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Regional connectivity for recolonizing American black bears (*Ursus americanus*) in southcentral USA

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ABSTRACT

Landscape connectivity is vital for species conservation in human-modified landscapes, lessening population declines and genetic depression caused by habitat loss and fragmentation. We used concepts from electronic circuit theory to identify potential areas for American black bears (*Ursus americanus*) that facilitate connectivity between key federally protected areas, determined if black bears used higher quality habitat than available, and examined their distribution relative to human disturbance. We developed a regional (Mississippi, Louisiana, eastern Texas, Arkansas, and Missouri, USA) model estimating landscape resistance to movement using GIS-based features considered to affect black bear space use: land cover type, distance to major rivers, road density, and highway presence. We selected national forests and national wildlife refuges as patches among which to model potential movement. Using citizen-reported black bear sightings from Mississippi and Missouri, we evaluated land cover selection at fine and coarse scales, and validated our model comparing current density between bear sightings and random locations. Black bear sightings occurred in areas of higher current density compared to random locations ($p < 0.001$), suggesting our connectivity model had good performance for characterizing areas bears will use at a coarse scale. However, black bears did not always choose high quality habitat for movement at a coarse scale, and avoided areas of human disturbance at a finer spatial scale. Contiguous forested areas outside protected areas and riparian corridors along major rivers were identified as most likely to facilitate connectivity. The relative importance of protected areas in maintaining regional connectivity was influenced by size, location, and amount of forest cover. Highways appeared as semi-permeable barriers to movement that intersected several connectivity pinch points. Management to maintain or improve connectivity in identified high connectivity areas, including forest retention, preservation of riparian buffers, and highway mitigation techniques at pinch points, may facilitate black bear recolonization and aid broader conservation objectives.

1. Introduction

Landscape connectivity has become one of the foundations of conservation biology and practice (Worboys et al., 2016), particularly in increasingly human-modified areas. Due to habitat loss and fragmentation, populations can become isolated, causing negative consequences (Crooks et al., 2011) including hindering dispersal (Taylor et al., 1993), population declines (Fahrig, 2003), and inbreeding depression (Clobert et al., 2012). Areas that facilitate movement (e.g. corridors, Cushman et al., 2013) are the basis of landscape connectivity, and support long-term persistence of populations in heterogeneous landscapes (Vasudev et al., 2015).

Connectivity modeling has emphasized developing reliable fine-grained linkage designs (< 30 m resolution), with less attention to coarse-grained (> 100 m), large-scale (e.g., nation, state, or ecoregion) designs (Beier et al., 2011). A common approach is to create a resistance map based on expert opinion and literature review, yet empirical data (e.g., radiotelemetry) collected in the landscape of interest should provide a useful addition for estimating relative land cover resistance to movement (Beier et al., 2008). When modeling resistance, a usual assumption is that habitat quality and permeability are positively related, and that both are the inverse of ecological cost of travel (Beier et al., 2008). A related hypothesis states that similarity between the areas used for dispersal and the habitat of a species can affect the permeability of those areas to movement, and adaptations for efficient and safe movement within habitat patches should also increase success for larger scale movements (Eycott et al., 2012; Prevedello & Vieira, 2010). Supporting this hypothesis, Eycott et al. (2012) found that areas which are structurally more similar to a species' habitat tend to increase movement rates.

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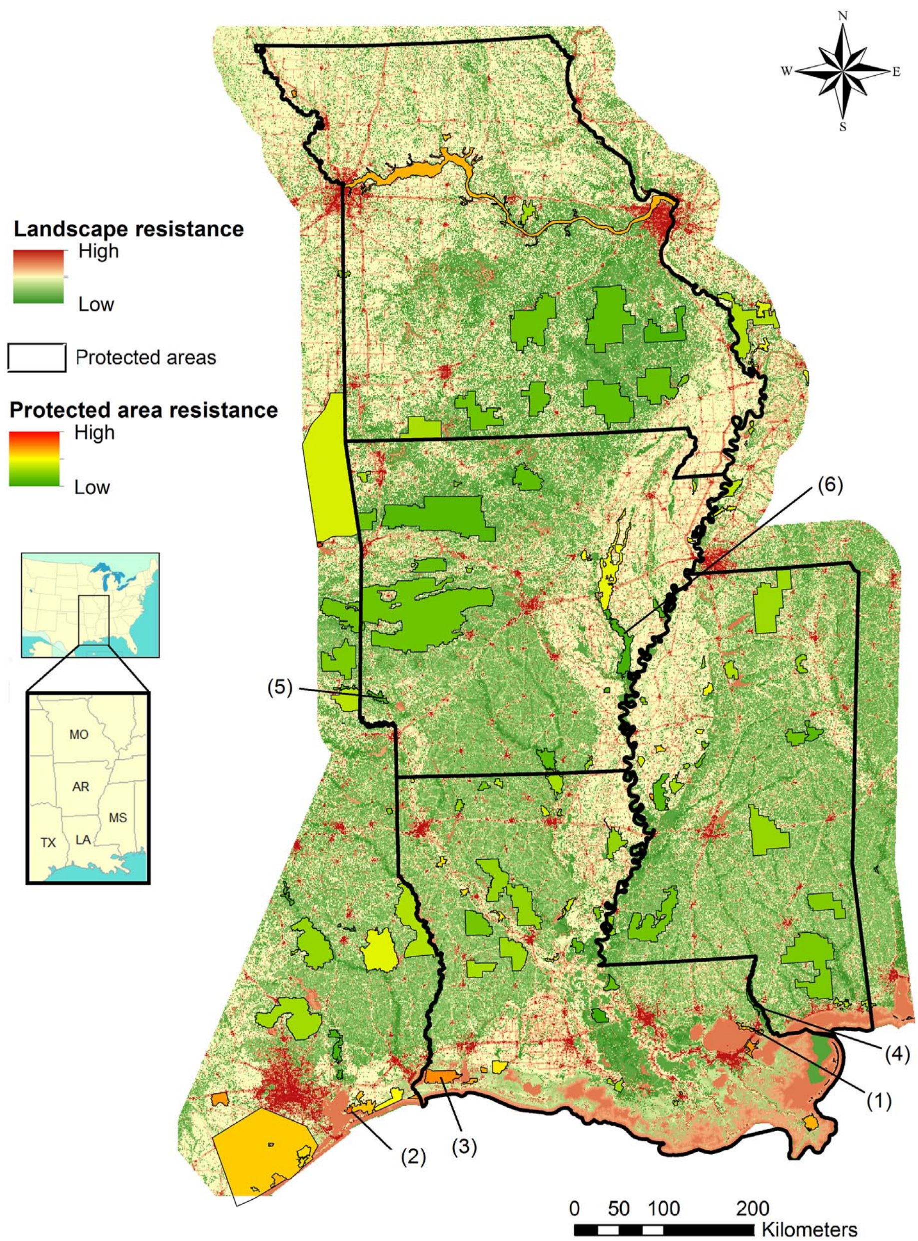

Fig. 1. Black bear movement resistance values (1-km^2 resolution) in southcentral USA. Protected areas (shaded polygons) with highest mean resistance: (1) Big Branch Marsh National Wildlife Refuge (NWF), (2) Texas Chenier Plain Refuges Complex, and (3) Sabine National Forest (NF). Lowest mean resistance: (4) Bogue Chitto NWR, (5) Pond Creek NWR, and (6) White River NWR Complex. AR = Arkansas. LA = Louisiana. MO = Missouri. MS = Mississippi. TX = Texas.

Large carnivores with extensive home ranges are more likely than smaller species to be negatively influenced by factors including habitat fragmentation and human disturbances, resulting in modified behavioral patterns and population declines (Crooks, 2002; Crooks et al., 2011; Young & Shivik, 2006), or even local extirpation (Ripple et al., 2014). Recolonization events are globally uncommon among large carnivores due to habitat loss and anthropogenic threats (Gittleman & Gompper, 2001; Hoffmann et al., 2011; Ripple et al., 2014), however in North America they have been documented for species including wolves (*Canis lupus*; Pletscher et al., 1997), brown bears (*Ursus arctos*; Bader, 2000), and American black bears (*U. americanus*; Onorato and Hellgren 2001; Bales et al., 2005; Frary et al., 2011; Simek et al., 2012; Wilton et al., 2014a).

During recolonization, anthropogenic factors such as public tolerance and legal protection interact with ecological factors, such as the presence of unoccupied habitat and population sources (Rice et al., 2009; Smith et al., 2014; Woodroffe & Redpath, 2015). For example, lack of legal protection might decrease survival for dispersing individuals, and public opposition can decrease the success of habitat restoration programs or impede translocations and reintroductions (Treves & Karanth, 2003). In addition, anthropogenic factors can also influence behavioral processes; animals may perceive human presence and activities as predation risk, and will therefore avoid it, even though no mortality results from such activities ("anthropogenic risk hypothesis"; Beale & Monaghan, 2004; Frid & Dill, 2002). Alternative mechanisms causing individuals to avoid disturbed areas may include lower resource availability, increased energetic costs, and decreased survival (Eycott et al., 2012).

Black bear recolonization in southcentral USA has been facilitated through successful reintroductions in Arkansas (Smith & Clark, 1994) and Louisiana (Benson, 2005; Van Why, 2003). Following enhanced legal protection and human tolerance, black bears are naturally recolonizing neighboring states, such as Missouri (Smith et al., 1991) and Mississippi (Simek et al., 2012). Although dispersal in large carnivores, such as bears, is mostly attributed to young males (Moore et al., 2014; Schwartz & Franzmann, 1992), the black bear population in Missouri and Mississippi has increased and expanded not only by dispersing males, but also by naturally dispersing females that establish home ranges and reproduce (e.g., Simek et al., 2012). Understanding movement behavior and responses to human disturbances is particularly