Prescribed fire effects on herpetofauna: review and management implications

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Prescribed burning is used to achieve a variety of silvicultural objectives, including controlling heavy fuel accumulation, exposing mineral soil, releasing available nutrients for seedbed preparation, and controlling certain insects, diseases, and competing vegetation (Hunter 1990, Pyne et al. 1996). Prescribed burning also is an important tool for wildlife management. Prescribed fires influence amount and type of food and cover by modifying habitat structure (Leopold 1933, Komarek 1963, Wade and Lunsford 1989, Hunter 1990, Cain et al. 1998). For example, prescribed burns can be used to alter succession by killing or reducing size of hardwood understory trees and shrubs and enhancing frequency, biomass, and diversity of herbaceous vegetation (Stransky and Harlow 1981, Brockway and Lewis 1997, Cain et al. 1998).

Despite a large body of knowledge concerning the use of prescribed burning for wildlife management (Lyon et al. 1978; Komarek 1981; Harlow and Van Lear 1981, 1987; Wood 1981; Hunter 1990), the responses to fire of amphibians and reptiles have received relatively little attention (Harlow and Van Lear 1981, 1987; Means and Campbell 1981; deMaynadier and Hunter 1995). Recent concerns and controversy over potentially declining amphibian populations (Pechmann and Wilbur 1994, Blaustein and Wake 1995) have increased interest in the effects of forest management practices on herpetofauna (deMaynadier and Hunter 1995). Hoping to highlight the benefits of fire for herpetofauna and to stimulate additional research, we review currently available information concerning effects of prescribed burning on amphibians and reptiles. We consider both direct responses of herpetofauna to fire and indirect effects via changes in upland and aquatic habitats. This review may serve as a general reference for resource managers and others interested in conserving and managing amphibians and reptiles.

Direct responses to fire

The immediate response of individual vertebrates to fire ranges from panic to calm movement away from fires (Lyon et al. 1978). Lyon et al. (1978) suggested that smaller and less mobile vertebrates such as amphibians and reptiles were most likely to exhibit panic and experience relatively high rates of direct mortality from fires. Compared to other vertebrates, amphibians, in particular, exhibit limited movements and poor dispersal capabilities (Sinsch 1990). Additionally, the moist, permeable skin and eggs of amphibians increase their vulnerability to heat and microhabitat drying (Stebbins and Cohen 1995). However, Komarek (1969) reported that, overall, amphibians and reptiles did not appear to be disturbed by approaching fire and responded in adaptive manners that minimized mortality. For example, large breeding choruses of frogs have been observed in wet areas immediately after fires, surrounded by still-smoking ashes (Vogl 1973). Presumably, these wet areas provided the frogs with suitable refugia and aquatic habitats may protect other herpetofauna from the direct effects of fires.

Kahn (1960) and Lillywhite and North (1974) found that in the chaparral of southern California, western fence lizards (*Sceloporus occidentalis*) survived fires by seeking refuge under surface objects. Subsequently, the lizards invaded burned areas from adjacent unburned habitats (Kahn

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1960) and selectively used burned and charred branches for perching (Lillywhite and North 1974, Lillywhite et al. 1977). Babbitt and Babbitt (1951) and Folk and Bales (1982) reported that box turtles (*Terrapene carolina*) and eastern mud turtles (*Kinosternon subrubrum*) survived fires by burrowing into the soil. In the mallee woodlands and heathlands of temperate Australia, the high incidence of burrowing by many amphibian species imparts considerable resilience to fire (Friend 1993). Many other species of herpetofauna seek cover in the burrows of tortoises (e.g., gopher tortoises [*Gopherus polyphemus*]), small mammals, and other wildlife species (Speake et al. 1979, Means and Campbell 1981, Jackson and Milstrey 1989, Lips 1991), and may use these habitats to avoid surface fires. More mobile species of herpetofauna (e.g., lizards and large snakes) may simply disperse from burning areas (Komarek 1969, Means and Campbell 1981, Patterson 1984).

Several reports have described population-level responses of amphibians and reptiles to wildfires and prescribed burns. Fire-induced mortality of most species was 10 or fewer individuals/burn in any of the habitats sampled, including wetlands (Babbitt and Babbitt 1951, Vogl 1973), prairies and prairie-woodlands (Bigham et al. 1964, Erwin and Stasiak 1979), deserts (Simmons 1989), chaparral (Howard et al. 1959), and forests (Means and Campbell 1981, Folk and Bales 1982). However, most studies did not provide baseline estimates of abundance, and it is unclear whether these mortality data reflect the deaths of only a few individuals or entire populations. Means and Campbell (1981) examined effects of prescribed burning on a population of eastern diamondback rattlesnakes (*Crotalus adamanteus*) in Florida. Of 68 individual rattlesnakes marked and captured in a 600-ha forest subjected to 5 prescribed fires in as many years, only 2 were killed by burning. Both snakes were in mid-ecdysis (shedding of skin), which may have hampered their sensory perception and consequently their ability to detect and disperse away from approaching fires (Means and Campbell 1981). After a prescribed burn in another study area, Means and Campbell (1981) captured 7 unharmed, adult *C. adamanteus* "crawling around in the smoking ashes." Again, the only recorded fatality, a 3-month-old juvenile, was in mid-ecdysis.

Figure 1. Eastern box turtle found alive immediately after a prescribed burn.

Among North American species of herpetofauna for which mortality data are available, only the eastern glass lizard (*Ophisaurus ventralis*) appears to incur significant direct mortality from prescribed burning (Means and Campbell 1981). Babbitt and Babbitt (1951) found 24 dead and 33 live eastern glass lizards on a 3-m transect of burned area along a highway in Florida. Means and Campbell (1981) also recorded 15 dead and 4 live eastern glass lizards after a prescribed burn. However, given the species' largely southeastern Coastal Plain distribution (Conant and Collins 1998), eastern glass lizards historically must have been exposed to large-scale disturbances, including frequent wildfires (Myers and Van Lear 1998). Thus, we suspect that any short-term mortality following fire is offset by maintaining grassland and pine flatwood habitats favored by this species (Conant and Collins 1998).

Although additional research is needed, at least one study indicates that fire intensity and seasonality may influence mortality rates of herpetofauna. In Australia, Griffiths and Christian (1996) documented no deaths of individually marked lizards from early dry-season fires, but 29% mortality from late dry-season fires. The authors attributed differences in mortality to the higher intensity of late-season fires coupled with seasonal changes in lizard habitat selection (e.g., shifts from aboveground perches to surface cover).

In summary, currently available information indicates that fire in general has little direct effect on most amphibians and reptiles, leading Means and Campbell (1981) to conclude that "it is illogical that animals associated with fire vegetation are not themselves at least behaviorally adapted to resist mortality by fire." High levels of fire-induced mortality also appear to be uncommon in many species of birds and mammals (Lyon et al. 1978, Wood 1981).

Indirect effects by modifying habitats

Upland habitats

Historically, fires were among the most important natural disturbances in many terrestrial ecosystems (Wahlenburg 1946, Hunter 1990, Rogers 1996, Myers and Van Lear 1998). Studies to date indicate that because prescribed burning often maintains or restores species composition and structure of naturally fire-dependent upland vegetation, herpetofauna historically adapted to these habitats not only tolerate but also benefit from such treatments. In the naturally fire-dependent chaparral communities of southern California (Hanes 1971), reptile species diversity is strongly correlated with vegetation density. Lillywhite (1977*a*, *b*) and Simovich (1979) found that richness of arboreal and terrestrial reptiles was lower in chaparral areas either converted to grasslands by unusually frequent (e.g., yearly) fires or allowed to succeed to a mature, densely vegetated stand in the absence of fire. Before fire-suppression efforts, patches of southern California chaparral apparently burned every 2–10 years, whereas large-scale, high-intensity fires occurred at 20- to 40-year intervals (Hanes 1971, Philpot 1977). Application of prescribed burns at these historical frequencies and intensities should benefit wildlife communities, including herpetofauna (Lillywhite 1977*a*, *b*; Wirtz 1977, Simovich 1979).

Similarly, natural and prescribed burns have increased overall herpetofaunal diversity in fire-maintained savannas of Africa (Barbault 1976) and Asia (Auffenberg 1981), and several fire-prone ecosystems in Australia and New Zealand (Catling and Newsome 1981, Braithwaite 1987, Friend 1993, Trainor and Woinarski 1994, Pianka 1996), although population declines have been documented for some species immediately after fires (Patterson 1984, Bamford 1992, Friend 1993).

Several studies from the xeric pine forests of Florida have documented the importance of fire for herpetofauna. In longleaf pine (*Pinus palustris*), turkey oak (*Quercus laevis*), and sand pine (*P. clausa*) scrub forests, several reptile species, including sand skinks (*Neoseps reynoldsi*), six-lined racerunners (*Cnemidophorus sexlineatus*), mole skinks (*Eumeces egregius*), and crowned snakes (*Tantilla relicta*), primarily are found in open, early-successional habitats with a high proportion of bare sand (Means and Campbell 1981, Campbell and Christman 1982, Stout et al. 1988, Greenberg et al. 1994). Historically, these habitats were created and maintained by relatively frequent (1- to 5-year intervals) small-scale burns and infrequent (i.e., $\geq$50-year intervals) but high-intensity, large-scale wildfires (Myers 1985, 1990). Thus, fire maintained a temporally shifting landscape mosaic of stand ages and conditions to which many herpetofauna were adapted (Means and Campbell 1981, Greenberg et al. 1994). In the absence of fire, many herpetofaunal species disappear as stands mature and succeed to hardwood associations (Campbell and Christman 1982, Greenberg et al. 1994). Eventually, a few reptile species asso-

Figure 2. Effects of repeated growing-season prescribed fires in a loblolly pine stand, South Carolina Coastal Plain. Foreground portion of stand has been burned each summer for 40 years, whereas fire exclusion in background has resulted in a dense hardwood midstory.

ciated with closed-canopy conditions (e.g., southeastern five-lined skinks [*E. inexpectatus*]) become dominant and overall herpetofaunal diversity declines (Greenberg et al. 1994).

In a mirror image of the usual concept of forest fragmentation (e.g., Harris 1984, Hunter 1990), stand maturation and succession without fire acts as a fragmenting agent of otherwise disturbance-maintained, open-habitat herpetofaunal communities (Greenberg et al. 1994). Campbell and Christman (1982) and Greenberg et al. (1994) suggested that under well-managed circumstances, clearcutting was sufficiently similar to the effects of high-intensity wildfires as to recommend its use to maintain early-successional reptile habitats in Florida sand-pine scrub. However, in many cases prescribed burning may be the only means to mimic the disturbance frequencies, intensities, scales, and effects of previous fire regimes (Means and Moler 1979, Sharitz et al. 1992, Brennan et al. 1998).

Means and Campbell (1981) examined herpetofaunal communities in longleaf pine and shortleaf pine (*P. echinata*) stands of peninsular Florida that had been annually burned for 60–70 years and in an unburned forest that had succeeded to a closed-canopy beech-magnolia (*Fagus grandifolia-Magnolia grandiflora*) association. Three species of amphibians (tiger salamander [*Ambystoma tigrinum*], oak toad [*Bufo quercicus*], and ornate chorus frog [*Pseudacris ornata*]), and 1 species of reptile (six-lined racerunner) were captured predominantly from the burned pine stands, whereas 3 amphibian species (marbled salamander [*A. opacum*], mole salamander [*A. talpoideum*], and slimy salamander [*Plethodon glutinosus*]) were captured almost exclusively in the hardwood forest. The authors suggested that these were real differences reflecting adaptations (or lack thereof) of individual species to fire.

In southern Florida, richness and abundance of amphibians and reptiles consistently were higher on plots of slash pine (*P. elliotii*) subjected to 3 different burn intervals (1, 2, and 7 years) than on a control plot protected from burning for 20 years (Mushinsky 1985). Even plots burned annually produced high numbers of species and individuals (Mushinsky 1985). Based on these results, Mushinsky (1986) recommended a 5- to 7-year prescribed-burn cycle to maintain diverse herpetofaunal communities in the sandhills of southern Florida.

Effects of upland fire suppression on one species may subsequently impact entire wildlife communities. The gopher tortoise is distributed across the southeastern Coastal Plain, but maintains its highest population densities in the longleaf pine–wiregrass (*Aristida stricta*)-turkey oak community of the Florida sandhills (Auffenberg and Franz 1982, Ernst et al. 1994). Wide patches of sand, scattered clumps of wiregrass, and a sparse overstory provide the best foraging and nesting habitats for this species (Landers and Speake 1980, Auffenberg and Franz 1982). Landers and Speake (1980) reported that these conditions resulted from periodic fires that occurred at intervals of 5–10 years, and similar habitats could be produced with prescribed burns every 2–4 years. They also found that prescribed burning was important to maintain gopher tortoise populations on sandhills sites that previously were converted to slash pine plantations.

Gopher tortoise populations have declined in many areas, and the species is federally listed as threatened across portions of its range (Diemer 1986, Ernst et al. 1994). In addition to urbanization, habitat alteration, and human exploitation, fire suppression has been implicated as a factor in gopher tortoise declines (Auffenberg and Franz 1982, Diemer 1986, Breininger et al. 1994). Without fire, shrub and hardwood succession closes the canopy and decreases availability of cover, forage, and nesting sites (Auffenberg and Franz 1982, Diemer 1986). However, loss of these habitats from fire suppression also is detrimental for many other animals that use gopher tortoise burrows for nesting, feeding, or cover. At least 332 species use burrows of gopher tortoises (Jackson and Milstrey 1989, Lips 1991), including several rare amphibians and reptiles (e.g., gopher frogs [*Rana capito*], sand skinks, pine snakes [*Pituophis melanoleucus*], indigo snakes [*Drymarchon corais*], and eastern diamondback rattlesnakes; Speake et al. 1979, Means and Campbell 1981, Jackson and Milstrey 1989).

In some cases, prescribed fire in upland habitats may benefit herpetofauna only if applied at the appropriate season or frequency. Reported population declines of the flatwoods salamander (*Ambystoma cingulatum*) in the southeastern Coastal Plain have been attributed in part to fire suppression and resultant loss of mature, open longleaf pine stands with a ground cover of grasses and forbs (Palis 1997). Historically, these stand conditions were perpetuated by both lightning-induced and human-caused fires that occurred at 2- to 4-year intervals primarily from late spring through summer (Landers et al. 1990, Brockway and Lewis 1997). Without fire or under altered fire regimes (e.g., infrequent winter burns), understory succession may not be sufficiently retarded to promote grass and forb establishment (Brockway and Lewis 1997, Palis 1997).

Restoration of some Coastal Plain fire-dependent communities and, by extension, the herpetofauna associated with them may be impossible without reintroducing growing-season fires (Sharitz et al. 1992). Forest fragmentation and urbanization no longer permit high-intensity summer fires at landscape scales (Sharitz et al. 1992, Wade 1993). Additionally, smoke-management issues and negative public perceptions about wildfires have resulted in widespread fire suppression in many ecosystems (Sharitz et al. 1992, Wade 1993, Rogers 1996, Brennan et al. 1998). Myers and Van Lear (1998) suggested that resource managers may have their best opportunities to recreate longleaf pine savannahs by applying growing-season prescribed burns to hurricane-impacted landscapes. As an alternative, growing-season burns could be implemented on more intermediate scales that approximate, if not duplicate, historic fire regimes (Sharitz et al. 1992). Additionally, Brockway and Lewis (1997) recently reported that frequent (e.g., 2-year intervals), dormant-season (i.e., winter) burns were an effective alternative to summer fires to maintain longleaf pine–wiregrass ecosystems.

Negative indirect impacts of prescribed fire on herpetofauna likely are greatest for species requiring leaf litter or other surface cover that is burned (Spellerberg 1975, McLeod and Gates 1998). Spellerberg (1975) and McLeod and Gates (1998) found that several snake species associated with moist, cool microclimates or leaf litter were significantly less abundant in burned stands than in unburned stands. However, Means and Campbell (1981) found no evidence of population declines for several species of Florida herpetofauna associated with leaf litter and other surface cover after prescribed burns. At least one study has documented negative impacts of fire on amphibians resulting from post-fire soil erosion. Gamradt and Kats (1997) reported that reduced numbers of egg masses of stream-breeding California newts (*Taricha torosa*) were related to sedimentation following a chaparral wildfire. Removal of ground cover also may increase the vulnerability of herpetofauna to predators (Auffenberg 1981), including humans (Wharton 1966). For example, Stoddard (1962) reported that to protect livestock, ranchers used prescribed fires to expose rattlesnakes.

Aquatic habitats

As incompatible as it may seem, prescribed fire potentially is an important tool to maintain aquatic habitats of some herpetofauna (Means and Campbell 1981, deMaynadier and Hunter 1995). For example, Carolina bays, pocosins, cypress (*Taxodium* spp.) ponds, shrub bogs, and other non-alluvial isolated wetlands are the primary natural lentic habitats on the southeastern Coastal Plain (Sharitz and Gibbons 1982, Sutter and Kral 1994, Sharitz and Gresham 1998). These wetlands are critical habitats for amphibian breeding and larval development and are used by numerous reptiles for cover, foraging, and hibernation (Means and Moler 1979, Sharitz and Gibbons 1982, Dodd 1992, Semlitsch et al. 1996, Russell and Hanlin 1999).

The primary natural processes that control vegetation of many Coastal Plain isolated wetlands are duration and magnitude of inundation and fire (Wharton 1978, Sutter and Kral 1994, Sharitz and Gresham 1998). Historically, wildfires entered isolated wetlands from the surrounding fire-adapted upland vegetation during periods of drought. Wharton (1978) recognized 2 fire cycles in Coastal Plain wetlands: short-interval fires that occurred every 3–9 years and long-interval fires that occurred at ≥20-year intervals. These periodic fires maintained open palustrine communities with sparse overstories (e.g., cypress) and abundant herbaceous vegetation (Sutter and Kral 1994, Sharitz and Gresham 1998).

Without fire, accumulation of organic matter creates substrate conditions that allow succession of many isolated wetlands to shrub thickets and eventually closed-canopy hardwood stands. In addition to canopy closure and loss of herbaceous vegetation, hardwood encroachment reduces groundwater levels and seepage, presumably through increased evapotranspiration (Sharitz and Gresham 1998). Eventually, permanent drying of the wetland may occur (Means and Moler 1979, Sharitz and Gresham 1998). Effects of fire suppression have been exacerbated by plowing "protective" fire breaks around many isolated wetland perimeters (Hipes and Jackson 1996; K. R. Russell, Clemson University, personal observation).

Means and Moler (1979) documented the importance of fire for shrub and herb bog habitats used by pine barrens treefrogs (*Hyla andersonii*) in peninsular Florida. Both bog types are important for pine barrens treefrogs; the dense thickets of shrub bogs provide arboreal habitat for adults, whereas the open seepage habitats of herb bogs are critical for larval development (Means and Moler 1979). Historically, fires entered herb bogs from the surrounding xeric pinelands every 3–8 years, whereas shrub bogs were maintained by fires at 20- to 50-year intervals (Wharton 1978). Without fire, both bog types succeed to hardwood forest (Wharton 1978). Means and Moler (1979) and Means and Campbell (1981) recommended periodic prescribed burning to maintain herb and bog habitats of pine barrens treefrogs.

Figure 3. Hardwood encroachment in basin of ephemeral isolated wetland resulting from fire suppression, South Carolina Coastal Plain. Hardwood succession eliminates herbaceous vegetation favored by many species of herpetofauna, and permanent drying of the wetland may occur.

Fire suppression and hardwood succession also threaten the wetland habitats of other herpetofauna, including the sphagnum bog, swamp, and meadow habitats of bog turtles ([*Clemmys muhlenbergii*]; Ernst et al. 1994, Carter et al. 1999) and the aquatic breeding sites of flatwoods salamanders and other amphibians (Palis 1997; S. H. Bennett, South Carolina Department of Natural Resources, personal communication). Despite an appeal by Means and Moler (1979) for additional studies, the effectiveness of prescribed burning regimes to maintain wetland-associated herpetofauna and other wildlife species remains largely unknown.

Herbicides as a substitute for prescribed fire

Using herbicides for silvicultural applications has greatly increased during the last several decades and is viewed by many as an adequate substitute for prescribed fire (Hunter 1990, Brennan et al. 1998). Concerns over crop-tree productivity, smoke management, more stringent air-quality standards, and litigation are in part responsible for the view that herbicides are an attractive alternative to achieve forest management objectives (National Research Council 1976, Wade 1993, Ottmar et al. 1996, Brennan et al. 1998). Because herbicides, like fire, eliminate competing vegetation, application of chemical compounds has potential in situations where wildlife managers struggle to control invasive hardwoods (Brennan et al. 1998). Additionally, herbicides offer potential advantages over prescribed burning, including increased selectivity and decreased risk of offsite damage (Hunter 1990).

Brennan et al. (1998) argue, however, that herbicides cannot duplicate the multiple ecosystem functions provided by fire and suggest that the greatest benefits to be derived from such chemicals to manage wildlife habitats occur when they are used in conjunction with, rather than in place of, prescribed fire. Until studies are available that evaluate the efficacy of herbicides to mimic landscape effects of fire and the direct impacts of these chemicals on amphibians and reptiles, using herbicide treatments to create and maintain suitable habitats for herpetofauna must be viewed cautiously.

Management implications and research needs

Our synthesis of the literature indicates that replacement of fire-adapted vegetation by fire-intolerant associations (Kuchler 1964) leads to concomitant declines in overall herpetofaunal abundance and diversity. However, even within fire-adapted ecosystems, some herpetofauna are dependent on later-successional or climax vegetation (Means and Campbell 1981). Prescribed fire is indicated as an appropriate management tool that can be used with other treatments to benefit herpetofauna by restoring a historical mosaic of successional stages, habitat structures, and plant species compositions (Means and Campbell 1981, Campbell and Christman 1982, Hunter 1990, Greenberg et al. 1994, deMaynadier and Hunter 1995). Any fire-induced mortality that does occur presumably is outweighed by maintaining preferred or required habitat features (Vogl 1973, Means and Campbell 1981). Likewise, although fire-induced disturbance may decrease herpetofaunal diversity within a particular patch, a mosaic of successional stages and habitat structures should increase diversity on a broader scale (Petraitis et al. 1989, Greenberg et al. 1994, McLeod and Gates 1998).

Because most studies of herpetofauna and prescribed burning have focused on fire-maintained ecosystems, caution must be exercised when extending conclusions to other regions where fire was a less frequent or intensive historical disturbance regime. Four recent studies from such areas have provided mixed results. Fair and Henke (1997) determined that Texas horned lizards (*Phrynosoma cornutum*) in southern Texas preferentially used recently burned areas, but they expressed concerns about fire-induced mortality. In Pennsylvania, Kirkland et al. (1996) reported significantly more amphibians in a recently burned oak-dominated stand than in adjacent unburned portions of the forest, but could not attribute this finding to fire *per se*. Prescribed burning in the Maryland Coastal Plain appeared to increase abundance of some herpetofauna while decreasing abundance of others, with negative effects most pronounced for species associated with leaf litter or other surface cover (McLeod and Gates 1998). Ford et al. (1999) documented that community restoration fires in the southern Appalachians had little effect on herpetofauna and concluded that concerns about the impacts of prescribed burning on these species in the region seemed unwarranted.

Even in fire-dependent ecosystems of the southeastern United States, where most studies indicate positive relationships between herpetofauna and prescribed burning, a lack of rigorous experimental design (e.g., small sample sizes, single or no controls, no treatment replication) in several studies ultimately may limit conclusions concerning these relationships (Greenberg et al. 1994, deMaynadier and Hunter 1995). Much of the literature on direct mortality of herpetofauna following fire consists of anecdotal reports that, although consistent, may be somewhat meaningless without a baseline (i.e., pre-fire) frame of reference. Likewise, without adequate controls and replication, reported differences in herpetofaunal species composition and abundance between burned and unburned sites may be attributable to edaphic or other influences, rather than fire or the lack thereof.

Our evaluation of the literature concerning herpetofauna and prescribed burning has led us to a series of recommendations, by no means comprehensive, for future research:

(1) Studies in ecosystems or regions where fire was or is a less dominant form of disturbance. For example, we recently initiated research to examine effects of prescribed burning on herpetofauna in mixed hardwood-pine forests of the South Carolina Piedmont, where historically fire occurred less frequently and on a smaller scale than in the Coastal Plain, but nevertheless was an important ecosystem process (Van Lear and Waldrop 1989).

(2) Studies that evaluate the combined effects of fire frequency, intensity, and seasonality on herpetofauna (e.g., Griffiths and Christian 1996). Such studies would be especially valuable to identify ways to blend current silvicultural uses of prescribed fire with the habitat needs and behaviors of herpetofauna.

(3) Potential use of herbicides as a substitute for prescribed fire or their use in combination with fire to favorably alter habitats for herpetofauna.

(4) Evaluating prescribed fire regimes to restore and maintain aquatic habitats of herpetofauna threatened by hardwood succession (Means and Moler 1979).

(5) Accurate determination of the distribution, habitat requirements, and demographic status of amphibians and reptiles in fire-maintained ecosystems. These data generally are lacking for many species of herpetofauna in the United States (Gibbons et al. 1997) and are needed before prescribed fire regimes can be tailored to achieve habitat management objectives.

(6) Studies of direct and indirect fire effects on herpetofauna that incorporate baseline estimates of species occurrence and population size, and rigorous experimental designs (e.g., true spatial

and temporal controls, treatment replication). In particular, more information is needed concerning both direct and indirect effects of fire on amphibians.

As natural resource scientists and managers, we must not only gain a better understanding of the effects of prescribed fire on wildlife, including herpetofauna, but also promote its use when clearly indicated as a prescription for wildlife management. A critical component of this promotion is the education of the public about the historical role of fire in many ecosystems and the importance of prescribed fire as a management tool. Without public support, the possibility of increasing prescribed burning is unlikely.

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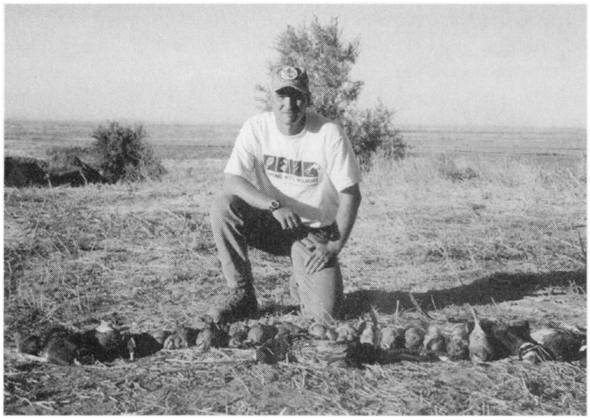

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