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Review

Swamp rabbits as indicators of wildlife habitat quality in bottomland hardwood forest ecosystems

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ABSTRACT

Reforestation of bottomland hardwood (BLH) forests has occurred within the Lower Mississippi Alluvial Valley (LMAV), USA, to support a wide range of ecosystem services, but especially wildlife habitat enhancement. As ecosystem restoration efforts proceed in BLH ecosystems, managers and policymakers are seeking criteria to evaluate wildlife habitat enhancement goals. Specialist wildlife that evolved within forest ecosystems can be sensitive to the composition, structure, and function of an ecosystem in relation to the system's natural or historical range of variation and thereby serve as indicators of habitat quality. The swamp rabbit (*Sylvilagus aquaticus*) is a specialist species of BLH forests throughout the LMAV and therefore may be an appropriate indicator species for this ecosystem. To address this, we reviewed peer-reviewed literature to evaluate the utility of swamp rabbits as an indicator species according to three commonly-used criteria: habitat factors defining swamp rabbit relationships to BLH forests, the importance of swamp rabbit habitat to other wildlife, and the efficiency of swamp rabbit monitoring. We conclude that the swamp rabbit is a suitable indicator of wildlife habitat quality in BLH ecosystems in the LMAV because they evolved and remain endemic to the ecosystem, use habitat that integrates desirable characteristics that positively influence wildlife biodiversity, and are easy to monitor routinely.

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1. Introduction

The scarcity of bottomland hardwood (BLH) forests due to widespread agricultural conversion has necessitated reforestation and protection of remaining high-quality natural areas throughout the Lower Mississippi Alluvial Valley (LMAV) of the mid-southern United States. These actions aim to restore the integrity of BLH ecosystems to support a wide range of ecosystem services, but especially wildlife habitat enhancement (King and Keeland, 1999). Restoring historical habitat conditions in the LMAV is constrained by enormous physical challenges due to the complexity of BLH ecosystems (Hodges, 1997; Allen et al., 2001), drastic changes in vegetation cover, and the permanence of drainage and flood control systems that support ongoing commercial agriculture. Endogenous (e.g., single tree fall) and exogenous (e.g., fire, flood, hurricane) disturbances create spatial and structural diversity, which thereby influence resource availability and spatial distribution of many

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wildlife species (e.g., Sousa, 1984; Johnson et al., 2003; Tews et al., 2004). In these systems, successional patterns and species composition are strongly influenced by flood events (Hodges, 1997; Kruse and Groninger, 2003).

As ecosystem restoration efforts proceed in BLH ecosystems, managers and policymakers are seeking criteria to evaluate wildlife habitat enhancement goals. Identification and use of indicator species that are sensitive to ecosystem structure and function are sought to fill this void (Andreasen et al., 2001; Niemi and McDonald, 2004). Indicators for forest integrity must encompass the capacity of the ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization similar to the system's natural or historic range of variation (Karr and Dudley, 1981; Grumbine, 1994). Indicator species can be used to examine associations between their abundance and co-occurrence with landscape and forest characteristics to provide insights into the ecological integrity of the larger system (Nilsson et al., 1995; Lawton et al., 1998; Hurme et al., 2008). For example, management recommendations that produced desired heterogeneous forest structures for northern goshawks (*Accipiter gentillis*) in ponderosa pine forests in the southwestern U.S. resulted in forests restored to conditions similar to pre-European settlement (Youtz et al., 2008). Vierikko et al. (2010) suggested that presence of the Siberian flying squirrel (*Pteromys volans*) may reflect habitat availability for species depending on dead and living wood in boreal forests of Finland and, therefore serve as a biodiversity indicator (Hurme et al., 2008). However, we are unaware of the use of indicator wildlife species in systems such as the LMAV that are driven by surface hydrology and where agriculture has been a dominant and competing land use to wildlife habitat.

Habitat monitoring in BLH ecosystems is needed to assess performance of efforts to restore and sustain high quality wildlife habitat. Biological and environmental data collection is difficult in these systems due to harsh conditions, difficult terrain, dynamic processes and fragmentation. Indicator species (i.e., an organism whose presence, absence, or abundance reflects a specific environmental condition) have a narrow range of ecological tolerance, where changes in the species population are believed to indicate the effects of change to their limited ecological niche (Simberloff, 1998; Siddig et al., 2016). Managers and biologists use these species as tools for monitoring habitat resources and environmental conditions (Landres et al., 1988; Lindenmayer et al., 2000; Siddig et al., 2016).

The swamp rabbit (*Sylvilagus aquaticus*) is a BLH specialist distributed throughout the LMAV (Fig. 1) and may be an appropriate indicator species for this ecosystem. Swamp rabbits are associated with forested wetland habitats that encompass a range of attributes associated with a structurally diverse BLH forest. Spatial and structural heterogeneity associated with pre-agricultural bottomland sites is considered desirable for restoration and management of wildlife habitat in the LMAV (Stanturf et al., 2000; LMVJV Forest Resource Conservation Working Group, 2007; Norris et al., 2008). Management of habitat to benefit swamp rabbits, specifically to improve structural diversity while maintaining habitat patch size, may positively affect other wildlife species in BLH ecosystems (LMVJV Forest Resource Conservation Working Group, 2007; Scharine et al., 2009).

Because swamp rabbits are a BLH species and have been well-studied, we evaluated the use of swamp rabbits as an indicator of BLH habitat quality. For indicator species to be an effective habitat monitoring tool, there must be a comprehensive understanding of important habitat characteristics that influence their habitat use and an understanding of how these characteristics influence the habitat needs of other species (Landres et al., 1988; Lindenmayer and Likens, 2011; Siddig et al., 2016). To make valid inferences indicator species also must be easy to routinely monitor (Noss, 1990; Dale and Beyeler, 2001; Carignan and Villard, 2002). To assess the potential utility of swamp rabbits as an indicator of habitat quality, we reviewed peer-reviewed literature to evaluate three criteria: habitat factors defining swamp rabbit relationships to BLH forests, the importance of swamp rabbit habitat to other wildlife, and the efficiency of swamp rabbit monitoring.

2. Swamp rabbits as components of BLH ecosystems: a review

We conducted a literature review to assess the swamp rabbit in the context of its potential use as an indicator species of habitat quality in BLH forests. We gathered peer-reviewed literature addressing swamp rabbit ecology throughout the species range via online search engines (Institute for Scientific Information Web of Science, Google Scholar) using the species taxonomic name as the search term. Thirty studies were reviewed; most focused on habitat use (9), home range and distribution (6), behavior (4), and population dynamics and viability (4) (Table 1). All papers identified the swamp rabbit as specialist species that persists only within the narrow range of environmental conditions associated with BLH ecosystems (Table 1). Specifically, we used this review to summarize information on swamp rabbit distribution, stand and landscape level habitat use, and swamp rabbit monitoring – all essential components in our analysis of swamp rabbits as an indicator species.

2.1. Distribution

Swamp rabbits evolved in and remain endemic to remaining BLH ecosystems within the southeastern and south central United States (Chapman and Feldhamer, 1981). Swamp rabbit populations exist at the northern fringe of the range in southern Illinois, Indiana, and Missouri, where they are patchily distributed in a metapopulation structure. These peripheral populations are typically associated with lower animal density and patchy distribution, as individuals encounter fewer optimal habitats and more hostile environmental conditions (Levin, 1970; Lesica and Allendorf, 1995; Wilson et al., 2009). Swamp rabbits experience low genetic connectivity due to restricted dispersal, linear distribution of habitat, and smaller population size due in part to BLH habitat loss and fragmentation (Roy Nielsen et al., 2008; Berkman et al., 2015; Robinson et al., 2016). Clearing, draining, and conversion of BLH forests to agriculture has led to habitat loss in both the northern and central portions of the swamp rabbit range, leading to population declines (Terrel, 1972; Dickson, 2001; Scharine et al., 2009).

2.2. Stand-level habitat components

Within BLH ecosystems, swamp rabbits select forest structures that produce the vertical and horizontal cover essential for concealment from predators. Swamp rabbits use various stand-level structures that provide cover, such as tree seedlings and saplings, woody vines, shrubs, herbaceous vegetation, coarse woody debris, and hollow tree boles (Fowler and Kissell, 2007; Smyth et al., 2007; Scharine et al., 2011). In southwestern Indiana and northwest Kentucky, swamp rabbit daytime forms (i.e., a nest-like cavity on the surface of the ground) included herbaceous vegetation (25%), brush piles (24%), cavities at the base of live trees (15%), downed hollow logs (15%), bases of trees (7%) and miscellaneous elements (13%) (Dumyahn et al., 2015).

Swamp rabbits use habitat attributes found in both young and mature BLH stands. Swamp rabbits use young BLH stands characterized by a dense understory of tree seedlings and herbaceous vegetation, as well as, mature BLH stands that contain course woody debris and have scattered patches of thick understory