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Wildfire affects space use and movement of white-tailed deer in a tropical pyric landscape

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ABSTRACT

Fire influences the distributions of cover and food resources for ungulates in frequently burned systems. Fire typically improves forage quality, and as a result, herbivores are often drawn to recently burned areas–a response termed the 'magnet effect.' Thus, fire can be an important tool for manipulating vegetation to benefit wildlife. However, most studies of ungulate responses to fire occur at broad temporal scales (multiple years post-burn), and the immediate effects of fire on ungulates are poorly understood. While conducting a study of white-tailed deer (*Odocoileus virginianus*) in southern Florida, we were able to evaluate a natural experiment investigating the effects of wildfire on the spatial ecology of deer. In May 2015, the Mud Lake Fire Complex burned approximately 10,250 ha in Big Cypress National Preserve. This area included portions of the home ranges of 19 of 79 deer that we were monitoring via GPS-telemetry and permitted a Before-After-Control-Impact design to investigate if fire altered the area of use and movement rates of deer at 1, 2, and 3 months following fire compared to the month before the fire. Relative to the white-tailed deer in the unburned areas, white-tailed deer in the burned areas increased movement rates, potentially because fire reduced concealment cover, resulting in increased predator detection and decreased predation risk. Counter to our predictions that fire would increase forage quality and result in decreased space use, white-tailed deer exposed to the fire increased their space use following the fire when compared to deer whose home range did not include burned areas. This appeared to be the outcome of balancing competing demands for site fidelity and to increase access to improved forage in the recently burned areas. In general, deer exposed to the fire increased their use of the burned area following the fire, but also maintained portions of their home ranges that were not burned. Our results provide a behavioral confirmation that white-tailed deer are attracted to recently burned areas and that they respond rapidly to the alteration of vegetation.

1. Introduction

In frequently burned ecosystems, fire influences the distribution of food resources, concealment cover and wildlife species. Following fire, plant regrowth is typically more palatable and of higher quality (Christensen, 1977; Batmanian and Haridasan, 1985; Singh, 1993; Van de Vijver et al., 1999; Eby et al., 2014), therefore many herbivores are drawn to recently burned patches (Moe et al., 1990; Murphy and Bowman, 2007; Klop et al., 2007; Sensenig et al., 2010; Raynor et al., 2015), a phenomenon that Archibald et al. (2005) termed the 'magnet effect' when describing the green magnet hypothesis. Fire alters vegetative structure, which may open sight lines and increase detection of predators that use concealment cover to stalk-and-ambush prey (Hopcraft et al., 2005). However, increased herbivore use of recently burned patches can also result in increased use of burned areas by predators (Paragi et al., 1997; Main and Richardson, 2002; McGregor et al., 2014) and the rapid removal of cover can impact predation rates if prey rely on concealment cover to avoid predators (Conner et al., 2011; Leahy et al., 2016).

Fire can have diverse effects on ungulate spatial ecology and demography. For example, Klop et al. (2007) used time since fire in resource selection functions to demonstrate that common duiker

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(*Sylvicapra grimmia*), red-flanked duiker (*Cephalophus rufilatus*), oribi (*Ourebia ourebi*), bushbuck (*Tragelaphus scriptus*), kob (*Kobus kob*), hartebeest (*Alcelaphus buselaphus*) and roan antelope (*Hippotragus equinus*) selected recently burned areas more than would be expected at random. Fire-mediated alteration in habitat selection have also been reported for North American ungulates including elk (*Cervus canadensis*), bison (*Bison bison*), moose (*Alces alces)* and deer (*Odocoileus* spp.; Irwin, 1975; Pearson et al., 1995; Raynor et al., 2015). Fire can result in increased density of moose (Peek, 1974; Hansen et al., 1973) and deer (*O. hemionus coloumbianus*; [Taber and Dasmann, 1957; Klinger et al., 1989]; *O. virginanus* [Vogel and Beck, 1970; Irwin, 1975]) due to immigration by yearlings, as well as increased reproductive rates and neonate survival (Taber and Dasmann, 1957; Peek, 1974). Several studies have demonstrated the long-term benefits of fire to herbivore populations (Vogl and Beck, 1970; Kruse, 1972; Peek, 1974; Irwin, 1975; Klinger et al., 1989; Pearson et al., 1995), and thus fire is an important habitat management technique in many ecosystems (Edwards, 1984).

However, for some species, such as white-tailed deer, investigations of movement and habitat selection do not universally support the green magnet hypothesis (Archibald et al., 2005). For example, Meek et al. (2008) documented avoidance of recent burns, by white-tailed deer in southern Texas; however, this avoidance may have been influenced by a post-fire drought that delayed the recovery of vegetation in the burned area. Female white-tailed deer avoid recent burns during fawn rearing perhaps because removal of cover is incompatible with the hiding strategy employed by fawns (Lashley et al., 2015a). Cherry et al. (2017) reported that during fawning, female white-tailed deer avoided areas following fire and that vigilance while foraging was inversely related to time since fire. However, they cautioned that the effects of fire on prey behavior are likely a function of attributes of the predator-prey system including the predator's hunting mode and the prey's escape tactics. No studies have reported the effect of fire on white-tailed deer movement in systems with a large stalk-and-ambush predator.

In southern Florida, white-tailed deer are the primary prey of a stalk-and-ambush predator, the endangered Florida panther (*Puma concolor coryi*). The remaining breeding populations of Florida panthers occur in an environment that is largely defined by the interactive effects of pyrogenic, hydrologic, and anthropogenic disturbance regimes. Fire improves white-tailed deer forage in southern Florida (Carlson et al., 1993) and Florida panthers increase use of burned areas during the first year following fire (Dees et al., 2001). Therefore, maintaining frequent fire may be important to sustaining populations of white-tailed deer and Florida panthers on the pyric landscape of southern Florida where historically, fires occurred every 1–3 years (Frost, 1988; Guyette et al., 2012). Lightning-initiated wildfires are relatively common in this system; however, governmental wildfire policy has limited the spatial extent of wildfires, and thus their effect on habitat conditions (Dombeck et al., 2004). Prescribed fire is now commonly used to maintain frequent fire in southern Florida. However, unlike wildfire, prescribed fire operations typically occur under conditions when fire can be controlled likely impacting fire effects on vegetation. There is a growing appreciation for the unique ecological role of wildfire and the importance of diversity of fire effects for wildlife management in frequently burned systems (Day et al., 2015; Lashley et al., 2015b; Bowman et al., 2016).

While conducting a field study on white-tailed deer in the Big Cypress Basin of southwestern Florida, lightning strikes ignited numerous fires in May 2015 across our study area. Because the fires burned across the home ranges of some of our GPS-instrumented white-tailed deer, we were able to evaluate a natural experiment examining the effects of wildfire on white-tailed deer space use and movement. We used this natural experiment to test 3 hypotheses. First, we tested the hypothesis that fire would alter resource availability and subsequently the area of space used. Given that resource availability is a primary driver of home range size (Adams, 2001), and fire improves forage conditions for white-tailed deer (Carlson et al., 1993), we predicted deer would decrease area of space use post-burn. Alternatively, white-tailed deer have high site fidelity to their home ranges (Nelson and Mech, 1992; Aycrigg and Porter, 1997; Lesage et al., 2000) and therefore, might not alter space use in response to the fire and temporal changes in resource availability. A third possibility would be that white-tailed deer could attempt to exploit adjacent burned areas while maintaining their home ranges resulting in increased size of area of use. Secondly, we tested the hypothesis that fire influenced predation risk by decreasing concealment cover. Increased movement can increase susceptibility to predation (Yoder et al., 2004) and therefore, activity rates are often inversely related to perceived predation risk (Lima and Dill, 1990). Because the primary predator in our study area uses a stalk-and-ambush hunting mode, we assumed the fire-mediated opening of sightlines would increase detection of predators, thereby reducing perceived predation risk. Therefore, we predicted that white-tailed deer in burned areas would have greater movement rates than white-tailed deer in unburned areas. Finally, we tested the green magnet hypotheses, which states that herbivores are attracted to resources in recently burned areas. We predicted that deer with access to the burned areas would increase use of those areas. Herein we report the results of this natural experiment investigating the behavioral response of white-tailed deer to wildfire.

2. Methods

2.1. Study area

We worked on the Big Cypress National Preserve (BCNP) and Florida Panther National Wildlife Refuge (FPNWR) in the Big Cypress Swamp physiogeographic region of southwestern Florida. The area experiences distinct wet and dry seasons and regional topography was characterized by minimal relief with slight ridges delineating relatively flat basins interspersed with depressions that can retain standing water throughout the dry season. The study site included pine forests, hardwood forests, cypress forests, prairies, and marshes.

2.2. Fire management

Numerous factors complicate fire management in BCNP including fuel loads that have increased due to historic fire suppression, invasive species, and altered hydrologic regime. Smoke management is challenging as there are nearby urban areas and major roads, including Interstate 75 (I-75) and US Highway 41 bisecting BCNP. There are approximately 2000 km^2 of burnable areas on BCNP, with a goal to maintain a 3–5-year return interval, which would equate to burning approximately 400–667 km^2 annually. Unfortunately, limited budgets, restrictions on acceptable burning conditions, and a shortage of fire management personnel often prevent the achievement of that annual goal (Fig. 1). Thus, fuel loads accumulate through time further complicating future prescribed fire and wildfire management. Historically, the response to wildfire in BCNP has been suppression through direct and indirect attack. However, the evolving fire philosophy is that wildfire is an important natural process, and that management strategies of confine and contain with natural barriers could harness wildfires to help meet fire management goals.

On 08 May 2015, lightning strikes ignited 15 fires across BCNP, collectively referred to as the Mud Lake Fire Complex (MLFC). The MLFC burned approximately 142 km^2 under the management of the local US Fish and Wildlife and National Park Service Interagency Type 3 Incident Management Team and transitioned to the Southern Area Type 1 (Red Team) Incident Management Team (IMT). The management strategy applied to manage the MLFC demonstrated a decision by the IMT to change wildfire response tactic in southern Florida – managers decided not to suppress the fire through direct or indirect methods. Rather, the strategy chosen for the MLFC was to confine and contain the fires using Minimum Impact Suppression Tactics (MIST) and natural