THE APPALACHIAN REGIONAL REFORESTATION INITIATIVE (ARRI)

FOREST RECLAMATION ADVISORY

Forest Reclamation Advisory No. 10 November 2013

REFORESTATION TO ENHANCE APPALACHIAN MINED LANDS AS HABITAT FOR TERRESTRIAL WILDLIFE

Petra Wood, Jeff Larkin, Jeremy Mizel, Carl Zipper, and Patrick Angel

Surface mining is widespread throughout the Appalachian coalfield, a region with extensive forests that are rich in wildlife. Game species for hunting, non-game wildlife species, and other organisms are important contributors to sustainable and productive ecosystems. Although small breaks in the forest canopy are important to wildlife diversity, most native Appalachian wildlife species require primarily forested habitats. This Forest Reclamation Advisory provides guidance on reforestation practices to provide high quality habitat for native forest wildlife on Appalachian coal mines.

Mined lands reclaimed using conventional methods – smooth-grading mine spoil and seeding fast-growing groundcovers – are used by a few wildlife species and can increase species diversity. But expansive areas of these lands have little habitat value in Appalachia, where most native wildlife species, require forested habitats (Wickham and others 2013). Conventional reclamation also inhibits forest succession and causes most native plant species to have poor colonization, growth, and survival. As a result, high-quality wildlife habitat rarely develops away from the forest-mine edge on surface mines reclaimed with conventional methods. Even popular game species often observed on conventionally reclaimed mined lands such as deer, elk, bear, and wild turkey are rarely seen far from the forest edge. However, improved wildlife habitat is a post-mining goal for many landowners and is achievable through application of the Forestry Reclamation Approach (FRA) to enhance natural succession (Groninger and others 2007) on active mines (Burger and others 2005), and through soil mitigation and tree/shrub planting on older mine sites that were reclaimed using conventional methods years ago ("legacy mines") (Burger and others 2013).

Appalachian Forest and Mined Land Habitats

Appalachian hardwood forests are some of the most biologically diverse temperate forests in the world (Hinkle and others 1993). They provide habitat for numerous wildlife species that require mature forest as well as those that require young forest conditions.

Many wildlife species (amphibians, reptiles, birds and mammals) that depend on young forests for foraging, cover or breeding (Gilbart 2012) are experiencing population declines (Litvaitis 1993). Native young forest communities consist of dense herb, vine, sapling, and shrub growth that exist for a relatively short time (≤12 years). Therefore, patches of young forest must be continuously created and dispersed across the landscape to ensure long-term viability of the many species dependent on these habitats. Wildlife agencies in every state of the eastern Coalfields list young forest communities as priority habitats.

More than one million acres of reclaimed mine lands occur in the eastern US (Zipper and others 2011) and additional mined lands are being created. Reforestation of mined lands has the potential to provide extensive areas of young forest habitat interspersed among unmined mature forests. Through succession, these young forests will become mature forests. A regional, landscape-scale effort to reforest mined lands has great potential to benefit wildlife species dependent on young and mature forest habitats.

Figure 1. American woodcock inhabits moist, young forest habitats and is considered a species of high conservation concern.

Golden-winged warbler, brown thrasher, and eastern whip-poor-will are a few of the non-game bird species that breed in young forests and are experiencing long-term population declines in the Appalachians (Sauer and others 2011). Like many species that are young forest specialists, these birds require habitat with dense patches of native shrubs interspersed with trees of varying size and herbaceous cover. Patches of young forest also provide important foraging habitat and cover for several Appalachian game species including cottontails, black bear, white-tailed deer, elk, ruffed grouse, northern bobwhite, and American Woodcock (Figure 1). Within most surface mines reclaimed using non-FRA methods, exotic shrub and grass species predominate and areas of dense native woody vegetation are typically absent or restricted to forest-mine edges. In contrast, forest reclamation can create a dense undergrowth of native shrubs, saplings, and forbs that species like cottontails require for protective cover from predators. These patches of dense woody and herbaceous cover provide abundant forage for game and non-game species in the form of insects, mast, seeds, buds, foliage, and fruits from vines and shrubs. Young forest habitat adjacent to mature forest also may benefit fisher, a forest dependent predator that has been reintroduced to several Appalachian states (Figure 2). Many mammal and bird species that are preyed upon by fisher and other carnivores use areas where young forest adjacent to mature forest creates structurally diverse habitat (Litvaitis 1993).

Ultimately, surface mines that persist as non-forest cover lead to forest fragmentation and reduced forest cover on the landscape which negatively affects wildlife species that require large, continuous blocks of forest (Wood and Williams 2013, Wood and others 2006). One such species is the cerulean warbler (Figure 3), a declining forest songbird (Sauer and others 2011) with a breeding range that has considerable overlap with the Appalachian Coalfield (Figure 4). Cerulean warbler and likely other mature forest songbirds are less abundant near the abrupt edges created by surface mines reclaimed to grassland (Wood and others 2006). For some species of woodland salamander, grassland patches act as barriers to movement between forest patches (Rittenhouse and Semlitsch 2006). Thus, surface mine reforestation may benefit mature forest wildlife in the short-term by creating more transitional forest-mine edges (feathered edges) and reducing forest fragmentation, and in the long-term by compensating for the loss of mature forest habitat.

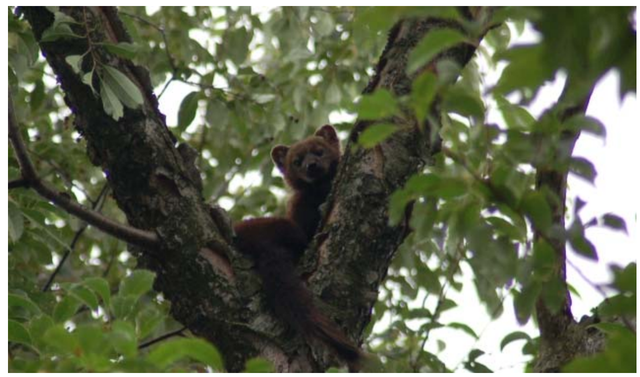

Figure 2. The fisher is a forest-dependent carnivore that is colonizing many Appalachian states after reintroductions in West Virginia, Tennessee, and Pennsylvania. Young forest along mature forest edges provides habitat for many of the fisher's favorite prey.

Figure 3 (above). Cerulean warbler male.

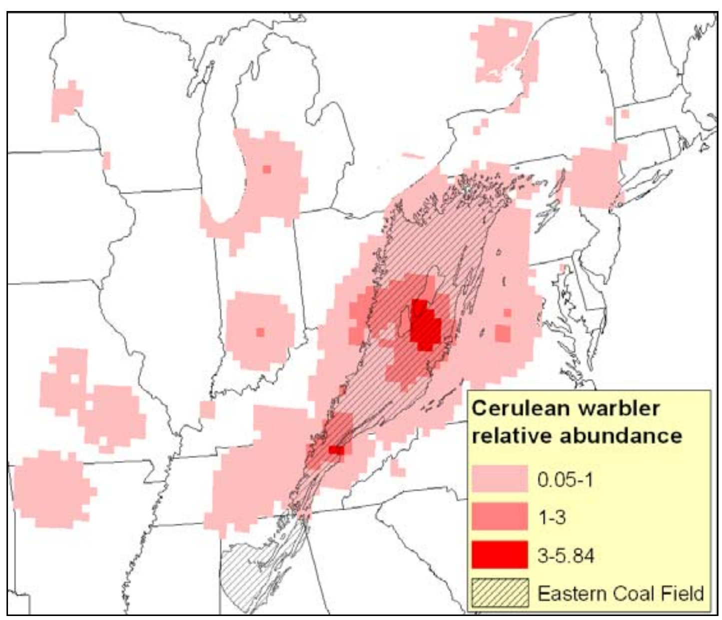

Figure 4 (right): The Eastern Coalfield and the breeding range of cerulean warbler (derived from Breeding Bird Survey counts; Sauer and others 2011).

Guidelines for Wildlife Habitat Enhancement on Mined Lands

1. Increase structural complexity of the soil surface; avoid or remediate soil compaction.

Structurally complex forest floors are important habitat features for many types of wildlife such as small mammals, snakes, and salamanders (Figure 5). Forested rock outcrops are unique habitats important to many species of Appalachian wildlife, particularly the Allegheny woodrat and green salamander. However, because rock outcrops are usually located along ridge tops or upper side slopes, these habitat features are often removed by mining. Conventional reclamation generally fails to restore these important structurally and biologically diverse components of eastern forests.

Figure 5. A red eft, the terrestrial life stage of the eastern newt.

On sites with active reclamation, avoid excessive smoothing and compacting of soil. A rough-graded soil surface with loose-soil conditions, exposed rocks and surface relief provides a more structurally diverse habitat than conventional smooth grading.

On legacy mines, compacted spoil can be loosened by a dozer equipped with a ripper tooth (Sweigard and others 2007). Ripping compacted spoil not only improves water infiltration and rooting conditions for trees and shrubs, but it also benefits burrowing species like salamanders, earthworms (food for woodcock and other wildlife), and small mammals which need loose, moist soil to burrow and forage. Small mammals and salamanders occur in greater abundance where spoil is not compacted (Larkin and others 2008, Wood and Williams 2013). These animals in turn are a food source for many species of predators.

Incorporating rocks on the surface (Figures 6 and 7) can provide additional structure and cover for ground-dwelling and burrowing species. After young forest and some tree canopy develops, large boulder piles (Figure 7) may provide habitat for Allegheny woodrats (Chamblin and others 2004) and many other species that use wooded rock outcrops, particularly if they are close to nearby forested areas that contain rock outcrops. Reintroduced fishers in Pennsylvania occasionally rested in ground dens within rock outcrops including an area of large boulders along a forest-reclaimed mine edge (Gess 2010).

Figure 6. Ripping of compacted mine soils reduces compaction and increases structural complexity of the surface by exposing large rocks. Such features provide habitat for small mammals, amphibians, and reptiles.

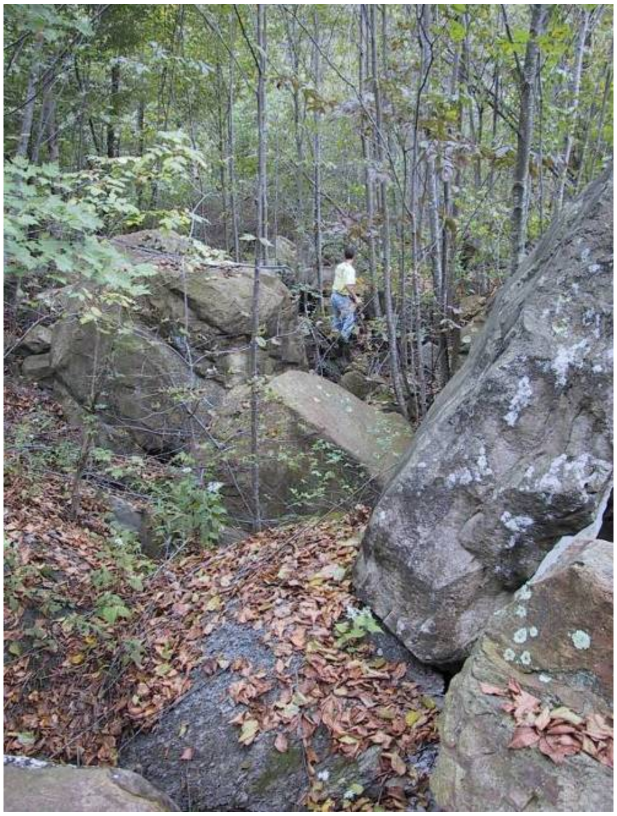

Figure 7. After trees establish, piles of large boulders can provide habitat needed by wildlife that use wooded rock outcrops such as Allegheny woodrats, bobcats, and bears.

2. Apply native forest soils with organic debris or high quality substitutes during reclamation

Salvaging and reapplying topsoil on active mines or bringing in topsoil for reclamation on legacy mines can accelerate development of high-quality young forest habitat (Skousen and others 2011). Native topsoil can contribute a seed bank of plant species such as black birch, blackberry, yellow-poplar, grapevine and many others that are not commonly planted or seeded by contractors during reclamation. Occasionally, oaks and hickories will sprout from seeds present in topsoil (Hall and others 2010). These volunteer species provide food sources and increase structural complexity of vegetation on reclaimed mines (Figure 8), often enabling greater wildlife diversity. Blackberry, for example, provides fruit for many wildlife species including seed predators, preferred nest patches for young forest songbirds like golden-winged warbler, and serves as cover for cottontails and other wildlife species. Salvaging native soils, with their organic matter and living creatures, may increase abundance of soil invertebrates (Richards and others 1993) which are prey for woodland salamanders, some songbirds, and small mammals. One study found American woodcock using reclaimed mines where better soil conditions produced complex vegetative structure and higher earthworm biomass (Gregg and others 2000). Salvaging native soils would help produce these conditions.

Figure 8. Young forest on a West Virginia surface mine with a dense undergrowth of volunteer shrubs. Mine operators salvaged and reapplied the topsoil, used reduced grading, and planted native hardwoods including white, chestnut, black, and northern red oaks. Trees are 10 years old in this photo.

When a limited amount of topsoil is available, distribute it across the mine surface, either by mixing it with mine spoil intended for surface construction (Skousen and others 2011) or by dumping piles across the mine-site surface (Hall and others 2010). These seed bank patches could yield dense shrubby vegetation in areas where forest seed sources are distant and plant colonization is limited. Soil also is an important inoculation source for mycorhizzal fungi which most woody species need to grow and thrive.

Native trees and shrubs also can invade and grow rapidly when favorable mine spoil materials are used as a topsoil substitute (Skousen and others 2011). After 1-2 years post-planting, young forest bird species such as indigo bunting and common yellowthroat (Figure 9) had colonized the interior of a surface mine that was reclaimed using FRA methods and salvaged topsoil (Figure 10).

Figure 9. Male common yellowthroat.

Figure 10. Herbaceous plants and shrubs rapidly developed (1-2 years post-planting) on an Ohio surface mine reclaimed using the FRA.

3. Add coarse woody debris to further promote surface complexity and provide cover for wildlife.

Incorporating woody residues on and into mine surfaces (e.g., roots, stumps, logs, and branches) accelerates forest development by improving water infiltration, decreasing soil temperature, increasing the soil water-holding capacity, and increasing soil colonization by nutrient-cycling microorganisms (Skousen and others 2011). The addition of coarse woody debris (Figure 11) also benefits ground-dwelling wildlife by providing surface cover and greater overall surface complexity. Decomposition of woody residues incorporated in the growth medium creates subsurface channels which burrowing species can use as retreats (Carrozzino and others 2011). Through the addition of woody residues, moisture-limited species such as salamanders and earthworms benefit from increased organic matter and water-holding capacity in soils.

Figure 11. Incorporating woody residues benefits ground-dwelling and burrowing species by providing surface cover and increasing surface complexity. Native vegetation is sprouting from these root wads that were left on the reclaimed mine surface.

4. Locate reforestation efforts where they maximize benefits for wildlife.

If an entire mine site cannot be planted to trees and shrubs, select areas to reforest that maximize benefits for wildlife. Greatest benefits for wildlife include reducing forest fragmentation, reducing the amount of forest-grassland edge, and connecting remnant forest patches.

Changes in microclimate caused by forest loss (e.g. increased wind, light, and ambient temperatures) can penetrate from edges into mature forests (Matlack 1993). This can negatively affect ground-foraging species by reducing litter depth and densities of litter-dwelling arthropods near forest edges (Ortega and Capen 1999). Some mature forest-dependent species such as the cerulean warbler reach their highest densities in large tracts of mature forest and away from abrupt edges (Wood and others 2006). Conversely, species that depend on young forest, such as the golden-winged warbler, establish breeding territories in young forest transition zones (Figure 12) but generally within 50 m of the mature forest edge (Patton and others 2010). Therefore, reforestation that extends from the forest-mine edge and creates a transitional, feathered edge (Figures 12 and 13) can reduce edge effects for cerulean warbler and other mature forest species while also providing young forest habitat for the golden-winged warbler and associated species. If the development of cerulean warbler habitat is a post-mining goal, reforestation efforts should also target ridgetops and north and east-facing slopes where cerulean warblers are most abundant in the Appalachians (Wood and others 2006).

Small mammal and woodland salamander species can move only short distances to reach suitable habitat (Waldrick 1997) and grassland patches are barriers to such movement (Rittenhouse and Semlitsch 2006). Therefore, reforesting areas that extend from the forest-mine edge, interconnect mature forest patches, or connect isolated forest patches to intact forest (Figure 13) will expand habitat for woodland salamanders and small mammals. Reforestation in these locations also benefits many forest wildlife species by increasing forest patch size. Further, planting native trees and shrubs within extensive areas of reclaimed grasslands can benefit elk as this species rarely uses open habitats >300m from a forest edge (Skovlin and others 2002).

Figure 12. A young forest transition zone between reclaimed mine land (foreground) and unmined mature forest (background). When the resources needed to reforest entire legacy mine sites are not available, establishing such transition zones can improve habitat.

5. Plant a variety of native trees and shrubs, particularly heavy-seeded (hard mast producing) tree species

Many of the plant species that establish easily as volunteers on mined lands have small seeds that are spread by wind and birds with relative ease. Heavy-seeded species such as oaks and hickories are less easily dispersed and rarely colonize the interior of large mining complexes unless planted. Re-establishing heavy-seeded native tree species provides an important food source for wildlife, a seed source to maintain habitat diversity, and habitat for the many wildlife species that depend on these tree species.

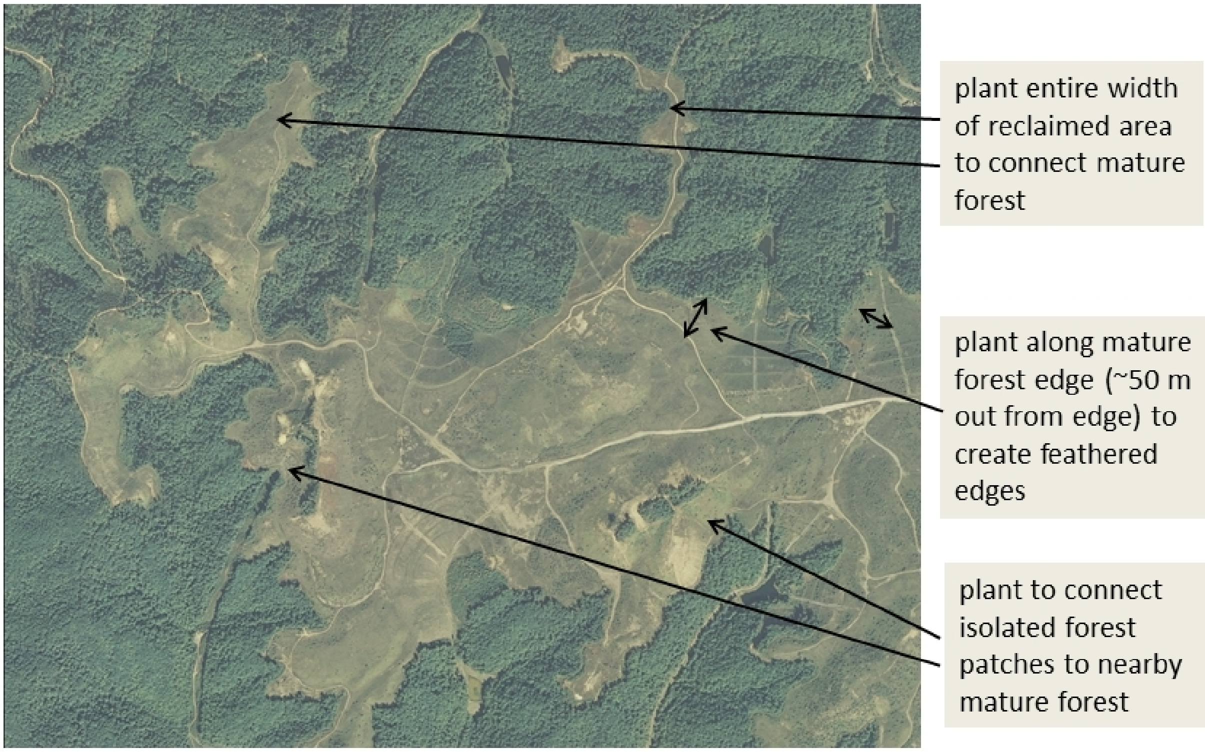

Figure 13. When the resources needed to reforest entire legacy mine sites are not available, focus reforestation efforts on areas adjacent to mature forest to create young forest transitions (see Figure 12) and on areas that interconnect mature forest or that connect isolated forest patches to nearby mature forest. This will increase forest patch size and decrease edge effects, improving habitat for mature forest wildlife. It also creates transitions between forest and reclaimed mine which are beneficial for young forest species.

Some forest songbirds prefer to forage and nest in hickories and species of white oaks, but avoid red oak species and red maples (Wood and others 2013). Oaks host high abundance and diversity of leaf insects in their canopies (Summerville and Crist 2008), and those insects are a food source for forest songbirds. Oak-hickory forests have deeper leaf litter because their leaves decompose slowly and thus have greater abundance of litter-foraging species like ovenbird than do forests dominated by red maple and yellow poplar (Mizel 2011). The mast from oaks and hickories is an important part of diets for gamebirds, deer, black bear, and many other wildlife species. Planting tree species that develop exfoliating bark such as white oak, hickory, and black locust provides future roost trees for bats. Several bat species, including the endangered Indiana bat, are dependent on mature trees of these and other species for roosting and maternity sites. Where the Indiana Bat is found pre-mining, forestry post-mining land use is required by federal regulations.

American chestnut, a consistent and prolific producer of hard mast, once provided food for numerous bird and mammal species. The American Chestnut Foundation has developed potentially blight-resistant chestnut varieties and surface mines are now being used for reintroduction to eastern forests. These chestnut varieties have shown excellent survival on mined lands reclaimed using the FRA (Skousen and others 2013) and on previously compacted mined lands that were prepared using deep soil ripping (McCarthy and others 2010). Establishing mined land forests with American chestnut would have substantial value for Appalachian wildlife.

Native mast-producing shrubs are important wildlife food sources. Pin cherry and *Rubus* species (blackberries and raspberries), for example, have high numbers of caterpillars and were selected as foraging sites by golden-winged warblers (Bellush 2012). American hazelnut, black chokeberry, chokecherry, elderberry, maple-leaf viburnum, gray dogwood, service berry, blackhaw, and hawthorns are just a few native shrub species that can be included in the tree planting mix. They can be planted singly among tree seedlings or in groups to help create patchy habitat structure. When planting shrubs in patches, we suggest patches no larger than 24x24 feet. To select which specific tree and shrub species to plant, follow the guidelines in Forest Reclamation Advisory #9 (Davis and others 2012) and plant native species that provide hard or soft mast as recommended by

Apsley and Gehrt (2006). Planting a variety of native trees and shrubs in their native range will provide habitat for a diverse wildlife community. Control competing non-native vegetation to increase survival of planted trees. In high elevation areas within the native range of red spruce, planting red spruce will provide a critical component of northern flying squirrel habitat.

Summary

When active mine operators follow FRA reclamation guidelines (Burger and others 2005), they create lands where forest development can occur rapidly. On legacy mines, ripping when needed to loosen compacted soil, planting native trees and shrubs, and controlling competing vegetation as needed for planted trees' survival will facilitate ecological succession (Burger and others 2013). Thus, forest reclamation can produce habitat that has the structural and compositional features needed by young forest wildlife in the short term. Over longer time periods, the mature forest that results from these efforts will benefit mature forest wildlife by reducing forest fragmentation and helping to compensate for habitat loss caused by mining. Surface mine reforestation represents an opportunity for landowners and mine operators to conduct reclamation that provides direct and far-reaching benefits by aiding conservation of Appalachian wildlife.

Summary of reforestation guidelines on mined lands to enhance habitat for Appalachian wildlife

Burrowing and ground-dwelling species (e.g. salamanders, earthworms, small mammals)

- Create loose, moist soil for burrowing by end-dumping or ripping
- Include single boulders or clusters of boulders on surface for protective cover
- Incorporate woody residues for surface complexity, aboveground cover, and subsurface retreats
- Apply native soils with organic matter to increase invertebrate prey
- Treat sites and plant native trees and shrubs in areas that connect to mature forest to promote colonization by wildlife species

Young forest species (e.g. cottontail, blue-winged warbler, golden-winged warbler, ruffed grouse)

- Use native soils which provide seed banks to quickly increase structural and compositional diversity of vegetation
- Use tree-compatible ground covers that will enable invasion by native plants
- Plant a variety of native shrubs and trees
- On legacy mines where reforestation resources are limited, treat and plant areas that connect to mature forest for increased habitat complexity across the landscape

Mature forest species (e.g. cerulean warbler, fisher, woodland salamanders)

- On legacy mines, treat and plant areas that connect to mature forest (especially isolated patches in mine interiors) to reduce edge effects and forest fragmentation and to increase forest patch size
- On active mines, reforest the complete mining disturbance, when possible
- Plant heavy-seeded (mast-producing) tree species (e.g., American chestnut, oaks, and hickories) throughout reclaimed area for food resources for many species (e.g. bear, deer), preferred nest sites for forest songbirds, and roost trees for bats
- Reforest mines near areas of high cerulean warbler density

Literature cited

Apsley, D., and S. Gehrt. 2006. Enhancing food (mast) production for woodland wildlife in Ohio. Ohio State University Extension Fact Sheet F-60-06. http://ohioline.osu.edu/for-fact/0060.html

Bellush, E.C. 2012. Foraging Ecology of the Golden-winged warbler (Vermivora chrysoptera): does plant species composition matter? MS Thesis, Indiana University of Pennsylvania, Indiana, PA.

Burger, J., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005. The Forestry Reclamation Approach. Forest Reclamation Advisory No. 2. U.S. Office of Surface Mining, ARRI.

Burger, J.A., C.E. Zipper , P.N. Angel, N. Hall, J.G. Skousen, C.D. Barton, S. Eggerud. 2013. Re-establishing native trees on legacy surface mines. Forest Reclamation Advisory No. 11. U.S. Office of Surface Mining, ARRI.

Carrozzino, A.L., D.F. Stauffer, C.A. Haas, and C.E. Zipper. 2011. Enhancing wildlife habitat on reclaimed mine lands. Virginia Cooperative Extension Publication 460-145.

Chamblin, H.D., P.B. Wood, and J.W. Edwards. 2004. Allegheny woodrat (*Neotoma magister*) use of rock drainage channels on reclaimed mines in southern West Virginia. American Midland Naturalist 151:346-354.

Davis, V., J.A. Burger, R. Rathfon, C.E. Zipper, and C.R. Miller. 2012. Selecting tree species for reforestation of Appalachian mined land. Forest Reclamation Advisory No. 9. U.S. Office of Surface Mining, ARRI.

Gess, S. 2010. Characteristic of Fisher (*Martes pennanti*) rest sites in south-central Pennsylvania. Thesis, Indiana University of Pennsylvania.

Gilbart, M. 2012. Under Cover: Wildlife of Shrublands and Young Forest. Wildlife Management Institute. Cabot, VT. 87 pages. http://youngforest.org/sites/default/files/Under_Cover-010412_FINAL.pdf

Gregg, I.D., P.B. Wood, and D.E. Samuel. 2000. American woodcock use of reclaimed surface mines in West Virginia.

Pages 9-22 in D.G. McAuley, J.G. Bruggink, and G.F. Sepik, eds. Proceedings of the Ninth American Woodcock Symposium. USGS/BRD/ITR-2000-0009. 117pp.

Groninger, J., J. Skousen, P. Angel, C. Barton, J. Burger, and C. Zipper. 2007. Mine reclamation practices to enhance forest development through natural succession. Forest Reclamation Advisory No. 5, U.S. Office of Surface Mining, ARRI.

Hall, S.L, C.D. Barton, and C.C. Baskin. 2010. Topsoil seed bank of an oak-hickory forest in eastern Kentucky as a restoration tool on surface mines. Restoration Ecology 18:834-842.

Hinkle CR, McComb, WC, Safley Jr. JM, Schmalzer PA. 1993. Mixed mesophytic forests. Pages 203-253 in Martin WH, Boyce SC, Echternacth AC, eds. Biodiversity of the Southeastern United States Upland Terrestrial Communities. Wiley, New York.

Larkin, J.L., D.S. Maehr, J.J. Krupa, J.J. Cox, K. Alexy, D. Unger, and C. Barton. 2008. Small mammal response to vegetation and spoil conditions on a reclaimed surface mine in Eastern Kentucky. Southeastern Naturalist 7:401-412.

Litvaitis, J.A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7:866-873.

Matlack, G.R. 1993. Microenvironment variation within and among forest edge sites in the eastern United States. Biological Conservation 66:185-194.

McCarthy, B.C., K.E. Gilland, J.M. Bauman, and C.H. Keiffer. 2010. Factors affecting performance of artificially regenerated American chestnut on reclaimed mine sites. pp. 582-597. *in* R.I. Barnhisel (ed) Proceedings, American Society of Mining and Reclamation.

Mizel, J.D. 2011. Avian assemblages and Red-eyed Vireo nest survival within mineland forest. Master's Thesis, West Virginia University, Morgantown, WV.

Ortega, Y.K, and D.E. Capen. 1999. Effects of forest roads on habitat quality for ovenbirds in a forested landscape. Auk 116:937-946.

Patton, L.L., D.S. Maehr, J E. Duchamp, S. Fei, J.W. Gassett and J.L. Larkin. 2010. Do the golden-winged warbler and blue-winged warbler exhibit species-specific differences in their breeding habitat use? Avian Conservation and Ecology 5(2): 2. [online] URL: http://www.ace-eco.org/vol5/iss2/art2/

Richards, I.G., J.P. Palmer, and P.A. Barratt. 1993. The reclamation of former coal mines and steelworks. Elsevier, Amsterdam.

Rittenhouse, T.A.G., and R.D. Semlitsch. 2006. Grasslands as movement barriers for a forest-associated salamander: migration behavior of adult and juvenile salamanders at a distinct habitat edge. Biological Conservation 131:14-22.

Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D J. Ziolkowski, Jr., and W.A. Link. 2011. The North American breeding bird survey, results and analysis 1966 - 2009. Version 3.23.2011. USGS Patuxent Wildlife Research Center, Laurel, MD.

Skousen, J., T. Cook, and E. Pena-Yewtukhiw. 2013. Survival and growth of chestnut backcross seeds and seedling on surface mines. Journal of Environmental Quality 42:690-695.

Skousen, J., C. Zipper, J. Burger, C. Barton, and P. Angel. 2011. Selecting materials for mine soil construction when establishing forests on Appalachian mine sites. Forest Reclamation Advisory No. 8. U.S. Office of Surface Mining, ARRI.

Skovlin, J.M., P. Zager, and B.K. Johnson. 2002. Elk Habitat Selection and Evaluation. *In* D.E. Toweill and J.W. Thomas eds., North American Elk: Ecology and Management. Smithsonian Institute Press. Washington, D.C.

Summerville, K.S., and T.O. Crist. 2008. Structure and conservation of lepidopteran communities in managed forests of northeastern North America: a review. The Canadian Entomologist 140:475–494.

Sweigard, R., J. Burger, D. Graves, C. Zipper, C. Barton, J. Skousen, and P. Angel. 2007. Loosening compacted soils on mined sites. Forest Reclamation Advisory No. 4, U.S. Office of Surface Mining, ARRI.

Waldrick, R. 1997. Effects of forestry practices on amphibian populations in eastern North America. *In* M. Green (ed.). Amphibians in Decline: Canadian Studies of a Global Problem, pp. 191-205. Society for the Study of Amphibians and Reptiles, St. Louis.

Wickham, J. D., P. B. Wood, M.C. Nicholson, W. Jenkins, D. Druckenbrod, G.W. Suter, M.P. Strager, C. Mazzarella, W. Galloway, and J. Amos. 2013. The overlooked terrestrial impacts of mountaintop mining. BioScience 63:335-349.

Wood, P.B. and J.M. Williams. 2013. Terrestrial salamander abundance on reclaimed mountaintop removal mines. Wildlife Society Bulletin.

Wood, P.B., S.B. Bosworth, and R. Dettmers. 2006. Cerulean warbler abundance and occurrence relative to large-scale edge and habitat characteristics. Condor 108:154–165.

Wood, P.B., J. Sheehan, P. Keyser, D. Buehler, J. Larkin, A. Rodewald, S. Stoleson, T.B., Wigley, J. Mizel, T. Boves, G. George, M. Bakermans, T. Beachy, A. Evans, M. McDermott, F. Newell, K. Perkins, and M. White. 2013. Management guidelines for enhancing Cerulean Warbler breeding habitat in Appalachian hardwood forests. American Bird Conservancy. The Plains, Virginia. 28 pp.

Zipper C.E., J.A. Burger, J.G. Skousen, P.N. Angel, C.D. Barton, V. Davis, J.A. Franklin. 2011. Restoring forests and associated ecosystem services on Appalachian coal surface mines. Environmental Management 47:751–765.

Acknowledgements

Photos used in this document were taken by Kyle Aldinger, Doug Becker, Jeff Larkin, Jeremy Mizel, Andy Newman, Matt Shumar, Petra Wood, and Carl Zipper.

Faculty and researchers from the following universities and organizations contributed to this Forest Reclamation Advisory: American Bird Conservancy, Appalachian Mountains Joint Venture, Berea College, Green Forests Work, Indiana University of Pennsylvania, Ohio University, Ohio State University, Pennsylvania State University, Purdue University, The American Chestnut Foundation, Southern Illinois University, United States Forest Service, United States Geological Survey, University of Kentucky, University of Maryland, University of Tennessee, Virginia Tech, West Virginia University, and Wilkes University.

Petra Wood (pbwood@wvu.edu), US Geological Survey and West Virginia University, Morgantown WV.

Jeff Larkin (larkin@iup.edu), Indiana University of Pennsylvania, Indiana PA.

Jeremy Mizel (Jeremy_Mizel@nps.gov), West Virginia University, Morgantown WV.

Carl Zipper (czip@vt.edu), Virginia Tech, Blacksburg VA.

Patrick Angel (pangel@osmre.gov), Office of Surface Mining, U.S.D.I., London KY.