Coal Mining and Wildlife in the Eastern United States: A Literature Review

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EXECUTIVE SUMMARY

The mining of coal in the eastern United States has had significant effects on wildlife populations and their habitats. The extraction of coal by various means (deep mining, longwall mining, contour mining, area mining, or mountaintop removal mining with valley fill) has a significant impact on terrestrial and aquatic ecosystems which can be felt for decades. The impacts have changed over time. Prior to state and federal regulation under the Surface Mining Control and Reclamation Act in 1977, severe environmental degradation was common, with serious impacts to aquatic and terrestrial ecosystems. The Surface Mining Control and Reclamation Act required the mining industry to address many of the significant environmental issues including reclamation of the mine site to approximate original contour and stabilization and revegetation of the site. These requirements reduced the impacts on wildlife resources and some wildlife populations responded favorably to reclaimed mine lands, including grassland birds and elk (*Cervus elaphus*). The goals of this literature review are to 1) review the extant literature on the effects of coal mining on aquatic and terrestrial wildlife populations and habitat; 2) review the literature relative to the effectiveness of reclamation practices in restoring conditions conducive for wildlife habitat; and 3) identify areas where research is needed to further the science needed to better mitigate the impacts of mining on wildlife resources. Significant issues related to wildlife impacts still remain, including addressing the landscape level effects of mining on wildlife populations, assessing the cumulative impacts of mining from multiple sites at the landscape scale, and developing reclamation practices that promote ecological restoration of native plant and animal communities, in addition to protection of soil and water resources.

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INTRODUCTION

The mining of coal in the eastern United States has had significant effects on wildlife populations and their habitats. The extraction of coal by various means (deep mining, longwall mining, contour mining, area mining, or mountaintop removal mining with valley fill) has a significant impact on terrestrial and aquatic ecosystems which can be felt for decades. Given the difficulty in extracting coal from geologic strata that are generally not readily accessible from the surface, it is inevitable that there will be some significant changes in the flora and fauna of the area within and surrounding the mine site. The impacts of coal mining on wildlife populations occur at two primary levels: 1) immediate, direct effects of mining in terms of direct mortality, disturbance and displacement of wildlife populations during mining activities, and 2) changes in wildlife populations associated with long-term changes in land cover associated with mine sites and their reclamation. The goals of this literature review are to 1) review the extant literature on the effects of coal mining on aquatic and terrestrial wildlife populations and habitat; 2) review the literature relative to the effectiveness of reclamation practices in restoring conditions conducive for wildlife habitat; and 3) identify areas where research is needed to further the science needed to better mitigate the impacts of mining on wildlife resources.

In conducting this review, it is important to recognize that impacts from coal mining have occurred over many decades. The impacts have changed over time as environmental regulations have been enacted and the mining industry has responded to new regulations and as mining technology and practices have changed. Mining that occurred prior to the Surface Mining Control and Reclamation Act of 1977 had different, often more severe impacts than mining that occurred after reclamation became required by law. Impacts also differ dependent on the mining practice involved. Deep mining has different impacts than does contour mining or mountaintop removal mining with valley fill. It is important to keep these distinctions in mind when reviewing the literature.

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METHODS FOR THE LITERATURE REVIEW

We searched the literature using various search engines available online including Web of Science and Google Scholar. Search terms including various combinations of coal, mine, mining, reclamation, reforestation, wildlife, habitat, birds, avian, fish, mammals, reptiles, amphibians, herptofiles, endangered species, as well as individual species (e.g., Henslow's Sparrow). We focused on searching for articles about effects of coal mining on wildlife or wildlife studies on mine sites during and after mining and reclamation. We defined wildlife to include free-ranging vertebrates but included additional studies on aquatic macro-invertebrates because these taxa are closely linked via food chains to higher orders of life. We also included literature on effects of mining on water quality as it relates to aquatic wildlife opportunistically as we came across these articles while searching for wildlife-related literature. Additional literature on water quality effects, effects on soil loss, and other environmental effects of mining are available. We did not specifically research all of the relevant laws related to coal mining and reclamation at the state level.

Once individual articles were located, we reviewed the literature cited within each article for additional relevant works and we reviewed all of the articles that cited the article we found. The search was limited geographically to the eastern United States, roughly defined as east of the Great Plains but included studies in Texas, Oklahoma, Nebraska, South Dakota, and North Dakota. The search was strictly limited to coal mining, including deep mining, longwall mining, contour mining, mountaintop removal with valley fill, and associated reclamation practices. The search was concentrated on contemporary literature, primarily since passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Additional literature that was deemed of historic relevance was included opportunistically. The review included articles published in the scientific, peer-reviewed literature, state and federal government reports, guidelines, environmental impact statements, and other public documents, proceedings from various conferences held on relevant topics, and graduate student Ph. D. dissertations and M. S. theses. The review is comprehensive in scope but is by no means complete. Additional literature will come to light over time and can be added to the database.

LITERATURE REVIEW

The literature review yielded almost 300 articles, reports, dissertations, theses, extension bulletins, and other documents of interest (Table 1). There has been a considerable amount of work on many species of wildlife, with the majority (74 citations) of the studies being on birds. In addition, there has been a lot of research (93 articles) on reclamation practices. Many of these articles are of interest to wildlife management as reclamation type relates directly to the ensuing structure and composition of wildlife habitat that is created or restored by reclamation.

The vast majority of the wildlife studies have been largely descriptive in nature, where wildlife populations were assessed on post-mined lands that had been reclaimed by a variety of practices. In some cases, populations on mined lands were compared to reference sites that were not mined. In very few cases were populations assessed in a before-after control-intervention (BACI) classical experimental design to document the changes that occurred. Lacki et al. (2005) is an exception. As such, most of the studies cited document the wildlife species that responded positively to a specific reclamation practice but these studies did not necessarily document which species responded negatively to that practice or to the mining itself. This is an important distinction to keep in mind while reviewing the literature relative to mining and wildlife.

Most mining studies also were conducted at a mine-site scale. The response of wildlife to the specific area within the footprint of the mine and the response to the reclamation practices used have been assessed. This can be considered the local (mine-site specific) response. Extremely few studies have assessed the effects of mining on landscape structure, composition, and function, and wildlife response to conditions at the landscape scale. Townsend et al. (2009) assessed land cover and land use change in the Central Appalachians from 1976 to 2006 based on analysis of LANDSAT imagery. The effects of mountain top removal-valley fill on landscape structure and composition have been described (Wickham et al. 2007). Wildlife response at the landscape scale generally has not been documented. Another important topic of interest is the use of native plants in reclamation. Traditional reclamation practices relied on exotic herbaceous and woody plants that quickly colonized the site, stabilized the soil, and allowed the mining company to meet the reclamation standards economically and efficiently. These practices may have been successful in terms of mitigating soil loss and protecting water quality but did not foster restoration of native plant communities that were valuable as wildlife habitat. As such, there is great interest in the development of reclamation practices that lead to ecological restoration of mine sites with native plant communities. The development of successful reclamation practices that lead to ecological restoration of native plant communities in a cost-effective way and the wildlife response to these reclamation practices continues to be an important topic for research.

Table 1. Summary of the available literature on the effects of coal mining on wildlife, broken out by topical area, 1950-2011.

Topical Area	Number of articles located
Wildlife- General	27
Birds	74
Grassland Birds	30
Ruffed Grouse	2
Wild Turkey	1
Northern Bobwhite	1
American Woodcock	1
Raptors	5
Mammals	51
Elk	10
White-tailed Deer	2
Bats	12
Small Mammals	15
Reptiles	11
Amphibians	31
Fish	30
Macroinvertebrates	17
Endangered Species	16
Wetlands	26
Wildlife Habitat	13
Reclamation	93
Reforestation	22
Exotics	3
Native Plants	8
Mountaintop Removal	14
PhD Dissertations	15
MS Theses	28

ENVIRONMENTAL LAWS, REGULATIONS AND IMPACT STATEMENTS

Coal mining in the United States is regulated by the Department of the Interior's Office of Surface Mining Reclamation and Enforcement (OSMRE) under provisions of the Surface Mining Control and Reclamation Act (SMCRA) of 1977, in conjunction with state mining and environmental agencies. Coal mining is also regulated by the Environmental Protection Agency (EPA), the U. S. Army Corps of Engineers (USACE), and individual state agencies through implementation of provisions of Section 402 and 404 of the Clean Water Act. Coal mining also comes under the provisions of the Endangered Species Act where potential "take" of endangered species might be involved, administered by the U. S. Fish and Wildlife Service. Individual states typically have laws and regulations related to coal mining and administer permits for mining, reclamation and abandoned mine lands. A recent Environmental Impact Statement, prepared by the EPA, USACE, USFWS, and the state of West Virginia, reviewed the environmental impacts associated with mountaintop removal mining with valley fill (USEPA 2005).

DIRECT EFFECTS OF MINING ON WILDLIFE

Very little literature exists on the direct effects of coal mining on wildlife. Mining certainly has direct effects as individuals and populations of species that occurred on the site pre-mining are killed or displaced. Direct mortality will occur when the species in question is not mobile enough to avoid mining equipment, typically for species of reptiles, amphibians, and small mammals. We did not find any literature that estimates the rates of direct mortality for any potentially affected species. Displacement of wildlife populations from the mine site is another direct effect of mining. As mining proceeds on a site, wildlife move to adjacent areas and establish territories and home ranges. We were unable to locate any studies that documented the extent of this displacement and the implications in terms of survival and reproduction for coal mining in the eastern United States. Some studies have been conducted on this topic in the western United States. In some species, reproduction is likely interrupted during the breeding season in which the displacement occurs. Survival of displaced individuals may be lower than survival would have been during the pre-mining period because displaced individuals may experience greater competition for resources in unfamiliar areas and may experience greater predation rates initially as they learn how to adjust to new surroundings.

WILDLIFE RESPONSE TO POST-MINING RECLAMATION

Wildlife response to post-mining reclamation is based on the wildlife species in question, their habitat requirements, the presence of a source population to colonize the mine site, and the structure and composition of the vegetation on the mine site post-reclamation and in the surrounding landscape. Wildlife response can be characterized in a variety of ways, including relative abundance on the site, survival, reproduction, movements, foraging behavior, and other behavioral traits. The majority of studies on wildlife response focused simply on documenting the numerical response of species in question on the mine site during some time period post-reclamation. To understand the full implications of wildlife response and effects on habitat quality, more in depth research is needed to document the demography (reproduction, survival, immigration, emigration) of the species that colonize mine sites post-reclamation.

BIRDS

The vast majority of studies conducted on wildlife response have focused on birds in part because birds are easily monitored using various count-based surveys. The effects of mining on avian communities occur initially by the removal of vegetation in preparation for mining. If the site is forested, vegetation removal occurs through timber harvest or clearing. Although few studies have been done to specifically evaluate the changes associated with mine sites from pre-mining to post-mining land uses, there is substantial literature of the effects of timber harvest on avian communities and populations- see review in Sallabanks et al. (2000). There are substantial differences in avian response to timber harvest for forest regeneration and avian response to timber harvest or clearing in preparation for mining because of the nature and timing of the revegetation that occurs. In timber harvest for forest management, tree regeneration begins within the first growing season post-harvest on the site and birds respond relatively quickly to the vigorous flush of woody regrowth. On mine sites, the reclamation process takes more time, and the vegetation responds more slowly, especially if the site is being reclaimed with shrubs and trees for reforestation.

On reclaimed mine lands which were originally forested, avian communities shift from forest bird communities to communities associated with early successional habitats, grassland birds and scrub-shrub birds. These changes in bird communities have conservation implications because in some cases there are forest bird species present that have declining populations and are of high conservation concern, such as the Cerulean Warbler (*Setophaga cerulea*) in the Appalachian Mountains (Buehler et al. 2006). Negative impacts on forest bird populations have to be weighed against positive gains in early successional bird populations. Many species associated with early successional habitats, such as the Henslow's Sparrow (*Ammodramus henslowii*) and the Golden-winged Warbler (*Vermivora chrysoptera*) are also of high conservation priority (Hunter et al. 2001, Buehler et al. 2007). Coal mining in the eastern United States seldom encounters bird species that are federally listed as threatened or endangered but see the list in Table 2 in the section on Endangered Species.

Most of the bird studies associated with mining have focused on characterizing songbird communities post-reclamation. Post-mining songbird studies have documented grassland bird response to reclamation when the reclamation has resulted in grassland cover. In general, grassland mine reclamation has been successful in creating habitat suitable for grassland bird use. The grassland species attracted to reclaimed mine lands include a diversity of songbirds and grassland raptors such as Northern Harriers (*Circus cyaneus*) and Short-eared Owls (*Asio flammeus*) (Rohrbaugh and Yahner 1996, Vukovich 2004, Vukovich et al. 2006).

Reclaimed mine sites in Pennsylvania, Kentucky, Illinois, Indiana, West Virginia, and Ohio are supporting breeding populations of Henslow's Sparrows (Bajema et al. 2001, Bajema and Lima 2001, DeVault et al. 2002, Scott et al. 2002, Mattice et al. 2005, Monroe and Ritchison 2005, Stauffer 2008, Stauffer et al. 2011)) and/or Grasshopper Sparrows *(Ammodramus savannarum*) (Whitmore 1979, Whitmore 1981, Wray et al. 1982, DeVault et al. 2002, Scott et al. 2002, Ammer 2003, Mattice et al. 2005, Galligan et al. 2006, Stauffer 2008, Stauffer et al. 2011), two grassland species of conservation concern. Reproductive rates by these species were comparable to reproduction in other settings (Ammer 2003, Monroe and Ritchison 2005, Galligan et al. 2006, Stauffer et al. 2011). No published survival data are available for grassland songbirds breeding on reclaimed mine lands. Adult and juvenile survival data are generally unavailable for most grassland songbirds (Perlut et al. 2008), because adult dispersal, depending on the species, may be high and return rates in ephemeral grassland habitats is often very poor (Jones et al. 2007). Without survival data, it is impossible to accurately determine whether reclaimed mine lands are providing conditions conducive for supporting source populations for priority species (Anders and Marshall 2005). Several authors have noted that reclaimed coal mine lands in the region were providing important grassland habitat contributing significantly to grassland bird conservation rangewide (Rohrbaugh and Yahner 1996, Bajema et al. 2001, Mattice et al. 2005, Monroe and Ritchison 2005, Stauffer et al. 2011).

Coal mining in the Appalachian region also has generally benefitted the Golden-winged Warbler. Golden-winged Warbler populations have been declining precipitously in the Appalachians (Buehler et al. 2007), and the species has been petitioned for listing under the Endangered Species Act in 2010 (USFWS 2011). Golden-winged populations occupy shrubby, early successional habitats often associated with reclamation of contour and area mines (Bulluck and Buehler 2008). Plant succession on mine lands is often slow, which provides for a prolonged period in which habitat conditions are conducive for Golden-winged Warblers. Succession on mine lands post-reclamation can be successfully set back by prescribed burning to further prolong the period of suitability for golden-wingeds (D. Buehler and K. Percy, unpubl. data). In some cases, however, recent coal mining may compromise golden-winged habitat where remining is occurring on old contour and area mine sites that are currently occupied by golden-wingeds (D. Buehler, unpubl. data). A mine land reclamation prescription is being developed for Golden-winged Warbler habitat restoration to address this issue (D. Buehler and K. Percy, unpubl. data).

Although grassland and scrub-shrub birds benefit from the early successional habitat developed from post-mining reclamation, forest-dwelling birds are adversely affected by land use change from forest to grassland, regardless of the origin of the change. Concern has been expressed related to habitat loss for Cerulean Warblers in the Appalachian Mountains associated with deforestation from coal mining (Buehler et al. 2006, Wood et al. 2006, Bulluck 2007). Cerulean Warbler populations have significantly declined since 1966 and have been petitioned for listing under the Endangered Species Act (USFWS 2006). Mining also affects forest songbirds in adjacent forested areas because of the creation of edge effects and because of forest fragmentation. Cerulean Warbler abundance, for example, was lower in forests adjacent to mountaintop removal mining with valley fill (Wood et al. 2006), although edges associated with contour mines in Tennessee were not associated with lower cerulean abundance (Beachy 2008). Cerulean Warbler reproduction was lower adjacent to forest disturbances from timber harvest than in undisturbed forest stands (Boves 2011). Similar relationships with cerulean reproduction and edges created by mining might be expected, although these relationships need to be documented.

Reclaimed coal mine lands can also provide habitat that supports upland game bird populations, including Northern Bobwhite (*Colinus virginiana*) (Beckerle 2004), American Woodcock (*Scolopax minor*) (Gregg 1997), Eastern Wild Turkey (*Meleagris gallopavo*) (Rice 1986), and Ruffed Grouse (*Bonasa umbellus*) (Kimmel and Samuel 1984). Although the potential for mine lands to contribute to Northern Bobwhite population recovery is cited in the National Bobwhite Conservation Initiative revised plan (Palmer et al. 2011), we were unable to locate any literature that demonstrated how this might be accomplished. Kentucky Department of Fish and Wildlife Resources (KDFWR), in cooperation with the University of Tennessee, is conducting a northern bobwhite population ecology and habitat management project on Peabody Wildlife Management Area, a reclaimed coal mining area, which will generate information on how bobwhites are doing on reclaimed mine grasslands and how to enhance their habitat (J. Morgan, KDFWR, pers. comm.). Reclamation of mine lands in grasses and legumes provided poor quality grouse brood habitat, although later successional stages provided better brood habitat quality (Kimmel and Samuel 1984). Wild Turkeys used reclaimed mine lands extensively and densities on mine lands exceeded densities on nearby control areas (Rice 1986).

MAMMALS

The effects of mining on mammal communities also occur initially by the removal of vegetation in preparation for mining. Changes in mammal communities are expected depending on the original cover type and the cover type post-reclamation.

The majority of mammalian studies have documented small mammal response to reclamation (Verts 1957, De Capita and Bookhout 1975, Sly 1976, Hansen and Warnock 1978, Brenner et al. 1982, Gust and Schmidly 1986, McGowan and Bookhout 1986, Urbanek and Klimstra 1986, Lacki et al. 1991, Krupa and Haskins 1996, Chamblin 2002, Chamblin et al. 2004, Dooley and Murray 2006, Larkin et al. 2008). The proximity of source populations after reclamation will in part determine the small mammal species that will repatriate a given mine site. Habitat structure and composition, including bare ground, herbaceous cover, shrubs and trees, rock outcrops, and course woody debris determine which species inhabit a given site. Mining and reclamation practices affect these structural conditions, and thus the small mammal community. As reclaimed mine lands undergo succession, the small mammal community changes accordingly, similar to what might be seen as old fields succeed into forest (Hansen and Warnock 1978). The nature of the reclamation practice, including how the soil is compacted, affects the resultant small mammal community (Larkin et al. 2008).

Studies on big game species in landscapes that include operational and reclaimed mine lands are limited to numerous studies on elk (*Cervus elaphus*) in Kentucky (Larkin et al. 2002, Cox 2003, Larkin et al. 2003, Seward 2003, Larkin et al. 2004, Wichrowski et al. 2005, Schneider et al. 2006, Olsson et al. 2007, Cox 2011), and Tennessee (Kindall et al. 2011, Lupardus et al. 2011) and very limited research on white-tailed deer (*Odocoileus virginianus*) (Cox 2003). The elk studies in Kentucky and Tennessee focused on elk survival, reproduction, food habits, habitat use and population growth and did not specifically focus on the relationship of elk to coal mining or to specific reclamation techniques. The elk restoration sites in Kentucky largely occurred on reclaimed mine lands with mine land grasslands accounting for 20% of the landscape (Larkin et al. 2002), whereas elk in Tennessee occurred in a forested landscape that included about 10% reclaimed mine land grasslands (Kindall et al. 2011). Elk in landscapes containing reclaimed mine grasslands forage extensively on grasses and forbs on mine sites (Schneider et al. 2006, Lupardus et al. 2011). The elk population has thrived in that setting in Kentucky (Schneider et al. 2006) but not in Tennessee (Kindall et al. 2011).

We found no literature on the effects of coal mining on black bear (*Ursus americanus*) populations. Black bears will be affected by coal mining in a variety of ways. Bears will likely respond to changes in land cover associated with mining. Increase in early successional habitat may increase summer soft mast food resources (e.g., blackberries) but will decrease fall-winter hard mast food resources (e.g, oak acorns) and potential den trees. Roads associated with mines may affect bear movements and distribution, especially if those roads provide access for bear hunters (Brody and Pelton 1989). Bear populations in eastern Kentucky have increased significantly in recent decades concomitant with extensive coal mining, suggestive that coal mining and black bear management may be compatible at least at the landscape level, especially if road access is limited (Unger 2007).

There is considerable interest in the relationship between bats and coal mining and reclamation. Over half of the 45 species of bats in North America have been recorded using abandoned deep mine shafts (Watkins 2002) and 10 of these species occur in eastern United States (Harvey 2000). Several of these species are endangered including Indiana bat (*Myotis sodalist*), Virginia big-eared bat (*Corynorhinus townsendii virginianus*), and gray bay (Myotis grisecens) (Currie 2000). A special symposium has been held recently on Indiana bats and coal mining (Vories and Harrington 2000). Abandoned coal mine shafts can be used by bats for seasonal roost sites and for hibernacula. Assessment and protection of these sites have become important components in bat conservation strategies (Watkins 2002). Bats may also be affected by deforestation associated with coal mining, by the creation of wetlands on mine sites, and by the effects of post-mining reclamation on foraging and roosting habitat. Strategies to mitigate these potential effects have been developed by state and federal agencies working in concert with industry and include the retention or creation of potential roost trees in areas adjacent to mine sites and provision of streamside buffers to protect foraging habitat (Wahrer 2000). A recent symposium addressed many of the contemporary issues in bat conservation related to coal mining (Vories et al. 2010). The relationship between bats and white-nose syndrome and mine sites is of particular research and conservation interest (Vories 2010).

There have been practically no studies on mammalian meso-predators on mine sites. The studies that have been done generally were descriptive in nature in terms of which species were present on mine lands post-reclamation (Yeager 1942, Brenner et al. 1982, Lacki et al. 1991, Pitts and Casebeer 2004). Yearsley and Samuel (1980) conducted a limited telemetry study on red fox (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*) habitat use on reclaimed mine lands in West Virginia.

REPTILES

Very few studies have been conducted on reptiles and their association with coal mining and reclamation. Most of this work has been limited to simply documenting which reptiles are present on a mine site post-reclamation (Williams 2003, Pitts and Casebeer 2004, Loughman 2005, Brenner 2007, Lannoo et al. 2009). A reclaimed mine site in Indiana supported 19 species of reptiles (1 lizard species, 5 turtle species, and 13 snake species), including several state-listed endangered and threatened species, similar in composition to native grasslands in the area (Lannoo et al. 2009). A West Virginia mine site supported five of 14 snake species found in the surrounding county (Loughman 2005). Reclaimed mountaintop removal mining sites in West Virginia had greater snake species richness and abundance than richness and abundance in intact forested control sites. Reclaimed sites with shrub-pole vegetation contained greater snake species richness and abundance than richness and abundance on sites still in grassland habitat (Williams 2003). Wetlands associated with mine reclamation or constructed to address acid mine drainage problems tend to enhance the reptile community on site by attracting turtles and snakes (Lacki et al. 1992). Copperbelly water snakes (*Nerodia erythrogaster neglect*), a federally threatened species, for example, were more common on sites post-reclamation than on the same sites pre-mining (Lacki et al. 2005).

AMPHIBIANS

Amphibians are considered good indicators of environmental stressors because they have unique life-history strategies linked to terrestrial and aquatic habitats, are sensitive to desiccation, and can absorb contaminants through their skin (Welsh and Ollivier 1998). Amphibian communities are of conservation concern because many species' populations are declining (Houlahan et al. 2000, Alford et al. 2001). Coal mining affects amphibian populations because of potential for direct mortality, removal of forest cover, changes in cover type, sedimentation of streams, and acidification of aquatic environments. Many amphibian species, especially *Plethodontid* salamanders, respond negatively to forest clearing in preparation for mining, or for other development purposes (Petranka et al. 1993, deMaynadier and Hunter Jr 1995, Ash 1997). The ability of salamanders and other amphibians to disperse from sites during clearing for mining is an open research question (deMaynadier and Hunter Jr 1995). Most amphibians may be locally extirpated from a given site during mining and may recolonize over time, dependent on the nature of the reclamation and the presence of nearby source populations for recolonization. Salamander populations were lesser in mountaintop removal mine sites reclaimed to grasslands or young forest compared to salamander abundance in intact forest, presumably because of the affinity of salamanders for moist sites with a well-developed litter layer (Williams 2003). Anuran abundance and species richness, in contrast, were similar between reclaimed mountaintop removal sites and intact reference forest sites, in part because of the greater mobility and less restrictive habitat requirements of anurans compared to salamanders (Williams 2003). Salamanders were absent from a reclaimed mine site in Virginia but were relatively common in intact reference forests (Carrozzino 2009).

Soil loss from mine sites, leading to sedimentation of streams, can also negatively affect amphibian populations. Silt levels below mountaintop removal mines in first order valley-fill streams in West Virginia were over four times greater than silt levels in first order reference streams. Salamander abundance was lesser in the valley-fill streams than salamander abundance in the reference streams apparently because of the sedimentation of valley-fill streams (Williams 2003).

Wetlands associated with mine sites can support amphibian populations that wouldn't otherwise have been present on the site (Myers and Klimstra 1963, Turner and Fowler 1981, Fowler et al. 1985, Lacki et al. 1992, Kirk 2000, Jansen et al. 2004, Timm and Meretsky 2004, Lannoo et al. 2009). However, acidification of streams and wetlands associated with mine sites can also negatively impact amphibian populations (Freda 1986, Middlekoop et al. 1998). Acidic water in wetlands and streams can cause direct mortality to larvae and adult amphibians and can also disrupt trophic relationships that amphibians rely on (Freda 1986).

FISH and AQUATIC ECOSYSTEMS

There has been considerable research attention and controversy related to the impacts of coal mining on aquatic ecosystems, especially as it relates to the impacts of mountaintop removal mining with valley fills. Numerous endangered fish and mussel species inhabit the streams of Appalachia where coal mining is common (Table 2). As a result, there is considerable concern related to potential take of endangered species and impacts on population viability. EPA has recently conducted a comprehensive literature review on the impacts of mountaintop removal with valley fill on aquatic ecosystems (USEPA 2011). Impacts of coal mining on aquatic ecosystems result from changes in land cover in the watershed from stable cover types, such as forest, to less stable, reclaimed cover types that are subject to soil loss. Although one of the primary goals of reclamation is to limit impacts on water quality and aquatic ecosystems, some impacts are unavoidable (USEPA 2005, 2011). Potential impacts include loss of headwater streams (mountaintop removal mining with valley fill), degradation in water quality including acidification, increased sediment loads, increased heavy metals (e. g., selenium), and changes in streambed configuration and stream flows (mountaintop removal with valley fill), ultimately leading to changes in biotic communities in terms of macroinvertebrates and vertebrates, such as fish (USEPA 2005, 2011). Macroinvertebrate populations are adversely affected when water quality declines (Clements et al. 1992, Diamond et al. 2002, Armstead et al. 2004, Kirk and Maggard 2004, Bruns 2005, Hartman et al. 2005, Pond et al. 2008, Brenner et al. 2009, USEPA 2011). Macroinvertebrate populations are important because they serve as the foundation for food chains supporting vertebrate populations (USEPA 2011) and are sensitive biological indicators of biological impairment in aquatic ecosystems (Clements et al. 1992, Diamond et al. 2002, Fulk and Autrey 2003, Kirk and Maggard 2004, Bruns 2005, Pond et al. 2008, Brenner et al. 2009, USEPA 2011). Pond et al. (2008) from one study in Kentucky assessing mountaintop removal sites, reported that mined sites showed impairment of downstream macroinvertebrate communities, whereas reference streams did not show impairment. As a result of mining impacts on aquatic ecosystems described above, fish species richness and abundance decline (Matter and Ney 1981, Diamond et al. 2002, Fulk and Autrey 2003, Ferreri et al. 2004, USEPA 2011).

Selenium is of particular concern in aquatic ecosystems associated with coal mining (USEPA 2011). Selenium is released into the environment from coal ash and coal mine waste, and enters aquatic ecosystems where aquatic organisms are exposed. Selenium can reach toxic concentration in aquatic ecosystems associated with coal mining and can essentially bio-accumulate through food chain transfer (Orr et al. 2006).

ENDANGERED SPECIES

Coal mining impacts on endangered species is of particular concern because of potential to further jeopardize populations of species that are already imperiled and because of the potential to affect mining operations and cause economic impacts under the legal restrictions on take under the Endangered Species Act. The number of federally listed threatened and endangered species that occur in eastern states where coal reserves are located is considerable (Table 2). There are many additional species that are state listed as endangered, threatened or species of conservation concern.

Several listed avian species occur in eastern states where coal mining occurs, although we did not locate any literature that documented effects of coal mining on these species, with the exception of documentation of Interior Least Terns (*Sterna antillarum*) nesting on the Big Brown mine in Texas (Kasner and Slack 2002). Several key mammalian species (e.g., Indiana Bat, Gray Bat, Ozark Big-eared Bat, Virginia Big-eared Bat) have received considerable conservation attention from state and federal agencies and the mining industry (Currie 2000, Vories 2010, Vories et al. 2010). Abandoned deep mine shafts have provided habitat for bats, including these endangered species. The listed flying squirrels are likely to be adversely affected by forest clearing associated with mining although we did not locate any literature that evaluated this potential conflict. There are several listed reptiles that occur in coal mining states, but we did not locate any literature that identified potential for take for these species. Research on the Copperbelly Water Snake on mine sites in Indiana suggested that snake populations increased after mining and reclamation (Lacki et al. 2005). Although there is considerable literature on effects of mining on amphibians (Table 1), little of the research has been specific to the species that are listed as endangered or threatened. Presumably amphibians would be adversely affected by forest clearing in preparation for mining but this has not been well documented in the literature specifically for mining. There are over forty federally listed species of fish that occur in the eastern United States in regions where there are coal reserves and mining. Historic impacts of coal mining on water quality have affected fisheries resources (Starnes and Gasper 1995), including some of the listed species (Starnes and Starnes 1981, Neves and Angermeier 1990, Schorr and Backer 2006).

Table 2. Federally-listed vertebrate Threatened and Endangered Species that occur in the eastern United States in areas where coal mining occurs. Source: USFWS Endangered Species Program website <u>http://www.fws.gov/endangered/species/us-species.html</u>; Coal reserves assessed from Coal Fields of the Conterminous United States by J. Tully, USGS Open-File Report OF 96-92.

Common Name	Scientific Name	States In Eastern Region In Which Species Occurs	Listing Status
Birds			
Crane, Whooping	*Grus Americana*	KS, ND, OK, TX Experimental Population (Non-essential) in most midwestern and southeastern states	E
Plover, Piping	*Charadrius melodus*	AL, AR, IA, KS, LO, MD, ND, OK, TX, VA IL, IN, OH, PA	T E
Stork, Wood	*Mycteria Americana*	AL, MS	E
Tern, Interior Least	*Sterna antillarum*	AR, IA, IL, IN, KS, KY, LA, MS, MO, ND, OK, SD, TN, TX	E
Warbler, Golden-cheeked	*Dendroica chrysoparia*	TX	E
Woodpecker, Red-cockaded	*Picoides borealis*	AL, AR, MO, MS, LO, TX, VA	E
Vireo, Black-capped	*Vireo atricapilla*	OK, TX	E
Mammals			
Bat, Indiana	*Myotis sodalis*	AL, AR, IL, IN, KY, MD, MS, MO, OH, PA, TN, VA, WV	E
Bat, Gray	*Myotis grisescens*	AL, AR, IL, IN, KS, KY, MO, OK, TN, VA, WV	E
Bat, Ozark Big-eared	*Corynorhinus townsendii ingens*	AR, MO, OK	E
Bat, Virginia Big-eared	*Corynorhinus townsendii virginianus*	KY, VA, WV	E
Squirrel, Carolina Northern Flying	*Glaucomys sabrinus coloratus*	TN, VA	E
Squirrel, Virginia Northern Flying	*Glaucomys sabrinus fuscus*	VA, WV	E
Reptiles			
Snake, Copperbelly Water	*Nerodia erythrogaster neglecta*	IN, OH	T
Tortoise, Gopher	*Gopherus polyphemus*	AL, LO, MS	T
Turtle, Alabama Red-belly	*Pseudemys alabamensis*	AL, MS	E
Turtle, Bog	*Clemmys muhlenbergii*	PA, MD	T
Turtle, Flattened Musk	*Sternotherus depressus*	AL	T
Turtle, Ringed Map	*Graptemys oculifera*	MS, LO	T
Turtle, Yellow-blotched Map	*Graptemys flavimaculata*	MS	T
Amphibians			
Frog, Mississippi Gopher	*Rana capito sevosa*	AL, LO, MS	E
Hellbender, Ozark	*Cryptobranchus alleganiensis bishopi*	AR, MO	E
Salamander, Barton Springs	*Eurycea sosorum*	TX	E

Table 2. (cont.)

Common Name	Scientific Name	States In Eastern Region In Which Species Occurs	Listing Status
Amphibians (cont.)			
Salamander, Cheat Mountain	*Plethodon nettingi*	WV	T
Salamander, Red Hills	*Phaeognathus hubrichti*	AL	T
Salamander, Shenandoah	*Plethodon shenandoah*	VA	E
Salamander, Texas Blind	*Typhlomolge rathbuni*	TX	E
Toad, Houston	*Bufo houstonensis*	TX	E
Fish			
Cavefish, Alabama	*Speoplatyrhinus poulsoni*	AL	E
Cavefish, Ozark	*Amblyopsis rosae*	AR, MO, OK	T
Chub, Slender	*Erimystax cahni*	TN, VA	T
Chub, Spotfin	*Erimonax monachus*	AL, TN, VA	T
Dace, Blackside	*Phoxinus cumberlandensis*	KY, TN, VA	T
Dace, Laurel	*Phoxinus saylori*	TN	E
Darter, Amber	*Percina antesella*	TN	E
Darter, Bayou	*Etheostoma rubrum*	MS	T
Darter, Bluemask	*Etheostoma sp.*	TN	E
Darter, Boulder	*Etheostoma wapiti*	AL, TN	E
Darter, Cumberland	*Etheostoma susanae*	KY, TN	E
Darter, Duskytail	*Etheostoma percnurum*	KY, TN, VA	E
Darter, Fountain	*Etheostoma fonticola*	TX	E
Darter, Goldline	*Percina aurolineata*	AL	T
Darter, Leopard	*Percina pantherina*	AR, OK	T
Darter, Niangua	*Etheostoma nianguae*	MO	T
Darter, Relict	*Etheostoma chienense*	KY	E
Darter, Rush	*Etheostoma phytophilum*	AL	E
Darter, Slackwater	*Etheostoma boschungi*	AL, TN	T
Darter, Snail	*Percina tanasi*	AL, TN	T
Darter, Vermilion	*Etheostoma chermocki*	AL	E
Darter, Watercress	*Etheostoma nuchale*	AL	E
Darter, Yellowcheek	*Etheostoma moorei*	AR	E
Gambusia, Big Bend	*Gambusia gaigei*	TX	E
Gambusia, San Marcos	*Gambusia georgei*	TX	E
Logperch, Roanoke	*Percina rex*	VA	E
Madtom, Chucky	*Noturus crypticus*	TN	E
Madtom, Neosho	*Noturus placidus*	MO, OK	T
Madtom, Pygmy	*Noturus stanauli*	TN	E
Madtom, Scioto	*Noturus trautmani*	OH	E
Madtom, Smoky	*Noturus baileyi*	TN	E
Madtom, Yellowfin	*Noturus flavipinnis*	TN, VA	T
Sawfish, Smalltooth	*Pristis pectinata*	AL, LO, MS, TX	E
Sculpin, Pygmy	*Cottus paulus*	AL	T
Shiner, Arkansas River	*Notropis girardi*	AR, KS, OK, TX	T
Shiner, Blue	*Cyprinella caerulea*	AL, TN	T
Shiner, Cahaba	*Notropis cahabae*	AL	E
Shiner, Palezone	*Notropis albizonatus*	AL, KY	E

Table 2. (cont.)

Common Name	Scientific Name	States In Eastern Region In Which Species Occurs	Listing Status
Fish (cont.)			
Shiner, Topeka	*Notropis topeka*	IA, KS, MO	E
Sturgeon, Alabama	*Scaphirhynchus suttkusi*	AL	E
Sturgeon, Gulf	*Acipenser oxyrinchus desotoi*	AL, LO, MS	E
Sturgeon, Pallid	*Scaphirhynchus albus*	AR, IL, IA, KS, KY, LO, MS, MO, ND, TN	E
Sturgeon, Shortnose	*Acipenser brevirostrum*	MD, PA, VA	E

Note: The above list of species and the states listed have been compiled for reference purposes but may not be complete in terms of the species listed and the states listed where coal reserves and mining are present. If questions exist, consult the local Ecological Services office of the U. S. Fish and Wildlife Service.

RESEARCH ON RECLAMATION PRACTICES

There has been considerable research on reclamation practices associated with coal mining in the eastern United States. We located almost 100 articles on various aspects of mine reclamation. Burger (2011) provides a review of the evolution of reclamation practices. Literature about the potential to create or restore wildlife habitat through the reclamation process goes back to the 1950s (Riley 1952, Riley 1957). The use and value of wetlands in the reclamation process has also been widely studied (Mitsch et al. 1983, Brooks et al. 1985, Lawrence et al. 1985, Brooks 1989, Wieder 1989, Brenner and Hofius 1990, Baker et al. 1991, Lacki et al. 1991, 1992, Atkinson and Cairns 1994, Brenner 1995, Brenner 2000, Jansen et al. 2004). With the advent of SMCRA in 1977, there was the need to develop reclamation practices that met SMCRA standards. Initial work in this respect focused on reclamation that quickly and effectively stabilized the site, minimized soil loss, and minimized impacts on water quality (e. g., (Brenner et al. 1975, Brenner 1979). In most cases, a grassland reclamation approach with exotic grasses (e. g., Tall Fescue, *Lolium arundinaceum)* and legumes (e.g., Sericea lespedeza, *Lespedeza cuneata*) were used because of their ability to readily become established and stabilize a site quickly and economically (Burger 2011). Many studies evaluated wildlife use of reclaimed grasslands and documented the vertebrates that inhabited reclaimed mine sites. In the 1990s, wildlife habitat became a common and acceptable post-mining land use. However in most cases, the reclamation strategy did not change from the grassland land use except to plant typically exotic, soft-mast bearing shrubs, such as Autumn Olive (*Elaeagnus umbellata*) and easily established and quick-growing but low value trees, such as Black Locust (*Robinia pseudoacacia*) (Burger 2011). Use of native species in reclamation has become a common theme recently (Boyce 2002, Beckerle 2004, Buckley and Franklin 2008), although the knowledge about which species to plant and how to use native species economically and efficiently remains an important research need (see Research Needs section below). Wildlife response to reclamation practices that feature native plant species has not been well documented, especially in comparative studies with traditional reclamation practices based on exotic species.

Cairns (1983) reviewed the management options for reclamation and noted the distinction between reclamation, rehabilitation, and ecological restoration. Numerous authors since 1980 have noted the desirability of ecological restoration (Cairns 1983, Brooks 1989, Atkinson and Cairns 1994, McCoy and Mushinsky 2002, Anderson et al. 2004, Angel et al. 2005, Burger 2011). The Appalachian Regional Reforestation Initiative (ARRI), established in 2004 by OSM, has produced extensive literature on the value of reforestation as a reclamation approach and the methods for effectively and economically achieving reforestation on mine sites (Angel et al. 2005, Groninger et al. 2007, Angel et al. 2009, Burger and Fannon 2009, Burger and Evans 2010, Zipper et al. 2011). ARRI is an important step towards ecological restoration because most of the Appalachian mine sites were forested prior to mining. As the area mined has increased in size with mountaintop removal mining with valley fill, the need for ecosystem restoration at a landscape scale has become apparent (Burger 2011). However, research on wildlife response to the reforestation reclamation option is just getting started. Because it takes decades for a reforestation reclamation project to realize its full potential, research on wildlife response to the full life-cycle of reforestation reclamation practices may take decades as well. The extensive research record on wildlife response to forest succession after various forest management practices can help bridge the gap-see review in Sallabanks et al. (2000).

RESEARCH NEEDS

In spite of the extensive literature base available on mining-wildlife relationships, there are still topical areas in which additional research is warranted. Key research areas include evaluation of landscape-scale and cumulative impacts for aquatic and terrestrial communities, and the need to develop and evaluate ecological restoration reclamation practices, as opposed to traditional functional reclamation practices. The following list covers topics that were apparent based on the literature review that has been conducted. However, a more comprehensive list of research needs should be developed from a facilitated discussion between the mining industry and interested members of the environmental regulatory, conservation, and research communities.

- Document landscape scale relationships between specific coal mining practices, specific reclamation practices and wildlife populations.
- Develop lists of native plant species suitable for ecological restoration and cost-effective reclamation and develop the site preparation and planting guidelines needed to ensure successful establishment.
- Assess the wildlife conservation implications of different reclamation options, especially related to different approaches to the reforestation reclamation option.

- Demographic studies on species that colonize mine sites after reclamation to assess habitat quality and population source/sink relationships.
- Effects of coal mining on bat populations and relationship with white nose syndrome.
- Amphibian dispersal ability in response to mining activities.
- Develop reclamation practices that specifically address wildlife conservation needs (e.g., Golden-winged Warbler and other early successional wildlife reclamation option).
- Develop methodology to document cumulative impacts from coal mining at the landscape scale for aquatic and terrestrial resources.
- Assess the human dimensions aspects of mine land management to determine the wants, needs and desires of people that live in mine land communities.
- Assess the extent of, and opportunities for, wildlife recreation on reclaimed mine lands.

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