SYNTHESIS OF THE EFFECTS OF FIRE ON SOUTHERN APPALACHIAN FAUNA

Amber L. Pitt, Robert F. Baldwin, Joseph J. Tavano, Thomas A. Waldrop, and Ross J. Phillips[1]

Abstract—We reviewed the effects of prescribed fire on wildlife in the southern Appalachian Mountains and placed our results in the context of regional, national, and global studies. We conducted a Web search of peer-reviewed literature and technical reports to evaluate the number of prescribed fire studies pertaining to geographical regions and taxonomic groups. We obtained 717 relevant, unique studies, the majority of which were from North America (n=513). The most studied taxonomic group globally was birds (n=244). Within the United States, most studies occured in the Southeast region (n=179), including 21 in the southern Appalachians. All southern Appalachian studies with wildlife as dependent variable were of prescribed fire. Our review of the papers specific to the southern Appalachians revealed no strong signals. The lack of strong signals that can be generalized across taxa or ecosystems may be due to the limited number of studies and their short-term, localized, and/or species-centric character. By focusing new research at multiple spatiotemporal scales, we may gain powerful, multi-scale inference.

INTRODUCTION

Fire has been a powerful force structuring ecosystems for millennia. In recent decades, fire and the use of fire for ecosystem management have received much research attention. While the use of fire to restore and maintain plant communities is relatively understood, there is no consensus as to how fire influences fauna, and fire-fauna relationships are more difficult to predict. The southern Appalachian Mountains comprise a globally-significant region of biological diversity that is maintained in part by disturbance; fire may have extensively influenced the distribution of plants and animals (Lorimer 1980, Van Lear and Waldrop 1989). The region has millennia of human occupation that may have, at least in part, played a role in fire maintenance (Delcourt and Delcourt 1997). The southern Appalachians have a number of plant communities known to be strongly influenced to entirely structured by fire. For example, Table Mountain pine (*Pinus pungens*) on dry ridges and southwest-facing slopes 1–4000 feet elevation is largely dependent on burns (Spira 2011). Furthermore, the most predominant fire frequency interval in the region is 11–30 years (fig. 1). Recent decades have seen rapid expansion of urban areas near wildlands, and amenity-based exurban growth directly on the edges of forest areas (Brown and others 2005, Turner and others 2003). Such human settlement alters the extent to which prescribed fire may be used to manage and restore ecosystems.

Prescribed fire has become an essential landscape-level management tool. It is one of the only circumstances in which managers directly manipulate disturbance. Prescribed fire is invoked to mimic disturbance at specific frequencies, intensities, and extents. For example, there are a few but rare examples of flood, grazing, and timber harvest used to recreate non-anthropogenic disturbance (Fuhlendorf and Engle 2001, Seymour and Hunter 1999). Yet, fire is used in a number of ecosystems as a management and restoration tool (Ford and others 2000, Noss and others 2006). A number of studies have been conducted of the effects of prescribed fire on wildlife. We seek to review those studies, compare research effort in the region with other areas of the world, and synthesize knowledge of fire effects on wildlife. We focus our review on effects of prescribed fire on birds, mammals, herpetofauna, and invertebrates in the southern Appalachians.

METHODS

We approached this review using both quantitative and qualitative methods. We conducted a web search of peer-reviewed literature and technical reports to evaluate the number of studies pertaining to geographical regions and taxonomic groups. Our literature searches were done using Google Scholar, Google, and Web of Knowledge search engines. Search terms included “fire” and “prescribed fire”, combined in different searches with “wildlife”, “bird”, “mammal”, “reptile”, “amphibian”, “invertebrate”, “insect”, “frog”, “salamander”, “snake”, “lizard”, “turtle”, and

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“avian”. We found a total of 941 references that we initially considered relevant. After further inspection, 226 were omitted due to their nature as conference abstracts, duplicative of other references (same research, different publication), general ecology reviews, or topically unsuitable (mis-classified by search terms).

A total of 717 studies was used to compare numbers of studies by world region, world region X taxonomic group, by North American region, and North American region X taxonomic group. Studies focused on the southern Appalachian region (n=21) were exhaustively read and categorized by effect (direct=behavioral, population/community, mortality; indirect=habitat), type of measurement (nest success/selection, roost selection, habitat selection, abundance, richness, population estimate), and taxonomic group. Southern Appalachian studies were further reviewed and summarized by above categories.

RESULTS

A total of 717 relevant, unique studies was obtained. By a large margin, the majority of studies (n=513) come from North America, followed by Australia (n=104), Europe (n=48), Africa (n=30), South America (n=13), and Asia (n=9; fig. 2). These totals are further subdivided by taxonomic group in figure 3. Worldwide, the most studied taxonomic group with respect to prescribed fire effects is birds (n=244), followed by mammals (189), invertebrates (n=155), and herpetofauna (n=152; fig. 3). Within the United States, most studies have been conducted in the Southeast (n=179), followed by the Midwest (n=98), Southwest (n=83), Pacific (n=64), Rocky Mountain (43), and Northeast (n=11) regions (fig. 4). In the United States, the most studied taxonomic group with respect to prescribed fire is birds (n=189), followed by mammals (n=121), invertebrates (n=91) and herpetofauna (n=90; fig. 5). While most studies from within the United States come from the Southeast region, the majority are in association with Coastal Plain/longleaf pine ecosystems. Relatively few studies have examined the effects of prescribed fire on fauna in the southern Appalachians (n=21; table 1), the majority of which came from a single research site in North Carolina (n=11; fig. 6). Most of the studies for the southern Appalachians were of direct effects at the population/community level, and only one attempted population estimation (small mammals). The preponderance of effects was neutral and positive (table 2). Depending on taxa, positive effects were strong (e.g., browse availability for white-tailed deer; Lashley and others 2011), or weak (e.g., behavioral shifts for myotis to exploit new snags; Johnson and others 2009).

Most studies were neutral in that they indicated no effect (no significant differences) for most taxa. Behavioral adaptations were noted that were not associated with differences in reproductive success (e.g., wood thrush nesting higher off the ground in burned areas). Negative effects were noted for salamanders, shrews, and ground and low-shrub-nesting birds (Matthews and others 2010, Greenberg and others 2007a, 2007b; Artman and others 2001). Interannual variability was large in some cases, outweighing treatment effects (e.g., shrews; Matthews and others 2009).

DISCUSSION

Globally, North America has benefitted from the greatest number of studies of the effects of fire on fauna—the Southeastern United States the best studied region of the continent. Within the Southeastern United States, most research is focused on the formerly extensive and emblematic fire-maintained long-leaf pine ecosystems. These are especially prevalent in coastal systems where habitat fragmentation and over-exploitation has rendered that once-extensive system a major conservation concern (Noss 2013). The southern Appalachians, despite a history of relatively frequent fire in many ecosystems (i.e., not only dry-slope, fire-maintained forests), have received much less research attention as to the effects of that fire on fauna. Of the studied fauna, birds have received the most attention, at habitat, community, population, and behavioral levels.

Our review of the 21 papers specific to prescribed fire in the southern Appalachians revealed no strong signals and mostly neutral effects. Effects of fire on fauna were consistent across the studies, in that there was an absence of strong, negative effects. No study illuminated acute or indirect effects that might result in population degradation to the extent that persistence could be negatively influenced. By contrast, a number of studies indicated positive, short-term effects. Of potential negative effects, reduction in leaf litter (some amphibians) and shrubs available for nesting (some birds) were noted as potential, short-term factors. But at the same time, those studies noted only weak negative effects and often, year-year differences in responses. All 21 studies were short term, covering effects spanning 1–6 years (predominately 1–2 years), and were site-based rather than landscape scale. The bias introduced by site-based, short duration studies was counterbalanced by a number of the studies that resulted from controlled experiments over multiple years (Green River; Wine Spring Creek).

The sample of papers for the southern Appalachians is small, and bias is large because there are few replicates within taxa. As a whole, the southern Appalachian literature suggests that prescribed fire can have many positive effects for a number of organisms (floral visiting insects, beetles, many bird species, deer, shrews, lizards, toads). No strong negative influences were noted, with the exception of terrestrial salamanders. Despite the lack of signal, there is consensus that habitat change happens as a result of prescribed fire; that change may have short-term effects on some taxa. Those changes may be temporarily negative (e.g., leaf litter and some salamander species in some sites, cover for ground nesting birds and shrews), temporarily positive (e.g., floral visiting insects, lizards), or neutral (e.g., bats may exploit gaps and new snags following fire), or strongly positive (e.g., availability of nutrition for white-tailed deer). As many species of wildlife exploit early seral stages, snags, gaps, and other artifacts of fire, the positive signals received for insects, bats, lizards, rodents, some birds, is not surprising. How such patterns would manifest over many years in a shifting mosaic of forest disturbance remains relatively unkown, which is true for forest disturbance generally, not just for fire (Clark 1991). Authors of some of the prescribed burning studies noted scale and timing effects; for example localized, short-term effects on ground nesting birds may be minimal but would intensify if cumulative over many burns in time and space (Artman and Downhower 2003, Artman and others 2001).

Amphibians have often been mentioned as of concern for prescribed burning; in the southern Appalachians there are contrasting results. There is some evidence that terrestrial salamanders should be studied more closely, as reductions in leaf litter and increased drying rates of organic matter may negatively impact these taxa (Matthews and others 2010). However, anurans seem to be little influenced. The most common terrestrial anuran is the American toad; its high capture rates may influence the perception that there is little effect on anurans (Greenberg and Waldrop 2008, Kirkland and Snoddy 1996). A recent telemetry study of toads in response to prescribed fire indicates that long distance breeding movements and high tolerance for dessication may contribute to the ability of this species to persist following that disturbance (Pitt and others 2013). Timing of prescribed burning has the potential to have the greatest influence on amphibians as amphibian movements in terrestrial environments is largely influenced by seasonal migration related to reproduction, and expansion of surface activities due to increased moisture (Baldwin and others 2006, Bellis 1962, Lamoureux and others 2002, Madison 1997, Petranka 1998).

The effect of fire on fauna has become increasingly well-studied; however, the results of studies of prescribed fire on fauna remain ambiguous, casting light on specific responses by individual populations and localities. The literature proves little basis to assess the potential long-term effects of prescribed fire on distribution of species. There is a preponderance of neutral and/or contradictory effects, indicating that something is missing in how these studies are being conducted. We suggest that missing element is scale. Studies that focus on localized areas are likely to also be short term and not reveal anything but short-term responses. Animals vary in their ability to move or otherwise behaviorally adapt to fires; population and community responses require long-term research to elucidate. Fire intensity, extent, and frequency all influence how severe and long lasting its impacts are on resident fauna (Noss and others 2006). This amount of variability in fire behavior combined with species' adaptations to fire and how those characteristics might interact with a particular burn in a particular time and place make generalizations from existing studies quite difficult. However, there are plant and animal communities that are known to be created and maintained by fire over the long term, easing management concerns somewhat. Fire leads to patchiness at the landscape scale and can change distribution of habitats over time and space (Vickery 2002). The fire regime at the region scale (e.g., fig. 1) has biogeographic effects; and yet this remains the least studied aspects of the effect of prescribed fire on fauna.

We suggest these extended spatial and temporal scales be the focus of new research for the southern Appalachians. Spatial ecology employed at extensive, ecoregional scales, combined with dendrochronological and historical research on past patterns, could reveal how fire has influenced distribution of habitats. Such coarse-grained analysis, when combined with data on faunal distributions could allow some inference as to past effects; when combined with fine-grained field analyses of behavioral and population-level effects, such as the 21 studies from the southern Appalachians, powerful, multi-scale inference may be achieved. And, the planning of future field research on prescribed fire could combine long-term effects (such as the multiple fuel reduction treatments from the Green River, NC studies), with more spatially extensive treatments. Source sink population dynamics are probably very important for understanding how wildlife respond to forest disturbance over time and space; while the design of such field studies is daunting, field study can be augmented with spatial modeling. The southern Appalachians, with its high heterogeneity of habitats at multiple spatial scales, might represent a particularly challenging venue for such research, compared to relatively simpler Western systems.

What may be of concern to forest and wildlife managers is the interaction of habitat fragmentation and climate change with distribution of wildlife populations, in light of fire. Future research could explore how the temporal and spatial distribution of prescribed fire of varying intensity could impact distribution of habitats and animal populations. Understanding more about how prescribed fire can maintain disturbance and diversity in the context of anthropogenic change could inform landscape-scale, ecosystem-based management.

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Table 1—Studies of effects of prescribed fire on fauna in the southern Appalachian region, USA

Effects	Measurement	Taxa	Relevant studies
Direct			
Behavioral	Nest success/ selection	Birds	Artman and others 2001
	Roost selection	Bats	Johnson 2009
	Habitat selection	Anurans	Pitt and others 2013
Population/ Community	Abundance	Herpetofauna	Ford and others 1999; Greenberg and Waldrop 2008; Love and others 2007; Ford and others 2010; Matthews and others 2010
		Small mammals	Ford and others 1999; Greenberg and others 2006; Greenberg and others 2007a; Matthews and others 2009; Raybuck and others 2012
		Birds	Artman and others 2001; Klaus and others 2010; Rush and others 2012
		Invertebrates	Campbell and others 2007b; Love and others 2007; Campbell and others 2008; Greenberg and others 2010
	Richness	Herpetofauna	Ford and others 1999; Greenberg and Waldrop 2008; Matthews and others 2010
		Small mammals	Ford and others 1999; Raybuck and others 2012
		Birds	Greenberg and others 2007b; Klaus and others 2010
		Invertebrates	Campbell and others 2007b; Campbell and others 2008
	Population estimate	Small mammals	Greenberg and others 2006
Direct Mortality		Anurans	Pitt and others 2013
Indirect			
Habitat			
		Herpetofauna	Greenberg and Waldrop 2008; Matthews and others 2010
		Small mammals	Greenberg and others 2006; Greenberg and others 2007a; Raybuck and others 2012
		Birds	Artman and others 2001; Artman and Downhower 2003; Greenberg and others 2007b; Klaus and others 2010; Rush and others 2012
		Bats	Johnson and others 2009
		Deer	Lashley and others 2011
		Invertebrates	Campbell and others 2007a; Greenberg and others 2010

Table 2—Assessment of the effects of prescribed fire on fauna in the southern Appalachians, from 21 studies, showing negative effects noted for herpetofauna (salamanders), birds (ground nesting birds), and small mammals (shrews)

Taxa	Positive effect	Negative effect	Neutral	Studies
Invertebrates	+,+,+		+,+	Campbell and others 2007a, 2007b, 2008;Greenberg and others 2010; Love and others 2007
Herpetofauna	+,+	+	+,+,+,+	Ford and others 1999, 2010; Greenberg and Waldrop 2008; Matthews and others 2010; Pitt and others 2013
Birds	+,+,+	+,+,+	+,+,+,+,+,+	Artman and Downhower 2003; Artman and others 2001; Klaus and others 2010; Rush and others 2012; Greenberg and others 2007b
Mammals	+,+,+,+	+,+,+,+	+,+,+,+,+,+	Ford and others 1999; Greenberg others 2006, 2007a; Lashley and others 2011; Matthews and others 2009; Raybuck and others 2012; Johnson and others 2009

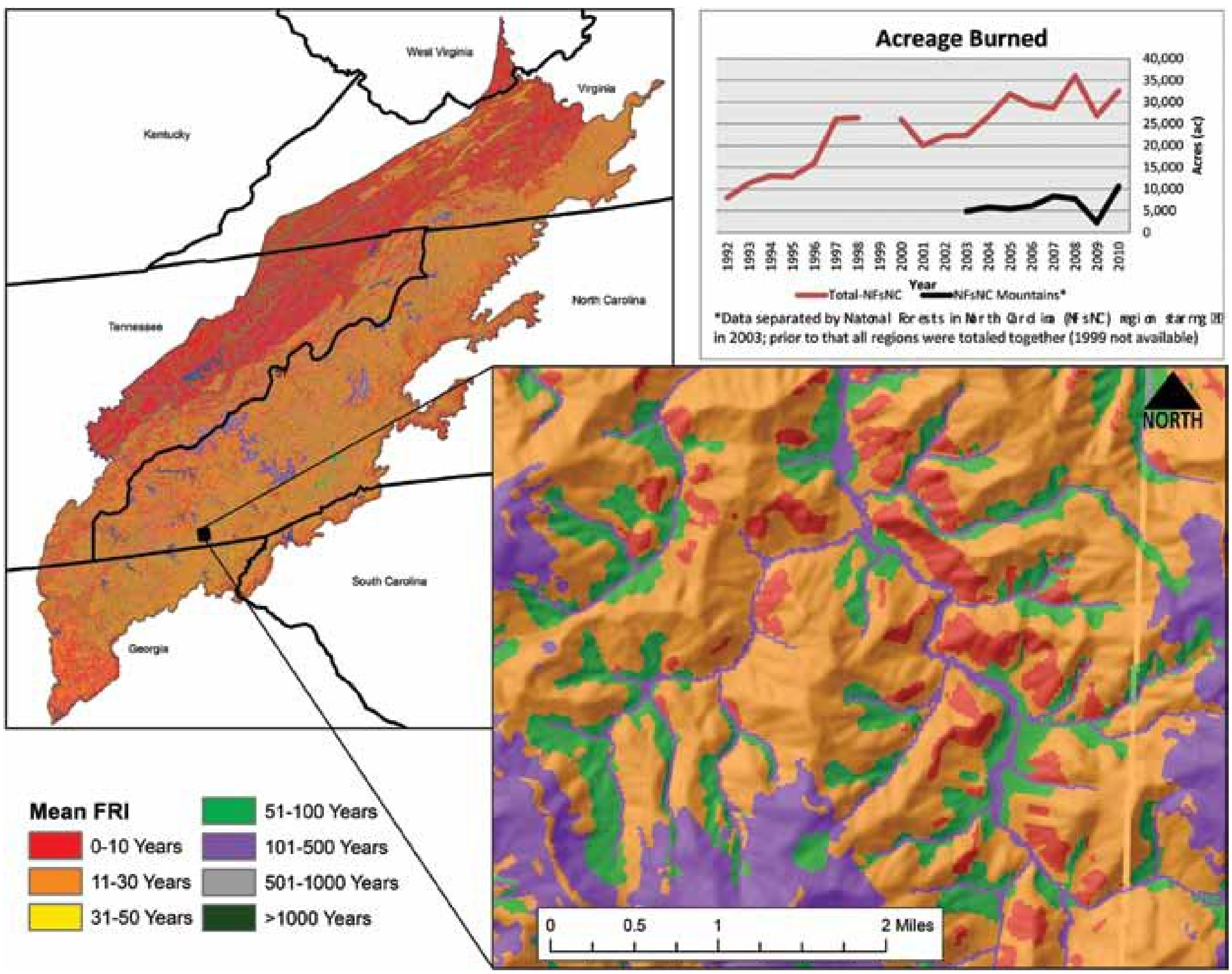

Figure 1—Mean Fire Return Interval estimated for the southern Appalachian region.

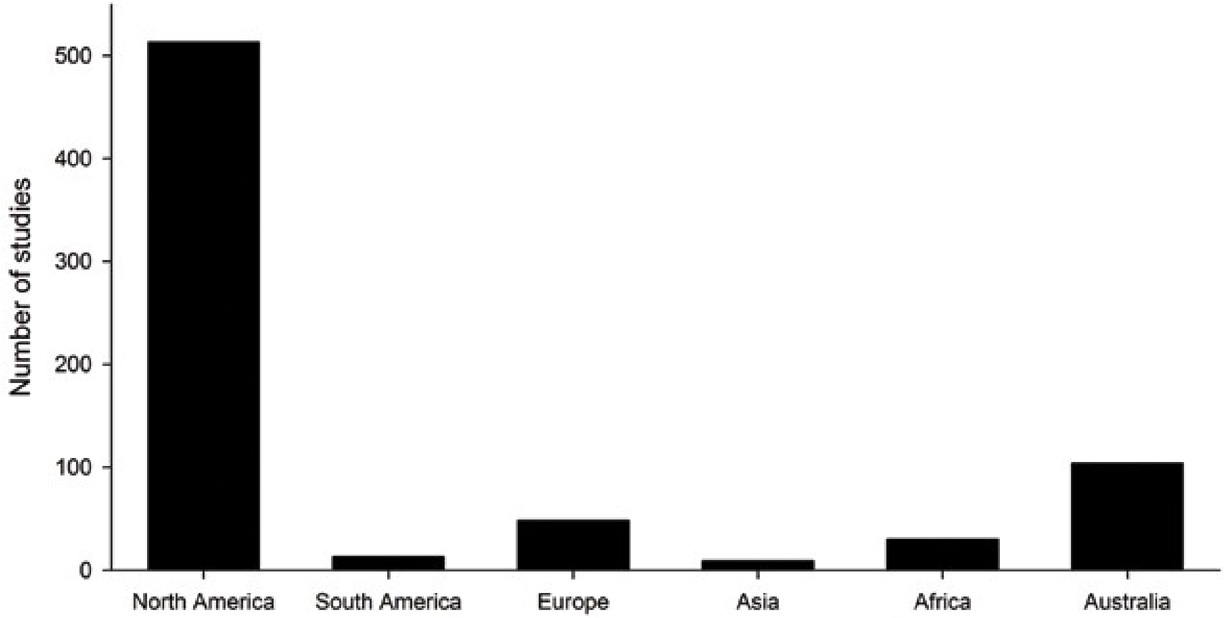

Figure 2—Studies of the effect of prescribed fire on wildlife by continent.

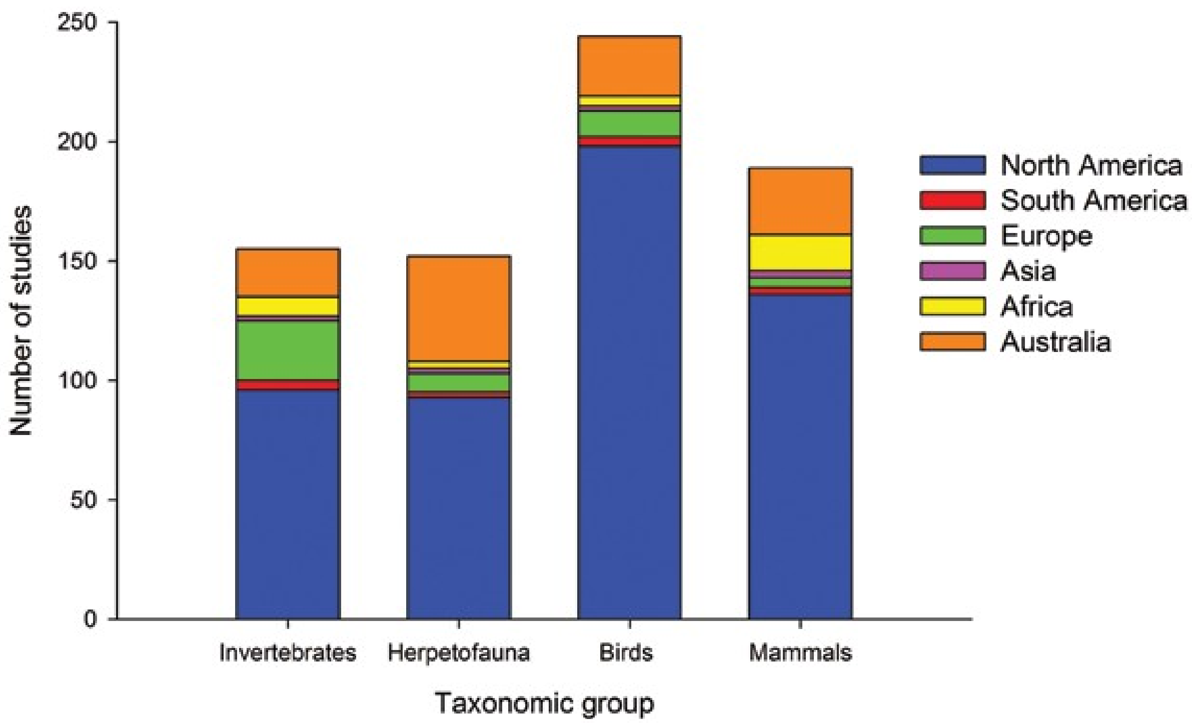

Figure 3—Studies of the effect of prescribed fire by taxonomic group and continent.

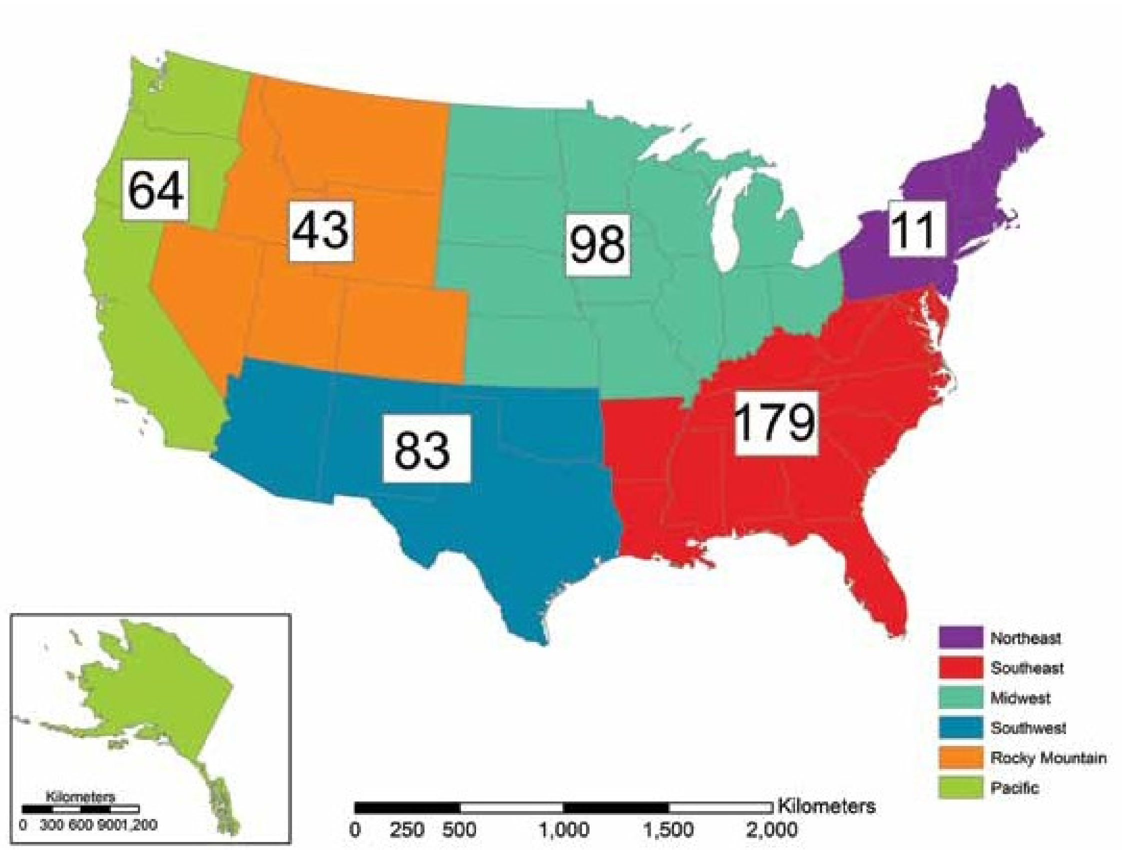

Figure 4—Studies of the effects of prescribed fire on fauna by region of the United States. Numbers represent the number of studies conducted per region.

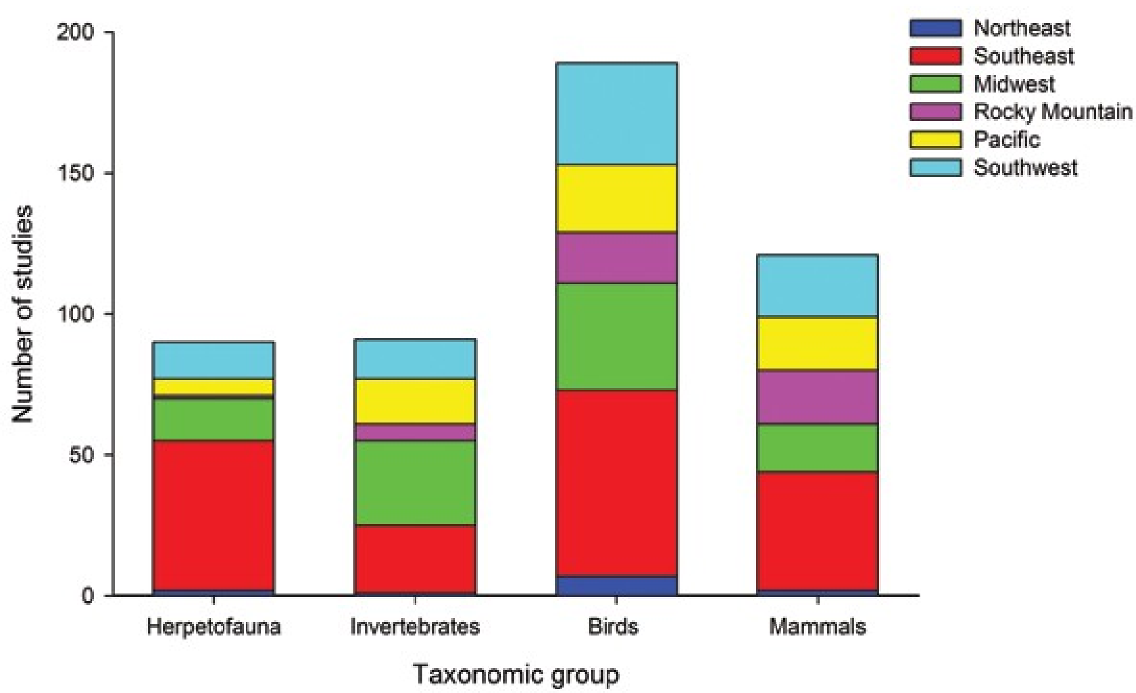

Figure 5—Studies of the effects of prescribed fire by taxonomic group and region of the United States.

Figure 6—Distribution of studies investigating the effects of prescribed fire on wildlife in the southern Appalachians of the United States.