn or not to burn or to suppress fires in a given landscape—are related to fuel load, which is dependent upon widely-varying spatial and temporal factors, such as the amount of rains received. Early dry season fires may be set on purpose to reduce fuel load and, thus, risk of major conflagrations later in the year. Other "back burn" fires are lit as part of the overall strategy to stop bushfires started or spread by people, lightning, and other factors. Fires, though useful in range management, pose existential threats to livestock if uncontrolled (a factor for both Aboriginal and non-Aboriginal owners). Fire must also be controlled in and around numerous sacred sites that Aboriginal people and representative entities own and manage. These and numerous other complexities create the panorama within which a certain vector of fire-spreading, the "firehawk" (a generic term for Black Kite [*Milvus migrans*], Whistling Kite [*Haliastur sphenurus*], and Brown Falcon [*Falco berigora*]), takes on singular significance to local people across the region, while remaining virtually unknown to outsiders.

Avian Fire-foraging and Fire-spreading

Tropical savannas on fire attract fire-foraging birds that prey on vertebrates and invertebrates fleeing flames and smoke, as well as on the remains of animals killed by fires (Sick 1968; Thiollay 1971)[1]. Prominent fire-foragers are raptors, such as *Milvus* kites (Figure 1), that congregate in the hundreds at active fire fronts, along with members of numerous other species. The behavior has been mentioned in West Africa (Dop and Robinson 2012; Thiollay 1971), East Africa (Komarek 1969), Papua New Guinea (Majnep and Bulmer 1977:144), Florida and Texas, USA (caracaras of the genera *Caracara*, *Ibycter*, and *Polyborus*: Bonnicksen 2000:196; Komarek 1969:176–181), Panama (Komarek 1969), and Brazil (Oliveira and Marquis 2002). Australian accounts of fire-foraging raptors include Bradstock et al. (2002), Finlayson and von Oertzen (1996), Hood (1941), Main (1981), McCulloch (1966), Recher (1981), and Woinarski (1999).

Among behaviors local people and scholars attribute to fire-foragers in Australia is fire-spreading, the transport of burning sticks. Firsthand observers

Figure 1. Black Kites at bushfire in Queensland. Photo by Dick Eussen.

typically describe the behavior as intentional, but others who have heard of fire-spreading often believe it to be accidental[2]. We characterize local ecological knowledge of fire-spreading as follows. Raptors fly into active fires to pick up smoldering sticks in talons or beaks, transporting them up to a kilometer away and dropping them either in brush or in grass. Sticks may be from human cooking fires or from burning or smoldering vegetation. The imputed intent of raptors is to spread fire to unburned locations—for example, the far side of a watercourse, road, or artificial break created by firefighters—to flush out prey via flames or smoke. The behavior may occur once or repeatedly during the fire, by a single bird or by a small percentage of the overall raptors present. Attempts may be unsuccessful, with burning sticks dropped short of unburned areas or dropped but not igniting vegetation.

To shed light on this obscure but important phenomenon affecting fire ecology and management, and lend credence to IEK and local ecological knowledge in general, our study examines what is known about fire-spreading raptors through examination of the literature, ethnographical interviews of reliable sources, and our own first-hand observations.

Methods

We employed descriptive ethno-ornithological methods (see Tidemann and Gosler 2010) to understand the basic parameters of fire-spreading as reported in the literature and by credible witnesses we interviewed. We searched published

and unpublished literature from a variety of popular and scholarly anthropological, ornithological, and ethno-ornithological sources for reports of interactions between people, birds, and fire in tropical savannas in general and, specifically, of purported fire-spreading behavior by raptors in northern Australia and elsewhere. Between 2011 and 2017, Gosford and Bonta solicited and compiled accounts and opinions of the relationships between birds and wildfires (Bonta et al. 2016; Gosford and Bonta 2015). Gosford, who resided in NT during this entire period, regularly followed up on promising leads with phone calls and visits to potential witnesses across the region. In 2016, Gosford, Bonta, Loveless, and Witwer visited the Roper River region, Katherine, and Darwin, NT, to carry out interviews and initiate collaborative research with land managers. In May 2017, Gosford and Bonta visited Ferguson in Tennant Creek to survey local landscapes where Ferguson had observed fire-spreading.

Authors' Direct Observations

Eussen and Ferguson, with decades of experience in the Australian tropical savanna and numerous encounters with bushfires, have observed fire-spreading in NT and QLD on repeated occasions. We summarize highlights of their observations.

Direct and Indirect Observations by Others

Observers of fire-spreading, and others who had heard of it from witnesses they considered reliable, became known to us via responses to Gosford's *Northern Myth* blog posts on the subject (Gosford 2011, 2013, 2015a, 2015c, 2016) and following a mention in the *Tennant and District Times* (from Tennant Creek, NT [Afianos 2013]). In addition to verbal accounts of fire-spreading, we solicited photos and videos, but did not receive anything viable. Responses, though sparse, involved observers with lengthy experience at fire fronts, such as land managers and, particularly, fire-fighters. We excluded from consideration firsthand reports that were vague, reports from informants who did not respond to follow-up requests, and secondhand reports without adequate substantiation or from informants who did not appear to be sufficiently qualified to provide correct observations.

Communications between Gosford and purported observers led to formal interview sessions in person, by telephone, and by email. Free, prior, informed consent was granted for interviews and for paraphrasing and reproduction of communications to Gosford and of interviews cited in this article and its Supplementary Materials. Though questionnaires were administered in two cases (Ferguson and Akerman), our primary method of garnering data was via open-ended ethnographic interviews (including follow-up interviews) that allowed us to seek clarification on several points of contention; most importantly, what exactly the observer remembered seeing, under what conditions, and whether the observer felt that fire-spreading was intentional, as compared to accidental behavior. We stress that because, prior to fieldwork, so few details on fire-spreading were available to us, our lines of questioning evolved as we came to better understand it from talking to knowledgeable observers—how the birds behaved, what types of landscapes and fires were involved, and so forth. This

emerges in the interviews reproduced in the Supplementary Materials, culminating with Nathan Ferguson in 2017 (see Supplementary Material).

Exclusion of New Data from Aboriginal Sources

Though they have influenced our interview questions to non-Aboriginal informants, we exclude from the current paper unpublished firsthand reports of fire-spreading we gathered from Aboriginal people, only incorporating certain observations Aboriginal fire rangers made about the relationship of fire-spreading to fire management. Our reasons are in line with the ISE Code of Ethics (International Society of Ethnobiology 2006). First, we seek to fully respect the process of procuring access from Traditional Owners. Edelman (2009) discusses the various legal connotations of "Traditional Owners"; broadly, the term refers to people with recognized and enforceable legal rights to control access to land ("country") and to sacred knowledge and traditions involving that land. Knowledge involving firehawk raptors is intimately connected to protected Dreaming (Dreamtime) ceremonies and sites. "Dreaming" is an English rendition of numerous, distinct Aboriginal religious conceptions centered on the activities of ancestral beings who created Australian landscapes and their inhabitants (the older term "Dreamtime" has been superseded in recognition of the ontological status of these ancestral beings, understood to be atemporal, eternal, or, at least, misleadingly defined in terms of Western concepts of time; see McGrath and Jebb [2015] for detailed treatments of Australian Aboriginal temporalities and spatialities as they are currently understood). Thus, we are still understanding how to reproduce selective, so-called "outside" accounts that fully protect "inside" sacred knowledge about firehawks. Second, we are also carefully negotiating co-authorship to ensure all voices and contributors are properly acknowledged. Patterned on ethnobiological publications cited below (e.g., Garde et al. 2009), we plan future collaborative publication with Aboriginal authors that will greatly deepen and broaden what we present in this article.

Results

Our review of the literature and our interviews show that avian fire-spreading by at least three species of raptors is generally known to rural residents across northern WA, NT, and QLD, particularly to Aboriginal people, who also represent it in religious ceremonies, and to non-Aboriginal people. A small subset of the population has actually witnessed the behavior. Table 1, Figure 2, treatments in the main text, and the Supplementary Materials (Supplementary Reports 1–7) summarize and map fire-spreading reports and cultural beliefs from seven non-Aboriginal informants and 12 Aboriginal groups.

Indigenous Ecological Knowledge of Fire-Spreading

Across the world, sacred traditions embedded within IEK connect raptors, crows, cockatoos, and many other birds to the origins and maintenance of fire as a human tool (Frazer 1930; Sault 2016). In Australia, IEK of fire-spreading by the

firehawk is often related to Dreaming fire ceremonies such as *Lorrkon* (Garde et al. 2009) and *Yabuduruwa* (Berndt and Berndt 1994; Maddock 1970; Waterman 1987). The multi-day *Yabuduruwa* ceremony of the Roper River region around Ngukurr incorporates reenactments of birds, often raptors, carrying, stealing, initiating, or otherwise concerned with the creation or propagation of fire in the landscape, and has been the subject of several exhaustive studies (Capell 1960a, 1960b; Elkin 1961, 1971; Holmes 1965; Maddock 1969). However, in this literature, only Maddock (1969), who refers to fire-spreading as the origin and inspiration of the ceremonial practice, distinguishes mythological Dreaming events from IEK of present-day raptor behavior.

An account from the Roper River region initiated the modern-day scholarly controversy over the veracity and intentionality of fire-spreading. From Lockwood's (1963) *I, The Aboriginal*, a popular ghost-written autobiography of the Alawa man Waipuldanya (Philip Roberts):

> The kitehawks—we call them firehawks—are inventive hunters. Much of their natural food is caught and eaten on the wing, especially around the perimeters of bushfires where they swoop on fleeing grasshoppers. … Firehawks often confused us in welcoming visitors to our tribal lands by deliberately setting fire to grass and bushland to assist their scavenging. I have seen a hawk pick up a smouldering stick in its claws and drop it in a fresh patch of dry grass half a mile away, then wait with its mates for the mad exodus of scorched and frightened rodents and reptiles. When that area was burnt out the process was repeated elsewhere. We call these fires Jarulan. (Lockwood 1963:92)

> Not only the hawks used the ruse of deliberate grass fires as an aid to hunting. We often did so ourselves, especially towards the end of the long dry season when food was scarce and ten-feet tall speargrass, which burnt readily, was a natural haven for game. It is possible that our forefathers learnt this trick from the birds. (Lockwood 1963:95)

Waipuldanya's account was lauded as proof of a previously-undocumented avian tool use (Montagu 1970); further direct and indirect mentions (Allaby 1982:9–10; Beck 1980:25; Dozier 1999; Haidle 2006[3]; Kaplan 2015; Leseberg and Campbell 2015; Olsen and Joseph 2011) bolstered the acceptance of fire-spreading in scientific and popular literature, sparking speculation on its significance:

> It is but a small step from [kites spreading fire] to … fire-raising; humans have done it, and so have the kites. The birds do not make fire for themselves, of course, any more than the first humans did. They merely take advantage of naturally occurring fire … This is not farming, but it is worth mentioning … to refute the belief that it is only we who have mastered the use of fire: we are not alone in taking that first step, which in our case led to farming. (Allaby 1982:9–10)

Especially notable in Waipuldanya's account, and reactions to it, are suggestions that humans have learned to utilize fire from watching birds. But Western scientific skepticism is also present in responses to Waipuldanya and to

Table 1. Local knowledge of fire-spreading in northern Australia.

R#[a]	Loc./Reg.[b]	Date/s[c]	Ethnic group/s[d]	Source[e]	Spp. involved (terms)[f]	Details[g]
1	Ngukurr NT		*Alawa*	Waipuldanya, via Lockwood (1963)	"kitehawk", "firehawk":?	IEK-I. Spreads grass and bushland fires; carries sticks up to 1 km. Resulting fires called *Jarulan*.
2	Nauiyu Nambiyu NT		*MalakMalak*, *Matngala*	Lindsay et al. (2001:78)	"chicken hawk", "*Kerrk*" (Mal.), "*Num*"(Mat.):BK	IEK-D. Fire-spreading occasionally seen. Related to Dreaming.
3	Arnhem Plateau NT		Ab. people	Garde et al. (2009:144–145)	"*karrkkanj*":BF	IEK-D. Spreads grass fires to unburnt grass patches and across creeks. Related to *Lorrkon* ceremony.
4	Maningrida NT		*Dalabon*	Maggie Tukumba, via Evans et al. (2004:56, 147)	"*karrkkanj*", "firehawk", "eaglehawk":?	IEK-D. Spreads fires.
5	Katherine Region NT		*Jawoyn*	Wiynjorrotj et al. (2005)	"*Karrkkayn*":BK	IEK-D. Fires-spreading. Also includes Square-tailed Kite (*Lophoictinia isura*) and possibly Brown Goshawk (*Accipiter fasciatus*).
6	Victoria R. NT		*Bilinarra*, *Gurindji*, *Malngin*	Hector et al. (2012:201)	"*Bulugura*" (Bil.), "*Pulukura*" (Gur.), "*Warluyawung*" (Gur.):WK	IEK-D. Starts grass fires.
7	Wilton R. area NT		Ab. people, relayed to D. Eussen	Eussen and Angelo (2003) [late 1960s]	"kites":BK-u,WK-u	IEK-I. Spreads fire by carrying sticks across creeks.
8	Melville I. NT		*Tiwi*, relayed to J. Lewis	S.R. 6 [2012]	"firehawk":?	IEK-I. Plantations burned at Pickertamoor. Imputed as cause of anomalous fire-jumping on several occasions.
9	Katherine Region NT		Ab. people, relayed to D. Angelo	Eussen and Angelo (2003); Martin (2004) [1992–2004]	"hawk", "firehawk":?	IEK-I.

Table 1. Continued.

R#[a]	Loc./Reg.[b]	Date/s[c]	Ethnic group/s[d]	Source[e]	Spp. involved (terms)[f]	Details[g]
10	N of De Grey WA		Ab. people, relayed to B. Baker	S.R. 1 [1969]	"shit-hawk":BK-u	IEK-I. Coastal scrub. Not uncommon behavior.
11	Drysdale R. area WA	June 28 1977	*Ngarinyin*, *Wunambal* & *Worora* men w/ K. Akerman	S.R. 5	BK	D. Open forest, only grass burning. c. 1 PM. 1 event, 1 bird. Carried short thin stick 15–20 m ahead of front, dropped, sparking grass fire. WK also present. 5 observers.
9	Katherine Region NT	1992-2004		D. Angelo (S.R.4)	"hawk", "firehawk":?	D and I. Various occasions seen. Also imputed by firefighters fighting grass fires.
10	N of De Grey WA	1969		B. Baker (S.R. 1; Afianos 2013)	"shit-hawk":BK-u	D. Coastal scrub. 1 bird, 1 event. 30–38 cm-long stick. Successful. 2+ observers 25 to 30 m away.
12	Broome-Derby Rd WA	May 1980 or May 1981		K. Akerman (S.R. 5)	BK	D. Open forest, only grass burning. c. 10:30 AM. 1 event, 1 bird. Stick carried 15 to 20 m ahead of front and dropped. WK also present. 1 observer.
13	Lakefield NP QLD	No date		Martin 2003	?	I.
14	Southwell Station Rd QLD	Sept. 8 2012		D. Eussen	BK	D. 1 unsuccessful attempt by 1 bird to move fire across road; 1 apparently successful attempt by another bird. 1 observer.
15	Ranger Uranium Mine NT	1980s		D. Eussen	WK	D. Grass fire, afternoon. BK also present. 2 WK of 12 present able to transport sticks up to 20 cm in length. Spread numerous small fires, in successful and unsuccessful attempts. In 1 event, WK 20 m from observer dropped burning stick in grass, igniting it. 1 observer, but others had also seen similar behavior.
16	Hodgson R. NT	No date given		B. White (S.R. 2)	"shit hawk", "kite hawk": BK-u	D. Group of birds. Successful. Repeated events. 1 observer.

Table 1. Continued.

R#[a]	Loc./Reg.[b]	Date/s[c]	Ethnic group/s[d]	Source[e]	Spp. involved (terms)[f]	Details[g]
17	Ivanhoe Station WA	Late 2002		M.J. (S.R. 7)	"kites":BK-u	D. Grass and scrub. Small number of birds, carrying sticks 7.5–10 cm long across river. Successful. Multiple events. 1 observer.
18	Warrego Rd, Tennant Creek NT	Mar. 15 2017		N. Ferguson (S. R. 3)	BF-u, BK, WK-u	D. Grasses and brush. 10:15 AM. 12–15 birds. Various events. 6–8 cm-long sticks. Unsuccessful. Various observers.
19	Kraut Downs, Tennant Creek NT	Mid-Sept 2016		N. Ferguson (S. R. 3)	BF-u, BK, WK-u	D. Grass and sparse brush. 1 bird, 1 event, successful.
20	Howard Springs NT	2000-2001 dry season		N. Ferguson (S. R. 3, Afianos 2013)	BF-u, BK, WK-u	D. Grass. 12-2 PM period. 100s of birds. 1 event. Carried 8–20 cm-long stick for 60 to 75 m. Event occurred 40 m from various observers. Successful.

[a] Record number: see also Figure 1. NT = Northern Territory; QLD = Queensland; WA = Western Australia.
[b] See Figure 2.
[c] No dates of observation given for Indigenous Ecological Knowledge of fire-spreading.
[d] Ab. = Aboriginal (ethnic group not specified). Column left blank if observation/s made by non-Aboriginal sources.
[e] S.R. = Supplementary Reports (previously unpublished data) [bracketed number indicates date/s of IEK transmission to outsider].
[f] "local name" (Indigenous language):species. BK = Black Kite; BF = Brown Falcon; WK = Whistling Kite; u = identification uncertain; ? = id unknown.
[g] IEK: Indigenous Ecological Knowledge. D/I: Direct/Indirect observation/s. "Direct": for IEK (IEK-D), knowledge transcribed directly by trained collaborator (not possible to determine whether Indigenous informant/s had personally seen the behavior); IEK-I refers to casual references made (to common knowledge of fire-spreading) to non-Indigenous observers. In the case of non-Aboriginal observers' records: D = observer saw fire-spreading her/himself; I = informant recounts credible observations made to her/him by others. "Event": fire-spreading by a raptor. "Successful": raptor was observed to pick up, carry, and drop a burning stick, igniting an unburned patch of vegetation, typically grass.

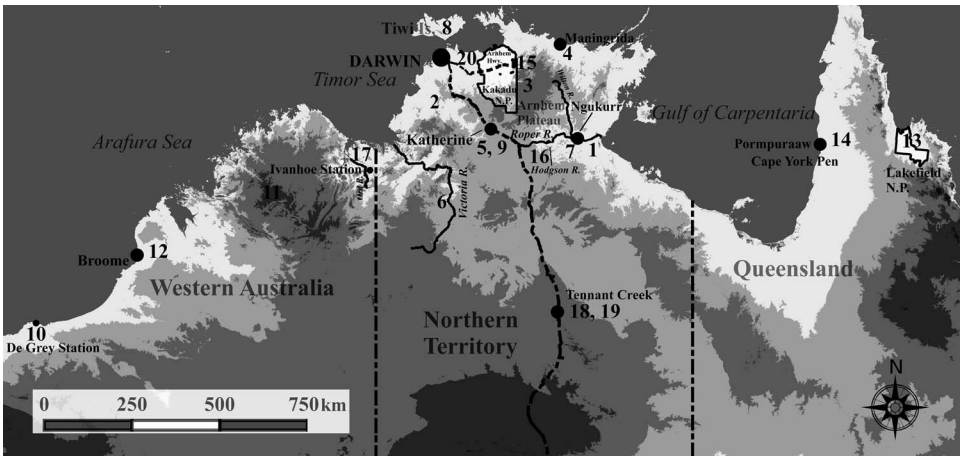

Figure 2. Records of fire-spreading by raptors in Northern Australia. Map by Erana Loveless. **MAP KEY: Sources of fire-spreading reports and local knowledge** (*Language group*) – Specific location: [1]Lockwood 1963 (*Alawa*); [2]Lindsay et al. 2001 (*MalakMalak* & *Matngala*)—Nauiyu Nambiyu area; [3]Garde et al. 2009 (Aboriginal); [4]Evans et al. 2004 (*Dalabon*); [5]Wiynjorrotj et al. 2005 (*Jawoyn*); [6]Hector et al. 2012 (*Gurindji*, *Bilinarra*, *Malngin*); [7]Eussen and Angelo 2003 (Aboriginal); [8]J. Lewis, pers. comm.(Tiwi) – Pickertaramoor; [9]Eussen and Angelo 2003 (Aboriginal and non-Aboriginal); [10]B. Baker, pers. comm. (Aboriginal and non-Aboriginal); [11]K. Akerman, pers. comm. (Aboriginal); [12]K. Akerman, pers.comm.—Broome-Derby Rd; [13]Martin 2003; [14]D. Eussen—Southwell Station Rd; [15]D. Eussen—Ranger Uranium Mine; [16]B. White, pers. comm.; [17]MJ, pers. comm.; [18]N. Ferguson—Warrego Rd; [19]N. Ferguson—Kraut Downs; [20]N. Ferguson—Howard Springs.

the sources that cite him uncritically, as well as to more recent ethnographic data reported by other sources, including by us (Gosford 2015b; Gosford and Bonta 2015). Fire-spreading, while typically accepted as non-mythological, is often discounted as an unintentional behavior (Goudsblom 1986:518–519). For example,

> Local Aboriginal people believe the Black kite actually sets fires by carrying burning sticks from fires to new locations and dropping them into dry grass and setting it alight. While we have seen birds occasionally pick up small smouldering sticks, they usually quickly drop them. They are likely to have accidentally picked up sticks while stooping for small fleeing prey close to the fire. (Braithwaite and Estbergs 1987:300)

McCrie and Noske (2015), Olsen (cited in Martin 2003), Shumaker et al. (2011), and raptor experts Steven Debus and Anthony Molyneux (comments in Gosford 2011) also suggest that fire-spreading is likely accidental. Though Waipuldanya's account bears the hallmarks of an authentic and faithful ethnography, Lockwood's use of non-Aboriginal concepts in its re-telling (Anonymous 1962) makes it less than rigorous by present-day standards, thus warranting cautious skepticism. However, a small, independent body of ethnobiological literature produced by collaborative ventures of Aboriginal and non-Aboriginal researchers (Evans et al. 2004; Garde et al. 2009; Hector et al. 2012; Lindsay et al. 2001; Wiynjorrotj et al. 2005) also includes IEK of fire-spreading,

encapsulating numerous direct observations from distinct parts of NT interwoven with religious beliefs. The literature, little-known outside Australia and not cited by recent skeptics, bears closer examination and is quite credible (Table 1:Records 2–6).

The six published accounts (including Table 1:Record 1) span 1963 to 2012 and reproduce or paraphrase IEK of fire-spreading recounted by women and men from eight Aboriginal groups in NT. The brief mentions speak exclusively of raptors picking up and carrying burning sticks in the talons, mostly in grasslands or open forests with a grassy understory, sometimes across creeks. Fire-spreading is understood as an intentional way to flush out prey. Species include Black Kite (*Milvus migrans*), Brown Falcon (*Falco berigora*), and Whistling Kite (*Haliastur sphenurus*). Dreaming occurrences and IEK, where mentioned together, are differentiated. A representative example is from a compendium of Aboriginal knowledge from the Arnhem Plateau (Garde et al. 2009:144–145):

> *[K]arrkkanj* the brown falcon … does more than just wait for the fire to burn into large patches of grass. This bird will swoop down, pick up a fire brand and fly off to drop it into another patch of grass. When a fire burns into a creek line and burns out, brown falcons have also been observed collecting fire brands and dropping them on the other unburnt side of the creek in order to continue the fire. This association of brown falcons and fire is celebrated in rituals associated with the hollow log ossuary ceremony known as lorrkkon. ….. As they depart the public camp in the early evening, men of a particular patrimoiety subsection … line up and in imitation of the brown falcon, they hold a fire brand aloft as they celebrate this special bird in song and ritual.

Additionally, five records of fire-spreading IEK transmitted from Aboriginal to non-Aboriginal people, published here for the first time (Table 1:Records 7–11; see also accompanying narratives in Supplementary Material), expand the scope of what we know of Aboriginal IEK both in geographical extent (Tiwi Islands NT; two WA records: see Figure 2) and in ethnic diversity. Thus, in all, we are able to identify 12 ethnic groups with first-hand knowledge of fire-spreading.

Non-Aboriginal Observations of Fire-Spreading

Below, and in the next section, we discuss reports from six non-Aboriginal observers who, in most cases, had previously heard of fire-spreading from Aboriginal people and, while skeptical, were eventually able to witness it themselves, sometimes in the accompaniment of Aboriginal people, on a single occasion or multiple occasions (see Table 1:Records 9–13, 16, 17; Supplementary Materials: Reports 1, 2, 4–7). Most of these data are either published here for the first time or are augmented accounts with new data we solicited based on prior publication in local magazines and newspapers; none have previously appeared in academic journals. These six individuals have each spent many years in the tropical Australian bush, either closely involved with managing wildfires or encountering them while driving or hiking.

Belief, albeit skeptical, in the reality of fire-spreading is as common to non-Aboriginal culture as it is to Aboriginal culture of northern Australia, though, in

the former context, it is shorn of any religious or traditional significance. Typically, non-Aboriginal people in the region have heard of fire-spreading secondhand (for example, we were told that tour guides to Kakadu National Park mention it to visitors), but quite rare is an informant who has unequivocally witnessed it and can recount convincing details under close scrutiny.

Two academic researchers report fire-spreading. Anthropologist Kim Akerman recounts having observed single Black Kites spreading fire twice during grass fires in WA (Table 1:Records 11 and 12; Supplementary Report 5). Anthropological linguist Denise Angelo relates having learned about fire-spreading from Aboriginal people and subsequently witnessing it on several occasions during her extensive bush work in the Katherine, NT region (Eussen and Angelo 2003; Martin 2004; Table 1:Record 9; Supplementary Report 4). It was well known to local firefighters, who attributed to raptors the potential to re-ignite already contained fires, a common and significant complaint among NT land managers (see Discussion).

Two eyewitnesses report intentional, cooperative fire-spreading. Bob White (Table 1:Record 16), while fighting a bushfire in the Roper River, NT region, watched a small group of raptors—presumably Black Kites—pick up numerous smouldering sticks and transport them ahead of a fire front, successfully helping the blaze spread up a small valley. "MJ," a Kimberley, WA cattle station caretaker manager (Table 1:Record 17; Supplementary Report 7), saw kites working together to move a late dry season fire across a river by picking up, transporting, and dropping small, burning sticks in grass, which immediately ignited in several places. The experience resulted in an uncontrollable blaze that destroyed part of the station's infrastructure. The observer later saw the larger group of hundreds of kites that had gathered for the fire actively pursuing prey in the intentionally burned area.

Direct Observation of Fire-spreading by the Authors

While driving past a smoky roadside fire on the Cape York Peninsula, QLD, Dick Eussen saw Black Kites swooping on prey amidst smoke and sparks, while others hopped about on the road in front of the fire as it burned itself out (Table 1:Record 14). He saw one bird swoop to grab a smoking stick in its talons, dropping it onto the road. The ember was apparently too hot for the kite to hold. Another was more successful, dropping a stick on the other side of the road in the unburnt grass, which soon flared up. (This is the only direct observation of fire-spreading that has come to us from Queensland.)

Another fire-spreading encounter occurred at the Ranger Uranium Mine near Kakadu, NT, where Eussen was a firefighter (Eussen and Angelo 2003; Martin 2003, 2004; Table 1:Record 15). One afternoon, while he was ensuring that a grass fire did not leap across a highway, he observed fire-foraging activities of both Whistling and Black Kites. Though the fire burned itself out, Eussen was alerted to a new blaze on the unburnt side of the road. He drove over and put it out, noting a Whistling Kite flying about 20 meters in front of him with a smoking stick in its talons. It dropped the stick and smoke began to curl from the dry grass, starting a spot fire that had to be immediately extinguished. In all, he put out seven fires, all caused by the kites. On that occasion, approximately 25 kites

were foraging at the edge of the dying fire, but only two were adept at transporting smoking sticks. One repeatedly swooped at a stick, only lifting it a meter or less before dropping it.

Nathan Ferguson, officer in charge of Tennant Creek's fire station in the Barkly Tablelands, has managed fire across most of the NT since 1998 and has observed fire-spreading about a dozen times since 2001 (Afianos 2013; Table 1:Records 18–20; Supplementary Report 3). Though he initially discounted secondhand reports, after long experience, he has learned to incorporate the possibility of avian fire-spreading as a variable in bushfire management and, where he does not directly observe it, he infers its occurrence because he can find no other explanation (e.g., wind) for fires that have been completely controlled but later re-ignite. His belief concurs both with Tiwi firefighters on Melville Island, NT, where firefighter Jason Lewis worked (Table 1:Record 8), and with firefighters in Katherine, NT, as reported by Angelo (Eussen and Angelo 2003; Martin 2004; Table 1:Record 9; Supplementary Report 4).

While Ferguson's most recent fire-spreading observation in March 2017 (Table 1:Record 18) involved unsuccessful attempts to transport burning sticks, previous observations that stand out most to him, from September 2016 and around 2000-2001 (Table 1:Records 19 and 20), were of a few kites, within gatherings of hundreds during very hot fires, successfully seizing burning sticks in their beaks, sometimes switching them to their talons, transporting them over 50 meters, dropping them, and, thus, igniting unburned grass. Like several other non-Aboriginal observers, and in concordance with Aboriginal IEK, Ferguson is adamant that fire-spreading behavior, whether successful or not in starting new fires, is intentional.

Discussion

Fire-spreading by raptors is found across a 2400 km E-W and 1000 km N-S swath of northern Australia. The behavior is likely known to most, if not all, Aboriginal groups within this region. Most accounts and traditions unequivocally indicate intentionality on the part of three raptor species and a handful provide evidence of cooperative fire-spreading by select individuals from within larger fire-foraging raptor assemblages.

Those who have not witnessed fire-spreading either discount its veracity or believe it to be unintentional. On the one hand, this belief is bolstered by the lack of unequivocal video or photographic evidence, though this article mitigates that circumstance by presenting IEK, as well as in-depth first-hand observer reports. On the other hand, though, lack of acceptance derives ultimately from the fact that biologists have not published the results of any attempted tests of hypotheses of fire-spreading behavior (or, if they have, these are not cited in ornithological literature and are unknown to us). We suspect that the primary barrier to this type of study has been the inherent risk associated with working at active fire fronts.

Equivocation exists in the identities of fire-spreading species. This difficulty of identification begins with Waipuldanya's "firehawk" account from the Roper River region (Lockwood 1963), which later writers assumed to be the Black Kite, even though the Brown Falcon (*Falco berigora*) has been mentioned to us unequivocally as the principal fire-spreader there. Three factors contribute to this confusion and are important to note for future research that seeks greater rigor: 1) those who recorded the IEK did not or could not allot sufficient resources—e.g., field trips to observe species in habitat, use of field guides and binoculars, persistent questioning—to understand exactly what species were being invoked; 2) most reports by both Aboriginal and non-Aboriginal observers do not involve the use of binoculars and, in many cases, particularly during wildfires, it is quite difficult to differentiate northern Australian raptor species, even for experienced viewers (see Debus 2012); and 3) the three main species clearly cited and distinguished as fire-spreaders are also by far the most abundant local raptor species across the tropical savanna region, but scarcer species may also be involved (e.g., Wiynjorrotj et al. 2005, who cite Square-tailed Kite [*Lophoictinia isura*] and possibly Brown Goshawk [*Accipiter fasciatus*]).

We hesitate to speculate on the temporal and spatial variation of fire-spreading, given that, while one of us (Ferguson) has observed it relatively frequently (paralleling several Aboriginal collaborators who have referred to it as common), others remember seeing it only once during an entire career in the bush. While it seems to be most common in the Barkly Tableland and Roper River regions, this locational bias is almost certainly an artifact of where we have concentrated our fieldwork.

Among fire managers, the correlation of avian fire-spreading to anomalous bushfire-jumping[4]—fires that flare up in new locations after having been fully controlled—is a serious issue not yet accorded sufficient credence by outsiders. According to fire managers with whom we spoke in Ngukurr, Katherine, and Tennant Creek, lack of credence afforded this phenomenon leads to impressions that local firefighters are inexperienced and may even be prevaricating, blaming the birds for their own shoddy work. Beyond this, resource managers working with the Yugul-Mangi Land and Sea Rangers (Ngukurr, NT) and the Jawoyn Rangers (Katherine, NT) believe that scientific acceptance of avian fire-spreading would aid planning for fire management and conservation efforts by allowing rangers to justify including it as a variable to consider in their work. Aboriginal ranger groups, funded largely by the Australian government, are tasked with protecting and restoring vast parts of the Australian North and fire management—to protect and sustain sacred sites, biodiversity, productivity of pasture for livestock, public safety, and so forth—is absolutely essential in this endeavor. In addition, non-Indigenous managers, such as Ferguson, can benefit by learning non-destructive ways of dealing with the raptors. An anecdote that came to us during the final revisions of this article serves to underscore the importance of this for the raptors: workers at a certain cattle station are accustomed to dealing with the problem of fire-spreading by taking shotguns to work and simply killing as many birds as necessary to protect pasture and livestock.

In our continuing research, we plan to utilize approaches combining controlled experiments (e.g., fire managers lighting fires purposely, under a

variety of conditions, to allow trained field technicians with adequate equipment to document, and then describe and quantify, fire-spreading behavior), ethno-ornithological interviews, and provision of protocols and equipment to bushworkers, most notably Aboriginal rangers, to enable them to record the behavior. We note that Aboriginal rangers themselves have requested this hybrid approach that respects IEK while incorporating a range of scientific tools and methods. It is paramount that natural scientists, particularly those also interested in ecological restoration and biodiversity conservation, collaborate closely with ethno-ornithologists and local people and learn how to apply rigorous interview techniques, not only to enhance their own studies, but also to learn about unknown or previously discounted avian behaviors that are potentially of great significance.

Though we have not yet found unequivocal accounts of fire-spreading outside Australia, this research has potential in other tropical savanna regions as well. Ethno-ornithological inquiry about birds and fire should be incorporated into anthropological, geographical, and historical investigations of landscape modification; the roles of birds in both religious and secular context are primordial and remain key in these endeavors, though they are too often overlooked. Our study opens broader questions about evolutionary origins of avian fire-spreading, effects on tropical savanna vegetation mosaics, and influences on human approaches to fire management. Though we are not necessarily claiming that Waipuldanya was correct in saying that our ancestors learned about fire setting from observing birds, we do suggest that researchers who engage IEK take such beliefs into consideration as we continue to deepen our knowledge of the intricate ways humans and other species have co-evolved and, in doing so, co-create tropical savannas.

Notes

[1] "Fire followers," sometimes used in place of "fire-foragers," is easily confused with "fire following birds" that make use of burned habitats (e.g., Parker III and Willis 1997; Woinarski 1999).

[2] Online accounts and conference presentations on fire-spreading in NT, WA, and QLD (Gosford 2011, 2013, 2015a, 2015b, 2015c, 2016) were picked up by international media in 2016 (e.g., Lagan 2016; Main 2016; McFarland 2016), which sparked discussion of whether or not the behavior is intentional.

[3] Haidle's study (2006) includes a diagram of Black Kite fire-spreading behavior, but concludes that it does not constitute tool-using per se.

[4] According to Ferguson, this can also be caused by fleeing mammals that have caught fire (Supplementary Report 3).

Acknowledgments

Penn State Altoona (Advisory Board Award for Research and Creative Activity; Division of Math and Natural Sciences travel grant) and Mrs. Hayley Witwer funded 2016-2017 fieldwork. We also wish to thank: Dave Watson (Charles Sturt University), Fleur

Ng'weno (Nairobi, Kenya), Nelson "chook-chook" Hall, Bobby Nungumajbarr, Walter Rogers (Ngukurr), Chris Watson (Melbourne and Alice Springs), Peter Cooke, Murray Garde, Deborah Bird-Rose, Ron and Wendy Levy (accommodation and support in Darwin), Andrew Campbell and staff (Research Institute for the Environment and Livelihoods at Charles Darwin University), and Samuel Bush-Blanasi (chairman, Northern Land Council). Invaluable support and guidance were also provided by Stephen Luntz (IFLS Australia), all the interviewees, and commentators on blog posts, articles, and conference presentations.

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