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Effects of forest management practices, weather, and indices of nest predator abundance on nest predation: A 12-year artificial nest study

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ABSTRACT

Nest predation is often the primary cause of avian nest failure, and factors influencing nest predation are diverse. To better understand how forest management practices, weather, and indices of nest predator abundance influence nest predation, we set artificial ground nests at 100 sites for 2 weeks each summer from 2002 to 2013 in a longleaf pine/wiregrass ecosystem. We modeled effects of prescribed fire, hardwood removal, rainfall, temperature, indices of mammalian and avian nest predator abundance, and proximity to wildlife food plots and agriculture, edges, and roads on nest predation. Annual nest predation rates ranged from 30% to 74% and averaged 53%. Occurrence of prescribed fire at a nest site <2 months prior to nest placement had a strong, positive association with nest predation but prescribed fires carried out >2 months prior to nest placement had little effect. Hardwood removal was also associated with increased rates of nest predation, but this effect appeared most prevalent 4–9 years following removals. Nest predation rates also increased when food plots or agricultural fields were within 50 m of nest sites. Higher temperatures were associated with greater rates of predation, but rainfall did not have a significant influence. There was a general lack of support for effects of predator indices on nest predation rates, except for a weak, negative association with raccoon relative abundance. This study shows the wide range of factors which may influence nest predation and importance of viewing effects of forest management practices on nest predation over the long term.

1. Introduction

Nest predation is often the primary cause of avian nest failure (Staller et al., 2005; Radar et al., 2007; Conner et al., 2010; Ellis-Felege et al., 2013) and nest predation rates may be influenced by a wide variety of environmental conditions and forest management practices (reviewed in Major and Kendal, 1996). Management activities may be undertaken for a variety of reasons including restoration or maintenance of ecosystems, improvement of habitat for game or declining species, and reduction of abundance of predators which negatively affect game or other species of importance. Regardless of the objective, management practices may have unintended consequences on ecosystems. Managers should therefore be interested in understanding how various forest management activities influence ecological processes.

Prescribed fire is a common management tool across the United States, with objectives often including fuel reduction, mid-story brush control, and wildlife habitat management (White, 1986; Van Lear et al., 2005; Stober and Jack, 2007). When fire has been suppressed in systems which depend on frequent fires (e.g., longleaf pine (*Pinus palustris*) savannas of the southeastern USA, oak (*Quercus* spp.) savannas of the midwestern USA), encroachment of shrubby vegetation occurs (White, 1986; Peterson and Reich, 2001; Provencher et al., 2001; Kirkman et al., 2004). When fire return intervals are maintained at the historical range, such hardwoods are largely confined to riparian areas and depressional wetlands (Kirkman et al., 2004). If fire is suppressed for an extended period of time however, hardwoods may encroach to such an extent that mechanical hardwood removal is required to restore the savanna (Provencher et al., 2001).

In areas where game and declining species are of interest, additional management practices often include establishment of wildlife food plots (Fulbright, 1999; Tranel et al., 2008) and control of mesomammalian predators (Ellis-Felege et al., 2012). Additionally, to facilitate management activities, roads are commonly established and edges formed.

All of these management activities have the potential to influence occurrence and movement of predators and susceptibility of avian nests to predation (Bayne and Hobson, 1997; Chalfoun et al., 2002; Gabrey et al., 2002; Easton and Martin, 2002; Conner and Perkins, 2003; Almario et al., 2009; Schneider et al., 2012).

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Forest managers must weigh multiple objectives and influences of management activities, intended and unintended, on the forest system; therefore, they require information on how management activities may influence nest predation. To this end, in 2002, we began a long-term study of nest predation using artificial nests. We examined how practices including prescribed fire, hardwood removal, and presence of agriculture, wildlife food plots, roads, and edges influenced nest predation rates over 12 years by monitoring artificial ground nests set in areas with varying forest management histories. Because factors outside of the manager's control may cause substantial variation in nest predation rates (Brzeziński et al., 2010), we also examined the influence of indices of mammalian and avian nest predator abundance and weather on nest predation rates. Although results of artificial nest studies may not reflect trends seen with natural nests (Burke et al., 2004; Thompson and Burhans, 2004), data from artificial nest studies can provide a starting point for understanding factors which may influence nest detection by predators, and allow an understanding of the relative importance of factors which influence nest predation.

2. Materials and methods

2.1. Study area

This study took place at the Joseph W. Jones Ecological Research Center at Ichauway (hereafter, Ichauway), a 12,000 ha property located in southwestern Georgia, USA. The landscape is dominated by longleaf pine and wiregrass (*Aristida stricta*). Most of the property is burned on a 2-year rotation, which maintains a diverse groundcover and open mid-story. Interspersed in the longleaf savannahs are slash and loblolly pine forests (*Pinus elliotti* and *Pinus taeda*, respectively), mixed pine and hardwood forests, and hardwood bottoms. Small agricultural fields and wildlife food plots are also cultivated throughout Ichauway. Agricultural fields averaged 3.30 ha (±SE 0.25 ha, range 0.10–104.44 ha) and were managed as crop and pasture land. Wildlife food plots averaged 0.38 ha (±0.01 ha, range 0.05–1.91 ha) and were managed for white-tailed deer (*Odocoileus virginianus*), northern bobwhite (*Colinus virginianus*), and wild turkey (*Meleagris gallopavo*).

2.2. Field methods

This study was carried out from 2002 through 2013. In mid to late June of each year, 2 fresh, farm-raised northern bobwhite eggs were placed in small wicker baskets and set on the ground 5 m from fixed telemetry stations at a randomly generated compass bearing. Eggs were refrigerated until use, and latex or nitrile gloves were worn when handling eggs to minimize transfer of human scent. Nests were checked once 2 weeks after setting. Telemetry stations were used to place nests because they were spread fairly evenly over the landscape, because stations were marked permanently and unobtrusively (with small metal tags nailed to trees, telephone poles, or road signs), and because stations were easily accessible along roads. We randomly selected 100 telemetry stations with a minimum distance of 60 m between stations to orient nest sites. The 100 nest sites were spread over three distinct regions: Dan Lilly ($N = 25$ nest sites), Turkey Woods ($N = 25$), and George Place ($N = 50$). The mean distance from a nest site to the nearest neighboring site was 229 m (±SE 14 m; range 61–698 m). For clarity, above and hereafter, the term "station" refers to telemetry stations which were used to orient nest sites ($N = 100$). "Site" or "nest site" refers to locations where nests were placed, as measured from telemetry stations ($N = 100$). "Nest" refers to any individual nest ($N = 1200$ over the course of study). "Region" refers to the areas described above as the Dan Lilly, Turkey Woods, and George Place.

Compass bearings varied between stations but were consistent for each station over the duration of the study; however, a number of marked trees were cut or fell down over the 12 years of the study. When this occurred, nests were placed as near to the original site as possible and stations were subsequently marked with either ribbon or pin flagging. Although previous research has shown that flags placed within 5 m of nests can increase rates of nest failure (reviewed in Major and Kendal, 1996), because flags were left up year-round and are commonly placed across Ichauway for other research projects, we believe it unlikely flags influenced predation rates in this study. No attempt was made to conceal nests; however, this does not necessarily mean that nests were left in the open. Nests were set in whatever ground cover existed at the nest site. At times this was very little. At other times, it was enough to obscure the nest. We did not attempt to mimic nests of any particular species because we were interested in predation of ground nests generally. We used ground nests because there are multiple ground nesting species of conservation and management interest in our study region (e.g., northern bobwhite, Bachman's sparrow (*Peucaea aestivalis*), wild turkey (*M. gallopavo*)).

2.2.1. Statistical methods

We considered nests missing one or both eggs to have been depredated, and nest predation was used as the response variable for all analyses (binary response, depredated or not depredated). We identified five groups of variables with the potential to influence nest predation: indices of predator abundance, landscape variables, hardwood removal history, prescribed fire history, and weather conditions. Within each variable group, we developed a model set describing various aspects of each variable grouping. In preliminary analyses, models within variable groups were assessed independently. The best-supported variables in each group were then combined for further analyses (see below for details).

As part of long-term monitoring activities, track count data were collected annually from 1 km transects on dirt roads raked for 3 nights each summer. We used records from 18 track counts in the vicinity of the nest sites to generate indices of abundance for seven mammalian nest predators including bobcats (*Lynx rufus*), coyotes (*Canis latrans*), foxes (gray (*Urocyon cinereoargenteus*) and red (*Vulpes vulpes*), combined), raccoons (*Procyon lotor*), nine-banded armadillos (*Dasypus novemcinctus*), Virginia opossums (*Didelphis virginiana*), and squirrels (gray (*Sciurus carolinensis*) and fox (*Sciurus niger*), combined). Striped skunks (*Mephitis mephitis*) also occur in the region but at such low densities they were rarely detected. We calculated the number of transects on which each species was detected each year as the index of abundance. Although snakes are a common nest predator, we did not include an index of snake abundance because snakes rarely depredate artificial nests (Marini and Melo, 1998; Thompson and Burhans, 2004).

As part of long-term monitoring activities, avian point counts were carried out each spring between mid-May and mid-July at sites across Ichauway. Surveys were conducted between one half hour before sunrise to 2 h after sunrise in temperatures <27 °C and with wind speeds <16 km/h. We used records of corvids (American crows, *Corvus brachyrhynchos*; fish crows, *Corvus ossifragus*; and blue jays, *Cyanocitta cristata*) from 49 (2002) or 50 (2003 to 2013) point count locations in the vicinity of the nest sites to calculate mean number of corvids observed per survey as an index of corvid abundance for each year. On this study site, using time-lapse videography, Conner et al. (2010) found 17% of predations of natural nests of shrub nesting birds were caused by raptors. However, raptor predations only occurred during the nestling