Title: Primate behavior in burned landscapes: Responses and insight into the origins of hominin fire use

Introduction:

Human fire use is a distinct and recognizable trait with far reaching consequences on the evolution of our species. Questions surrounding the origins of human-controlled fire have implications for the evolution of cognition as well as cranial and post-cranial anatomy, among others (Twomey 2013). Insight into extant primate-fire interactions as an analog for hominin fire-interactions can provide insight into the origins of human fire use (Herzog 2015). The Pyrophilic Primate Hypothesis states that primate interaction with increasingly fire-prone environments led to adaptations such as exploiting suddenly available (food) resources that were more efficiently accessible (Parker et al. 2016). If naturally occurring fires impacted hominin behavior in a selectively advantageous way, it is possible that extant chimpanzee populations may exhibit similar responses to fire as well. There is some evidence to support this. At Fongoli, southeastern Senegal, chimpanzees have been observed monitoring and avoiding fire (Pruetz and LaDuke 2010). Even if not outright resource exploitation, such behaviors are in many ways indicative of a deeper knowledge of fire and fire movement, necessitating further expiration into the veracity of chimpanzee-fire interactions.

Literature review:

Hypotheses regarding fire-prone environments as the impetus for behavioral change in animals, and its implications on human evolution, have been proposed since the mid twentieth century (Komarek 1969). These early explanations of the interaction between hominins and burned landscapes relied on pre-existing frameworks of culturally dependent fire use.

Over the last decade and a half, fire and the impacts of burned landscapes on hominin evolution have gained increased prominence in our reconstructions of paleoecology. This recent literature emphasizes several functional advantages of exploiting a post-fire environments and how those selective advantages shaped hominin evolution including increased predation detection (e.g. Hoare 2019; Herzog et al. 2020), foraging efficiency (Herzog et al. 2022; Sandgathe 2017), and reduction in food processing cost (Parker et al. 2016). The literature concerned with predation detection posits that an increase in traversability of the landscape in combination with a decrease in ambushable areas makes these zones preferable after burning (Hoare 2019). Examinations of foraging efficiency pre- and post-fire centering on ease of access and the relative abundance of high value food items like cooked food (Hoare 2019; Herzog et al. 2022), have provided evidence of a caloric incentive to exploit these burned areas. Processing cost analyses have also shown that cooked food, and the lower caloric intake required to digest it, is an important factor in reducing the cost of caloric acquisition (Herzog et al. 2022). Beyond this there is also an emphasis on reduced handling cost such as in reduced chewing effort (Parker et al. 2016). These functional advantages of fire exploitation affirm the evolutionary pressures

inherent to fire-prone environments and why understanding them matters for understanding human evolution.

Fire regimes as a means of understanding fire-prone paleoenvironments over both temporal and spatial scales have an important role in our interpretations of paleo-fire ecology (Whitlock et al. 2010). A fire regime refers to the average climate and how variable it is, in combination with how the climate reacts with vegetation and landscape as constant forces affecting fire ecology (Whitlock et al. 2010). The most common contexts in which fire regimes appear in the literature is that of both changing regimes and hominin impact on preexisting fire regimes (e.g. Attwell et al. 2015; Parker et al. 2016). The importance of fire regimes in the literature provides the opportunity to not only define clear analytical boundaries in both time and space, but provides a vehicle through which comparison can be made between modern communities and our paleo hominin ancestors.

The recent work into fire-hominin interactions studies has been related to a variety of factors, including the increase of study sites in fire-prone environments (Sandgathe 2017). These study sites and the resulting data which subsequently emerge are imperative to establishing analogous environments to Plio-Pleistocene habitats and reconstructing hominin fire interactions (e.g. Pruetz and Herzog 2017; Hoare 2019; Herzog et al. 2022; Herzog et al. 2020). Without these sites, the literature would not only suffer, but would be wholly impossible. Due to this there is a great need to increase the number of study sites at fire-prone localities. It is only with more data from non-human primates that we're able to truly build and refine accurate models of hominin interactions with fire-prone landscapes.

Statement of Problem and Justification:

The number of areas where we can study primate responses to fire is extremely limited. Issa Valley is well situated to be an important contributor to this topic. This is due to a variety of factors including the relatively high frequency of fires at Issa in which over 70% of the landscape (Piel et al. 2019), the long term ecological and primatological data which has been collected ranging from rainfall statistics to camera trap data (D'Ammando et al. 2022), and the similarity of Issa ecology to the mosaic savannah hominins evolved in as seen in studies already comparing food modalities of chimps at Issa to Plio-Pleistocene environments (Drummond-Clarke et al. 2022). These factors in combination with the need to increase the scope of research on primate fire interactions makes Issa an excellent match for this study's objectives.

Objectives and Significance:

The goal of this project is to observe how primate behavior changes in response to fire and burned land cover. I am interested in establishing a firm understanding of exactly how

‘fire-prone’ Issa Valley is by using the previously existing ecological data collected over the last fifteen years. I hope to establish a better understanding of how primates utilize these environments post burn. This includes alterations to methods of resource acquisition and resource quality. Included within alterations to resource acquisition I hope to better understand how fire affects ranging patterns across species. Finally, I will assess whether seasonal variability has an effect on the foraging or landscape traversal strategies employed by primates at Issa, and whether seasonal variability in fire is a valid evolutionary factor to consider when exploring the origins of hominin fire interactions.

1. Examine how ‘fire-prone’ Issa valley is via remote sensing such as camera traps, temperature sensors, and temperature-indicating paints.
    a. Compare to other sites active in research on primate fire.
    b. Determine whether sites with seasonal fire caused by humans are valid as analogs for hominin interactions with fire by comparing the most commonly burnt ecologies, floral communities in burn and post burn environments, and the percent of total landscape burnt by humans in season fires to naturally occurring fires.
2. Examine the degree to which primates at Issa Valley utilize post burn environments
    a. Assess how methods of resource extraction alter
        i. if there is any significant change in resource quality which may incentive primate interaction such as access to cooked food or other newly available food goods.
        ii. Assess any changes to primate mobility caused by fire, either in accessibility or traversability of a burned area via ongoing chimpanzee observational studies.
3. Assess if seasonal variability in fire intensity is a determining factor in primate behavior towards fire
    a. Develop a strategy for determining fire intensity, and subsequently being able to compare burn intensity on a temporal basis at Issa Valley.
        i. I.e. buren area, fire temp, vegetation burn extent, ect.
    b. Use comparisons of seasonal changes in fire intensity at Issa to assess the effects of seasonal variability of fire in primate response strategies.
        i. Whether primates respond to fires at Issa differently depending on the intensity of a particular fire event.

By conducting this project there will be a broader understanding of fire ecology at Issa Valley, as well as the ability to gain a more nuanced understanding of interactions between fire and primates. Contributing to the understanding of fire ecology at Issa Valley is imperative to understanding the evolutionary pressures faunal communities in that area are under. Furthermore,

understanding the fire ecology of Issa specifically allows for a comparison to be made across fire-prone areas due to naturally occurring fire opposed to human ignited fires. By exploring the strategies employed by primates at Issa in response to fire the ability to model the behavior of hominins in response to fire in mosaic savannahs is greatly increased.

Hypotheses:

H1: The seasonal fires at Issa, despite being human caused, are comparable to seasonal fires at other primate study sites and Plio-Pleistocene hominin environments.

H2: Primates at Issa Valley change behavior to better interact with fires and environments post burning

H3: Seasonal variations in the intensity of fires have an effect on the strategies employed by primates at Issa Valley.

Methodologies:

Site Comparison To compare the fires of Issa and other study sites over a long period of time I will rely on the ecological data collected at these sites since their inception as the basis for this work. In the case of Issa there is roughly a decade and a half of ecological data which can be used to compare against other sites. This data in combination with contemporary burn observations will give insight into the nature of fires at Issa, as analysis of both long-term trends and short-term phenomena provide crucial insight into fire ecology. Comparison will be done on the basis of chimp home range burn %, post-burn area interaction frequency, post-burn floral ecology, post-burn faunal ecology, and fire stimulated behavioral change in faunal communities. Analysis will be done by assessing the significance of differences in these variables compared to the study site Fongoli. For example, to assess post-burn area interaction frequency the percentage of burnt land in a home range would be weighed against the number of interactions observed between primates and post-burn areas, which would then be tested against the same statistic from Fongoli to determine the significance of their difference.

Primate Behavior Observation To assess primate interactions with fire at Issa I will use an ad libitum sampling method as the basis for recording observations. During times of high seasonal fire I plan on utilizing the already ongoing focal sampling as well to increase the probability of observing primate fire interactions. Specific behaviors which will be looked for during times of increased fire abundance include fire specific calls, movement with clear indication of knowledge of how fire moves, and fire avoidance. In areas post burn, behaviors such as travel modes associated with open burnt landscapes, novel foraging techniques, and time

spent in post burn landscapes will be specifically monitored for. The biggest issue with studying fire interaction is actually observing it, as creating the conditions for experimentation in this context is extremely unethical, leaving little to do but wait and observe if something occurs.

Seasonal Variation Analysis To determine the effects of seasonal variability at Issa I must first determine the amount fire intensity varies each year. To do this I will use the previously existing ecological data that has been collected from the past fifteen years to determine change on a seasonal time scale. The statistical method for doing so will be through a regression analysis in order to test the change in fire intensity over time. Once an understanding is gained of how much seasonal variation there was over the course of that fifteen year period it can be compared against primate behavior recorded during high burn periods. Specific behaviors to be observed for seasonal variability include foraging strategies, time spent foraging, foraging range, and time spent processing foraged food (i.e. chewing/digesting). Once these two data sets are collected they can be compared against each other for overlap in seasonal variability in burn ecology and primate behavior.

Expected Outcomes:

This study aims to increase the body of literature concerning primate interactions with fire, and post burn landscapes, as a means of better being able to model hominin interactions with fire. The assessment of Issa as a comparable site to the fire-prone environments hominins evolved serves to validate the comparison between the two as well as expand our understanding of what constitutes ‘fire-prone’ and what the limitations of its definition are in the context of hominin fire use.

References

Attwell, Laura, Kris Kovarovic, and Jeremy R. Kendal. "Fire in the Plio-Pleistocene: the functions of hominin fire use, and the mechanistic, developmental and evolutionary consequences." *Journal of anthropological sciences* 93 (2015).

D'Ammando, Giacomo, et al. "Ecological drivers of habitat use by meso mammals in a miombo ecosystem in the Issa Valley, Tanzania." *Frontiers in Ecology and Evolution* 10 (2022): 773568.

Drummond-Clarke, Rhianna C., et al. "Positional behaviour of chimpanzees living in the savannah-mosaic environment of Issa Valley, Tanzania: Insights to the origins of human bipedalism." (2022): 45.

Herzog, Nicole M., et al. "Fire's impact on threat detection and risk perception among vervet monkeys: implications for hominin evolution." *Journal of Human Evolution* 145 (2020): 102836.

Herzog, Nicole M., Jill D. Pruetz, and Kristen Hawkes. "Investigating foundations for hominin fire exploitation: Savanna-dwelling chimpanzees (Pan troglodytes verus) in fire-altered landscapes." *Journal of Human Evolution* 167 (2022): 103193.

Herzog, Nicole Marie. *Primate behavioral responses to burning as a model for hominin fire use*. The University of Utah, 2015.

Hoare, Sally. "The possible role of predator–prey dynamics as an influence on early hominin use of burned landscapes." *Evolutionary Anthropology: Issues, News, and Reviews* 28.6 (2019): 295-302.

Komarek, Edwin V. "Fire and animal behavior." (1969): 161-207.

Parker, Christopher H., et al. "The pyrophilic primate hypothesis." *Evolutionary Anthropology: Issues, News, and Reviews* 25.2 (2016): 54-63.

Piel, Alex K., et al. "Chimpanzees and their mammalian sympatriates in the Issa Valley, Tanzania." *African Journal of Ecology* 57.1 (2019): 31-40.

Piel, Alex K., et al. "The diet of open-habitat chimpanzees (Pan troglodytes schweinfurthii) in the Issa valley, western Tanzania." *Journal of Human Evolution* 112 (2017): 57-69.

Pruetz, Jill D., and Thomas C. LaDuke. "Brief communication: Reaction to fire by savanna chimpanzees (Pan troglodytes verus) at Fongoli, Senegal: Conceptualization of "fire behavior" and the case for a chimpanzee model." *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists* 141.4 (2010): 646-650.

Sandgathe, Dennis M. "Identifying and describing pattern and process in the evolution of hominin use of fire." *Current Anthropology* 58.S16 (2017): S360-S370.

Twomey, Terrence. "The cognitive implications of controlled fire use by early humans." *Cambridge Archaeological Journal* 23.1 (2013): 113-128.

Whitlock, Cathy, et al. "Paleoecological perspectives on fire ecology: revisiting the fire-regime concept." *The Open Ecology Journal* 3.1 (2010).