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POWELL RIVER PROJECT

RECLAMATION GUIDELINES FOR SURFACE MINED LAND

Enhancing Wildlife Habitat on Reclaimed Mine Lands

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Introduction

We monitored wildlife use of reclaimed mine land areas of varying ages and vegetation types at two locations in southwestern Virginia in May through July of 2007 and 2008. Bird, salamander, and frog communities were studied to gain an understanding of how site use and species composition were affected by postmining vegetation characteristics. Mined-land communities were compared with wildlife communities in nearby nonmined forests to better understand how mining and reclamation practices affect wildlife. Here, as an outcome of that study and considering prior research, we provide recommendations for reclamation practices to enhance use of mined land by wildlife.

The study areas were located at the Powell River Project (PRP) Research and Education Center in Wise County and on the Public Access Land for Sportsman (PALS) in Dickenson County. These areas contained both mined and nonmined sites varying in age, vegetative cover, and elevation. Elevations at PRP ranged from approximately 2,450 to 2,700 feet; PALS ranged from 2,200 to 3,050 feet.

Sampling points for birds (102 points) were distributed among six cover types (figures 1-6), including relatively undisturbed forest, regenerating forests harvested as clearcuts (nonmined areas), and reclaimed mine areas of different ages. Amphibians were sampled using artificial cover surveys, night searches, and evening frog call surveys at water bodies. The complete study can be found in Carrozzino (2009).

Overview of Research Findings

As expected, mature forests generally had more canopy cover, a higher canopy, and greater tree densities than the other site types. Herbaceous groundcover was high on early successional reclaimed sites and managed pasture. The tendency of trees to grow close together in isolated clumps ("patchiness") was highest in pre-SMCRA and pasture cover types, and patchiness of woody stems was high on all reclaimed cover types. Coniferous density was highest on early and mid-successional reclaimed sites, because pines were planted during reclamation.

Birds were diverse and abundant in all habitats studied. In total, 80 bird species were observed, with 75 species sighted on mined areas during the breeding season. Thus, it is clear that reclaimed areas provide habitat for many bird species. We identified groups (guilds) of birds that responded to different habitat types in a similar manner (table 1). The types of birds found in each group were similar to what would be expected in habitats on nonmined areas with similar features. Species

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Figure 1. Managed pasturelands are mined areas that have been leased consistently for grazing purposes after reclamation. Typically, they are mostly grassland with patches of shrubby vegetation.

Figure 2. The early successional sites usually were dominated by thick herbaceous vegetation, such as tall fescue and sericea lespedeza, usually with small patches of woody species such as young eastern white pine (*Pinus strobus*), black locust (*Robinia psuedoacacia*), and autumn olive (*Elaeagnus umbellata*), as shown in the foreground of this photo. Early and mid-successional sites (see figure 3) were typical of southwestern Virginia mine areas reclaimed to unmanaged forest postmining land uses during the late 1980s and early 1990s.

Figure 3. The mid-successional sites were dominated by dense eastern white pine that had a closed canopy, often with patchy herbaceous vegetation due to heavy shading by the tree canopy.

Figure 4. Pre-SMCRA sites (lands mined prior to the passage of the Surface Mining Control and Reclamation Act in 1977) were characterized by a variety of vegetation and cover types. Open areas and densely vegetated patches with brambles and young trees are common along the bench, or flat compacted area where heavy machinery was active during mining. In many cases, maturing forest patches develop on the outslope, or steep area, below the bench where excess rocky material was placed during mining.

Figure 5. Recently harvested forests had been clearcut within the last 18 years, and natural regeneration was resulting in a young hardwood forest.

Figure 6**.** Mature forests were dominated by mature hardwoods and had not been harvested or mined within the past 65 to 100 years.

Table 1. Representative bird species identified as part of four functional groups or guilds with similar habitat requirements.[a]

	Habitat Type[b]					
	Pasture	Early successional	Mid successional	Pre-SMCRA	Harvested	Mature forest
Early successional guild						
Common yellowthroat (*Geothlypis trichas*)	U	C	U	U		+
Eastern meadowlark (*Sturnella magna*)	U	U	U			
Grasshopper sparrow (*Ammodramus savannarum*)	U	U	U			
Field sparrow (*Spizella pusilla*)	A	A	C	U		U
Prairie warbler (*Dendroica discolor*)	R	A	U		U	U
Mature forest guild						
Blue-headed vireo (*Vireo solitarius*)		+		U		R
Black-throated green warbler (*Dendroica virens*)			U	R	U	U
Northern parula (*Parula americana*)				U		U
Ovenbird (*Seiurus aurocapillus*)			U	U	C	C
Wood thrush (*Hylocichla mustelina*)	U	U	U	U	R	R
Shrubland generalists						
American robin (*Turdus migratorius*)	U	U	U	U	U	+
Indigo bunting (*Passerina cyanea*)	A	A	A	A	A	C
Northern cardinal (*Cardinalis cardinalis*)	R	R	R	C	R	R
White-eyed vireo (*Vireo griseus*)		U	U	U	R	U
Yellow-breasted chat (*Icteria virens*)	R	A	C	U	A	R
Forest generalists						
Blue jay (*Cyanocitta cristata*)	U	+	U	R	U	U
Carolina chickadee (*Poecile carolinensis*)	U	U	U	C	U	R
Dark-eyed junco (*Junco hyemalis*)				U		
Mourning dove (*Zenaida macroura*)	U	U	U	U	C	U
Scarlet tanager (*Piranga olivacea*)		+	U	U	R	R

A = Abundant; relative abundance > 0.4 birds observed per station per visit.
C = Common; relative abundance 0.2-0.3 birds observed per station per visit.
R = Regular; relative abundance 0.1-0.2 birds observed per station per visit.
U = Uncommon; relative abundance 0.01-0.1 birds observed per station per visit.
+ = Incidental; relative abundance < 0.01 birds observed per station per visit.
[a] Complete species lists can be found in Carrozzino (2009).
[b] Habitat types are represented by figures 1-6.

grouped into shrubland generalists (e.g., northern cardinal, yellow-breasted chat), forest generalists (e.g., scarlet tanager, blue jay), early successional species (e.g., common yellowthroat, prairie warbler), and mature forest species (e.g., northern parula, wood thrush). Species within these guilds can be managed as a group because they respond similarly to habitat features.

Several species of conservation concern were found on the study areas, particularly those that rely on early successional habitat. Many bird species that breed in early successional areas are declining throughout the eastern United States because of loss of habitat. Golden-winged (*Vermivora chrysoptera*) and blue-winged warblers were observed in early successional habitat on reclaimed mines (figure 7). Both species depend on areas that mimic natural disturbances. The Virginia Department of Game and Inland Fisheries (2005) identified "species of greatest conservation need" in the Virginia Wildlife Action Plan. Species of concern observed frequently during this study on or near reclaimed mines included black-and-white warbler (*Mniotilta varia*), prairie warbler, field sparrow, yellow-breasted chat, and eastern towhee.

Because of the difficulty of detecting terrestrial salamanders and the drought conditions encountered in both 2007 and 2008, we observed few individuals. When summer months are very dry, many amphibians limit the time they spend on the surface and thus were difficult to observe.

We found six species of salamanders under cover objects or actively foraging on the surface (table 2). The species captured most frequently were red-spotted newt

Figure 7. The blue-winged warbler (*Vermivora pinus*) is a species of concern in the eastern United States due to loss of habitat. It prefers early to mid-successional habitat, especially forest clearings and forest/field edges.

(nine observations) and northern slimy salamander (18 observations; figure 8). Most salamanders were found in mature forest (42 observations) and on pre-SMCRA sites (21 observations); with only one individual found in pine cover on a mid-successional reclaimed site.

The pre-SMCRA sites had more large deciduous (hardwood) trees than the post-SMCRA early and mid-successional sites. It is possible that salamanders were present on these sites because they prefer mature hardwoods, which are the dominant vegetation in their native habitat, the adjacent nonmined forest. Because salamanders require trees for shading and moist soils, they are likely return later in the successional process; several salamander species were found on the pre-SMCRA sites, often in association with the deciduous trees and shrubs that have become established on these areas.

Table 2. Amphibians encountered during the study period.

Salamander species	Frog and toad species
Longtail salamander (*Eurycea longicauda*)	American toad (*Bufo americanus*)
Northern red salamander (*Pseudotriton ruber*)	Bullfrog (*Rana catesbeiana*)
Northern slimy salamander (*Plethodon glutinosus*)	Fowler's toad (*Bufo woodhousei fowleri*)
Red-spotted newt (*Notophthalmus viridescens*)	Gray treefrog (*Hyla versicolor*)
Southern two-lined salamander (*Eurycea cirrigera*)	Green frog (*Rana clamitans*)
	Pickerel frog (*Rana palustris*)
	Spring peeper (*Pseudacris crucifer*)
	Upland chorus frog (*Pseudacris feriarum*)

Figure 8. Northern slimy salamanders were frequently found under cover objects.

We identified eight frog species during late-spring and summer frog call surveys at mine ponds or wetlands or when encountered while on-site for other purposes (table 2). Spring peepers were heard most frequently near water bodies and calling from water pockets at the base of pre-SMCRA highwalls. We often heard spring peepers in full chorus, where calls are constant, continuous, and overlapping, indicating the presence of many individuals. We also frequently heard bullfrogs and green frogs at lower call intensities.

Reclamation Practices to Improve Wildlife Habitat

It is clear from this study that a variety of birds, salamanders, and frogs use reclaimed mine areas. Several groups of bird species that respond similarly to habitat characteristics were using mined areas, and the types of birds found in each group were similar to what would be expected in habitats on nonmined areas with similar features.

We found several salamander species on the pre-SMCRA mines, often in association with the deciduous trees and shrubs that have become established on these areas. Frogs were found to be using mine ponds and wetlands as habitat.

By considering our results, along with well-known patterns in wildlife-habitat relationships and the results of prior studies conducted by other researchers, we can suggest reclamation practices that could be applied to enhance wildlife use of reclaimed mine areas.

Managing and reclaiming land to establish vegetation patches (e.g., grasslands, forest, wetlands, early successional) of different stages can provide habitat for diverse wildlife and aquatic species. Restoring a diverse community of native and site-adapted vegetation that includes a variety of structural features is the first step to attract wildlife species (Brenner and Kelly 1981; Camenzind 1984; Parmenter and MacMahon 1990).

Birds are generally one of the first types of wildlife to visit a mine site following reclamation due to their mobility and active search for suitable habitat (Brändle et al. 2003). Many bird species are not restricted to a single vegetation type, but rather depend on some combination of early successional habitat, open areas, and young and mature forests to find food and shelter and raise young (Hunter et al. 2001; figure 9). The number of bird species in a given area has been shown to increase with variation in species, ages, and sizes of vegetation (Karr 1968; Roth 1976).

Figure 9. Eastern towhees (*Pipilo erythrophthalmus*) prefer a mix of vegetation types including forest edges, overgrown fields and woodlands, and shrubby thickets.

Some research suggests amphibian populations initially are displaced by large-scale disturbances, but habitat can be provided for them through the development of wetlands and retention ponds (Fowler et al. 1985; Bradley 1987; Brenner and Hofius 1990; Lacki et al. 1992) and by retaining some patches of native forest (Schaid et al. 1983; Homyack and Haas 2009). Mid- to late-successional deciduous forest is needed to provide adequate canopy cover, leaf litter, and downed woody debris for salamander habitat (Hyde and Simons 2001). Frogs, along with some salamander species, require wetlands or ponds for foraging and breeding sites.

Although mining activities can have negative impacts on wildlife populations, animals can return to reclaimed areas after mining if reclamation produces suitable habitat and individuals that can serve as colonists persist in the surrounding area. Site characteristics created by reclamation and the development of

postmining vegetation and habitat features influence the types of wildlife that use mine sites. The reclamation process provides habitat management opportunities for some species; through various reclamation techniques and procedures, mine lands can be manipulated to attract and support desired wildlife species (Scott and Zimmerman 1984). The following recommended actions may improve the condition of wildlife habitat on reclaimed mine sites.

Leave Loose Soils and Re-establish Woody Species

Woody canopy cover is an important habitat feature for many animal species, including many birds. Tree canopy cover also will improve habitat for salamanders that require shade and leaf litter to retain soil-surface moisture and provide foraging habitat. Even in relatively open areas, establishing some trees will provide cover and nesting sites for certain early successional birds.

Limiting the use of heavy equipment during reclamation reduces soil compaction. It is well known that loose, noncompacted soil can provide an excellent rooting medium for native or planted trees and shrubs (Sweigard et al. 2007). Planted trees survive well when favorable soil is allowed to remain loose during reclamation, and nonplanted trees can become established naturally when compaction does not hinder rooting. Loose surface soils are also favorable for wildlife for other reasons: Some wildlife species, especially salamanders, require access to below-ground retreats, which is especially important during dry, hot summers.

Where topsoil can be salvaged for surface placement during reclamation, this practice can enhance the site's suitability for wildlife. A diversity of native vegetation will enhance the mine site's suitability for birds and will aid natural invasion by nonplanted vegetation.

Also, use of soil materials that contain stumps and other woody debris on the surface can enhance habitat for a variety of species, including salamanders, hastening the return of a full suite of wildlife to the mined area. Such materials can provide cover for small mammals, reptiles, and amphibians. Also, when dead woody materials such as tree branches, stumps, and old roots embedded in surface soils decompose, they can provide channels to the subsurface that can be used by burrowing animals.

Diversify Vegetation on the Landscape

Although large expanses of reclaimed grasslands may provide habitat for some area-sensitive grassland birds (e.g., grasshopper sparrow, eastern meadowlark), some birds will benefit from a variety of cover types and age classes in close proximity. Many bird species, especially those dependent on disturbance, are not restricted to a single vegetation type but rather are associated with a variety of vegetation types and ages (McGarigal and McComb 1995). Some forest-dwelling species are known to rely on early successional habitat at some stages in their life cycles (Vega Rivera et al. 1998; Bulluck and Buehler 2006), likely for protection from predators or increased food abundance (Marshall et al. 2003).

Establishing a variety of vegetation types can create habitat for many wildlife species. One way to accomplish this is to plant different tree species groupings or mixes on different areas of the mine site. For example, several tree species that grow best in moist soils can be planted near reconstructed water channels, while the more common native hardwoods can be planted on drier soils, away from the waterways.

It is also possible to vary the planted tree species over the site, ensuring that planted trees are well-suited to landscape conditions — such as slope position and aspect — and to soil type (Burger and Zipper 2010).

Many professional tree-planting firms have the capability to vary tree and shrub species over the site in response to site and soil conditions, if requested by the mining operator. Planting a variety of tree and shrub species and placing each species group where it is best suited to site conditions can increase the planted trees' survival and growth.

As an additional benefit, a variety of woody species can also improve the site's suitability for wildlife. The Forest Reclamation Approach, a five-step protocol to promote the restoration of hardwood forests on reclaimed mine lands that is being used by many mining firms (Burger et al. 2005), can be applied while planting different groups of tree species on different parts of the landscape.

Reclamation practices also affect postmining vegetation by establishing site conditions that influence natural invasion by nonplanted vegetation. In her study, Holl (2001 and 2002) found most plant species on older mine sites were not planted, but arrived on site through natural processes, most likely as seed carried by wind, birds, and other wildlife.

The Forestry Reclamation Approach encourages natural invasion by using "tree-compatible," nonaggressive herbaceous vegetation, by establishing noncompacted soil conditions, and by planting other native shrub and tree species in addition to hardwood timber species (e.g., oaks) that will attract birds and other wildlife, anticipating that they will carry seed into the reclamation area.

Native woody vegetation is particularly important for birds that depend on food sources such as berries and seeds (figure 10). Serviceberry (*Amelanchie*r spp.), dogwood (*Cornus* spp.), and blueberry (*Vaccinum* spp.) are all native species that provide fruits for wildlife. Mast-producing trees such as oak (*Quercus* spp.), hickory (*Carya* spp.), American beech (*Fagus grandifolia*), and walnut (*Juglans* spp.) provide an important food source for wildlife. Given time and suitable soil conditions, native herbaceous species will establish themselves on mine sites, suggesting diversification can occur as a natural process (Strong 2000).

Figure 10. Northern cardinals, classified in the shrubland generalist group, depend on nuts and seeds as an important food source.

Several researchers have found colonization by native vegetation can be both rapid and diverse on coal surface mines when soils are not compacted and have pH, soluble salt, and textural characteristics similar to native forest soils. This commonly occurs when soils derived from weathered, brown sandstone are used in reclamation (Angel et al. 2008; Burger and Zipper 2010).

Other researchers have observed that establishment of native vegetation is both rapid and diverse when seed-bearing topsoil materials are included in the surface soil mix (Wade 1989; Hall et al. 2009). Thus, where topsoil and/or weathered rock materials can be salvaged and placed on the surface during reclamation, a diversity of vegetation can be created on mine sites. If such soil materials are available for surface application only in some areas and not over the entire site, placing them on the surface where they are available can increase postmining vegetation and habitat diversity.

Another way to establish diverse vegetation would be to use differing herbaceous revegetation mixes on various areas of the site. Recent research concludes that a variety of reclamation strategies can be applied to establish tree-compatible vegetative cover that encourages native invasion while allowing excellent survival of planted trees.

For example, Fields-Johnson et al. (2010) found revegetation with an annual rye grass cover provided near complete groundcover during the first year and a significant mat of dead biomass that allowed invasion by native herbs and plants in the second year after seeding. These results were obtained on loosely graded, acre-size experimental plots on two Virginia surface mines.

Researchers in Tennessee have been successful in establishing short-statured, native, warm-season grasses, seeded with short-lived, rapidly establishing species, such as annual rye grass, as tree-compatible groundcover (Rizza et al. 2007).

These techniques have not been applied and found effective over entire mine sites and have not been approved for routine use by regulatory authorities. However, mining operators desiring to increase vegetative diversity may wish to work with regulatory authorities to apply such treatments on areas of the mine site where success is most likely, such as near site edges, adjacent to native forest and other seed sources, and on short or shallow slopes where reduced initial vegetative cover does not cause excessive soil loss.

These areas will most likely revegetate with volunteer species if they are reclaimed using loose grading and favorable soils. The cost of tree-compatible vegetative cover treatments that capitalize on the invasion of native vegetation is likely to be less than traditional groundcover seeding.

The introduction of some hearty native wildflowers or forbs (e.g., goldenrod [*Solidago* spp.]) or flowering shrubs (e.g., blueberry [*Vaccinium* spp.], blackberry

[*Rubus* spp.] hawthorn [*Crataegus* spp.]) on reclaimed sites would benefit many bird species greatly. Many wildflowers have been identified for conservation and restoration uses in Virginia (Department of Conservation and Recreation 2006) and also could be used as seasonal herbaceous cover. Native flowering plants provide nectar and seeds for birds, attract pollinators (e.g., bees) that help native plant communities develop, and attract insects eaten by many bird and amphibian species.

Herbaceous vegetation under a forest canopy greatly increases foraging opportunities for salamanders (Jaeger 1978). Many herbaceous species are common invaders on reclaimed mine areas, especially when the Forestry Reclamation Approach is employed.

Retain Remnant Patches of Native Vegetation, Particularly Mature Forest

Retaining native vegetation within or adjacent to reclaimed sites when possible can enhance wildlife habitat for many species (Schaid et al. 1983). Remnant forested patches in areas that cannot be used safely or effectively for coal extraction can provide important habitat for many species.

Although we observed few salamanders using remnant forested patches, these areas provide important refuge and sources for recolonization for salamanders because of greater canopy cover, leaf litter, and soil moisture. Forest birds also benefit from remnant patches left undisturbed, and the presence of native vegetation in remnant patches provides a seed source for re-establishment following reclamation.

Some remnant patches provide important cover for ecosystem function, such as natural riparian buffers or temporary ponds that provide hydrologic benefits to the environment in addition to wildlife habitat. It is particularly important to retain forested areas near streams with rocks and decaying woody debris as cover for terrestrial salamanders (Williams 2004; Kelly 2005). Canopy cover and woody debris often are lacking on traditionally reclaimed areas for many years following disturbance.

Use Treatment Ponds and Wetlands to Provide Wildlife Habitat

Wetlands and ponds established for water quality treatment provide habitat for reptiles and amphibians (Fowler et al. 1985; Brenner and Hofius 1990; figure 11), assuming the water quality in the wetland and/or surrounding bodies of water is suitable to support their annual reproductive life cycle (Lacki et al. 1992). Many mine ponds are not exceedingly acidic and do not require chemical treatment, resulting in excellent habitat for aquatic and semi-aquatic amphibians. Even in cases where water quality may be a concern, amphibians are somewhat tolerant of slightly acidic waters because the pH in many natural wetlands is low. However, tolerance varies with species and individuals; generally embryos and larvae are most susceptible to extreme acidity (Freda 1986).

Figure 11. A retention pond at Powell River Project provides habitat for amphibians.

When vegetation is planted or becomes established naturally in ponds or wetlands, these water bodies provide habitat and attract reptiles and amphibians (Bradley 1987). Emergent vegetation provides sites for the attachment of amphibian eggs, cover for larvae, and a food source for some invertebrate prey. Some birds also use wetland habitat as a hunting ground for insect or amphibian prey.

Wetlands provide multiple ecosystem services, such as improving water quality, aiding groundwater recharge, capturing sediments following heavy rains, producing organic biomass materials that are utilized by aquatic species, and attracting birds and other wildlife to the site (Atkinson et al. 1997). A diversity of water body characteristics is desirable, including size, amount of sun or shade, and amount of edge vegetation. Greater benefit accrues when constructed water bodies are clustered in close proximity to natural temporary or permanent water bodies.

Conclusions

Although coal mining dramatically changes the environment, reclaimed mine sites can provide wildlife habitat. Our research shows that a diversity of bird species use mined sites, suggesting important habitat characteristics are present. Amphibians are particularly sensitive to habitat degradation and act as indicators of environmental quality. Birds are early founders of wildlife communities and disperse seeds to aid the establishment of vegetation in new areas (Brändle et al. 2003; Walker and del Moral 2003).

In the eastern United States, many populations of birds that breed in early successional habitat are declining because of loss of habitat (Askins 2001; Hunter et al. 2001; Askins et al. 2007; figure 12). Reclaimed mines provide a diverse vegetation structure and composition that may be used by many bird species, including early successional habitat in the years immediately following reclamation.

The reclamation process provides a unique opportunity to create wildlife habitat. Reducing soil compaction, encouraging a diversity of native vegetation and land cover types, retaining patches of native vegetation, and utilizing treatment ponds and wetlands during the reclamation process can enhance use of reclaimed coal mines by wildlife in Appalachia.

Figure 12. Reclaimed areas can provide habitat for Northern bobwhite (*Colinus virginianus*), a species that is declining in some areas due to the aging of early successional areas into mature forest.

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References

Angel, P., C. Barton, R. Warner, C. Agouridis, T. Taylor, and S. Hall. 2008. Tree growth, natural regeneration, and hydrologic characteristics of three loose-graded surface mine spoil types in Kentucky. In *Proceedings, 25th Annual Meetings of the American Society of Mining and Reclamation*, 28-65. 2 vols. Held June 14-19, 2008, in Richmond, Va. Red Hook, N.Y.: Curran Associates.

Askins, R. A. 2001. Sustaining biological diversity in early successional communities: The challenge of managing unpopular habitats. *Wildlife Society Bulletin* 29:407-12.

Askins, R. A., F. Chávez-Ramírez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. *Conservation of Grassland Birds in North America: Understanding Ecological Processes in Different Regions*. Ornithological Monographs Series No. 64. The American Ornithologists' Union. Berkeley: University of California Press.

Atkinson R. B., C. E. Zipper, W. L. Daniels, and J. Cairns Jr. 1997. *Constructing Wetlands During Reclamation to Improve Wildlife Habitat*. Virginia Cooperative Extension (VCE) Publication 460-129.

Bradley, P. J. 1987. *The Effect of Strip Mining and Reclamation on Herpetofaunal Communities*. Master's Thesis, University of Texas at Arlington.

Brändle, M., W. Durka, H. Krug, and R. Brandl. 2003. The assembly of local flora and fauna: Plants and birds in non-reclaimed mining sites. *Ecography* 26:652-60.

Brenner, F. J., and D. L. Hofius. 1990. Wildlife use of mitigated wetlands on surface mine lands in western Pennsylvania. In Vol. 2 of *Proceedings of the 1990 Mining and Reclamation Conference and Exhibition*, ed. J. Skousen, J. Sencindiver, and D. Samuel, 373-82. Held April 23-26, 1990, in Charleston, W.Va. Morgantown: West Virginia University.

Brenner, F. J., and J. Kelly. 1981. Characteristics of bird communities on surface mined lands in Pennsylvania. *Environmental Management* 5:441-49.

Bulluck, L. P., and D. A. Buehler. 2006. Avian use of early successional habitats: Are regenerating forests, utility right-of-ways and reclaimed surface mines the same? *Forest Ecology and Management* 236:76-84.

Burger, J., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005. The Forestry Reclamation Approach. Appalachian Regional Reforestation Initiative. Forest Reclamation Advisory No. 2. *http://arri.osmre.gov/FRA.shtm.*

Burger, J. A., and C. E. Zipper. 2010. *How to Restore Forests on Surface-Mined Land*. VCE Publication 460-123.

Camenzind, F. J. 1984. Wildlife and coal development: An overview. *Minerals and the Environment* 6:94-100.

Carrozzino, A. L. 2009. *Evaluating Wildlife Response to Vegetation Restoration on Reclaimed Mine Land in Southwestern Virginia*. Master's Thesis, Virginia Tech. *http://scholar.lib.vt.edu/theses/available/etd-05042009-150307/.*

Fields-Johnson, C., C. E. Zipper, J. A. Burger, and D. M. Evans. 2010. Second year response of Appalachian mixed hardwoods to soil surface grading and herbaceous ground cover on reclaimed mine land. In *Proceedings, 27th Annual National Meetings of the American Society of Mining and Reclamation*, ed. R. I. Barnhisel, 305-18. Held June 5-10, 2010, in Pittsburgh, Pa. Lexington, Ky.: ASMR.

Fowler, D. K., D. M. Hill, and L. J. Fowler. 1985. Colonization of coal surface mine sediment ponds in southern Appalachia by aquatic organisms and breeding amphibians. In *Proceedings, Wetlands and Water Management on Mined Lands,* ed. R. P. Brooks, D. E. Samuel, and J. B. Hill, 261-85. Held October 23, 1985, in University Park, Pa. University Park: Pennsylvania State University

Freda, J. 1986. The influence of acidic pond water on amphibians: A review. *Water, Air, and Soil Pollution* 30:439-50.

Hall, S., C. Barton, and C. Baskin. 2009. Seed viability in stockpiled topsoil on a surface mine in Appalachia. *Restoration Ecology* 27:381-97.

Holl, K. D., C. E. Zipper, and J. A. Burger. 2001. *Recovery of Native Plant Communities After Mining*. VCE Publication 460-140.

Holl, K. D. 2002. The effect of coal surface mine revegetation practices on long-term vegetation recovery. *Journal of Applied Ecology* 39:960-70.

Homyack, J. A., and C. A. Haas. 2009. Long-term effects of experimental forest harvesting on abundance and reproductive demography of terrestrial salamanders. *Biological Conservation* 142:110-21.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. *The Wildlife Society Bulletin* 29:440-55.

Hyde, E. J., and T. R. Simons. 2001. Sampling plethodontid salamanders: Sources of variability. *Journal of Wildlife Management* 65:624-32.

Jaeger, R. G. 1978. Plant climbing by salamanders: Periodic availability of plant dwelling prey. *Copeia* 4:686-91.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in East-Central Illinois. *Condor* 70:348-57.

Kelly, K. M. 2005. *Model Validation and Improvement Using New Data on Habitat Characteristics Important to Forest Salamanders, and Short-Term Effects of Forestry Practices on Salamander Movement and Population Estimates.* Master's Thesis, Virginia Tech. *http://scholar.lib.vt.edu/theses/available/etd-12242005-175725/.*

Lacki, M. J., J. W. Hummer, and H. J. Webster. 1992. Mine-drainage treatment wetland as habitat for herptofaunal wildlife. *Environmental Management* 16:513-20.

Marshall, M. R., J. A. DeCecco, A. B. Williams, G. A. Gale, and R. J. Cooper. 2003. Use of regenerating clearcuts by late-successional bird species and their young during the post-fledgling period. *Forest Ecology and Management* 183:127-35.

McGarigal, K., and W. C McComb. 1995. Relationships between landscape structure and breeding birds in the Oregon Coast Range. *Ecological Monographs* 65:235-60.

Parmenter, R. R., and J. A. MacMahon. 1992. Faunal community development on disturbed lands: An indicator of reclamation succession. In *Evaluating Reclamation Success: The Ecological Consideration — Proceedings of a Symposium*, ed. J. C. Chambers and G. L. Wade, 73-89. (Contains selected papers from the 1990 Mining and Reclamation Conference and Exhibition of the American Society for Surface Mining and Reclamation, held April 23-26, 1990, in Charleston, W.Va.) U.S. Department of Agriculture. U.S. Forest Service. Northeast Forest Experiment Station General Technical Report NE-164. Radnor, Pa.: Northeastern Forest Experiment Station.

Rizza J., J. A. Franklin, and D. S. Buckley. 2007. *Afforestation: Effects of native and non-native ground cover treatments*. *Ecological Restoration* 25:146-48.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. *Ecology* 57:773-82.

Schaid, T. A., D. W. Uresk, W. L. Tucker, and R. L. Linder. 1983. Effects of surface mining on the vesper sparrow in the Northern Great Plains. *Journal of Range Management* 36:500-03.

Scott, M. D., and G. M. Zimmerman. 1984. Wildlife management at surface coal mines in the Northwest. *Wildlife Society Bulletin* 12:364-70.

Strong, W. L. 2000. Vegetation development on reclaimed lands in the Coal Valley Mine of western Alberta, Canada. *Canadian Journal of Botany* 78:110-18.

Sweigard, R., J. Burger, C. Zipper, J. Skousen, C. Barton, and P. Angel. 2007. Low Compaction Grading to Enhance Reforestation Success on Coal Surface Mines. Appalachian Regional Reforestion Initiative. Forest Reclamation Advisory No. 3.

Vega Rivera, R. H., J. H. Rappole, W. J. McShea, and C. A. Haas. 1998. Wood thrush postfledgling movements and habitat use in Northern Virginia. *Condor* 100:69-78.

Virginia Department of Conservation and Recreation (VDCR). Natural Heritage Program and Virginia Native Plant Society. 2006. *Native Plants for Conservation, Restoration and Landscaping: Western Virginia*. Richmond: VDCR.

Virginia Department of Game and Inland Fisheries. 2005. *Virginia's Comprehensive Wildlife Conservation Strategy*. Richmond: Virginia Department of Game and Inland Fisheries.

Wade, G. 1989. Grass competition and establishment of native species from forest soil seed banks. *Landscape and Urban Planning* 17:135-49.

Walker, L. R., and R. del Moral. 2003. *Primary Succession and Ecosystem Rehabilitation*. Cambridge, U.K.: Cambridge University Press.

Williams, L. A. 2004. *Amphibian Population and Community Characteristics, Habitat Relationships, and First-Year Responses to Clearcutting in a Central Appalachian Industrial Forest.* Master's Thesis, Virginia Tech. *http://scholar.lib.vt.edu/theses/available/etd-10042004-085130/.*