POTENTIAL EFFECTS OF FORESTRY OPERATIONS AND ASSOCIATED BEST MANAGEMENT PRACTICES ON RIPARIAN WILDLIFE SPECIES IN THE SOUTHEASTERN UNITED STATES

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Abstract—The US Fish and Wildlife Service is considering the addition of 374 riparian and aquatic species in the southeastern United States to the federal Threatened and Endangered Species List. This recommendation is a result of a 2011 petition, which recognized forest operations as having negative effects on 51 percent of the listed species, citing research conducted in the absence of Best Management Practices (BMPs) (Federal Register 76(187):59836-59862). We conducted a literature review to evaluate how BMPs might benefit these species, but found that information specific to these riparian species and forest operations was generally limited. Available literature pertaining to BMP effects and these riparian species generally contained broader conclusions, which were often conducted at higher taxonomic levels. We were able to develop some broad interpretations that support the benefits of BMP implementation to many of these species. Our review indicated that BMPs (i.e., streamside management zones) can limit sediment and nutrient inputs, reduce thermal pollution, enhance water quality, and safeguard riparian ecosystems to a degree that should provide some level of protection for most of the investigated species. Stream crossing BMPs and stream crossing designs should be beneficial by restricting sediment input and by minimizing potentially negative changes to stream channel hydrology. Our findings generally support the need for additional research regarding the specific effects of BMPs on stream and riparian biota.

INTRODUCTION

Following the Clean Water Act of 1972, Forestry Best Management Practices (BMPs) have been developed to address potential water quality issues during forestry operations (Aust and Blinn 2004, Ice 2004, Shepard 2006). Potential impacts of sedimentation, temperature change, and chemical regimes have been addressed through the implementation of forestry BMPs (Anderson and Lockaby 2011, Aust and Blinn 2004). Streamside Management Zones (SMZs), sediment control mechanisms, and stream crossing designs can reduce, prevent, or eliminate negative ecological alterations that would otherwise be associated with harvesting operations (Aust and others 2011, Lakel and others 2006). A significant amount of research has shown that BMP implementation is associated with good water quality (Shepard 2006). When compared to natural stands, managed stands can support similar species diversity (Wigley 1997).

In 2011, the US Fish and Wildlife Service began the review process on a petition that requested 374 riparian and stream species from the southeastern United States be added to the federal Threatened and Endangered species list. This petition identified logging as a threat for 51 percent of the listed species and supported this statement predominantly with research conducted in the absence of appropriate forestry BMPs. The overall objective of our project was to conduct a literature review to evaluate how BMP implementation could potentially enhance water quality, preserve natural riparian habitat, and safeguard these petitioned species during harvesting operations. For this paper we chose to concentrate on the animal species.

METHODS

Our literature search included peer reviewed articles, government publications, theses, dissertations, and books. Specific information on habitat needs, life history, and home ranges of these species were obtained and placed into an appendix. This information was predominantly acquired through peer reviewed journal articles, textbooks, and government publications. Because significant research gaps existed

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between forestry operations and potential species level impacts, we frequently reviewed research findings for larger taxonomic classifications and for studies that were conducted at sites similar to conditions in the southeastern United States. With over 200 references, we compiled a significant amount of information regarding BMP implementation and resulting impacts on wildlife populations within the southeastern United States. The organization of our results does not necessarily follow a strict taxonomic classification grouping, but instead are organized based on the organization in the Federal Register listing (Federal Register 76(187):59836-59862).

RESULTS

Mammals

Insular cotton rat (*Sigmodon hispidus insulicola*), Sherman's short tailed shrew (*Blarina carolinensis shermani*), and the Pine Island Rice Rat or Marsh Rice Rat (*Oryzomys palustris*) (2 populations) were mammals listed in this petition. These rodents are successional species that thrive in harvested environments. The cotton rat prefers dense vegetation found in 3 to 10 year old clearcuts (Mengak and Laerm 2007). Small mammal abundance is generally, positively affected by 10 m riparian buffers (Constantine and others 2004). SMZs in the southeastern United States have been shown to be sufficient to support small mammal populations (Miller and others 2004). Forest edges, skid roads, and clearcut openings support higher densities, higher species richness, and greater diversity in small mammal populations (Moseley and others 2009).

Birds

Black rails (*Laterallus jamaicensis*), sandhill cranes (*Grus canadensis pratensis*), and seaside sparrows (*Ammodrammus maritimus macgillivraii*) are restricted to marshland habitats, and are not associated with forested habitat. In fact, woodland expansion and encroachment negatively impacts sandhill crane and seaside sparrow habitat (Elderd and Nott 2008, Johnson 2000). In order to preserve sandhill crane habitat at Rowe Sanctuary in Nebraska, woody vegetation that encroaches into water channels is managed through the use of heavy machinery (Kinzel and others 2009). Timber harvesting does not typically occur in marshlands, and therefore would not have an effect on these avian species.

Reptiles

To protect reptile habitat and water quality, a 30 to 60 m wide SMZ has been recommended (Rudolph and Dickson 1990, Semlitsch and Bodie 2003). Vegetative structure has been shown to influence reptile populations. Narrow SMZs can produce dense understory, which negatively influences reptile abundance (Rudolph and Dickson 1990). Maintaining riparian buffers increases turtle diversity (Sterrett and others 2010). In the southeastern United States, timber harvesting can create heterogenic environments, providing reptiles with egg laying and basking habitat in an otherwise forested environment (Moseley and others 2009, Russell and others 2002).

Amphibians

The southeastern United States is the "hotspot" of the nation's amphibian biodiversity (Weir and Greis, 2002). This diverse population is primarily threatened by habitat loss from conversion of forested land to urban, industrial, and agricultural uses (Weir and Greis 2002). The width of an SMZ influences amphibian abundance. Wider SMZs (30 to 95 m) support the greatest abundance, while narrower zones (0 to 20 m) commonly have the lowest abundance (Rudolph and Dickson 1990). The recommended width of SMZ to maintain amphibian abundance is at least 30 m (Rudolph and Dickson, 1990). Potential effects of harvesting operations on amphibians are complex, and could vary at a species level as well as by region (Alix and others 2014, deMaynadier and Hunger 1995). Foley (1994) found in his study in Texas that there were no differences in numbers of amphibians inside and outside a 65 foot SMZ among control, select cut, and clearcut treatments. Forest road and skid trails can potentially create suitable habitat for amphibians by creating artificial aquatic habitats and vernal pools for reproduction (Adams and Hook 1993, deMaynadier and Hunter 2000, Russell and others 2002).

Fish

General potential threats to the 48 species of fish listed in this petition include impoundment, channelization, altered hydrology, sedimentation, thermal pollution, dissolved oxygen, and changes in watershed land use. Riparian buffers as well as stream crossing selection and design specifically address the aforementioned potential threats to fish populations. Riparian buffers and SMZs safeguard fish from potential sedimentation, temperature level alterations, and detritus input by providing fish habitat, promoting species diversity, and maintaining water quality (Anbumozhi and others 2005). Moring (1982) found a 30 m wide unharvested riparian buffer was sufficient to protect salmon eggs from sedimentation. Clearing of riparian strips in excess of 1km. can substantially affect fish assemblage (Jones and others 1999, Quist and Schultz 2014). Stream crossing BMPs address fish mobility and potential threats of impoundment. While bridges commonly allow for adequate fish mobility, culverts may require certain design specifications to properly enable fish passage (Aust and others 2011, Kidd and others 2014). A significant number of studies have been conducted to investigate fish mobility in the presence of culverts (David and others 2014, Foster and Keller 2011, Jensen

2014). Culvert designs should focus on hydraulic velocity, entrance attractiveness, and species specific fish swimming abilities (Hotchkiss and Frei 2007, Jensen 2014). Culvert length, velocity, and depth are important factors to consider when designing a culvert for fish populations. Studies have shown that retrofitting could enhance fish passage in existing culverts (David and others 2014). Spoiler baffles and even mussel spats can enable fish passage (David and others 2014, Feurich and others 2012).

Amphipods and Isopods

As cave dwelling species, the amphipods and isopods listed in this petition can be impacted by energy base alterations, physical and hydrological disturbances, and temperature alterations (Holsinger 1972). In many states, forestry BMPs are in place to protect karst environments and cave entrances. Fifty foot riparian buffers are recommended for sensitive areas such as cave entrances, sinkholes, and areas above the cave passage (Personal communication. Daniel Feller. 2013. Western Region Ecologist, MD Department of Natural Resources, Appalachian Lab, 301 Braddock Rd., Frostburg, MD 21532). Consultation by a professional is an important component of preharvest planning in these areas (Zokaites 1997). Erosion control implementations and proper waste wood placement ensure that environmental conditions and energy base levels are not influenced by sedimentation or debris (Zokaites 1997).

Mussels

Dams are a major factor in freshwater mussel decline in the southeastern United States. Before impoundment of the Tennessee River, there were 100 species of mussels. Following impoundment by hydrological dams, those numbers were reduced to less than half, with only 44 species of mussels remaining (Watters 2009). Impoundments, sedimentation, channelization, dredging, loss of riparian buffers, and invasive exotics threaten mussel populations (Clayton and others 2001, Poole and Downing 2004, Thorp and Rogers 2011, Watters and others 2009). Stream crossing design and riparian buffers are BMPs that address potential sedimentation and hydrological issues. SMZs and riparian buffers can preserve mussel habitat, reduce potential sedimentation, preserve temperature levels, and enhance in channel diversity. Riparian buffers have been shown to maintain species richness and abundance. Poole and Downing (2004) found that having ≥ 50 percent forested riparian buffers had sustained mussel diversity, whereas ≤ 50 percent riparian buffers lost mussel diversity. Stream reaches having 80 percent riparian buffers lost almost no species (Poole and Downing 2004). Where possible, to promote motility, bridges are the preferred stream crossing. Culverts can be designed in a way that prevents potential impoundment, with bottomless culverts being the preferred design. By focusing on hydraulic velocity, turbulence scour and the threat of impoundment can be eliminated. Mussel habitat can be preserved by ensuring heterogeneous substrate and allowing for fish host passage.

Crayfish

Threats to the 83 listed crayfish include sedimentation, limited ranges, invasive species, and a loss of riparian buffers (Herrig and Shute 2002, Lodge and others 2000, Parkyn and Collier 2004). Adequate riparian buffers and proper stream crossings can reduce or eliminate these potential threats during harvesting operations and protect essential habitat (Graynoth 1979, Parkyn and Collier 2004). If not properly designed, culverts could potentially restrict crayfish motility, limit dispersal, increase predation, alter riverbed channels, and create substrate homogeneity. Elevated water velocity beyond a species motility threshold can cause an inability for crayfish to maintain their position within a culvert (known as “slippage”). Slippage can occur at velocities as low as 2 cm/s downstream, and upstream at velocities of between 30 and 40 cm/s, depending on the species (Foster and Keller 2011, Louca and others 2014). Higher culvert velocities can serve as a selective environmental filter, selecting for the more tolerant of velocity, and far more aggressive nonnative rusty crayfish (Foster and Keller 2011). In a mixed agricultural and urban environment, there was an increase in brown rat predation on crayfish within and around culverts whose increased water velocity inhibited crayfish movement (Louca and others 2014). Corrugations, oxidized culvert bottoms, or natural substrate on the bottom of culverts can assist with reducing this slippage and enabling crayfish passage (Foster and Keller 2011). Louca and others (2014) recommended that water velocity be less than 30 cm/s to mitigate flow effects on crayfish passage. While further research is needed on individual species and their motility thresholds, proper culvert design ensures crayfish population motility during and following harvesting operations.

Snails

Snails have very limited ranges, and potential threats to populations include impoundments, sediment, and chemicals (Johnson 2009). BMPs that minimize sediment, such as riparian buffers, should be beneficial to snail populations (Herrig and Shute 2002, Johnson 2009). If water velocities are too high within culverts, slippage may occur, resulting in an inability to move through a culvert (Resh 2005, Rivera 2008). High velocity culverts can potentially serve as a biological filter, perhaps even selecting for more robust, invasive species of snail (Clennon and others 2007, Rivera 2008). Dissipating erosional energy, providing substrate heterogeneity, and implementing a culvert at a similar slope to the streambed should reduce stream velocity and enable snail passage (Resh 2005). There is very little information on forestry BMPs in relation to snails, particularly in North America, and additional research is needed.

Butterflies and Moths

In North America, moths are the better Lepidoptera biodiversity indicator, as compared to butterflies in tropical regions (Summerville and others 2004). Vegetative changes (as a result of host plants), changes in light penetration, habitat heterogeneity, moisture, temperature, humidity, and canopy cover changes may alter butterfly and moth abundance, diversity, and community composition (Hamer and others 2003, Summerville and others 2004, Summerville and others 2009). Research suggests that studies showing a decline in lepidopteran biodiversity following harvesting may be a result of homogenized tree communities in secondary successional forests (Summerville and others 2008). Lepidoptera in Indiana were found to be more resilient to shelterwood harvests than clearcut harvests (Summerville 2013). Plant community composition, biogeographic history, and spatial heterogeneity of host plants for female oviposition are all important components in maintaining lepidopteran community structure (Summerville and others 2008). BMPs that maintain SMZs and promote a diversity of forest classes should safeguard moth and butterfly species by maintaining host plant requirements and protecting and potential streamside changes (Summerville and others 2009).

Based upon studies in other countries and with different species, forestry effects on butterflies are complex: some species are favored by light increases, while others can potentially be harmed. Hamer and others (2003) found that in Borneo's selectively logged areas, butterfly diversity increased, yet assemblages differed significantly. Some North American butterflies, such as skippers, thrive in sunny environments and managed disturbance can encourage localized skipper recolonization and increase skipper population numbers (Swengel 2001).

Stoneflies, Dragonflies, and Caddisflies

Potential threats for stoneflies, dragonflies, and caddisflies include sedimentation, vegetative alteration, and altered hydrology. Leaving riparian buffers have been shown to benefit these invertebrates, as buffers can stabilize benthic food webs, ensure temperature stability, and maintain detritus input, light levels, and algae production. Quinn and others (2004) found that clearcut sites with continuous riparian buffers had stable populations of caddisflies while clearcut sites with patchy buffers had lower numbers. Davies (1994) found that SMZ width influenced stoneflies in Australia, and that they were most affected by buffers less than 30 m. Although not in North America, a study in South Africa suggested that riparian buffers should be at least 20 m to protect riparian vegetation for dragonfly populations, as smaller buffers could shift species compositions to that of a generalist community (Samways 1996). Culverts may affect caddisfly flight. Blakely and others (2003) found that road culverts in New Jersey reduced upstream adult caddisfly abundance by 250 percent when compared to downstream, but as the upstream numbers did not fall to zero, culverts were not found to be absolute dispersal barriers. Harding and others (2005) found that culvert hindrance of upstream flight in caddisflies was predominately due to urban surroundings, predation, confounding flight cues, and gradients in humidity, light, and temperature. In an urban environment, only 30 to 50 percent of caddisflies enter the culvert, and of these, about 10 to 30 percent do not reach the exit, partially due to spider predation (Harding and others 2005). Further research is needed to assess potential culvert impacts in a forested environment. BMPs like SMZs that reduce sediment, manage for habitat heterogeneity, and preserve litter food sources will benefit these species.

Beetles

Of the petitioned beetles, 17 out of 18 are cave beetles. Potential threats and appropriate BMPs previously mentioned for amphipods and isopods can also be applied to cave beetles, such as a recommended 50 foot SMZ. Cobblestone tiger beetles (*Cicindela marginipennis*) have and very restricted habitat and are adapted to natural disturbances such as flooding, fire, and ice scouring (Hudgins and others 2012, Leonard and Bell 1999). Although it is unlikely to be affiliated with forestry operations, the Cobblestone tiger beetle's need for low vegetation and cobblestone habitat could make it susceptible to sediment deposits burying cobble and allowing vegetation growth (Hudgins and others 2011). BMPs that address sedimentation issues (i.e., riparian buffers) would benefit this species by minimizing channelization and substrate alteration.

Vascular and Nonvascular Plants

The greatest potential threat for riparian vascular plants is direct removal, so SMZs would likely greatly benefit the species listed in this petition. Riparian buffers have been shown to benefit riparian vascular species. Hibbs and Bower (2001) examined an Oregon riparian forest and found conversion to a riparian buffer maintained species structure and composition. Habitat alteration is the greatest potential threat for nonvascular plants in this petition. Two aquatic species (moss and hornwort) are limited by sediment and temperature increases. Two riparian liverworts are limited by canopy removals. BMPs that reduce sediment and SMZs appear to be beneficial for these species.

CONCLUSION

In conducting our literature review, we found that the effects of BMPs on the vast majority of the species listed in this petition have not been evaluated. Even interpretations of effects on larger taxonomic classifications require additional research, particularly in the southeastern United States. Numerous studies on potential forestry impacts on wildlife did not employ BMPs, including those studies cited in the 2011 petition, of which ascribed negative impacts to forestry related practices. Negative harvesting impacts that were ascribed to 51 percent of the species cited studies that were conducted in the absence of BMPs, and many of these same species were not affiliated with forestry operations.

Forestry BMPs are designed to limit sediment, nutrients, and pollutants from entering the streams, protecting water quality and safeguarding riparian habitat. Typically, the most important operations for reducing sediment involve roads, skid trails, and stream crossings. Since many of the species are potentially negatively affected by sediment and state BMP programs are specifically directed towards the development and implementation of forestry BMP on such operational areas, BMPs almost undoubtedly benefit species negatively affected by sediment.

Riparian buffers and SMZs have been consistently shown to benefit riparian and stream dwelling species. They provide heterogeneous vegetation and riparian habitat, trap sediment and attached nutrients, provide thermal protection for streams, and serve as low impact zones in managed landscapes. The simple act of maintaining SMZs, as is recommended by all southeastern states, should enhance the habitat and stream conditions for many of these species. Sensitive areas such as karsts and sinkholes should generally be avoided, and riparian buffers should be considered during forestry operations.

Stream crossing BMPs, such as portable panel bridges or geoweb fords, which do not restrict channel flow, are a beneficial BMPs to riparian wildlife that may be impacted by channel restrictions, scouring, habitat homogeneity, and velocity changes. However, culvert options that reduce or eliminate potential mobility impacts on wildlife are available.

In providing economic incentives to landowners, timber harvesting maintains forested land and retains forested buffers along streams. Many land use changes, such as urbanization, had a greater potential to negatively impact wildlife populations. Forest management can reduce fragmentation, maintain riparian buffers, and control sediment in ways that may not necessarily be required by other land use changes. In maintaining forested habitat, applying appropriate BMPs to reduce sediment, and by minimizing and implementing appropriate and adequately designed stream crossings, riparian wildlife can be safeguarded and preserved in the presence of forestry operations.

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