CASE STUDY: PRIORITIZATION STRATEGIES FOR REFORESTATION OF MINELANDS TO BENEFIT CERULEAN WARBLERS[1]

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Abstract. The central Appalachian landscape is being heavily altered by surface coal mining. The practice of Mountaintop Removal/Valley Fill (MTRVF) mining has transformed large areas of mature forest to non-forest and created much forest edge, affecting habitat quality for mature forest wildlife. The Appalachian Regional Reforestation Initiative is working to restore mined areas to native hardwood forest conditions, and strategies are needed to prioritize restoration efforts for wildlife. We present mineland reforestation guidelines for the imperiled Cerulean Warbler, considered a useful umbrella species, in its breeding range. In 2009, we surveyed forest predicted to have Cerulean Warblers near mined areas in the MTRVF region of West Virginia and Kentucky. We visited 36 transect routes and completed songbird surveys on 151 points along these routes. Cerulean Warblers were present at points with fewer large-scale canopy disturbances and more mature oak-hickory forest. We tested the accuracy of a predictive map for this species and demonstrated that it can be useful to guide reforestation efforts. We then developed a map of hot spot locations that can be used to determine potential habitat suitability. Restoration efforts would have greatest benefit for Cerulean Warblers and other mature forest birds if concentrated near a relative-abundance hot spot, on north- and east-facing ridgetops surrounded by mature deciduous forest, and prioritized to reduce edges and connect isolated forest patches. Our multi-scale approach for prioritizing restoration efforts using an umbrella species may be applied to restore habitat impacted by a variety of landscape disturbances.

Additional Key Words: Birds, Central Appalachians, Kentucky, Mountaintop mining, Reclamation, *Setophaga cerulea*, Surface mining, West Virginia

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Introduction

Anthropogenic disturbances such as resource extraction are increasingly transforming landscapes globally. Coal mining continues to be a significant industry and is prevalent in more than 60 countries across the globe. Currently, ~7,000 million tons of coal are produced each year (Rutledge, 2011), which removes or fragments significant areas of wildlife habitat. Post-mining restoration is necessary to restore ecosystem functions to the land and effectively improve habitat for native species of wildlife (Zipper et al. 2011).

Forest fragmentation and loss of habitat at local and regional scales are important factors contributing to declines of forest bird populations (O'Conner et al., 1996; Sauer et al., 2011). In a 65-county area of the central Appalachians, Mountaintop Removal/Valley Fill (MTRVF) mining has transformed topography, vegetation, and hydrology since the 1990s, and is now the dominant driver of land-use change in the region (Saylor, 2008). Wickham et al. (2007) estimated that during 1992-2006, MTRVF mining occurring within 19 counties changed ~92,500 ha of mature forest to non-forest and that 1,806-128,883 ha of interior forest were changed to edge forest. In addition, MTRVF has adverse impacts on watershed health, human health, groundwater, forest vegetation, and forest interior breeding birds (US EPA, 2005; Wickham et al., 2013).

Mature forest habitats within the MTRVF region have high breeding bird diversity; however, these bird species are affected by forest lost to mining. Many forest species are sensitive to the amount of interior forest and avoid extensive edge or have reduced reproductive success as a result of edge effects (Flaspohler et al., 2001). One species of conservation concern in the MTRVF region is the Cerulean Warbler (*Setophaga cerulea*), a small (11.5 cm, 8-10 g), canopy-dwelling Neotropical migrant that breeds in mature, deciduous forest throughout the Eastern and Midwestern United States and winters in the Andes Mountains (Hamel, 2000). According to Sauer et al. (2011), the Cerulean Warbler has declined 3.0% annually since 1966, which is an estimated total population reduction of 74% (Sauer et al., 2011). Thogmartin et al. (2006) projected an 83% probability that the species will experience a 90% decrease in 100 years. Consequently, the Cerulean Warbler is considered a species of special concern over its breeding range and a focal species of research and management priority. Cerulean Warblers reach their highest population densities in the central Appalachians (Fig. 1), and they are particularly abundant in eastern Kentucky and West Virginia where MTRVF is prevalent. Although Cerulean Warblers may be present in forest adjacent to reclaimed mines, they have decreased abundance and territory density due to edge and area effects (Weakland and Wood, 2005; Wood et al., 2006).

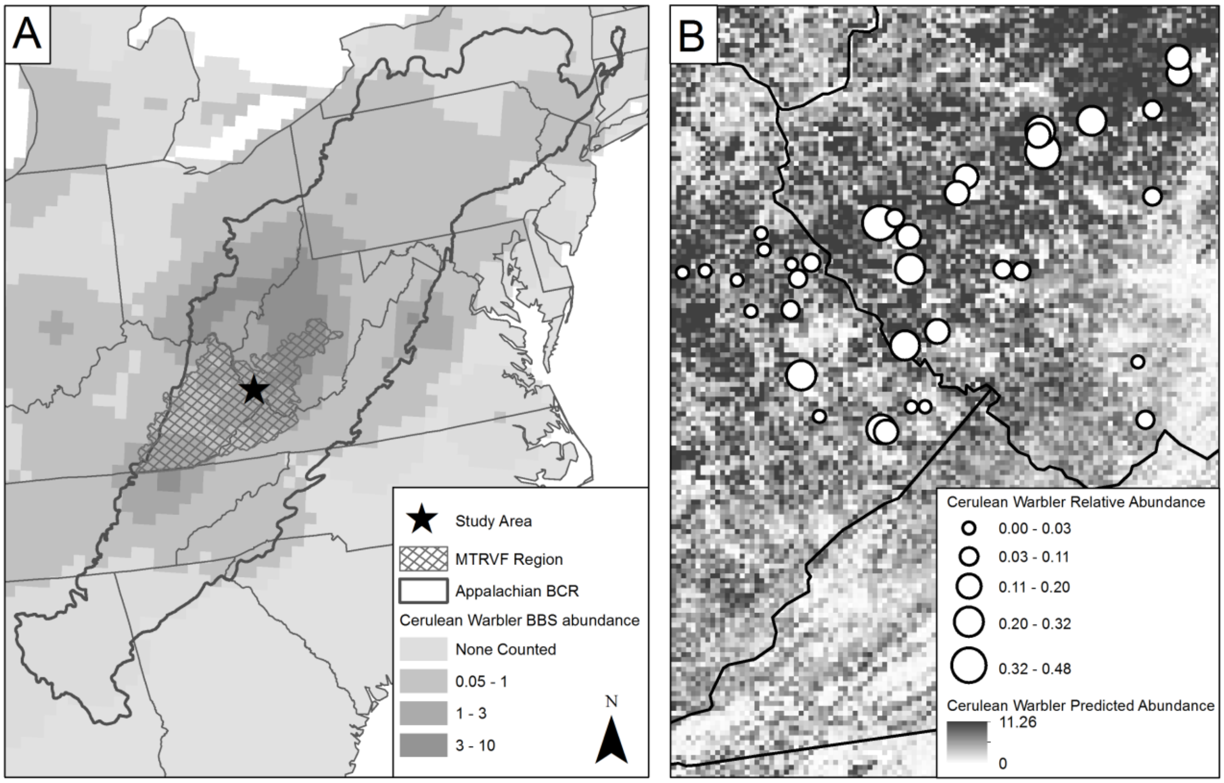

Figure 1. Study area location (A) within the Mountaintop Removal/Valley Fill (MTRVF) mining region, relative to Cerulean Warbler breeding distribution and relative abundance based on Breeding Bird Survey (BBS) data (Sauer et al., 2011). (B) Cerulean Warbler male abundance from transect surveys conducted in 2009 (circles) was higher within areas predicted to have higher abundance by Shumar (2009).

Following the passage of the Surface Mine Control and Reclamation Act of 1977 (SMCRA), the reclamation of mine lands created extensive grasslands that remained in an arrested stage of succession because of poor soils and compaction (Zipper et al., 2011) and that are embedded within a mature forest landscape (Weakland and Wood, 2005; Fig. 2). Mine reclamation guidelines developed through the Appalachian Regional Reforestation Initiative (ARRI) promote restoration of native hardwood forest conditions on active mines (Burger et al., 2005) and legacy mine lands (Burger et al., 2011). Reforesting mined lands adjacent to existing forest can reduce negative edge and area effects on interior forest species thus improving suitability for forest-dependent birds such as Cerulean Warblers. The Forestry Reclamation Approach (FRA) is a science-based technique for reclaiming coal-mined land to hardwood forest while complying with existing State and Federal mining laws (Burger et al., 2005). The FRA accelerates natural forest succession by (1) creating a suitable rooting medium for tree growth, (2) limiting soil compaction by loosely grading topsoil, (3) using ground covers that encourage tree growth, (4) planting early-successional tree species and commercially-valuable crop trees, and (5) using proper tree planting techniques (Burger et al., 2005).

Figure 2. A mountaintop removal mine in southwestern West Virginia reclaimed to grassland and embedded within a mature forest landscape. [Photo by Scott Bosworth]

To optimize reforestation efforts, it is important to identify and prioritize mined lands that have the highest potential for improving habitat for species of conservation concern. Distribution modeling can highlight important areas of high suitability throughout a species' range. Predictive maps created with a hierarchical spatial model of abundance for the Cerulean Warbler over the extent of the Appalachian Mountains Bird Conservation Region (BCR28) predicted counts for Cerulean Warblers similar to actual counts with moderate to high overall accuracy (R^2 = 0.71; Shumar, 2009). Additionally, insight gained from single-species models can be applied to the management of multiple species (Sheehan et al., 2013). In the Appalachian region, the Cerulean

Warbler acts as an umbrella species, where applied forest management for the species benefits a host of other avian species (Wood et al., 2013).

Maps of predicted Cerulean Warbler abundance can be used to identify and prioritize mined lands for reforestation when conservation of forest-dependent species is a restoration objective. Reforestation efforts could restore forested habitat for the Cerulean Warbler and other forest-dependent species over the long term, while in the near term provide shrubland habitat for young forest dependent species such as the Golden-winged Warbler (*Vermivora chrysoptera*). The objectives of this paper were to identify prioritization strategies for forest restoration that will best benefit Cerulean Warblers and mature forest songbirds on formerly mined lands. Our specific objectives were to (1) determine accuracy of the Cerulean Warbler predictive abundance map based on field survey results and (2) develop multi-scale guidelines for prioritizing reforestation of minelands for the benefit of mature forest birds based on the predictive map and the life history, presence/absence data and the fine-scale habitat associations of the Cerulean Warbler.

Methods

Study area

The study area was located within the Appalachian Bird Conservation Region (BCR28), in the core of the Cerulean Warbler's breeding range (Fig. 1A). BCR28 is dominated by oak-hickory (*Quercus* and *Carya* spp.), mixed-mesophytic, and northern hardwood forest types but contains diverse habitat types partly as a result of the large range in latitude, longitude, and elevation (0-1,981 m above sea level) and the mountainous topography. The MTRVF region, located centrally in BCR28, comprises approximately 10% of the region (~42,600 km^2) and contains primarily mature forest, although some of the land is used for timber production.

Site selection

To identify potential survey areas, we developed a map of surface-mined lands in the core breeding range of the Cerulean Warbler using remotely-sensed landcover data and digitized mine permit boundaries. This was overlaid on the map of predicted Cerulean Warbler abundance developed from statistical models that related abundance to environmental characteristics (Shumar, 2009). Mines were identified from landcover layers (2001 National Land Cover Dataset; NLCD), 2007-2008 aerial photographs, and mining permit shapefiles or pointfiles obtained from the West Virginia Division of Environmental Protection and Kentucky Division of Mine Permits.

The final map was used to identify mined lands that lie adjacent to forested habitat predicted to be suitable for Cerulean Warblers.

In May-June 2009, we visited 36 sites (Fig. 1B) to evaluate the accuracy of the spatial data and habitat modeling. The number of sites was limited by logistical constraints in terms of the narrow seasonal window for surveys and large geographic extent to cover. Sites were representative of mature forest within the MTRVF region of West Virginia and Kentucky, represented a range of predicted relative abundances for Cerulean Warblers, and were near mines in various stages of reclamation. Before conducting surveys, we visited sites to confirm that they contained potential breeding habitat for Cerulean Warblers that they could be accessed from public roads, and that access to property was not restricted.

We established survey transects on forested ridgetops near reclaimed mines but usually >1 km from mine edges due to lower Cerulean Warbler abundance near mine edges (Wood et al., 2006). We focused on ridgetops because Cerulean Warblers in the region are found at highest densities on ridgetops (Weakland and Wood, 2005). Elevations of transects were 219-793 m. The predominant forest types were mixed oak and oak-hickory deciduous forest, but we also surveyed some mixed oak-pine (*Pinus* spp.) forest in Kentucky.

<u>Bird and habitat surveys</u>

We sampled 36 transects in 2009: 20 in West Virginia and 16 in Kentucky, and conducted a total of 151 point count surveys on the transects. Transect length was 0.5-2.1 km (mean=1.4 km), depending on the amount of habitat available and accessibility.

Route-level abundance of Cerulean Warblers was quantified using transect surveys. Between 19 May and 16 June, we conducted surveys along the 36 routes between sunrise and 5 hours past sunrise. Due to logistical constraints, surveys in West Virginia were conducted first. We surveyed only in optimal weather conditions (no heavy winds or precipitation). We walked a steady pace along each route with one observer recording all Cerulean Warblers detected by sight or sound within 125 m of the transect, the song detection distance for Cerulean Warblers (Rosenberg and Blancher, 2005). We recorded initial location and sex of each Cerulean Warbler.

We quantified point-level Cerulean Warbler relative abundance on point count surveys. Every 300 m along a transect, one person conducted a standardized point count; typically 4-6 points per route dependent on route length. We recorded all individual Cerulean Warblers detected by sight or sound within a 10-minute period and within 125 m of the observer. We recorded sex and response type (song, call, visual observation, or flyover) for each bird. Two observers (MEM and MBS) skilled in avian survey techniques and bird identification by sight and sound completed all surveys. A double-observer training period preceded surveys at the start of the season to reduce observer differences.

Immediately after each point count, we broadcast up to 5 variations of Cerulean Warbler song to illicit a response from territorial males to increase detection of birds that were potentially missed during transect surveys. One minute of song broadcast was followed by a one minute silent listening period. The playback period was repeated for a second iteration. We recorded sex and distance of approach for all Cerulean Warblers responding.

At each point count location, we recorded basic habitat measurements including forest type (deciduous or mixed deciduous/coniferous, if >1 conifer was present per prism plot) and predominant seral stage (early-, mid-, or late-successional or combination of the 2 most predominant). Early-successional was defined as a stand in shrub-sapling phase, mid-successional was a stand with little understory and in pole-intermediate stage, and late-successional were areas of mature trees where understory reinitiation had occurred (Smith et al., 1997). We measured basal area with a 10-factor prism and identified the principal tree species present in the overstory of the prism plot. Within a 10 m radius of the point center, we estimated density of understory vegetation < 3 m tall as a rank of 1-4 (1 = open understory with <5% cover, up to 4 = thick understory with >60% cover) and canopy closure ranked 1-4 using a densiometer (1 = open canopy with <5% cover and 4 = closed canopy with >90% cover). Canopy disturbances that occurred within 10 m of each point count location were noted and included any major disturbance of mature forested habitat such as secondary paved or gravel roads (~65% of disturbances recorded), powerlines, burned forest, young harvests, or fields. Canopy disturbances often extended beyond 10 m of the point count station. Elevation and aspect were derived from the 30 m USGS National Elevation Dataset (NED). Aspect was transformed using Beers et al. (1966), which gives greatest weight to more productive northeastern slopes.

Statistical analyses

We evaluated accuracy of the Cerulean Warbler predicted abundance map developed by Shumar (2009) at two scales (the point-level and the route-level) with Pearson product-moment correlation. We report the correlation coefficient (R) which ranges 1 to -1 and values close to ±1 imply a more linear correlation. At the point-level, we compared relative abundance of Cerulean Warblers at each point count location from the field data to predicted abundance at each point from the predictive map. Point-level abundance was the number of singing males detected within 125 m during point count surveys plus new males detected during song playback. At the route-level, we compared abundance of Cerulean Warblers detected on each transect to the predicted abundance. Route-level abundance was the sum of all males detected within 125 m of the transect and included all unique individuals detected along the transect and during playback. New individuals were detected at only 4 of the 151 points during playback, indicating that the broadcast was not attracting males beyond 125 m.

Because Cerulean Warblers become less vocal later in the breeding season, we divided the survey data in half and defined two periods: early (19 May-2 June) and late (6-16 June). In Kentucky for example, this species will sing through the middle of June (Hartman et al., 2009), but less consistently after May when many young have already fledged (Matthew White, personal communication). We completed separate correlation analyses for each period.

We compared habitat metrics (Table 1) at point count locations with Cerulean Warblers present to locations where they were absent using t-tests accounting for unequal variances ($P \leq 0.05$ significance level). We analyzed the tree species (or genera) that were present at >30% of either presence or absence points to identify tree species important to Cerulean Warblers.

Hot spot identification

To facilitate the prioritization process, we created a map of hot spot locations based on the predicted abundance map for Cerulean Warblers. We identified hot spots of relative abundance by resampling the map using focal neighborhood statistics in ArcGIS® (ESRI, 2006). For each cell in the original map, this technique calculated the mean predicted relative abundance of the surrounding 8 cells (3x3; a rectangular neighborhood representing ~22 km^2). This results in higher relative abundance for cells of high abundance surrounded by high abundance than for cells of high abundance surrounded by low abundance. The top 5% of cells from the resampled map of the MTRVF region were designated hot spots and included areas with ≥10 aggregated cells (Fig. 3).

Results

Cerulean Warbler detections and habitat

We detected Cerulean Warblers at 55% of point counts in West Virginia, 25% of points in Kentucky, and 42% of all points. Playback surveys increased the total detected at only 2.6% of points. Cerulean Warblers were detected on 29 of 36 survey routes (80%); routes were purposely placed where Cerulean Warblers were predicted to occur. Thus, we detected Cerulean Warblers on a high proportion of routes where we predicted they would be present. The maximum number of singing males detected on any route was 16 (mean=4.83; SE=0.75).

Four of 10 habitat variables analyzed differed significantly between points with Cerulean Warblers present and absent (Table 1). Points where Cerulean Warblers were detected had a less dense understory, less canopy disturbance present, and more often had hickory species and white oak present in the canopy than at locations where Cerulean Warblers were not detected. Cerulean Warblers rarely occurred in mixed forest; they were present at only 5% of points in mixed forest but at 95% of points in deciduous forest (Table 2). The age of forest also influenced the occurrence of Cerulean Warbles since they were detected at 90% of sampling routes that had a late-successional component (Table 2). At locations with a major canopy disturbance, Cerulean warblers were detected at 49% of the sampling points compared to 64% at points without canopy disturbance.

Accuracy of Cerulean Warbler predictive map

Neither index of abundance (point-level or route-level) had a strong correlation with the predicted abundance of Cerulean Warblers. However, strength of correlation at the route level (R=0.47, p=0.004) was higher than at the point level (R=0.26, p=0.001).

Stronger relationships occurred when dividing the data into early and late periods. At the point level, there was a significant correlation (R=0.27, p=0.018) for the early period but not the late period (R=0.07, p=0.548). The route level showed a similar pattern, with the early period having a significant and strong correlation (R=0.66, p=0.003) and the late period showing no correlation (R=0.03, p=0.901).

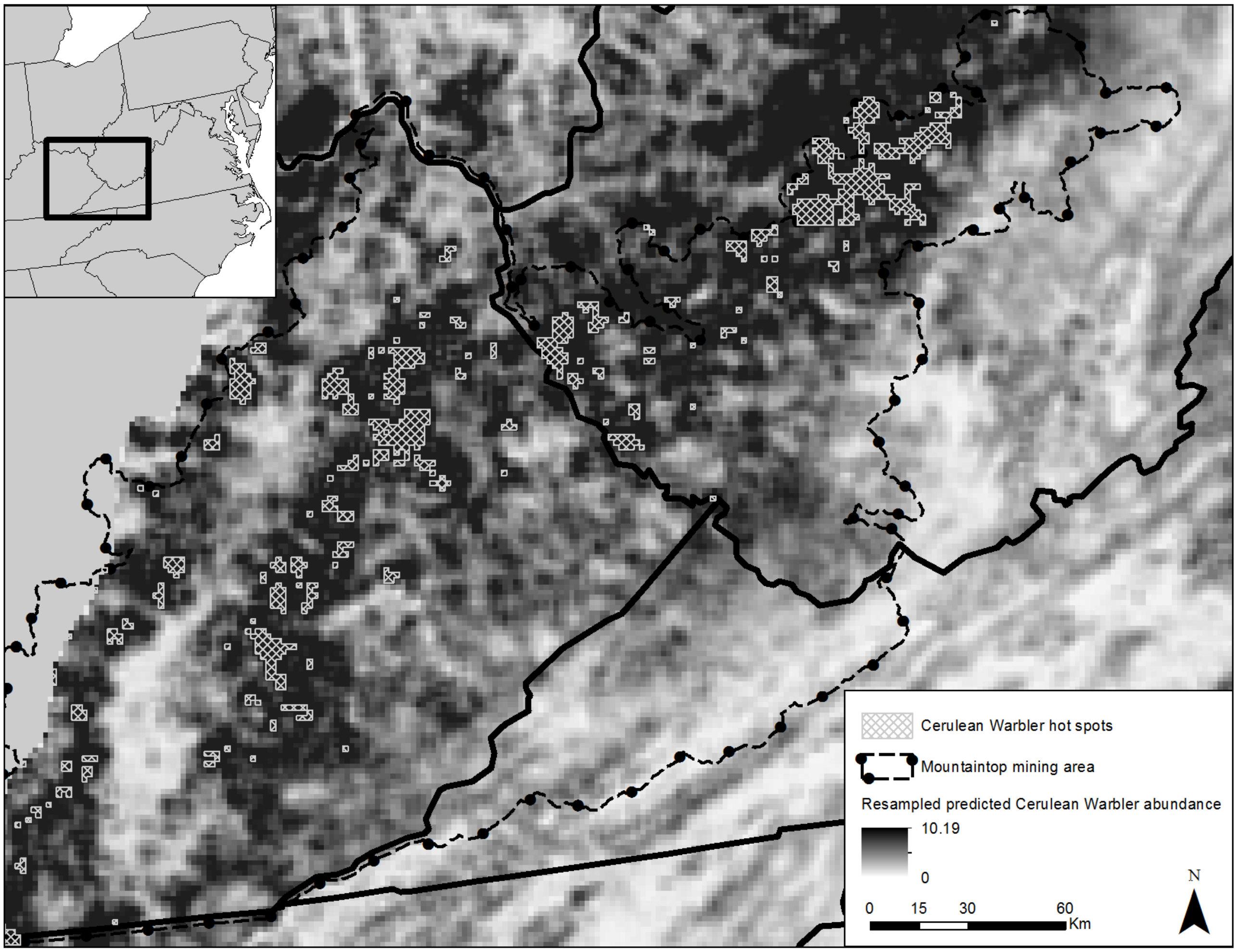

Figure 3. Predicted hot spot areas for Cerulean Warblers taken from the top 5% of cells from the predicted abundance map after it was resampled to take into account neighboring cells (3x3) within the resampled mountaintop mining area boundary. Each cell is ~22 km^2. GIS layers of this predictive map can be obtained from the Appalachian Regional Reforestation Initiative as well as the Appalachian Mountains Joint Venture.

Table 1. Comparison of habitat metrics at point count locations with Cerulean Warblers absent and present during bird surveys in the mountaintop mining region of West Virginia and Kentucky, 2009.

	Absent (n = 88)			Present (n = 63)				
Variable	**Mean**	**SE**	**Range**	**Mean**	**SE**	**Range**	**t**	**p**
Basal area (m^2/ha)	15.7	1.0	0 - 36.7	18.1	1.4	0 - 39.0	1.47	0.07
Understory (<3 m) cover rank[a]	3.2	0.1	1 - 4	3.0	0.1	1 - 4	**-1.75**	**0.04**
Canopy closure rank[b]	2.6	0.1	1 - 4	2.7	0.1	1 - 4	0.17	0.43
Elevation (m)	432.9	15.0	242 - 767	447.2	13.2	241 - 743	0.72	0.24
Aspect, transformed[c]	0.89	0.08	0 - 2	1.04	0.09	0 - 2	1.25	0.11
Canopy disturbance present (% points)[d]	64.0	5.0		49.0	6.0		**-1.76**	**0.04**
Tree species (% points)[e]								
Ash spp.	10.2	3.2		6.3	3.1			
Black locust	9.1	3.1		1.6	1.6			
Black oak	9.1	3.1		12.7	4.2			
Chestnut oak	46.6	5.3		34.9	6.1		-1.44	0.08
Hickory spp.	29.5	4.9		50.8	6.3		**2.65**	**0.004**
Pine spp.	13.6	4.0		3.2	2.2			
Red maple	39.8	5.2		38.1	6.2		-0.21	0.42
Red oak	28.4	4.8		23.8	5.4			
Scarlet oak	10.2	3.2		9.5	3.7			
Sugar maple	11.4	3.4		6.3	3.1			
Tulip poplar	9.1	3.1		9.5	3.7			
White oak	15.9	3.9		30.2	5.8		**2.03**	**0.02**

[a]Ranked 1-4, where 1 = open understory (<5%) and 4 = thick understory (>60%).

[b]Ranked 1-4, where 1 = open canopy (<5%) and 4 = closed canopy (>90%).

[c]Aspect was transformed with northeastern slopes given the highest value (Beers et al., 1966).

[d]Percent of points where a major canopy disturbance was present.

[e]Percent of points where each species was present as a principal overstory tree. Tree species present at < 5% of all points were omitted. Only those present at >30% of present or absent points were analyzed.

Table 2. Comparison of forest type and age at points where Cerulean Warblers were present and absent during bird surveys in the mountaintop mining region of West Virginia and Kentucky, 2009.

		Percent		Percent
Variable	**n**	**Absent**	**Present**	**Present**[a]
Forest type				
Deciduous	135	56	44	95
Mixed	16	81	19	5
Forest seral stage[b]				
ES	5	80	20	2
ES/MS	1	100	0	0
MS	20	75	25	8
MS/LS	4	50	50	3
LS	69	51	49	54
LS/ES	52	60	40	33

[a]Percentage of presence points (n = 63) that fall into each category.

[b]ES=early successional; MS=mid-successional; LS=late successional. Two codes indicates that two age classes predominated.

Discussion

Habitat associations at points where we detected Cerulean Warblers followed patterns predicted by earlier studies. They avoid large-scale disturbances and edges (Weakland and Wood, 2005; Perkins, 2006) and thus likely avoided canopy disturbances such as fields or powerlines that occurred at some of our surveyed sites. However, Cerulean Warblers occurred in more than 1/3 of points that had a major canopy disturbance, usually a secondary road, which corresponds to results from similar studies (Weakland and Wood, 2005). The species prefers broken canopy or small canopy gaps (Hamel, 2000; Perkins, 2006) and their abundance can substantially increase in areas with low amounts of canopy closure as a result of timber harvests (Boves et al., 2013b; Wood et al., 2013). Thus, it is not surprising that there was not a difference in canopy closure between points with Cerulean Warblers present and absent.

Tree species associations were similar to previous studies (Rosenberg et al., 2000; George, 2009; Boves et al., 2013a) with Cerulean Warblers occurring more often where hickory species and white oak predominated. White oak is a preferred tree species for nesting Cerulean Warblers

(Boves et al., 2013a) and hickory species are used for foraging and singing (George, 2009; Wood and Perkins, 2012). Forest seral stage was an important variable; 90% of points with Cerulean Warblers present included late-successional forest. The species breeds almost exclusively in mature forest and as our data support, avoid mixed forest. Thus, reforestation efforts that focus on minelands adjacent to mature oak-hickory forest, and thereby increase the size of contiguous forest, would improve habitat suitability for Cerulean Warblers.

Although overall correlations were low between our survey abundance indices and predicted abundance at the point and route levels, the route-level prediction proved more accurate, especially considering only the early time period. Fine-scale species models have been successful at small extents (Dettmers and Bart, 1999; Buehler et al., 2006) but often do not perform well when tested in other geographic regions or over broader extents (Heglund, 2002). Poor performance may result from a mismatch in the resolution of environmental data to species survey data, or lack of important environmental covariates at the point-level scale (Heglund, 2002; Shumar, 2009). Further, species of conservation concern may exist below thresholds where they can occupy all suitable habitat, thus presenting overly pessimistic model performance. However, based on the correlation coefficient of R=0.66 for early surveys (>0.5 is considered a strong relationship; Cohen, 1988) and because 80% of routes had Cerulean Warblers detected, our predicted abundance map (Fig. 1) can serve as an initial guide for identifying areas of high abundance for this species.

Prioritizing for Reclamation

One objective of this study was to identify a process that would prioritize which mines to target for forest reclamation for Cerulean Warblers and other mature forest birds. Because the MTRVF region contains many areas with high predicted abundance of Cerulean Warblers and a large number of surface mines, a multi-step and multi-scale approach is needed to identify highest priority areas for reforestation based on predicted Cerulean Warbler abundance.

The first step is to identify specific mines to target for reforestation (Fig. 4). Surface mines near one of the hot spots identified from our analysis (Fig. 3) would be considered high priority for hardwood reforestation. Once mines are identified as high priority for reforestation from a biological perspective, others (ARRI or the U.S. Office of Surface Mining, OSM) could work with interested landowners to determine which mines are candidates for reforestation from a logistic and regulatory perspective.

The next step in the prioritization process is to evaluate specific areas within the boundaries of high priority mines for reforestation based on fine-scale habitat metrics (Fig. 4). The following fine-scale criteria can help a landowner identify specific areas on their particular mine that would be high priority for reforestation.

In the Central Appalachians, Cerulean Warblers reach their highest abundances in large tracts of mature forest (Hamel, 2000), away from an abrupt mineland/forest edge (Weakland and Wood 2005; Wood et al., 2006; this study), on or near ridgetops (Rosenberg et al., 2000; Weakland and Wood, 2005), and on northern and east-facing aspects (Wood et al., 2006; Hartman et al., 2009). Thus, targeting reforestation efforts along mature deciduous forest edges, along ridgetops, and away from southwestern-facing slopes would provide most immediate benefits for Cerulean Warblers and other species dependent upon large tracts of mature, undisturbed forest, especially canopy-nesting species. Additionally, if there are mature forest patches in close proximity to each other, reforesting mineland between them would increase forest patch size more quickly, reduce forest fragmentation, and increase forest connectivity (Fig. 4). This targeted management will benefit other species under the umbrella of Cerulean Warblers (Wood et al., 2013).

Guidelines have been developed through ARRI to promote mine reclamation efforts that will expedite the establishment of native hardwood forest on active (e.g., Burger et al., 2005) and legacy mine lands (Burger et al., 2011). Encouraging structural complexity and floristic richness similar to natural forest would maximize bird species recolonization in a variety of restoration settings (Twedt et al., 2002; Munro et al., 2011). In the MTRVF region, highest priority would be to target reforestation efforts at locations that are most likely to improve habitat suitability for the Cerulean Warbler and other forest songbirds. After reforestation, it is important to evaluate restoration success, and an adaptive management framework can be used to monitor the success of reforestation efforts to adapt management practices and increase future success. Post- reforestation surveys are needed long-term to track recolonization by mature forest birds, and the rate and extent of recovery can help determine restoration success (Passell, 2000). Ecological recovery as indicated by mature forest bird presence, diversity, and nest success (Twedt et al., 2002) could be measured on reforested minelands and compared to unmined mature forest plots.

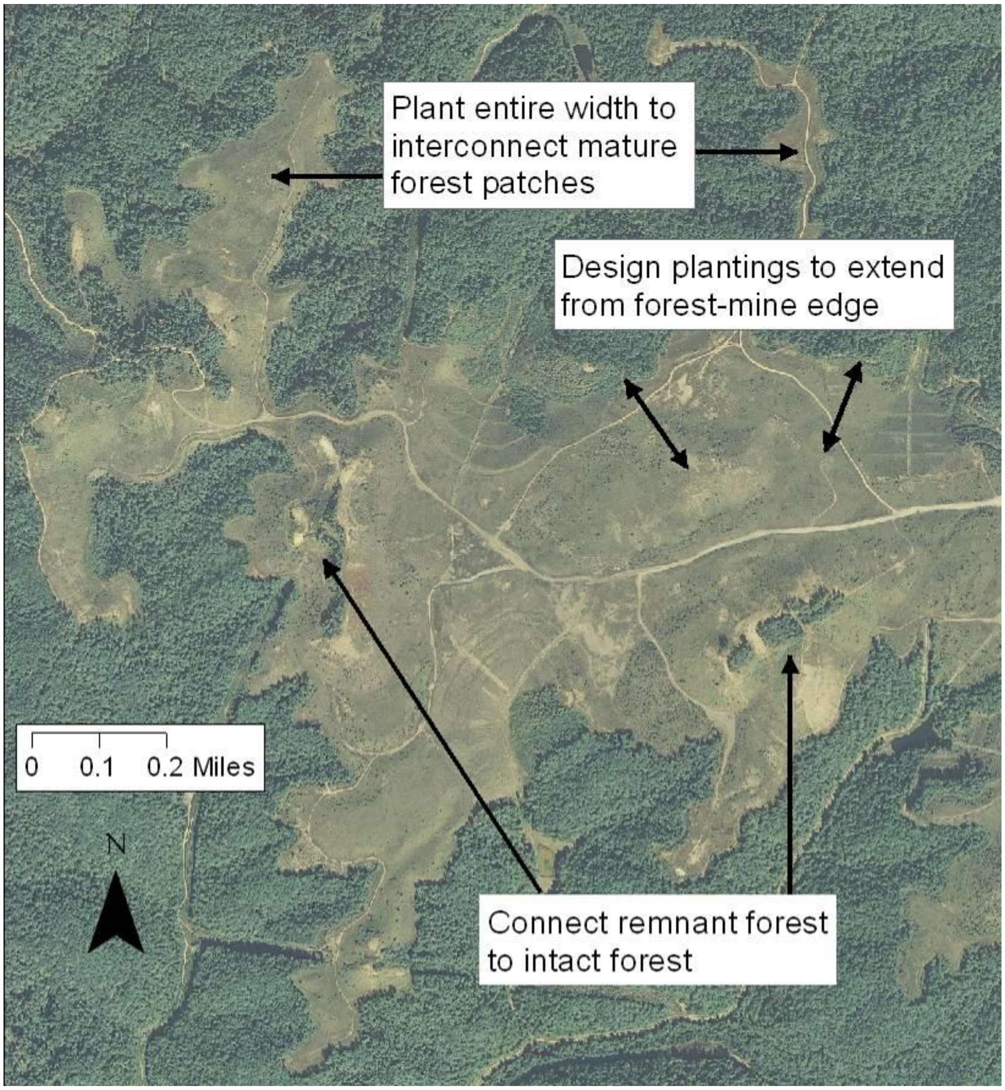

Figure 4. Illustration of the prioritization process for selecting specific sites within a mine to reforest.

Implementation of reforestation efforts can be accomplished with support from landowner outreach and incentive programs that already exist within the OSM, U.S. Fish and Wildlife Service, and other agencies. Our prioritization strategy for increasing conservation value of formerly mined lands is compatible with the ARRI objectives of hardwood reforestation and can help in the recovery of habitat for the Cerulean Warbler and other forest birds of high conservation concern, while providing habitat for shrubland dependent species in the short-term. Our multi-scale approach for prioritizing restoration efforts using an umbrella species may be applied to restore habitat impacted by a variety of landscape disturbances.

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