Evaluating wildlife response to vegetation restoration on reclaimed mine lands in southwestern Virginia

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(ABSTRACT)

Coal mining has had profound impacts in the Appalachian region, initiating a need to understand the implications of traditional and current reclamation practices on wildlife. I evaluated wildlife use of reclaimed sites of varying ages and cover types in southwestern Virginia. I compared reclaimed sites to another form of anthropogenic disturbance (clearcut) and relatively undisturbed mature forest. Birds were surveyed during early mornings throughout the breeding season in 2007 and 2008 using the point count method. Amphibians were surveyed using artificial cover, constrained-time night searches, and auditory pond surveys. Microhabitat data were collected at each sampling point and were combined with landscape-level GIS information to relate habitat characteristics and wildlife patterns.

I observed 80 bird species using reclaimed areas, clearcuts, and mature forest. Pre-regulation sites (prior to the Surface Mining Control and Reclamation Act of 1977) supported the highest number of species overall. Cluster analysis identified 4 bird associations based on habitat characteristics. I developed site-specific, landscape-level, and mixed-scale logistic regression models to identify habitat characteristics that best predicted the presence of 27 species. For 18 species, mixed-scale models performed best, suggesting the importance of a multi-scale approach to habitat analysis.

Salamanders were generally not detected on reclaimed areas, possibly due to the lack of soil moisture, leaf litter, and woody debris on young sites. Frogs were present in all water bodies surveyed, suggesting the importance of managing ponds and wetlands on reclaimed sites. Identifying and focusing on important habitat characteristics will help managers enhance post-mining land for wildlife.

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Introduction

Historically, coal mining has played an integral role in both the economy and the generation of energy in the United States. Coal is found beneath 31 states in the U.S., although there are 3 main regions where deposits are clustered: Appalachia, the Midwest, and the West (Fig. 1). Most of the coal extracted (92%) is used to generate electric power, which is clearly the driving force for coal consumption in the United States (EIA 2008). Of the U.S. electric power generated in 2006, coal contributed the largest proportion (49%), followed by natural gas (20%) and nuclear (19%) energy (EIA 2008). Coal consumption is highly dependent on the current price of coal, a function of mining costs and inflation, and consumption of electric power, which varies with weather and economic growth. Even while "greener" alternatives for energy are currently and will be actively pursued, coal will remain a dominant player in energy production. An efficient and productive use of this resource is essential to ensure that coal is available for use in the future.

Impacts of coal mining on natural resources

Coal mining causes dramatic changes in the landscape. Vegetation is eliminated during surface mining and the re-establishment of vegetative cover can be challenging and almost impossible without fertilization and other soil treatments. Often, the nutrient-rich topsoil is buried during reclamation, leaving an inappropriate substrate to support desired vegetation (U.S. Forest Service 1982). Water resources are disrupted or eliminated during earth moving, and potential runoff can lead to heavy metal toxicity, sedimentation, and changes in the pH of local waters (Leedy et al. 1981). Sometimes headwater streams are covered over as spoil is removed from mountaintops and pushed into valley fills. The influence of compaction on many reclaimed sites may create perched water tables, producing artificial wetlands in areas where they were not previously found. Even air quality can be affected from heavy machinery traffic on the site. The impacts of coal mining on the environment clearly can be substantial and widespread (U.S. Forest Service 1982).

One of the major resources affected by mining practices is the native soil on the site. Materials are often moved, inverted, and mixed so as to create entirely new growth media for vegetation. The instability of these altered soils can lead to erosion, causing heavy sedimentation and potential toxicity to local streams (Leedy et al. 1981). The original, weathered, topsoil often ends up buried beneath the unweathered spoil that is removed last from the site. If spoil banks rich in pyritic or sulfuric materials are exposed to the elements, highly acidic conditions can result causing acid mine drainage (AMD) and toxicity (Leedy et al. 1981). Following mining operations, compaction from heavy equipment and grading is a problem at most sites, and can prevent water penetration and vegetative rooting in the soil. Steep slopes, soil stability issues, a coarse, rocky soil structure, low water holding capacity, and available rooting depth are all concerns following mining. Ideally, these issues should be anticipated and planned for prior to any mining operations. Mine soil reconstruction requires a forward-thinking attitude toward the post-mining land use, and also warrants identifying any acidity, soil texture, or nutrient issues that may affect subsequent plant growth *before* mining begins (Daniels and Zipper 1997). A heterogenous soil structure can support different types of vegetation, creating habitat for a diversity of wildlife species. Many herptiles and birds that require various cover types to support their life cycles (Galan 1997).

Wildlife are often displaced from their native environments after mining, and may not return without the appropriate resources necessary for their survival. Disturbances to wildlife during a mining operation include more than just excavation at the actual mine pit. Impacts can be widespread and affect areas adjacent to and far from the mine site. Some other disturbances impacting wildlife and their habitat include the construction and use of temporary road systems, heavy machinery, noise, erosion, changes in topography and landforms, loss of native vegetation and cover, and sometimes environmental contamination. In particular, wildlife dependent on aquatic resources can be dramatically impacted. Habitat complexity is often reduced following mining or other disturbances, causing a shift in the composition of wildlife communities such as birds (Wray et al. 1982). The size and extent of the mining disturbance is a crucial component of the environmental impact on avian species (Yahner et al. 1978).

Vegetation reclamation and wildlife response

Wildlife studies on land disturbed by coal mining began before the establishment of regulations requiring reclamation. Initial studies in the Midwest (Myers and Klimstra 1963, Karr 1968) found that the topography and hydrology of mined sites was indeed drastically changed, yet a variety of wildlife species were still able to establish on the site. These studies suggested that wildlife community diversity, especially for birds, generally increased with vegetational structural complexity (Karr 1968). They also concluded that surface mines tend to be inhabited by plant and animal species pre-adapted to the post-mining conditions (Myers and Klimstra 1963). For example, plant species that can tolerate low nutrient or acidic soil conditions (such as various species of goldenrod, *Solidago* spp.) and wildlife species that require early successional habitats (such as many grassland birds) are typically the pioneer species that inhabit the area following mining. Wildlife such as birds and bats often serve as seed dispersal agents on barren sites that lack initial seed banks. These early initiators contribute greatly to the revegetation process by transferring seeds to the area through droppings or food transfer (Walker and del

Moral 2003). Mining disturbances impacting forestland have been shown to have a marked effect on the avifauna found in the larger geographic area beyond the mine site (Yahner et al. 1975).

Following the passage of the U.S. Surface Mining Control and Reclamation Act (SMCRA) of 1977, efforts to study the effects of these regulations on the environment increased, particularly in the eastern United States. Mine reclamation was to be regulated by the U.S. Office of Surface Mining (OSM) in the Department of Interior, and also by individual state agencies. Regulatory agencies would now monitor the progress of a site for several years after mining is complete, while holding the mining company responsible for the site in the form of a monetary bond. Coal operators were now required to meet certain environmental protection performance standards prior to release of the site after coal extraction. These standards include restoring the site to the “approximate original contour,” preventing and/or treating any hydrologic consequences or toxicities from disturbance, and revegetating mine spoils such that plant succession and regeneration can take place (Office of Surface Mining Reclamation and Control 2008). Ultimately, mine operators were required to restore the land to an “equal or better” post-mining land use as compared to the pre-mining conditions on the site. Mine operators are also required to study and document the pre-mining conditions of the site, especially any potential acidity in the soil column.

A more informed public also began to question the practices and environmental costs to society of coal mining. Randall et al. (1978) found that perceived costs of damage to the public included numerous factors such as water pollution, degradation of wildlife habitat and outdoor recreational sites, and aesthetic damages. Thus, even following reclamation, there are still some long-term environmental costs that must be paid by society.

The reclamation process can be used as a way to diversify both terrestrial and aquatic habitats. Restoring a diverse community of native vegetation that includes a variety of topographic features is the first step to attracting various wildlife species (Camerzind 1984). The creation of patches of different cover types (e.g., grasslands, forest, wetland, early successional, etc.) and different successional stages can provide habitat for diverse wildlife and aquatic species. Introducing a heterogeneous mixture of native and site-adapted vegetation on a landscape scale can provide important food and cover for wildlife species (Brenner and Kelly 1981, Paramenter and MacMahon 1990). By planting native trees and shrubs along terraces and contours, wildlife food and cover can be provided. Native vegetation generally has a greater nutrient content and is used to a greater degree by wildlife than exotic or non-native species commonly planted during reclamation (Brenner et al. 1984). The creation of ponds and wetlands (Bradley 1987) as well as rocky outcrops (Rumble 1989) can serve to attract wildlife to the reclaimed site. Wetlands used for "water quality improvement" can provide excellent habitat for reptiles and amphibians, depending on the specific site conditions (Lacki et al. 1992). There is the chance to "improve" habitat, or at least provide substrates or topography that may be lacking in adjacent areas, if planned properly ahead of time (Scott and Zimmerman 1984). There is even the opportunity to create habitat for game birds, such as ruffed grouse (*Bonasa umbellus*) or wild turkey (*Meleagris gallopavo*), or sport fishes, such as largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*), to facilitate land use by hunters and anglers (Bromley and Cushwa 1990, Leedy et al. 1981). Both consumptive and non-consumptive recreational activities can be provided for as part of post-mining land uses.

Preserving areas around and between mining areas to retain at least some of the natural vegetation may provide buffers, refuges, and seed banks during reclamation. Schaid et al. (1983)

suggested retaining brush lines between and around mining sites, along access roads, and around equipment storage areas to provide some brushy habitat necessary for the vesper sparrow (*Pooecetes gramineus*) in Wyoming. Lacki et al. (2004) stressed the importance of forest corridors for birds, especially riparian buffer strips, to allow movement between suitable habitats and access to necessary resources, particularly for dispersing juveniles. Open habitat species may also rely on features like utility-right-of-ways to connect isolated patches of suitable open habitat (e.g., clearcut) surrounded by unsuitable forest (Dunning et al. 1995). With proper planning and reclamation procedures, some areas can be restored to the former wildlife diversity (Simmons 2005).

The effectiveness of traditional reclamation practices has been argued by some researchers. On older mine sites in Alberta, Canada, 77% of plant species identified were indigenous, although indigenous species represented < 5% of the total vegetative cover (Strong 2000). This finding suggests that natural revegetation is occurring on mine sites, but widespread establishment may be severely inhibited by non-native species planted as part of the traditional reclamation process. Some avian species may prefer sites left to "natural reclamation" (i.e., natural succession on disturbed lands), rather than the graded landscape seeded to grasses of traditional reclamation (Steele and Grant 1982). Steep slopes, cliffs, depressions, and gullies also can provide essential nesting and foraging habitat for some avian species. Successful reclamation requires more than just adequate establishment of vegetation to prevent erosion, it demands an integrated approach of various disciplines of ecology (Huttl and Gerwin 2005).

The process of reclamation has also been confused with other restoration ecology terms such as restoration and reforestation. The purpose of reclamation is to "stabilize a landscape and increase the utility or economic value of a site" (Walker and del Moral 2003, p. 283).

Restoration involves the recovery of an ecosystem to its pre-disturbance structure and function. In many cases, ecosystems that have been impacted heavily by humans are difficult to completely restore, especially in a short period of time (Walker and del Moral 2003). Reclamation is used more frequently to control environmental issues and establish some utility on heavily disturbed sites such as coal mines. Reforestation involves the establishment and growth of timber, including native, mixed woody cover as well as plantations of native or non-native species designed to produce merchantable timber.

Although complete restoration may never be achievable in some areas, some kind of site treatment is necessary to begin the rehabilitation process. Large numbers of native plant species, usually generalists that can tolerate at least some adverse growing conditions (such as low nutrient availability and soil compaction), are able to colonize a reclaimed site within 10-15 years post-disturbance if given the chance. Generally, species that are seeded on reclaimed coal mines are considered invasive, or are at least not native to the site, providing only an "artificial" reclamation that protects the site from erosion in the short-term (Holl 2002, Scott et al. 2002). Bird communities in Indonesia depended on rudimentary reclamation practices as a "jump start" to the much longer revegetation and reinhabitation process. Richness and diversity of bird populations began to increase after only 3 years following reclamation, but was still much lower than the richness and diversity found on adjacent unmined sites (Passell 2000).

Coal Mining and Reclamation in Appalachia

In 2007, there were 1,200 operational mines producing 377 million short tons (2000 lbs., 910 kg) of coal in underground and surface mines in Appalachia (Energy Information Administration 2008). Most of the current coal extraction in Virginia is located in the southwestern coalfields, with 85% of the coal extracted from Wise, Dickenson, and Buchanan counties (DMME Division of Mineral Resources 2004).

Coal mining in Appalachia is inherently more difficult than mining in other regions. The coal seams in this region are thin and covered with large amounts of overburden, or undesirable rock material. Also, the topography of the region (steep slopes and narrow valleys) makes extraction of coal difficult. In addition, the coal deposits in Appalachia are high in sulfur and can frequently lead to the exposure of acidic soils and the generation of acid mine drainage and other environmental problems (Shover et al. 1986). However, natural recovery of vegetation in the Southeast occurs rapidly compared to other areas because of the relatively mild climate and adequate precipitation, even considering the propensity for acid generating soils, variable topography, and elevated temperature of mine spoils (Holl 2002).

Because of the regulations set forth by SMCRA, the mining industry is required to reclaim lands that have been subjected to coal mining to an acceptable land use. In the eastern United States, mine companies are held to a 5 year post-closure bond period to ensure that the land is environmentally safe and able to support a vegetative community. If objectives are met after this period, the bond money is released back to the mining company. Limited research has been done on the continued progression of vegetation on reclaimed areas after bond release (Holl and Cairns 1994). The success of reclamation may not be effectively judged after only 5 years since vegetation establishment in these disturbed sites takes much longer (Holl and Cairns 1994). In addition, relatively little research has been conducted to evaluate wildlife response to specific reclamation efforts, especially response to forestland reclamation. Evaluation is needed of long-term vegetation development and wildlife use on these reclaimed sites, as well as on sites that were mined prior to 1977 and not regulated by SMCRA.

Prior to SMCRA (pre-SMCRA), reclamation of impacted land was not usually considered because of the lack of sufficient regulations, and most sites were abandoned for decades without remedial treatment to promote vegetation growth and wildlife recolonization (Shover et al. 1986). Historically, the “shoot and shove” method was employed, resulting in an exposed highwall, compacted bench of rocky spoils, and a steep outslope of spoils that were bulldozed over the edge of the bench (Fig. 2; Haering et al. 2004). The resulting post-mining landscape was a series of these highwall/bench/outslope structures, with islands of natural soils and undisturbed vegetation between.

Historically, influence from Native Americans and early Europeans left the Southern Appalachian region covered in a mosaic of cover types, including old fields and early successional habitat interspersed with forest. They often burned and girdled trees to improve habitat for game or to create open areas for farming and to collect wood for building materials and fuel (Yarnell 1999). Today this cover type is less common as much of the early successional land has reverted back to forest. Reclamation efforts in Appalachia may also be particularly valuable to certain wildlife species. For example, in West Virginia, which is 74% forested, the addition of grasslands via reclamation practices provided essential habitat for native grassland bird species (Whitmore and Hall 1978). Uncommon grassland birds have benefited greatly from the creation of new grasslands that are not farmed, grazed, or mowed (Ingold 2002). Many tracts of land are large enough to provide habitat for even area-sensitive grassland birds (Bajema et al. 2001). Some researchers have suggested that the use of fast-growing, hearty non-native grass species may still provide adequate habitat for grassland birds (Scott et al. 2002). On the other hand, “created” or “artificial” grasslands surrounded by forests may act as population sinks by attracting predators to the area, and could have a negative effect on avian survival (Wray et al.

1982). It has also been suggested that the use of non-native or invasive species of vegetation can prevent or hinder natural succession on the site (Holl 2002).

Intensive reclamation efforts can accelerate the process of avian succession on the site (Curtis et al. 1978). In the Appalachians, it may take 8-9 years following mining to produce habitat that attracts the highest abundance and diversity of birds (Crawford et al. 1978). Once canopy closure reduces understory vegetation structure, there could be a reduction of bird species richness on older surface mines (Chapman at al. 1978). Abandoned benches and highwalls left to be colonized by native hardwood and pine species may be able to support unique bird communities (Curtis et al. 1978). Although pre-SMCRA sites were not actively seeded or planted (excepting a few eastern white pines [*Pinus strobus*] to conceal highwalls), the rough-graded soil with low vegetative cover provided a better long-term medium for the establishment and growth of woody species than traditionally reclaimed sites (Holl and Cairns 1994). However, the vegetative composition and structure on the oldest pre-SMCRA sites may still never be comparable to undisturbed second-growth hardwood forests (Holl and Cairins 1994).

In the early days of reclamation, most mined sites were converted to pastureland or fields as this use was deemed an "easier" and "cheaper" way to meet the requirements of SMCRA in a short period of time (Nieman and Merkin 1995). These designated pasturelands often were never maintained by livestock grazing and eventually would revert to a poor-quality forest (Burger and Zipper 2002). Planting invasive, highly competitive herbaceous vegetation, such as Kentucky-31 tall fescue (*Festuca arundinacea*), serecia lespedeza (*Lespedeza cuneata*), and redtop (*Agrostis alba*), slows and inhibits the colonization of native vegetation, especially woody species. Even as early attempts at forestry post-mining land use were made in the late-1990s, establishment of hardwoods was limited to pine, autumn olive, and black locust because of competition with invasive grasses and compaction (Burger 2006). Due to increasing public preferences for outdoor recreation (including hunting and wildlife viewing), forestland and wildlife habitat are land uses currently desired by society and may be more profitable in the future especially compared to ungrazed pastureland (Nieman and Merkin 1995). Through proper planning, we can use reclaimed mine lands to create custom wildlife habitat, recreational areas, and harvestable timber to benefit society. Even new environmental needs, such as the growth of switchgrass (*Panicum virgatum*) for biofuel production could be addressed on reclaimed mine sites.

Historically, there has been a lack of incentive to recreate forests as a post-mining land use. Many areas disturbed for mining are forested, which results in a marked loss of habitat for forest-obligate wildlife species (Balcerzak and Wood 2003). Proper reclamation practices to restore forestland can benefit all parties involved in the coal mining process: landowners benefit from the resulting timber resource of significant economic value, miners benefit from reduced costs of reclamation and compliance with regulations, and society benefits as a whole from wildlife habitat, watershed protection, and other ecosystem services (Burger 2006). The recently developed Appalachian Regional Reforestation Initiative (ARRI) encourages regulators to change their perspectives about forest restoration and provides the proper site preparation information to effect this change. The Forest Reclamation Approach (FRA) provides 5 guidelines for recreating healthy forests (Burger et al. 2005) and, over the past few years, has shifted post-mining land use to predominantly forested in Virginia. By determining the objectives for the post-mining land use and planning ahead before mining begins, the post-mining landscape can be both “attractive and productive” (Nieman and Merkin 1995).

Although new initiatives are developing to restore surface mines to forestland, pursuing this option under current permit practices remains challenging. Each site is evaluated 5 years after the completion of mining operations in the East (10 years in the West because of variable precipitation and weather conditions) for vegetative cover and water quality issues (Office of Surface Mining Reclamation and Control 2008). Because of competition with planted grasses and the time and conditions required for initial tree development, many sites that are designated to be returned to forestland are not considered to meet vegetative cover requirements after only 5 years post-mining. Effectively returning mined sites to forestland requires leaving the site rough graded, with limited compaction, and limiting initial vegetative cover to prevent seedling competition with grasses and forbs (Burger 2006). Many sites reclaimed to forest with proper planning exhibit timber productivity that is as good as or even better than the pre-mined forest (Burger 2006).

Much of the area utilized for coal mining in Virginia is forested ridge tops. The historical forest types in the Central Appalachian coal-bearing region are oak-hickory forest and Appalachian mixed hardwoods forest (Torbert and Burger 2000). These forests types were particularly dependent on fairly frequent disturbance regimen, including fire, windthrow, and ice storms. As these disturbances have been suppressed because of changing views and public safety (e.g., fire suppression), these forest types are changing. If continued oak dominance is desired in the Central Appalachian forests, some disturbance will be necessary. By using the appropriate post-mining treatments, it is possible to establish oak-dominated hardwoods on these mined sites (Burger et al. 2005).

Birds are generally one of the earliest species to visit a site following reclamation due to their mobility and active search for suitable habitat (Brändle et al. 2003). Although many studies have been conducted with birds on reclaimed sites, most have focused on the response of a single avian species (Balcerzak and Wood 2003, Bajema et al. 2001) or assemblage, such as grassland birds (Ingold 2002, Scott et al. 2002, Wray et al. 1992, Whitmore and Hall 1978). My study considered presence and habitat use at the community level by evaluating avian use on reclaimed mined sites of varying ages and cover types in southwestern Virginia. My hypothesis is that composition of wildlife communities will differ between disturbed and undisturbed sites and will be a function of the current habitat characteristics of a given site. I expect early-successional species and those tolerant of disturbance to be dominant in disturbed areas. I expect that more sensitive or specialist species may be lacking from areas disturbed by mining. I anticipate that over time these disturbed sites will improve as habitat for more sensitive species, although they may never reach their previous "undisturbed" potential.

In this study, mined sites were compared to local clearcuts and relatively undisturbed reference forests to better understand the impacts of mining and reclamation on wildlife. Clearcuts are generally composed of dense saplings with occasional patches of herbaceous cover, whereas reclaimed sites are typically planted with large expanses of herbaceous species to prevent erosion (Bulluck and Buehler 2006). Although these cover types are inherently very different, clearcuts represent another common form of anthropogenic disturbance to wildlife habitat in Virginia. In the eastern U.S., many populations of birds that breed in early successional habitat are declining because of loss of habitat (Askins 2001, Askins et al. 2007, Hunter et al. 2001). Early successional habitat may also provide important cover for post-fledgling juvenile and adult late-successional bird species (Marshall et al. 2003). Although natural disturbances such as fire have been eliminated from the landscape, clearcutting has diminished on National Forest land, and farming has slowed in the Appalachians, early successional habitat may be provided for birds on reclaimed mine sites.

Research at the Powell River Project has been integral to the education of mine operators, landowners, and state agencies that oversee mining operations, and has facilitated an important working relationship between mining companies and researchers. Results from research at the Powell River Project have been used as a model for many other mined areas in Appalachia. My work is the one of the first wildlife community studies to be conducted on-site, and is intended to contribute to the understanding of how wildlife use these reclaimed lands. The resulting information will also be made available to mine operators and regulators in the field to simultaneously help them meet their goals and aid in providing habitat for wildlife.

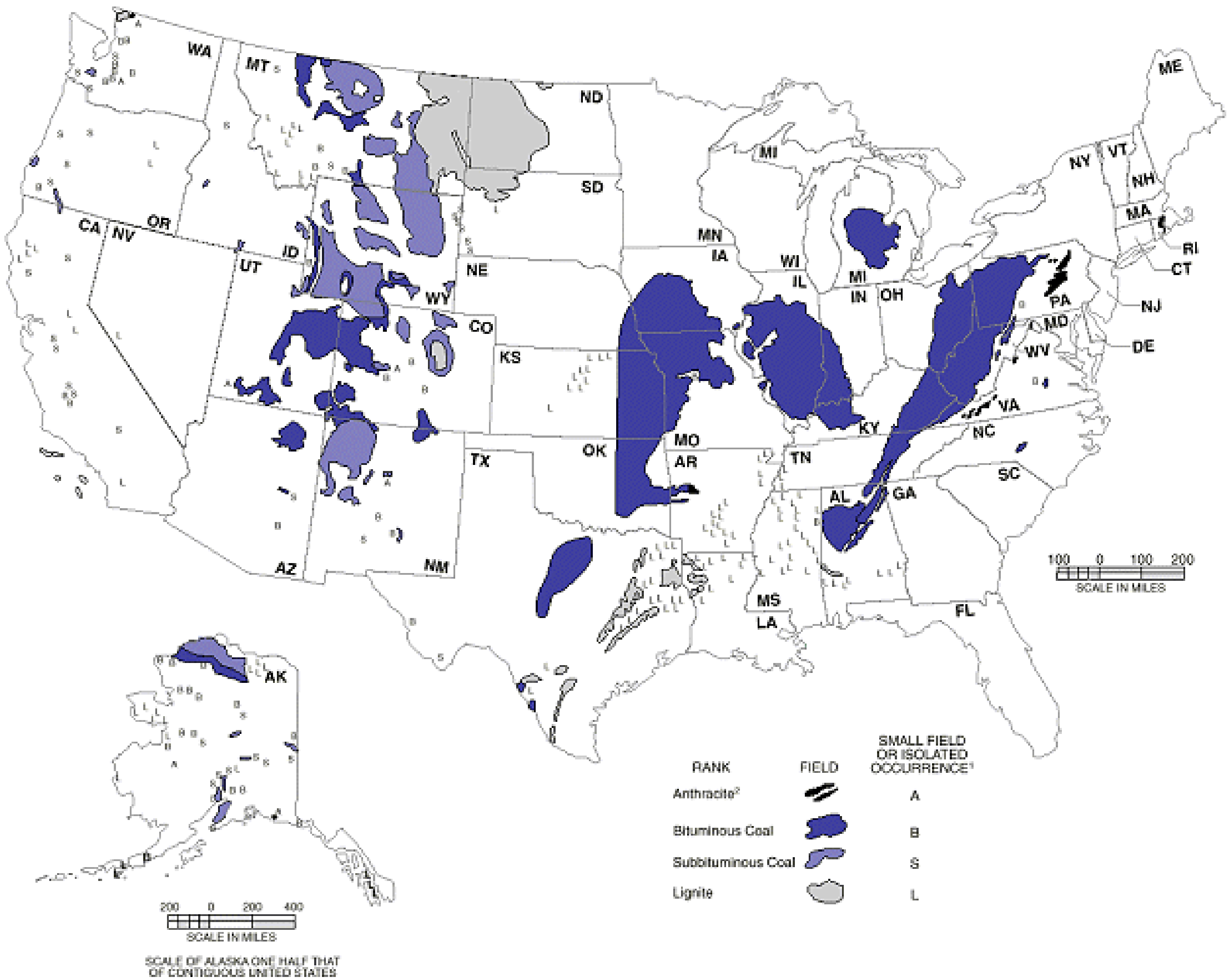

Figure 1. Distribution of coal types (anthracite, bituminous coal, subbituminous coal, and lignite) across the United States (Energy Information Administration 2006).

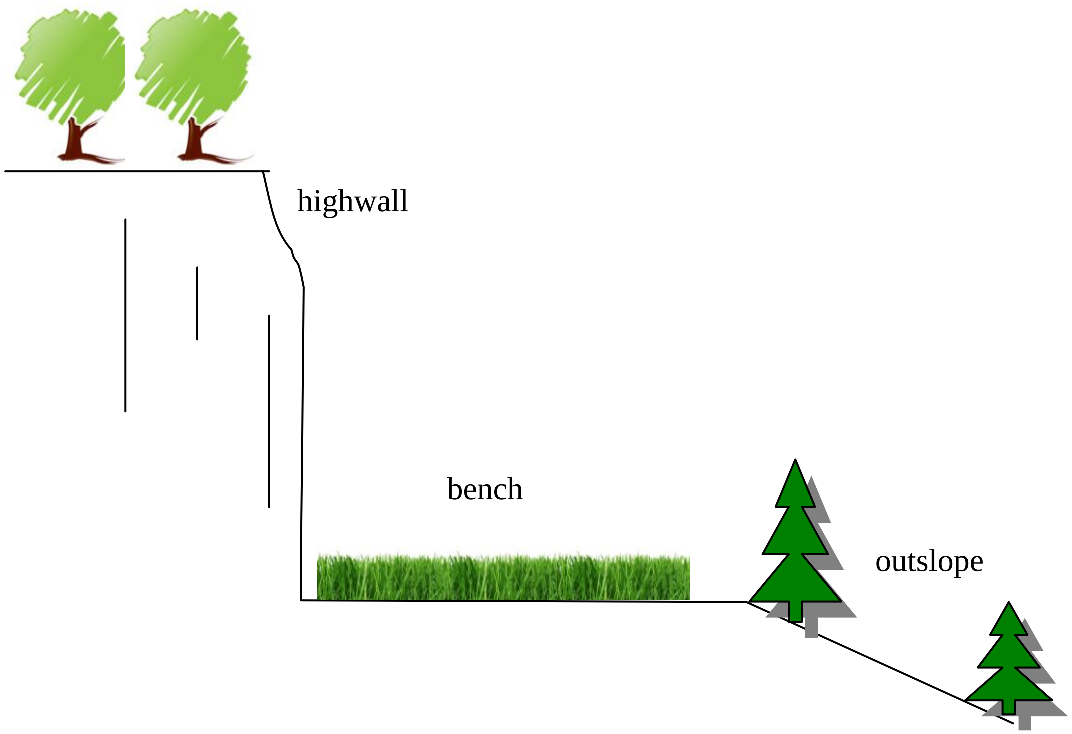

Figure 2. Highwall-bench-outslope structure of pre-SMCRA sites. Mature forest was usually found above the highwall. The bench, where heavy machinery was active during mining, would typically be flat and heavily compacted. Spoil material from the operation would have been "shoved" over the outslope. Pre-SMCRA sites were colonized by pioneer vegetation species and were not typically subjected to any reclamation treatment or plantings.

Objectives

This research is intended to contribute to our understanding of wildlife use of reclaimed mine lands. My hypothesis is that composition of wildlife communities will differ between disturbed and undisturbed sites and will be a function of the current habitat characteristics of a given site. I expect early-successional species and those tolerant of disturbance to be dominant in disturbed areas. I expect that more sensitive or specialist species may be lacking from areas disturbed by mining. I anticipate that over time these disturbed sites will improve as habitat for more sensitive species, although they may never reach their previous "undisturbed" potential.

My objectives were:

1. To determine avian and amphibian community composition of different age classes of reclaimed mine lands that have been restored to wildlife habitat and forest post-mining land uses.
2. Compare avian and amphibian communities of reclaimed wildlife habitat and forest communities to: (1) reference forests that have not been recently disturbed by mining or harvesting, and (2) forests that are regenerating after recent harvest.
3. Compare the structure and composition of reference forests to that of forests established on reclaimed sites, and compare the response of selected wildlife species to habitat patterns on reference and reclaimed sites.
4. Develop guidelines that can be used to suggest standards for reclaiming sites with forests that will meet avian and amphibian objectives.

Study Areas

The study areas were located in southwestern Virginia (Fig. 3). These areas contained both mined and unmined sites varying in age and treatment. All sites sampled in the study were either subjected to disturbance (coal mining or harvesting), or were relatively undisturbed second-growth forest. The majority of both areas had been logged historically, creating a relatively young (< 100 years old) forest.

The study areas are located in the Northern Cumberland Mountains (part of the Cumberland Plateau physiographic province), a sub-region of the Central Appalachian Mountains in the Tennessee River drainage. Elevation of this region is around 760 m (Woodward and Hoffman 1991), yet the topography is rough with some summits reaching over 1200 m. Rainfall averages 105-125 cm per year (Woodward and Hoffman 1991) and mean annual temperature ranges from 13-16ºC (McNabb and Avers 1994). The forest cover is largely mesophytic, composed of a diverse assemblage of hardwoods and conifers (Woodward and Hoffman 1991). The principal cover type is oak-hickory, including red oak (*Quercus rubra*), white oak (*Quercus alba*), red maple (*Acer rubrum*), flowering dogwood (*Cornus florida*), pignut hickory (*Carya glabra*), and white pine (*Pinus strobus*) (McNab and Avers 1994).

Because of mining disturbance on the study areas, some landscape characteristics have been drastically altered. Principal cover types vary and are highly dependent on age of the site since mining and site treatment. Pine is the dominant species planted on reclaimed sites - specifically white, loblolly (*Pinus taeda*), and Virginia pines (*Pinus virginiana*). Black locust (*Robinia pseudoacacia*) and autumn olive (*Eleagnus umbellata*) are also frequently planted on reclaimed sites. Autumn olive is not native to North America and loblolly pine, while native to Virginia, did not occur historically in the mountain region.

Powell River Project (PRP)

The Powell River Project is a cooperative mine reclamation research program located on 700 hectares (1,730 acres) in Wise County, Virginia, near the communities of Wise and Norton. The area is owned by Penn Virginia Resources Corporation, a large landholding company interested in energy resources. Ring Brothers Coal Company and others mined the land extensively using deep mines and contour mining methods from about the late 1950s through 1977 (Haering et al. 2004). Since 1980, Red River Coal Company has been actively remining the site using second-cut contour surface mining methods followed by reclamation practices currently required by SMCRA. Most of the soil strata at Powell River have a net calcareous content (a natural liming agent), reducing the amount of acidity problems produced during the weathering process (Haering et al. 2004).

The mission of the Powell River Project, a cooperative program between Virginia Tech and other educational institutions along with Virginia's natural resource agencies, is "to conduct research and education programs to enhance restoration of mined lands and to benefit communities and businesses in southwestern Virginia's coalfield region" (Zipper 1999). Current research at Powell River includes studies on reforestation of reclaimed mine lands, obtaining and maintaining prime pastureland for livestock grazing, analyzing overburden composition and textures for various vegetation growth responses, and the use of artificial wetlands to benefit water quality.

The Forestland Group Public Access Lands for Sportsmen (PALS) Site

The PALS site in Dickenson County, Virginia is a 7,700 hectare (19,000 acre) property currently owned by The Forestland Group, LLC, a timber investment management organization managing over 1.8 million acres in 16 different states (The Forestland Group 2001). In cooperation with the Virginia Department of Inland Fisheries and Game (VDGIF), this site has been designated as Public Access Land for Sportsmen (PALS) and is open to the public for hunting, trapping, and fishing use (VDGIF 2007).

Some areas on the PALS site have been mined recently and historically by Paramont Coal Company and associates. Many older sites have not been subjected to post-SMCRA reclamation, but are typical of the highwall/bench/outslope pre-SMCRA terrain. These older sites are composed of pioneer vegetation rather than subjected to traditional reclamation practices (i.e., seedings and plantings). Other areas on the PALS site were mined recently, and have designated post-mining land uses such as managed pastureland, forestland, and wildlife habitat. Natural gas extraction also occurs on the PALS site. The goal of the Forestland Group for this property is to manage to promote timber resources as a viable, economic, and long-term land use on reclaimed mine lands.

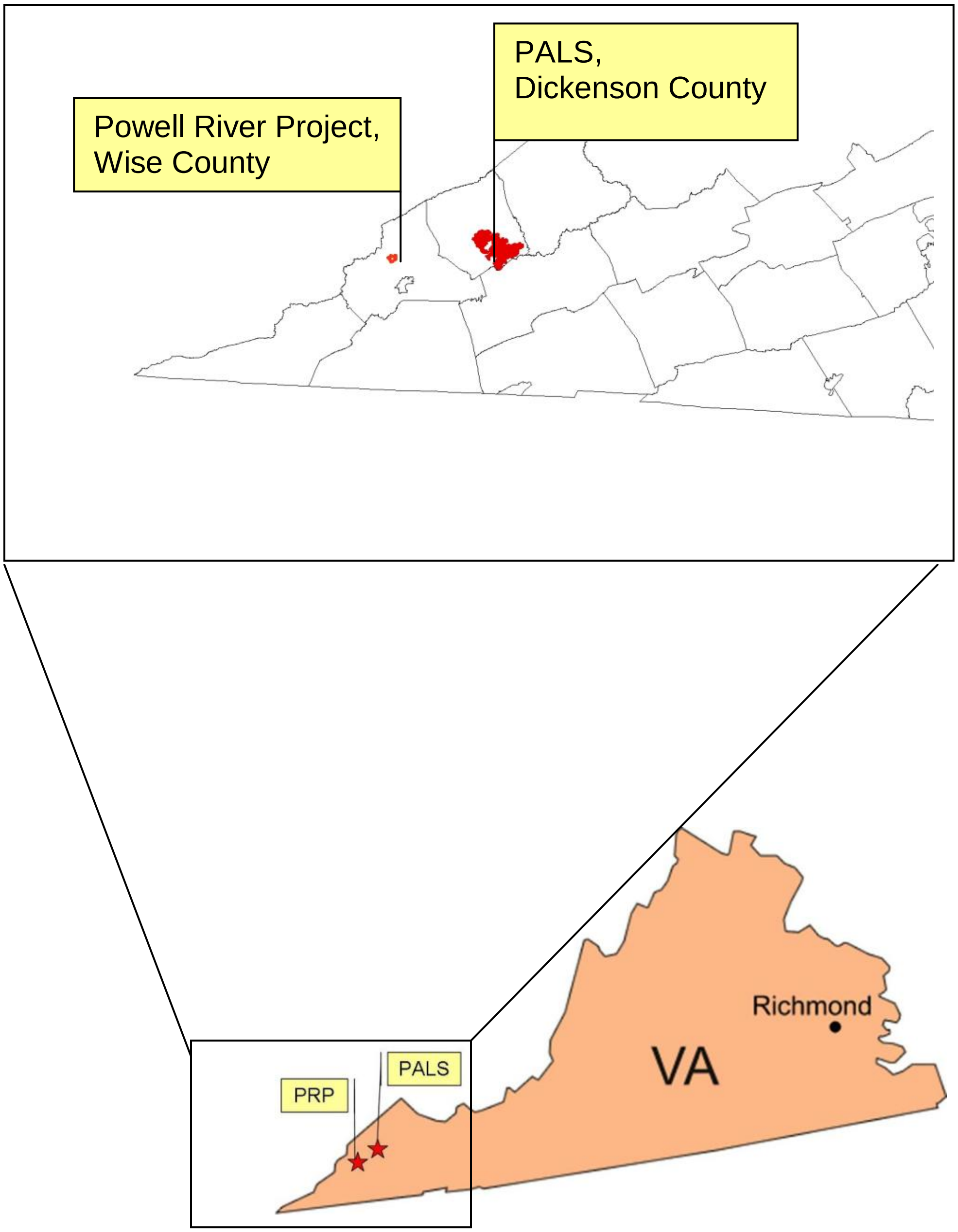

Figure 3. Powell River Project (PRP) location in Wise County and Public Access Land for Sportsmen (PALS) location in Dickenson County, Virginia.

Methods

Sampling point selection

Both locales contain patches that have been mined, some that have been harvested for timber, and others that were left relatively undisturbed (Fig. 4). I located as many homogeneous patches as possible that were large enough (>~1 ha) to effectively sample (Fig. 5). These potential patches were then stratified by locale (Powell River or PALS), cover type (hardwood, pine, mixed, pasture), and approximate age since disturbance (5-12 years, 13-25 years, 30-60 years, 65-100 years). Even though some patches included > 1 sampling point, points were > 100 m apart and considered to be independent from one another. A total of 102 sampling points (considered the sampling units for this study) was surveyed; 66 points at the PALS site and 36 points at the Powell River Project (Table 1).

Habitat Sampling

Landscape-level habitat sampling

Because of the heterogenous nature of the mined landscape, it was important to describe characteristics of sampled patches and availability of other proximal cover types. I used Virginia Base Mapping Program (2007) aerial imagery with 0.6 m (2 feet) resolution in ArcGIS 9.2 for landscape-level analyses.

I used aerial photography to delineate both study areas into 6 cover types: water, open, shrub, pine, mature mixed forest, and disturbance (e.g., active mining operations, large roads, etc.). Patches were delineated at a resolution of about 25 m. I measured area and perimeter of each patch that contained one or more sampling points. I also measured the distance from each patch to the nearest patch of each cover type. Larger scale, landscape matrix characteristics (Table 2) were also measured using circular buffers around each sampling point with radii of 100 m, 500 m, and 1000 m.

Site-specific habitat sampling

Microhabitat data were collected in May and June 2007 at both study areas in southwestern Virginia. In 2008, 33 points with potential for change (i.e., early successional or clearcut) were re-sampled.

I adapted the habitat sampling methods proposed by Noon (1981), which consisted of circular 0.04 ha plots for sampling vegetation. I used an array of 4 plots to summarize the characteristics of each sampling point (Fig. 6). The central plot was superimposed over the bird sampling point, with 3 additional habitat plots located 30 m from the central plot and at an 120º azimuth from the next radial plot (with a random start azimuth). When 11.3 m radius circular plots were not feasible because of terrain or area constraints, I used 10 x 10 m square plots.

Prior to vegetation sampling, I selected variables thought to represent important habitat characteristics for birds. I measured and recorded the DBH (diameter at breast height) and species of all trees > 3 cm in diameter. Trees were placed into the appropriate diameter size classes (3-8cm, 8-15 cm, 15-23 cm, >23 cm) and identified to species. I estimated woody stem density by using 4 transects (2 x 10 m) at each plot following the cardinal directions from plot center. At 10 x 10 m plots, only 2 stem transects were used. Woody stems were included in the stem count if they were at least 0.5 m tall. I used the point-intercept method over 4 transects (10 m) to calculate percent canopy, herbaceous, and leaf litter cover by recording presence or absence of cover at 2 m intervals (20 points total).

I used a clinometer to measure maximum canopy height (tallest tree in the plot) and the maximum percent slope at each plot. I used the point-quarter method to estimate log density in each plot, and used the point quarter correction factor developed by Warde and Petranka (1981) to account for quarters with missing data (i.e., no logs present). I also recorded dominant shrub and ground cover species qualitatively in each plot. I averaged the information from the 4 plots to summarize habitat data for each sampling point (n=102). I calculated the coefficient of variation across plots for tree density and stem density as an index of habitat heterogeneity (Table 3).

Bird Sampling

I used the point count method to survey birds in 2007 and 2008. Point counts are an efficient way to sample birds over large areas in both forested and non-forested environments. Count information can easily be associated with habitat data by surveying the same plots on multiple occasions (Bibby et al. 1992).

Surveys were conducted May 14 through July 11, 2007 and May 13 through July 9, 2008. Each sampling point was visited 5 times over the course of the breeding season. Points were visited by an individual observer who identified all birds heard or seen within 50 m. We surveyed birds beginning at sunrise and finished within 3 hours on days with no precipitation and minimal winds (< 16 kph). Each count lasted 5 minutes, with 1 minute prior to the beginning of the count designated as a "settling period" to allow birds to resume normal activity following travel to the point. A time period of 5 minutes has been shown to be more efficient than and just as effective as longer counts when tallying birds in the Central Appalachians (Gates 1995). The observer surveyed 6-12 sampling points per morning, based on proximity of points to each other and the site layout. Following the first visit, route assignments were alternated between observers to reduce sampling bias. The point order was also rearranged for each visit to ensure that all points were sampled at different times during morning survey hours. Technicians and I were responsible for individual point counts and had similar training in bird identification.

Along with identification to species, the observer estimated the distance to the bird and recorded whether the bird was identified by sight, song, or both. The observer also noted whether the bird was sighted within the patch being surveyed (primary use) or whether the bird was using an adjacent patch of habitat (secondary use). Any additional behavioral or observational information was recorded when the opportunity permitted, such as sex of the bird, nesting behavior, or interactions with conspecifics or other species. To help alleviate non-detection bias for species that are typically non-vocal (e.g. raptors), we kept a list of all birds observed on each site in addition to information collected during point counts.

Analyses

Habitat

I used analysis of variance (ANOVA) to compare habitat characteristics among the 6 cover types to confirm that the habitat type classification of points was meaningful. I also used a paired t-test to compare microhabitat data collected at the 33 points sampled in both years. I determined that there were no significant changes ($P > 0.05$) in habitat characteristics between years, so I averaged the results for 2007 and 2008 and used the mean in the final habitat data set.

I used principal components analysis (PCA) to help identify redundant or unnecessary microhabitat variables prior to developing bird-habitat models. I determined that slope, log density, and percent leaf cover were of limited importance for birds, and these were eliminated from further analysis. I also used PCA to conduct an ordination of all points surveyed to investigate patterns in habitat structure among cover types.

Birds

I estimated relative abundance for each species by calculating the number of observations per point per visit, effectively a measure of number of observations per unit effort. I also determined the number of species observed (i.e., species richness) at each point and within each cover type. I used cluster analysis to compare the 27 most common bird species based on their relative abundances at each sampling point. I used Euclidean distance for determining similarity between species, and then constructed a cluster tree using the average linkage method (Pielou 1984).

I grouped species into foraging, nesting, and migration status guilds to better understand the composition of the community and use of habitat types by different functional guilds. Foraging guilds were: carnivorous, frugivorous, granivorous, insectivorous, or omnivorous. Nesting guilds consisted of cavity, ground, parasitic, structural, and tree and shrub nesters. Migration status was identified as Neotropical or long-distance migrants, short-distance migrants, or resident species (Sibley 2003).

Bird-habitat relationships

I developed a PCA ordination of the 102 sampling points based on site-specific habitat characteristics. I then determined the average of principal components 1 and 2 for the sampling points where each bird species (n=80) was detected. I plotted these mean values on the first two principal components axes to show the relationship among species.

I then combined habitat data with bird observations for each of the 102 sampling points. For logistic regression modeling, each bird species was recorded as either present or absent at each sampling point. Once the data were compiled, I ran all possible site-specific (n=26 variables) and landscape-level (n=33) single variable logistic habitat models for each of the 27 selected common bird species (observed at >20 sampling points). It is useful to perform a series of single variable analyses to eliminate unimportant variables before proceeding to multiple variable analyses (Anderson and Shugart 1974).

After identifying significant individual habitat variables, I constructed multivariable logistic regression models. In addition to developing models with significant variables, I also conducted stepwise logistic regression procedures (SAS 2003) to provide more information for additional model construction. If a stepwise model was found to include correlated variables, it was eliminated from analysis. I used information-theoretic procedures to evaluate all competing single variable and multivariable models and to identify the "best" model from the set of models analyzed to predict presence for each species. I used the Akaike Information Criterion (AIC) corrected for small sample sizes (AIC_c) as the primary indicator of how "good" each model was compared to the others (Burnham and Anderson 2002). Burnham and Anderson suggest that the model with the lowest AIC is the most "parsimonious," meaning that it is the simplest combination of variables that will yield the best predictions. Models with $\Delta AIC < 2$ had "substantial" empirical support as the best model and were considered to be equivalent to each other (Burnham and Anderson 2002). Models with $\Delta AIC > 4$ had "considerably less" support as the best model and were not considered to be highly informative (Burnham and Anderson 2002). I also used the Receiver Operating Characteristic (ROC) to describe the ability of a model to accurately discriminate the presence or absence of a given species. A ROC of 0.5 suggests that the model would have as much predicative power as flipping a coin, 0.7-0.8 suggests "acceptable discrimination", and 0.8-0.9 suggests "excellent discrimination" (Hosmer and Lemeshow 2000). Similar procedures were used to analyze both the site-specific and landscape-level habitat data (Fig. 7).

Following the selection of the "best" logistic models (using AIC_c) with site-specific and landscape-level habitat data, I combined important variables to create a series of mixed-scale models to further describe avian species presence (Fig. 7). Mixed scale analysis was important to understand how the site-specific and landscape-level variables may interact to best describe avian presence (Taylor and Krawchuk 2006). For the mixed models, the variable set for each species included individually significant variables ($P < 0.05$) and those that were part of a significant multivariable model from each scale. Mixed models could include any combination of site-specific and landscape-level variables. By developing the best possible models with the data at hand, we can then predict if observation of a species is likely in a given habitat patch. This predictive ability will also help managers determine what practices can be implemented to improve the habitat for a target species or species group.

Table 1. Vegetation cover type classification and sampling point distribution at the Powell River Project (PRP) and Public Access Lands for Sportsmen (PALS) sites in southwest Virginia.

	Number of sampling points		
Cover type	**PALS**	**PRP**	**TOTAL**
Early successional reclaimed (~5-12 years)	9	10	19
Mid-successional reclaimed (~13-25 years)	4	7	11
Harvested (1990-2005)	5	2	7
Managed pastureland	13	3	16
Pre-SMCRA (~30-60 years)	27	6	33
Reference/mature (~65-100 years)	8	8	16
TOTAL	**66**	**36**	**102**

Table 2. Variable codes and descriptions for landscape-level habitat data collected from PRP and PALS in 2009. Variables were selected *a priori* and then incorporated into logistic regression models.

Habitat variable code	Description
AREAHA	Area of patch (ha)
PERIMETER	Perimeter of patch (m)
EDGE DIV	Edge diversity = perimeter/ 2*sqrt(area*π)
DWATER	Distance to nearest water source (m)
DOPEN	Distance to nearest open habitat (m)
DMATURE	Distance to nearest mature forest (m)
DSHRUB	Distance to nearest early successional habitat (m)
DPINE	Distance to nearest pine patch (m)
DDISTURB	Distance to nearest human disturbance (m)
EDGEHA_100	Density of edge (m/ha) within 100 m radius
EDGEHA_500	Density of edge (m/ha) within 500 m radius
EDGEHA_1000	Density of edge (m/ha) within 1000 m radius
SAMEPATCH_100	Number of patches of same cover type within 100 m radius
SAMEPATCH_500	Number of patches of same cover type within 500 m radius
SAMEPATCH_1000	Number of patches of same cover type within 1000 m radius
PWATER_100	% cover of water within 100 m radius
POPEN_100	% cover of open habitat within 100 m radius
PMATURE_100	% cover of mature mixed forest within 100 m radius
PSHRUB_100	% cover of early successional habitat within 100 m radius
PPINE_100	% cover of pine within 100 m radius
PDISTURB_100	% cover of human disturbances within 100 m radius
PWATER_500	% cover of water within 500 m radius
POPEN_500	% cover of open habitat within 500 m radius
PMATURE_500	% cover of mature mixed forest within 500 m radius
PSHRUB_500	% cover of early successional habitat within 500 m radius
PPINE_500	% cover of pine within 500 m radius
PDISTURB_500	% cover of human disturbances within 500 m radius
PWATER_1000	% cover of water within 1000 m radius
POPEN_1000	% cover of open habitat within 1000 m radius
PMATURE_1000	% cover of mature mixed forest within 1000 m radius
PSHRUB_1000	% cover of early successional habitat within 1000 m radius
PPINE_1000	% cover of pine within 1000 m radius
PDISTURB_1000	% cover of human disturbances within 1000 m radius

Table 3. Variable codes and descriptions for site-specific habitat data collected at PRP and PALS in 2007 and 2008. Variables were selected *a priori* and then incorporated into logistic and linear regression models.

Habitat variable code	Description
CANCOV	Canopy cover (%)
CANHT	Maximum canopy height (m)
GRASSCOV	Herbaceous vegetation cover (%)
DENS	Density (trees/ha) of size class S (3-8 cm DBH)
DENA	Density (trees/ha) of size class A (8-15 cm DBH)
DENB	Density (trees/ha) of size class B (15-23 cm DBH)
DENMAT	Density (trees/ha) of mature trees (> 23 cm DBH)
TOTALDEN	Density of trees in all size classes (trees/ha)
CVS	Coefficient of variation of size class S (3-8 cm DBH)
CVA	Coefficient of variation of size class A (8-15 cm DBH)
CVB	Coefficient of variation of size class B (15-23 cm DBH)
CVMAT	Coefficient of variation of mature trees (> 23 cm DBH)
CVTOT	Coefficient of variation of trees > 3 cm DBH
CONDENS	Conifer density (trees/ha) of size class S (3-8 cm DBH)
CONDENA	Conifer density (trees/ha) of size class A (8-15 cm DBH)
CONDENB	Conifer density (trees/ha) of size class B (15-23 cm DBH)
CONDENMAT	Conifer density (trees/ha) of mature trees (> 23 cm DBH)
SUMCONDEN	Conifer density of trees in all size classes (trees/ha)
HWDENS	Hardwood density (trees/ha) of size class S (3-8 cm DBH)
HWDENA	Hardwood density (trees/ha) of size class A (8-15 cm DBH)
HWDENB	Hardwood density (trees/ha) of size class B (15-23 cm DBH)
HWDENMAT	Hardwood density (trees/ha) of mature trees (> 23 cm DBH)
SUMHWDEN	Hardwood density of trees in all size classes (trees/ha)
MCSTEM	Coniferous stem density (stems/ha)
MDSTEM	Deciduous stem density (stems/ha)
CVSTEM	Coefficient of variation of all woody stems < 3 cm DBH

Figure 4. Example of the heterogenous composition of the mined landscape at the Powell River Project, Wise County, Virginia.

Figure 5. Example of the sampling scheme for a given sampling point (Po038) from the Powell River Project, Wise County, Virginia. Patch indicated is planted white pine ~ 30 years old. The star represents the bird sampling point and triangles represent habitat sampling plots.

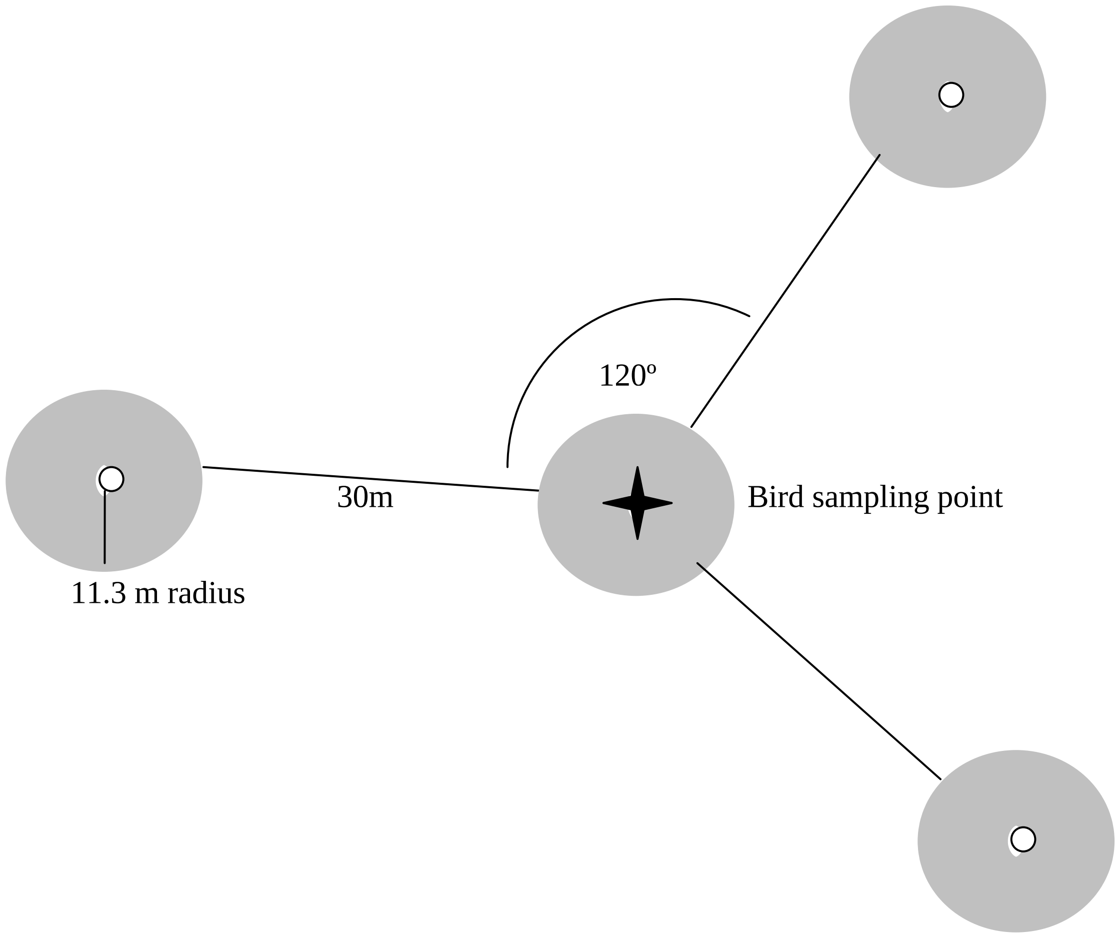

Figure 6. Sampling design used for habitat data collection, modified from Noon (1981). Each circle represents a plot (n=4) to describe habitat characteristics at each bird sampling point (star).

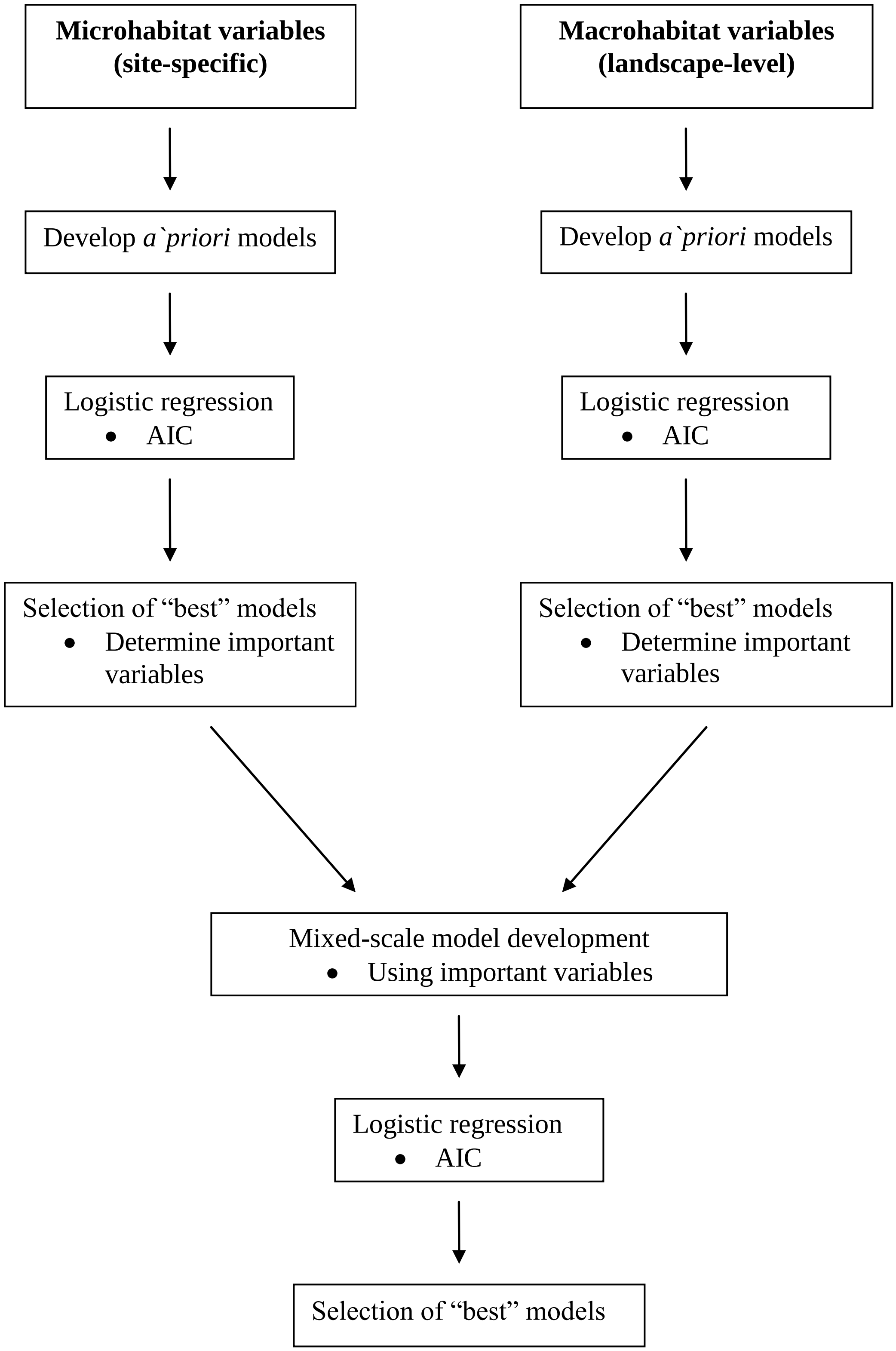

Figure 7. Conceptual design of logistic regression model development to predict the presence of a species based on site-specific (microhabitat) and landscape-level (macrohabitat) characteristics.

Results

Habitat

General patterns

Six cover types were represented on both study areas. Mature forests had higher average values for canopy cover, canopy height, and tree densities (Table 4). Herbaceous ground cover was high on early successional reclaimed sites and pasture. Patchiness of trees > 3 cm DBH (CVTOT) was highest in pre-SMCRA and pasture cover types, and patchiness of woody stems < 3 cm DBH (CVSTEM) was high on all reclaimed cover types. Coniferous density was highest on early and mid-successional reclaimed sites, likely because of pine used in reclamation plantings.

I averaged landscape-level habitat characteristics based on the information collected around the 102 sampling points from VBMP aerial photography to observe general trends (Table 5). Average values indicate long distances from most patches to a water source (mean = 820 m), but relatively short distances to shrub cover (mean = 46 m). Within the 100 m buffer, most patches were isolated from other patches of the same cover type (mean = 1.1), whereas the average number of similar patches within 1000 m was around 5.4. Average percent mature forest cover in the 1000 m buffer was 67% reflecting the remote nature of the study areas, as well as the dominant cover type present prior to mining disturbances.

Birds

General patterns

I observed 80 species over the course of the study (Table 6). Fifty-seven species were observed in both years. In 2007, I observed 68 bird species including 11 unique species. In 2008, I observed 69 species, 12 of which were unique to that year. I also observed some behaviors (i.e., carrying nesting material, food items) which could be indicative of nesting or caring for young (Table 7). I eliminated from analysis birds that could not be identified to species and those for which we could not determine whether the bird was within the sampling radius. Observations eliminated included birds that were observed using adjacent patches (secondary use), flyovers (e.g. wood duck and mallard), and woodpeckers identified by drumming.

Overall species richness per cover type ranged from 40 species observed in harvested areas to 55 species in the pre-SMCRA cover type. Fifty-three species were detected in early successional reclaimed habitat, 51 species in mature forest, 47 species in pastureland, and 45 species in mid-successional reclaimed habitat (Table 6). However, when a random subset of sampling points (n=7; without replacement) was selected for over-represented cover types over 1000 iterations, species richness was very similar across the cover types (Table 8). Nineteen bird species were heard or seen using all 6 cover types and 15 species were observed only once or in a single cover type.

At the individual sampling points, species richness ranged from 8 to 23 species. Including both years of data, the lowest count was taken from point Po003 (8 species) located in the 1990 clearcut at the Powell River Project. The highest count (23 species) was recorded at 3 points located on the PALS site: Pa028, Pa062, and Pa067. Pa028 was a remnant patch of forest along a stream between two early successional reclaimed areas. Pa062 was located in the 2005 Rasnick clearcut, and Pa067 was a small pine patch > 20 years old located within a large managed pasture. The average species count per point was 16 across all sampling points.

Species were classified into functional guilds to provide additional summary information. Species lists for all guilds are included in Appendix B. Half of the species using reclaimed, harvested, and mature reference sites (n=40) were Neotropical migrants (Table 7), arriving at these sites for the breeding season from Central or South America. The foraging preferences of species were predominantly insectivorous (51%) or omnivorous (37%). More than half of species nested in open cup nests in above ground-level vegetation (55%), 16% were cavity nesters, and 22% nested at ground level (Table 9).

Ordination and cluster analyses of birds

I used cluster analysis based on relative abundance of species at each point to see if certain species were frequently observed together at a given point. The species grouped as most similar included American robin, downy woodpecker, and white-eyed vireo (Fig. 8). Scarlet tanager and wood thrush, and pileated woodpecker and blue jay also separated as very similar clusters. The dendrogram does show evidence of "chaining," or an asymmetrical branching structure, suggesting that few discrete groups can be identified from the data with the approach taken. The most distinct species from all other species were indigo bunting and field sparrow, which were the most common and were frequently seen in a variety of cover types.

Cluster analysis of average PCA habitat scores on the first two axes showed a more distinct clustering pattern; the most similar habitat relationships were seen between black-capped chickadee and dark-eyed junco (Fig. 9). The wood thrush and yellow-billed cuckoo, and blue jay and cedar waxwing also were quite similar. There were 4 clusters identified that represent general assemblages of birds. The first group identified consisted of species that mostly prefer mature forest. The next group consisted of early successional and grassland birds. The last group split into shrubland and forest generalists.

Bird-habitat relationships

Sampling point ordination

I used principal components analysis (PCA) to ordinate the 102 sampling points based on habitat characteristics of each point (Table 10, Fig. 10). The first component summarized 27.9% of the variability in the data, and the second accounted for an additional 18.8%. For the first principal component, high positive values reflected greater tree density and canopy cover. Negative scores for the first component represented greater herbaceous cover and tree patchiness. The second principal component represents a hardwood to conifer gradient, with conifers more common in reclaimed areas that were planted to pine. Principal component scores of points tended to show relatively clear separation between mature forest and pasture.

I overlaid means of the principal components for each cover type with the average PCA for each bird species (N=80) at points where they occurred (Fig. 11). The figure tends to show late successional forest species (e.g., veery, acadian flycatcher) in the lower right and early successional species in the upper left (e.g., killdeer, eastern meadowlark). Interpretation of the axes supports this trend as canopy cover and total tree density were associated with positive values on the x-axis (Factor 2), and density of mature trees and canopy height were associated with negative values on the y-axis (Factor 1). For example, species such as the blue-headed vireo and veery were most common at sites that resembled the average characteristics of mature reference forest.

Site-specific habitat models

The most common habitat variables occurring in the best site-specific models were percent canopy cover (4 species), canopy height (6 species), and percent herbaceous cover (7 species) (Table 11). These 3 variables were all highly correlated ($r > 0.7$) with each other, so I avoided including them together in any given model by substituting or selecting the most ecologically relevant variable. All models included in the site-specific analyses can be found in Appendix E.

The model with the highest Akaike weight and highest Receiver Operating Characteristic (ROC) was for the black-and-white warbler (w_i= 1.000, ROC= 0.844), which was commonly observed in mature forest. Generalist species, such as the Carolina wren, were found in multiple habitat types and received lower diagnostic scores (w_i= 0.376, ROC= 0.629), suggesting that the "best" model may not be as robust for describing their presence. I was unable to use any of the site-specific habitat variables (or any combination of variables) to reliably predict presence for the American crow, American robin, downy woodpecker, and pileated woodpecker.

Early successional species tended to respond positively to herbaceous cover, dispersion of vegetation, and density of small stems and trees. Many of these species (e.g., American goldfinch, indigo bunting) showed a negative response to canopy cover, canopy height, and density of larger trees. The common yellowthroat and field sparrow specifically responded positively to smaller conifers, suggesting that pines planted as part of the reclamation process may provide important habitat for these species.

Species normally associated with mature forests (e.g., ovenbird, wood thrush) tended to respond positively to canopy cover, canopy height, and density of larger trees, and negatively to variables such as herbaceous cover, and density of small trees and stems. Many also responded to dispersion of moderately large trees. Some species, such as hooded warbler and northern cardinal, responded negatively to conifers, suggesting the avoidance of more open, early-successional areas planted with pines.

Landscape-level habitat models

The most common habitat variables identified in the best models were the proportion of mature forest within a 100 m buffer (11 species), proportion open habitat within a 1000 m buffer (6 species), and distance to mature forest (6 species) (Table 12). Also common were the proportion of pine within a 100 m buffer (5 species) and perimeter of the patch (5 species). All models included in the landscape level analyses can be found in Appendix F.

The model with the highest ROC was for the field sparrow (ROC= 0.923). Other more generalist species, such as the American crow, were found in multiple habitat types and received lower diagnostic scores (w_i= 0.137, ROC= 0.551), suggesting that the "best" model may not be as robust for describing their presence. In contrast to the site-specific model analysis, I was able to develop a significant model for all 27 focal species, including those that were not significant at the site-specific level. Landscape level habitat data may provide better information for predicting presence of generalist species.

Early successional species (e.g., field sparrow, yellow-breasted chat) tended to respond positively to the proportion of open and shrub habitats, and distance to mature forest. Many of these species showed a negative response to proportion mature forest and distance to shrub, open, or disturbed habitats. Some species, such as the blue-winged warbler, showed a positive relationship with perimeter of the patch and edge density, suggesting their dependence on edge habitat.

Species normally associated with mature forests (e.g., pileated woodpecker, tufted titmouse) tended to respond positively to proportions of mature forest and pine, and negatively to variables such as proportions of open and disturbed habitats. Some species, such as the wood thrush, responded positively to distance to pine, suggesting the avoidance of more open, early-successional areas planted with pines.

Mixed-scale habitat models

Mixed model combinations for the 27 species consisted of variables from the significant ($P < 0.05$) models at each scale (Appendix G). The mixed model with the highest ROC value was for indigo bunting (ROC=0.992) (Table 13), the most common species on the study areas. The best mixed model for indigo bunting (AIC_c= 21.76) was much improved from the best site-specific (AIC_c=36.13) and the landscape level (AIC_c= 33.42) models. All models included in mixed-scale analyses can be found in Appendix F.

For most species (n=18), the combination of site-specific and landscape level information provided the best model (based on AIC_c) to describe presence (Table 14). In general, mixed models also performed better than site-specific and landscape level models based on ROC values. For ovenbird (AIC_c = 70.4) and scarlet tanager (AIC_c =102.6) the site-specific models provided more useful information than any landscape level or mixed models. For several of the generalist species (n=7), especially those for which site-specific models were not significant, the landscape level analysis provided the best models.

Summary of results by species

The American crow was most abundant on mid-successional reclaimed sites, but was found using all 6 cover types. Based on habitat characteristics where they were observed, crows were grouped into the shrubland generalist assemblage. Landscape-level analysis best described crow presence; the best model for crows included a negative relationship to distance to pine, which was common on mid-successional reclaimed sites.

American goldfinches were also observed using all 6 cover types, but were most common in early successional reclaimed and harvested habitat. Based on habitat characteristics where they were observed, goldfinches were grouped into the early successional assemblage. Mixed-scale analysis best described goldfinch presence; the best model included a positive relationship to the heterogeneity of small trees 3-8 cm DBH, and negative relationships to the percent mature forest within 100 m and the percent open habitat within 1000 m.

American robins were infrequently observed using all 6 cover types. Based on habitat characteristics where they were observed, robins were grouped into the shrubland generalist assemblage. Landscape-level analysis best described robin presence; the best model for robins included negative relationships with the percent open habitat within 1000 m and the percent mature forest within 100 m.

The black-and-white warbler was most abundant on pre-SMCRA and mature forested sites, but was found using all 6 cover types. Based on habitat characteristics where they were observed, black-and-white warblers were grouped into the forest generalist assemblage. Mixed-scale analysis best described black-and-white warbler presence; the best model included negative relationships with the density of woody stems < 3 cm DBH, the percent disturbed habitat within 1000 m, and percent open habitat within 500 m. The best model also included positive relationships with edge/ha within a 1000 m buffer, percent mature forest within 100 m, and edge diversity.

Black-throated green warblers were observed in all cover types except early successional reclaimed and pasture. Based on habitat characteristics where they were observed, black-throated green warblers were grouped into the mature forest assemblage. Landscape-level analysis best described black-throated green warbler presence; the best model included negative relationships with the percent open habitat within 500 m and the percent shrub habitat within 1000 m. The best model for black-throated green warbler also included a positive relationship with percent mature forest within 100 m.

Blue jays were observed in all cover types, but were most common on pre-SMCRA sites. Based on habitat characteristics where they were observed, blue jays were grouped into the forest generalist assemblage. Mixed-scale analysis best described blue jay presence; the best model included negative relationships with the distance to mature forest and the percent pine within 1000 m. The best model for blue jay also included a positive relationship with the heterogeneity of woody stems < 3cm DBH.

The blue-winged warbler was observed in all 6 cover types, but was most abundant in early successional habitat. Based on habitat characteristics where they were observed, blue-winged warblers were grouped into the shrubland generalist assemblage. Landscape-level analysis best described blue-winged warbler presence; the best model included negative relationships with patch perimeter, edge diversity, distance to open habitat, and percent water within 1000 m. The best model also included a positive relationship with percent shrub habitat within 100 m.

Carolina chickadees were observed in all cover types, but were most common in mature forest. Based on habitat characteristics where they were observed, chickadees were grouped into the forest generalist assemblage. Mixed-scale analysis best described chickadee presence; the best model included a positive relationship with percent canopy cover. The best model also included negative relationships with the density of coniferous stems < 3 cm DBH, distance to mature forest, and percent open habitat within 1000 m.

The Carolina wren was observed in all 6 cover types, but was most abundant on pre-SMCRA sites. Based on habitat characteristics where they were observed, Carolina wrens were grouped into the shrubland generalist assemblage. Landscape-level analysis best described Carolina wren presence; the best model included negative relationships with patch perimeter and percent open habitat within 1000 m. The best model also included positive relationships with distance to water, percent water within 500 m, and edge/ha within 1000 m.

The chipping sparrow was observed in all 6 cover types, but was most abundant in pasture and on pre-SMCRA sites. Based on habitat characteristics where they were observed, chipping sparrows were grouped into the early successional assemblage. Mixed-scale analysis best described chipping sparrow presence; the best model included negative relationships with total density of trees and area of the patch.

Common yellowthroats were observed in all cover types except harvested areas. They were most common in early successional reclaimed habitat. Based on habitat characteristics where they were observed, yellowthroats were grouped into the early successional assemblage. Mixed-scale analysis best described yellowthroat presence; the best model included positive relationships with percent herbaceous cover and percent pine within 100 m.

The downy woodpecker was infrequently observed in all 6 cover types. Based on habitat characteristics where they were observed, downy woodpeckers were grouped into the shrubland generalist assemblage. Landscape-level analysis best described downy woodpecker presence; the best model included a negative relationship with distance to shrub habitat.

The eastern towhee was observed frequently in all 6 cover types, but was most abundant in harvested areas. Based on habitat characteristics where they were observed, towhees were grouped into the shrubland generalist assemblage. Mixed-scale analysis best described towhee presence; the best model included negative relationships with area of the patch and percent mature forest within 100 m, and a positive relationship with total density of hardwoods.

The field sparrow was observed in all cover types except for harvested areas, but was very abundant in pasture and early successional habitat. Based on habitat characteristics where they were observed, field sparrows were grouped into the early successional assemblage. Mixed-scale analysis best described field sparrow presence; the best model included negative relationships with distance to water and percent mature forest within 100 m, and positive relationships with percent herbaceous cover and percent open habitat within 500 m.

Hooded warblers were observed in all 6 cover types, but were most common in mature forest. Based on habitat characteristics where they were observed, hooded warblers were grouped into the forest generalist assemblage. Mixed-scale analysis best described hooded warbler presence; the best model included negative relationships with percent herbaceous cover and density of conifers 15-23 cm DBH, and a positive relationship with distance to open habitat.

Indigo buntings were the most common bird on the study areas. They were observed in all 6 cover types, but were least common in mature forest. Based on habitat characteristics where they were observed, indigo buntings were grouped into the shrubland generalist assemblage. Mixed-scale analysis best described bunting presence; the best model included negative relationships with percent canopy cover and distance to open habitat, and a positive relationship with the heterogeneity of woody stems < 3 cm DBH.

The mourning dove was observed in all 6 cover types, but was most abundant in harvested areas. Based on habitat characteristics where they were observed, doves were grouped into the forest generalist assemblage. Landscape-level analysis best described mourning dove presence; the best model included positive relationships with distance to water, percent open habitat within 100 m and percent shrub habitat within 500 m. The best model also included a negative relationship to distance to shrub.

The northern cardinal was observed in all 6 cover types, but was most abundant on pre-SMCRA sites. Based on habitat characteristics where they were observed, cardinals were grouped into the shrubland generalist assemblage. Mixed-scale analysis best described cardinal presence; the best model included positive relationships with heterogeneity of trees 15-23 cm DBH, heterogeneity of all trees, and percent shrub habitat within 500 m.

Ovenbirds were observed in all cover types except for early successional reclaimed areas and pastureland. They were most common in mature forest. Based on habitat characteristics where they were observed, ovenbirds were grouped into the mature forest assemblage. Site-specific analysis best described ovenbird presence; the best model included negative relationships with percent herbaceous cover and density of deciduous woody stems < 3 cm DBH, and a positive relationship with density of trees > 23 cm DBH.

Pileated woodpeckers were observed occasionally in all cover types except for harvested areas. Based on habitat characteristics where they were observed, pileated woodpeckers were grouped into the forest generalist assemblage. Landscape-level analysis best described pileated woodpecker presence; the best model included positive relationships with edge/ha within 100 m and percent mature forest within 100 m, and a negative relationship with the percent open habitat within 1000 m.

Prairie warblers were observed in all cover types except for pre-SMCRA sites. They were most common in early successional habitat. Based on habitat characteristics where they were observed, prairie warblers were grouped into the early successional assemblage. Mixed-scale analysis best described prairie warbler presence; the best model included positive relationships with percent herbaceous cover, density of coniferous stems < 3 cm DBH, and the number of patches of the same cover type within 500 m. The best model also showed negative relationships to heterogeneity of small trees 3-8 cm DBH, percent mature forest within 100 m, and percent pine within 1000 m.

The red-eyed vireo was observed in all 6 cover types, but was most abundant in mature forest. Based on habitat characteristics where they were observed, red-eyed vireos were grouped into the forest generalist assemblage. Mixed-scale analysis best described red-eyed vireo presence; the best model included positive relationships with percent canopy cover and heterogeneity of trees 8-15 cm DBH. The best model also included a negative relationship to the number of patches of the same cover type within 500 m.

The scarlet tanager was observed in all cover types except for pasture. Based on habitat characteristics where they were observed, scarlet tanagers were grouped into the forest generalist assemblage. Site-specific analysis best described tanager presence; the best model included negative relationships with percent herbaceous cover and density of hardwoods 15-23 cm DBH. The best model also included a positive relationship to the density of hardwoods 8-15 cm DBH.

Tufted titmice were observed occasionally in all cover types, but were most common in mature forest and pre-SMCRA areas. Based on habitat characteristics where they were observed, titmice were grouped into the forest generalist assemblage. Mixed-scale analysis best described tufted titmouse presence; the best model included positive relationships with heterogeneity of woody stems < 3 cm, percent mature forest within 100 m, and percent pine within 100 m.

White-eyed vireos were observed occasionally in all cover types, but were most common in harvested areas. Based on habitat characteristics where they were observed, white-eyed vireos were grouped into the shrubland generalist assemblage. Mixed-scale analysis best described white-eyed vireo presence; the best model included negative relationships with heterogeneity of trees 3-8 cm DBH and percent open habitat within 100 m, and a positive relationship with heterogeneity of woody stems < 3 cm.

Wood thrushes were observed occasionally in all cover types, but were most common in mature forest. Based on habitat characteristics where they were observed, wood thrushes were grouped into the mature forest assemblage. Mixed-scale analysis best described wood thrush presence; the best model included positive relationships with percent canopy cover, total density of conifers, and distance to pine.

The yellow-breasted chat was observed in all 6 cover types, but was most common in early successional and harvested areas. Based on habitat characteristics where they were observed, chats were grouped into the shrubland generalist assemblage. Mixed-scale analysis best described chat presence; the best model included positive relationships with density of trees 3-8 cm DBH, distance to mature forest, and percent shrub habitat within 500 m. The best model also included a negative relationship to area of the patch.

Table 4. Means by cover type of site-specific habitat variables recorded at PRP and PALS in 2007 and 2008. Values within each variable with the same letter were not significantly different (P >0.05) based on Tukey's Studentized Range (HSD) test. Variable codes can be found in Table 3.

Variable	**Cover type**					
	Early reclaimed n=19	**Mid reclaimed n=11**	**Harvested n=7**	**Pasture n=16**	**Pre-SMCRA n=33**	**Mature n=16**
CANCOV	31 C	60 B	51 B	11 D	42 BC	85 A
CANHT	5.3 D	10.2 CD	16.2 B	6.0 D	12.1 BC	32.8 A
GRASSCOV	70 B	46 C	16 D	95 A	50 BC	2 D
DENS	761 AB	514 ABC	813 A	130 C	248 C	345 BC
DENA	176 B	419 A	137 B	48 B	132 B	184 B
DENB	22 C	147 A	37 C	9 C	47 BC	104 AB
DENMAT	0 B	10 B	24 B	0 B	19 B	83 A
TOTALDEN	863 BC	1790 A	1111 AB	196 C	892 BC	1432 AB
CVS	55.6 ABC	74.8 BC	47.2 ABC	96.1 AB	102.2 A	40.8 C
CVA	62.9 AB	51.7 AB	48.2 B	110.1 AB	114.4 A	47.6 B
CVB	35.1 B	30.6 B	56.4 AB	77.7 AB	129.3 A	52.8 B
CVMAT	0 B	0 B	0 B	0 B	0 B	41.3 A
CVTOT	50.7 BC	26.8 C	45.5 BC	100.9 A	88.3 AB	33.2 C
CONDENS	508 A	551 A	0 B	0 B	45 B	38 B
CONDENA	266 B	821 A	0 B	3 B	48 B	24 B
CONDENB	60 B	439 A	0 B	3 B	29 B	56 B
CONDENMAT	0 A	37 A	7 A	0 A	22 A	62 A
SUMCONDEN	835 B	1848 A	7 C	6 C	144 BC	180 BC
HWDENS	917 A	667 AB	631 AB	270 B	200 B	184 B
HWDENA	135 B	513 A	125 B	156 B	118 B	136 B
HWDENB	3 C	53 BC	69 AB	36 BC	75 AB	108 A
HWDENMAT	0 C	4 C	73 B	3 C	38 BC	167 A
SUMHWDEN	1056 AB	1239 A	898 AB	465 B	431 B	595 AB
MCSTEM	109 A	52 AB	16 B	2 B	11 B	53 AB
MDSTEM	1283 B	719 B	6886 A	342 B	1240 B	5283 A
CVSTEM	84.5 AB	91.7 A	41.2 B	91.1 A	95.6 A	53.7 AB

Table 5. Means and standard deviations of landscape level habitat variables measured from Virginia Base Mapping Program (VBMP) aerial photography (2007) for 102 sampling points on the PRP and PALS sites, southwestern Virginia. Variable codes can be found in Table 2.

			Range	
Variable	**Mean**	**SE**	**Min**	**Max**
AREAHA (ha)	7.5	1.1	0.3	46.4
PERIMETER (m)	1198	99	238	4223
ED	1.50	0.03	1.06	2.23
DWATER (m)	820	78	27	2997
DOPEN (m)	67	9	0	440
DMATURE (m)	70	7	0	269
DSHRUB (m)	46	6	0	269
DPINE (m)	352	40	0	1434
DDISTURB (m)	74	9	1	404
EDGEHA_100 (m/ha)	105.3	6	0	256.5
EDGEHA_500 (m/ha)	74.9	2.8	13.9	152.3
EDGEHA_1000 (m/ha)	65.9	2.2	6.8	120.8
SAMEPATCH_100 (#)	1.1	0.0	1	3
SAMEPATCH_500 (#)	2.3	0.2	1	7
SAMEPATCH_1000 (#)	5.4	0.4	1	15
PWATER_100 (%)	0.0	0.0	0	1.5
POPEN_100 (%)	23.7	3.1	0	99.9
PMATURE_100 (%)	41.8	3.3	0	99.9
PSHRUB_100 (%)	26.5	3.0	0	99.9
PPINE_100 (%)	7.3	1.8	0	72.9
PDISTURB_100 (%)	0.6	0.4	0	32.8
PWATER_500 (%)	0.3	0.0	0	2.1
POPEN_500 (%)	13.1	1.3	0	60.8
PMATURE_500 (%)	63.6	2.0	18.0	93.4
PSHRUB_500 (%)	16.7	1.4	0	69.6
PPINE_500 (%)	4.2	0.	0	41.2
PDISTURB_500 (%)	2.3	0.8	0	45.3
PWATER_1000 (%)	0.2	0.0	0	0.8
POPEN_1000 (%)	10.3	0.8	0.1	29.5
PMATURE_1000 (%)	67.5	1.8	24.0	87.8
PSHRUB_1000 (%)	13.8	1.0	2.2	52.6
PPINE_1000 (%)	4.0	0.4	0	19.3
PDISTURB_1000 (%)	4.1	1.0	0	46.5

Table 6. Relative abundance as measured by number of observations per point per visit of 80 species observed at PRP and PALS, southwestern Virginia. A star (*) identifies a bird observed in 2007 only; a dagger (†) identifies birds observed in 2008 only.

	Cover type					
	Early Successional	Mid-successional	Harvested	Pasture	Pre-SMCRA	Reference
Species	n=19	n=11	n=7	n=16	n=33	n=16
Acadian flycatcher *						0.006
American crow	0.074	0.136	0.043	0.081	0.078	0.057
American goldfinch	0.329	0.145	0.312	0.45	0.102	0.012
American kestrel *					0.01	
American robin *	0.047	0.036	0.074	0.031	0.022	0.006
American woodcock *					0.012	0.006
Barn swallow				0.031		
Black-and-white warbler	0.031	0.036	0.19	0.025	0.406	0.22
Black-billed cuckoo †	0.021				0.006	
Blackburnian warbler †						0.006
Black-capped chickadee				0.031	0.034	0.019
Black-throated blue warbler	0.01	0.027			0.01	0.05
Black-throated green warbler		0.018	0.043		0.122	0.094
Blue jay	0.005	0.027	0.014	0.012	0.101	0.037
Blue-gray gnatcatcher	0.031				0.037	
Blue-headed vireo	0.005				0.025	0.101
Blue-winged warbler	0.207	0.154	0.105	0.081	0.119	0.044
Brown thrasher	0.011	0.036		0.025		
Brown-headed cowbird	0.016	0.009	0.128	0.087		0.006
Carolina chickadee	0.021	0.081	0.086	0.031	0.241	0.169
Carolina wren	0.195	0.245	0.209	0.05	0.306	0.1
Cedar waxwing †	0.021		0.028	0.019	0.015	0.037

Table 6. (continued)

Species	Cover type: Early Successional n=19[a]	Mid-successional n=11	Harvested n=7	Pasture n=16	Pre-SMCRA n=33	Reference n=16
Cerulean warbler *		0.018	0.057			0.025
Chestnut-sided warbler †		0.009	0.033			0.019
Chimney swift †				0.019		
Chipping sparrow	0.089	0.064	0.014	0.175	0.168	0.05
Cliff swallow †				0.006		
Common grackle *				0.006		0.006
Common raven †		0.009				
Common yellowthroat	0.229	0.081		0.044	0.052	0.006
Cooper's hawk *		0.018	0.017			
Dark-eyed junco †					0.024	
Downy woodpecker	0.01	0.054	0.017	0.012	0.031	0.019
Eastern bluebird	0.005	0.009		0.031		
Eastern meadowlark	0.016	0.018		0.075		
Eastern phoebe	0.01		0.057		0.053	
Eastern towhee	0.518	0.527	0.769	0.512	0.213	0.157
Eastern wood-pewee			0.088	0.006	0.003	0.012
European starling	0.005			0.294		
Field sparrow	1.094	0.309		1.106	0.044	0.031
Golden-winged warbler	0.053			0.006	0.003	0.006
Grasshopper sparrow	0.048	0.018		0.3		
Gray catbird	0.01	0.018	0.074		0.006	0.031
Hairy woodpecker				0.006	0.006	0.012
Hooded warbler	0.111	0.227	0.417	0.025	0.248	0.623
Indigo bunting	1.214	1.154	0.714	1.35	0.974	0.232
Kentucky warbler			0.017		0.003	0.006

Table 6. (continued)

Species	Early Successional n=19	Mid-successional n=11	Harvested n=7	Pasture n=16	Pre-SMCRA n=33	Reference n=16
	Cover type					
Killdeer *	0.005					
Magnolia warbler *						0.031
Mourning dove	0.037	0.027	0.219	0.087	0.086	0.057
Northern bobwhite	0.089	0.027		0.044	0.016	
Northern cardinal	0.174	0.182	0.148	0.156	0.261	0.101
Northern mockingbird*	0.016	0.009	0.014	0.006	0.003	
Northern parula					0.019	0.045
Ovenbird		0.027	0.262		0.053	0.347
Pileated woodpecker	0.005	0.027		0.037	0.091	0.031
Pine warbler	0.005	0.009			0.003	
Prairie warbler	0.624	0.082	0.014	0.119		0.012
Red-bellied woodpecker	0.005		0.014			
Red-eyed vireo	0.116	0.354	0.362	0.09	0.578	0.636
Red-headed woodpecker †					0.003	
Red-shouldered hawk*				0.006		
Red-tailed hawk						0.006
Red-winged blackbird	0.026	0.009		0.012	0.012	
Rough-winged swallow †	0.01					
Ruby-throated hummingbird	0.005		0.059	0.025	0.006	0.006
Scarlet tanager	0.005	0.018	0.114		0.079	0.107
Song sparrow	0.016	0.027		0.075		
Swainson's warbler †		0.009			0.003	0.025
Tree swallow	0.016			0.037		
Tufted titmouse	0.048	0.118	0.057	0.056	0.189	0.152
Veery †						0.006

Table 6. (continued)

Species	Early Successional n=19	Mid-successional n=11	Harvested n=7	Pasture n=16	Pre-SMCRA n=33	Reference n=16
	Cover type					
White-breasted nuthatch			0.014		0.006	0.012
White-eyed vireo	0.063	0.036	0.133		0.015	0.025
Wild turkey		0.018		0.044	0.009	0.019
Wood thrush	0.016	0.073	0.119	0.031	0.051	0.163
Worm-eating warbler	0.016				0.003	
Yellow-billed cuckoo	0.016	0.018	0.014		0.025	0.031
Yellow-breasted chat	0.561	0.236	0.557	0.144	0.09	0.144
Yellow-throated vireo †					0.003	

[a] n= Number of sampling points within each cover type.

Table 7. Observations of birds carrying nesting material or food items at PRP and PALS, southwestern Virginia in 2007 and 2008.

date	point	cover	species	sex	observations
17-May-2008	Pa085	pre-SMCRA	Red-eyed vireo	-	carrying nesting material
5-Jun-2008	Pa043	mid-successional reclaimed	Blue-winged warbler	M	chipping with food item (insect)
7-Jun-2007	Po030	early successional reclaimed	Indigo bunting	F	carrying nesting material, calling to male
8-Jun-2008	Pa070	pasture	Field sparrow	M	carrying nesting material
16-Jun-2008	Pa085	pre-SMCRA	Northern cardinal	M	chipping, chasing female
17-Jun-2008	Pa067	mid-successional reclaimed	Grasshopper sparrow	M	carrying food item
17-Jun-2008	Pa067	mid-successional reclaimed	Grasshopper sparrow	F	carrying food item
29-Jun-2007	Pa074	pasture	Field sparrow	-	carrying nesting material
2-Jul-2008	Pa088	pasture	Indigo bunting	M	chipping with food item
7-Jul-2008	Pa075	pasture	Field sparrow	-	carrying food item

Table 8. Overall species richness per cover type at PRP and PALS, southwestern Virginia in 2007-2008. Species richness was adjusted for over-represented cover types by taking a random subset of 7 points 1000 times and averaging the results. Because only 7 harvested points were surveyed, a random subset was not taken from the harvested cover type.

			Random subset of 7 points (1000 iterations)	
Cover type	**# of points**	**Total # of species**	**Mean # of species**	**Range**
Early successional reclaimed	19	53	36.9	27 - 45
Mid-successional reclaimed	11	45	40.7	34 - 45
Harvested	7	40	-	-
Managed pastureland	16	47	37.6	31 - 44
Pre-SMCRA	33	55	37.4	29 - 45
Reference/mature	16	51	41.2	34 - 48

Table 9. Functional guild assignments[a] of the total number of bird species (N=80) observed at PRP and PALS, southwestern Virginia in 2007 and 2008.

Migration status	%	Foraging guild	%	Nesting guild	%
Neotropical	50.00	Carnivorous	5.00	Cavity	16.25
Short-dist	18.75	Frugivorous	2.50	Ground	22.50
Resident	31.25	Granivorous	3.75	Parasitic	1.25
		Insectivorous	51.25	Structural	5.00
		Omnivorous	37.50	Vertical Veg.	55.00

[a] Sibley, D. A. 2003. The Sibley field guide to birds of eastern North America.

Table 10. Principal Components Analysis factor pattern for site-specific habitat variables measured at PRP and PALS in 2007 and 2008. Sample size was 102.

	Factor Pattern	
Variable	**1**	**2**
CANCOV	0.86434	-0.35169
CANHT	0.59461	-0.70988
GRASSCOV	-0.74199	0.42659
DENS	0.42547	0.41250
DENA	0.73474	0.44299
DENB	0.61110	-0.11374
DENMAT	0.49651	-0.70511
TOTALDEN	0.84903	0.18443
CVS	-0.56214	-0.07914
CVA	-0.53742	-0.02084
CVB	-0.25610	-0.20100
CVMAT	0.24270	-0.35784
CVTOT	-0.64669	-0.05847
CONDENS	0.38428	0.59295
CONDENA	0.54956	0.62046
CONDENB	0.49540	0.32576
CONDENMAT	0.33752	-0.25413
SUMCONDEN	0.57448	0.61133
HWDENS	0.18725	0.47449
HWDENA	0.52387	0.47272
HWDENB	0.41475	-0.46967
HWDENMAT	0.48030	-0.72193
SUMHWDEN	0.40712	0.44292
MCSTEM	0.19361	0.22058
MDSTEM	0.40955	-0.51227
CVSTEM	-0.41386	0.13851
Eigenvalues	7.2539	4.8964
Cumulative variance accounted for	27.9	46.7

Table 11. Logistic regression results from analysis of 27 common bird species (observed at >20 sampling points) and site-specific habitat data in 2007 and 2008 at PRP and PALS, southwestern Virginia. The “best” model based on ΔAIC_c out of all single-variable, stepwise, and multiple regressions analyzed is reported here.

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
American crow [e]	50	-	-	-	-	-	-
American goldfinch	51	Intercept	0.3832	0.393	< 0.0001	0.770	0.5370
		% canopy cover	-0.0308				
		CV of stems < 3 cm DBH	0.0121				
American robin [e]	25	-	-	-	-	-	-
Black-and-white warbler	62	Intercept	6.1858	1.000	< 0.0001	0.844	0.8210
		% herbaceous cover	-0.00694				
		Density of deciduous stems < 3 cm DBH	-0.00056				
		Total density of conifers	-0.00176				
Black-throated green warbler [f]	21	Intercept	-3.9558	0.765	< 0.0001	0.788	0.6558
		Canopy height	0.093				
		CV of trees 15-23 cm DBH	0.012				
Blue jay	25	Intercept	-1.645	0.259	0.0062	0.718	0.5231
		Density of conifers 3-8 cm DBH	-0.00331				
		CV of stems < 3 cm DBH	0.00959				
Blue-winged warbler	46	Intercept	-0.0688	0.694	< 0.0001	0.746	0.1796
		Density of trees 3-8 cm DBH	0.00333				
		Total density of trees	-0.00127				
		Canopy height	-0.0147				

Table 11. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Carolina chickadee [f]	47	Intercept	0.3764	0.948	< 0.0001	0.759	0.3454
		% herbaceous cover	-0.0301				
		CV of trees 3-8cm DBH	0.0172				
Carolina wren [f]	72	Intercept	0.1003	0.376	0.0060	0.629	0.1317
		Total density of hardwoods	0.00132				
Chipping sparrow [f]	46	Intercept	0.2807	0.516	< 0.0001	0.755	0.8162
		Total density of trees	-0.0008				
		CV of all trees	0.00855				
		Density of deciduous stems < 3 cm DBH	-0.00015				
Common yellowthroat	38	Intercept	-0.3017	0.440	< 0.0001	0.714	0.5963
		Density of conifers	0.000809				
		Density of deciduous stems < 3 cm DBH	0.00033				
Downy woodpecker [e]	21	-	-	-	-	-	-
Eastern towhee [f]	81	Intercept	1.4832	0.971	< 0.0001	0.848	0.8100
		Canopy height	-0.1376				
		Total density of hardwoods	0.00429				

Table 11. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Field sparrow	52	Intercept	-5.5968	0.983	< 0.0001	0.915	0.0132
		% herbaceous cover	0.0789				
		Density of trees 3-8 cm DBH	0.00222				
		Total density of conifers	0.00109				
		CV of trees > 23 cm DBH	0.0256				
Hooded warbler [f]	72	Intercept	4.4408	0.757	< 0.0001	0.845	0.0582
		% herbaceous cover	-0.0541				
		Density of conifers 15-23 cm DBH	-0.00311				
Indigo bunting	93	Intercept	1.1142	0.583	< 0.0001	0.946	0.9996
		Density of trees > 23 cm DBH	-0.0408				
		CV of stems < 3cm DBH	0.061				
Mourning dove [f]	44	Intercept	0.0294	0.987	< 0.0001	0.761	0.7111
		Density of deciduous stems < 3 cm DBH	0.000346				
		Density of coniferous stems < 3 cm DBH	-0.0155				
		Density of trees > 23 cm DBH	-0.029				
Northern Cardinal [f]	75	Intercept	-0.2421	0.893	< 0.0001	0.807	0.7629
		Density of conifers > 23 cm DBH	-0.0194				
		CV of trees 3-8 cm DBH	0.0149				
		CV of trees 15-23 cm DBH	0.0108				

Table 11. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Ovenbird [f]	26	Intercept	1.3493	0.885	< 0.0001	0.915	0.8369
		% herbaceous cover	-0.0607				
		Density of deciduous stems < 3 cm DBH	-0.00034				
		Density of trees > 23 cm DBH	0.0273				
Pileated woodpecker [e]	26	-	-	-	-	-	-
Prairie warbler	35	Intercept	-1.0056	0.535	< 0.0001	0.927	0.6921
		% herbaceous cover	0.0424				
		CV of trees 3-8 cm DBH	-0.0282				
		Density of hardwoods 3-8 cm DBH	0.00148				
		Density of hardwoods 8-15 cm DBH	0.00273				
		Density of hardwoods 15-23 cm DBH	-0.0205				
Red-eyed vireo [f]	87	Intercept	-2.5636	0.785	< 0.0001	0.914	0.4124
		% canopy cover	0.108				
		CV of trees 8-15 cm DBH	0.0136				
Scarlet tanager [f]	31	Intercept	-0.02	0.889	< 0.0001	0.821	0.7311
		% herbaceous cover	-0.0232				
		Density of hardwoods 15-23 cm DBH	-0.00498				
		Density of hardwoods 8-15 cm DBH	0.0151				

Table 11. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Tufted titmouse [f]	63	Intercept	-1.9291	0.404	0.0008	0.718	0.2739
		% canopy cover	0.0297				
		CV of stems < 3 cm DBH	0.0138				
White-eyed vireo [f]	25	Intercept	-0.4892	0.607	0.0004	0.742	0.9591
		CV of trees 3-8 cm DBH	0.0166				
		CV of stems < 3 cm DBH	-0.0311				
Wood thrush [f]	37	Intercept	-2.771	0.342	< 0.0001	0.794	0.7548
		% canopy cover	0.0455				
Yellow-breasted chat [f]	64	Intercept	0.4105	0.561	< 0.0001	0.821	0.4012
		Density of trees 3-8 cm DBH	0.0051				
		Canopy height	-0.1028				

[a] Akaike weight (w_i) of the best model, compared to all other models analyzed.
[b] Significance level reported from the Likelihood ratio Chi-square test for overall fit of the model.
[c] Receiver Operating Characteristic, measure of the concordance of the data with the model.
[d] Significance level reported in the Chi square goodness-of-fit test. Values > 0.05 indicate that the data fit the model.
[e] No predictor variables were significant at $P < 0.05$.
[f] Model identified by the stepwise procedure using $P < 0.05$ to select significant predictors.

Table 12. Logistic regression results from analysis of 27 common bird species (observed at >20 sampling points) and landscape level habitat data in 2007 and 2008 at PRP and PALS, southwestern Virginia. The "best" model based on ΔAIC_c out of all single-variable, stepwise, and multiple regressions analyzed is reported here.

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
American crow	50	Intercept	0.3085	0.137	0.0463	0.551	0.7614
		Distance to pine	-0.00101				
American goldfinch [e]	51	Intercept	2.1601	0.855	< 0.0001	0.787	0.6873
		% mature_100 m buffer	-0.0753				
		% open_ 1000 m buffer	-0.0344				
American robin [e]	25	Intercept	0.5575	0.464	0.0007	0.744	0.8643
		% open_1000 m buffer	-0.104				
		% mature_100 m buffer	-0.0211				
Black-and-white warbler [e]	62	Intercept	-6.6227	0.997	< 0.0001	0.920	0.5769
		Edge/ha_ 1000 m buffer	0.0484				
		% disturbed_ 1000 m buffer	-0.1458				
		% open_500 m buffer	-0.078				
		% mature_ 100 m buffer	0.0423				
		Edge diversity	2.7041				
Black-throated green warbler [e]	21	Intercept	2.2008	0.992	< 0.0001	0.911	0.0103
		% open_ 500 m buffer	-0.2261				
		% shrub_1000 m buffer	-0.2568				
		% mature_ 100 m buffer	0.0233				

Table 12. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Blue jay [e]	25	Intercept	-1.2003	0.671	< 0.0001	0.803	0.8332
		Distance to mature forest	-0.0219				
		Edge/ha_ 500 m buffer	0.0326				
		% pine_ 1000 m buffer	-0.3886				
Blue-winged warbler [e]	46	Intercept	4.5412	0.992	< 0.0001	0.907	0.5326
		Perimeter of patch (m)	-0.00096				
		Edge diversity	-2.4651				
		Distance to open	-0.00992				
		% shrub_100 m buffer	0.0483				
		% water_ 1000 m buffer	-4.3358				
Carolina chickadee [e]	47	Intercept	2.2974	0.862	< 0.0001	0.814	0.3221
		Distance to mature forest	-0.0178				
		% open_1000 m buffer	-0.0997				
Carolina wren [e]	72	Intercept	-0.7762	0.946	< 0.0001	0.893	0.6560
		Perimeter of patch (m)	-0.001				
		Distance to water	0.00173				
		Edge/ha_ 1000 m buffer	0.0503				
		% open_1000 m buffer	-0.1706				
		% water_ 500 m buffer	1.604				

Table 12. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Chipping sparrow [e]	46	Intercept	0.4824	0.631	< 0.0001	0.748	0.0931
		Perimeter of patch (m)	-0.00079				
		% open_100 m buffer	0.0258				
		% water_ 1000 m buffer	-1.8744				
Common yellowthroat [e]	38	Intercept	2.2656	0.661	< 0.0001	0.762	0.6586
		% pine_100 m buffer	-2.1863				
		Edge diversity	0.0799				
Downy woodpecker	21	Intercept	-0.904	0.190	0.0243	0.561	0.8424
		Distance to shrub	-0.0128				
Eastern towhee	81	Intercept	4.6199	0.544	< 0.0001	0.897	0.6994
		Perimeter of patch (m)	-0.00048				
		% mature_100 m buffer	-0.0419				
		Distance to shrub	-0.00765				
Field sparrow [e]	52	Intercept	1.7198	0.910	< 0.0001	0.923	0.0990
		Distance to water	-0.0011				
		% open_500 m buffer	0.1891				
		% mature_100 m buffer	-0.0526				
		% pine_ 500 m buffer	-0.0935				

Table 12. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Hooded warbler	72	Intercept	1.3937	0.976	< 0.0001	0.848	0.8132
		Distance to open	0.0131				
		Distance to mature forest	-0.0192				
Indigo bunting [e]	93	Intercept	7.4057	0.531	< 0.0001	0.871	0.9277
		Perimeter of patch (m)	-0.00135				
		Distance to open	-0.02				
Mourning dove [e]	44	Intercept	-3.0069	0.949	< 0.0001	0.806	0.3961
		Distance to water	0.0016				
		% open_100 m buffer	0.0172				
		% shrub_500 m buffer	0.0601				
Northern cardinal	75	Intercept	3.0742	0.827	< 0.0001	0.789	0.1587
		Distance to shrub	-0.0156				
		% open_1000 m buffer	-0.1074				
Ovenbird [e]	26	Intercept	-4.3086	0.434	< 0.0001	0.845	0.0283
		% mature_100 m buffer	0.0529				
		% pine_100 m buffer	0.055				
Pileated woodpecker [e]	26	Intercept	-2.9849	0.837	< 0.0001	0.783	0.1101
		Edge/ha_100 m buffer	0.0172				
		% open_1000 m buffer	-0.1116				
		% mature_100 m buffer	0.0198				

Table 12. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Prairie warbler [e]	35	Intercept	0.1251	0.759	< 0.0001	0.872	0.2433
		# patches of same cover type_ 500 m buffer	0.654				
		% mature_100 m buffer	-0.0505				
		% pine_1000 m buffer	-0.1858				
Red-eyed vireo	87	Intercept	-0.7637	0.928	< 0.0001	0.895	0.9814
		% mature_100 m buffer	0.0637				
		Distance to open	0.0432				
Scarlet tanager	31	Intercept	0.1909	0.303	< 0.0001	0.749	0.3562
		% disturbed_500 m buffer	-0.1045				
		Distance to mature forest	-0.0169				
Tufted titmouse [e]	63	Intercept	-0.7249	0.401	0.0006	0.714	0.9944
		% mature_100 m buffer	0.0256				
		% pine_100 m buffer	0.0288				
White-eyed vireo [e]	25	Intercept	-0.9114	0.736	0.0001	0.809	0.3470
		% open_100 m buffer	-0.0315				
		% shrub_100 m buffer	0.036				
		% shrub_500 m buffer	-0.0618				
		% pine_100 m buffer	0.0276				

Table 12. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Wood thrush [e]	37	Intercept	-1.1087	0.999	< 0.0001	0.839	0.3385
		Distance to mature forest	-0.0174				
		Distance to pine	0.00285				
		% pine_100 m buffer	0.0695				
Yellow-breasted chat [e]	64	Intercept	-0.7384	0.987	< 0.0001	0.839	0.3385
		Area of patch (ha)	-0.1029				
		Distance to mature forest	0.0183				
		% shrub_100 m buffer	0.0448				

[a] Akaike weight (w_i) of the best model, compared to all other models analyzed.
[b] Significance level reported from the Likelihood ratio Chi-square test for overall fit of the model.
[c] Receiver Operating Characteristic, measure of the concordance of the data with the model.
[d] Significance level reported in the Chi square goodness-of-fit test. Values > 0.05 indicate that the data fit the model.
[e] Model identified by the stepwise procedure using P < 0.05 to select significant predictors.

Table 13. Logistic regression results from analysis of 27 common bird species (observed at >20 sampling points) and mixed scale habitat data (site-specific and landscape level) in 2007 and 2008 at PRP and PALS, southwestern Virginia. The "best" model based on ΔAIC_c out of all single-variable, stepwise, and multiple regressions analyzed is reported here.

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
American crow [e]	50	-	-	-	-	-	-
American goldfinch [f]	51	Intercept	1.2065	0.884	<0.0001	0.821	0.8400
		CV of trees 3-8 cm DBH	0.012				
		% mature_100 m buffer	-0.0363				
		% open_1000 m buffer	-0.0646				
American robin [e]	25	-	-	-	-	-	-
Black-and-white warbler [f]	62	Intercept	-6.4579	0.999	<0.0001	0.933	0.0785
		Density of deciduous stems < 3 cm DBH	-0.00039				
		Edge/ha_1000 m buffer	0.0479				
		% disturbed_1000 m buffer	-0.1884				
		% open_500 m buffer	-0.1135				
		% mature_100 m buffer	0.0546				
		Edge diversity	3.3832				
Black-throated green warbler	21	Intercept	-3.9188	0.339	<0.0001	0.834	0.7396
		% herbaceous cover	0.01				
		% mature_100 m buffer	0.045				
		% shrub_500 m buffer	-0.0307				

Table 13. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Blue jay [f]	25	Intercept	-0.8547	0.834	<0.0001	0.831	0.6164
		CV of stems < 3 cm DBH	0.0222				
		Distance to mature forest	-0.0288				
		% pine_1000 m buffer	-0.3064				
Blue-winged warbler	46	Intercept	4.3649	0.681	<0.0001	0.905	0.3691
		Canopy height	0.0171				
		Perimeter of patch (m)	-0.00096				
		Distance to open	-0.0107				
		% shrub_100 m buffer	0.0489				
		% water_1000 m buffer	-4.1518				
		ED	-2.4837				
Carolina chickadee	47	Intercept	2.1684	0.630	<0.0001	0.856	0.7648
		% canopy cover	0.0217				
		Density of coniferous stems < 3 cm DBH	-0.0109				
		Distance to mature forest	-0.0141				
		% open_1000 m buffer	-0.1612				

Table 13. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Carolina wren	72	Intercept	-0.5186	0.502	<0.0001	0.904	0.2991
		Total density of hardwoods	0.00119				
		Perimeter of patch (m)	-0.0011				
		Distance to water	0.00153				
		Edge/ha_1000 m buffer	0.0385				
		% open_1000 m buffer	-0.1696				
		% water_500 m buffer	1.5255				
Chipping sparrow [f]	46	Intercept	1.3257	0.873	< 0.0001	0.761	0.4386
		Total density of trees	-0.00182				
		Area of patch (ha)	-0.0614				
Common yellowthroat [f]	38	Intercept	-2.0362	0.547	< 0.0001	0.783	0.5148
		% herbaceous cover	0.0184				
		% pine_100 m buffer	0.0886				
Downy woodpecker [e]	21	-	-	-	-	-	-
Eastern towhee [f]	81	Intercept	4.0044	0.999	< 0.0001	0.923	0.9942
		Total density of hardwoods	0.00524				
		% mature_100 m buffer	-0.0714				
		Area of patch (ha)	-0.1379				

Table 13. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Field sparrow [f]	52	Intercept	-1.2186	0.965	< 0.0001	0.927	0.2201
		% herbaceous cover	0.0396				
		Distance to water	-0.00119				
		% open_500 m buffer	0.1546				
		% mature_100 m buffer	-0.0295				
Hooded warbler	72	Intercept	3.8258	0.906	< 0.0001	0.864	0.4629
		% herbaceous cover	-0.0515				
		Density of conifers 15-23 cm DBH	-0.00378				
		Distance to open	0.0156				
Indigo bunting [f]	93	Intercept	3.9499	0.995	< 0.0001	0.992	0.9998
		CV of stems < 3 cm DBH	0.224				
		% canopy cover	-0.1004				
		Distance to open	-0.0383				
Mourning dove [f]	44	Intercept	1.9902	0.443	< 0.0001	0.753	0.1073
		Density of coniferous stems < 3 cm DBH	-0.0166				
		Distance to shrub	-0.0158				
		Edge/ha_100 m buffer	-0.0109				

Table 13. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Northern cardinal [f]	75	Intercept	-3.257	0.999	< 0.0001	0.932	< 0.0001
		CV of trees 15-23 cm DBH	0.0263				
		CV of all trees	0.024				
		Distance to shrub	-0.0123				
		% shrub_500 m buffer	0.1749				
Ovenbird	26	Intercept	0.894	0.593	< 0.0001	0.914	0.0406
		% herbaceous cover	-0.0607				
		Density of deciduous stems < 3 cm DBH	-0.00035				
		Density of trees > 23 cm DBH	0.0232				
		% mature_100 m buffer	0.0112				
Pileated woodpecker [e]	26	-	-	-	-	-	-
Prairie warbler [f]	35	Intercept	-1.4543	0.999	< 0.0001	0.942	0.6640
		% herbaceous cover	0.0378				
		CV of trees 3-8 cm DBH	-0.0226				
		Density of coniferous stems < 3 cm DBH	0.0113				
		# patches of same cover type_500 m	0.8839				
		% mature_100 m buffer	-0.0442				
		% pine_1000 m buffer	-0.2222				

Table 13. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Red-eyed vireo [f]	87	Intercept	-1.6528	0.955	< 0.0001	0.955	0.9980
		% canopy cover	0.1446				
		CV of trees 8-15 cm DBH	0.0169				
		# patches of same cover type_500 m buffer	-0.8095				
Scarlet tanager	31	Intercept	0.0171	0.730	< 0.0001	0.821	0.4584
		% herbaceous cover	-0.0221				
		Density of hardwoods 8-15 cm DBH	-0.00479				
		Density of hardwoods 15-23 cm DBH	0.0145				
		Distance to mature	-0.00133				
Tufted titmouse [f]	63	Intercept	-1.7725	0.555	0.0002	0.750	0.1123
		CV of stems < 3 cm DBH	0.011				
		% mature_100 m buffer	0.0289				
		% pine_100 m buffer	0.0297				
White-eyed vireo [f]	25	Intercept	-0.2183	0.509	<0.0001	0.802	0.4562
		CV of trees 3-8 cm DBH	-0.03				
		CV of stems < 3 cm DBH	0.0183				
		% open_100 m buffer	-0.0301				

Table 13. (continued)

Species	# points present (n=102)	Variable	Coeff.	w_i[a]	Model sig[b]	ROC[c]	GOF sig[d]
Wood thrush [f]	37	Intercept	-4.4013	0.761	< 0.0001	0.872	0.4358
		% canopy cover	0.0472				
		Total density of conifers	0.000731				
		Distance to pine	0.00298				
Yellow-breasted chat [f]	64	Intercept	-2.3159	0.999	< 0.0001	0.909	0.2916
		Density of trees 3-8 cm DBH	0.00413				
		Area of patch (ha)	-0.1273				
		Distance to mature forest	0.0257				
		% shrub_500 m buffer	0.0664				

[a] Akaike weight (w_i) of the best model, compared to all other models analyzed.
[b] Significance level reported from the Likelihood ratio Chi-square test for overall fit of the model.
[c] Receiver Operating Characteristic, measure of the concordance of the data with the model.
[d] Significance level reported in the Chi square goodness-of-fit test. Values > 0.05 indicate that the data fit the model.
[e] No site-specific predictor variables were significant at $P < 0.05$.
[f] Model identified by the stepwise procedure using $P < 0.05$ to select significant predictors.

Table 14. Summary of site-specific, landscape level, and mixed-scale models for 27 bird species observed at PRP and PALS, southwestern Virginia in 2007 and 2008. Number of parameters in the model (K), AIC corrected for small sample size (AIC_c), Receiver Operating Characteristic (ROC), and significance of the model (P) and shown here. AIC_c was used to determine the best model for each species.

	Site-specific				Landscape				Mixed			
Species	**K**	**AICc**	**ROC**	**P**	**K**	**AICc**	**ROC**	**P**	**K**	**AICc**	**ROC**	**P**
American crow	-	-	-	-	**2**	**141.514**	**0.551**	**0.0463**	-	-	-	-
American goldfinch	3	123.441	0.770	< 0.0001	3	118.281	0.787	< 0.0001	**4**	**114.434**	**0.821**	**<0.0001**
American robin	-	-	-	-	**3**	**105.577**	**0.744**	**0.0007**	-	-	-	-
Black-and-white warbler	4	103.098	0.844	< 0.0001	6	85.523	0.920	< 0.0001	**7**	**80.339**	**0.933**	**<0.0001**
Black-throated green warbler	3	90.462	0.788	< 0.0001	**4**	**64.775**	**0.911**	**< 0.0001**	4	87.231	0.339	<0.0001
Blue jay	3	110.049	0.718	0.0062	4	97.223	0.803	< 0.0001	**4**	**92.399**	**0.831**	**<0.0001**
Blue-winged warbler	4	125.749	0.746	< 0.0001	**6**	**95.947**	**0.907**	**< 0.0001**	7	98.063	0.905	<0.0001
Carolina chickadee	3	123.279	0.759	< 0.0001	3	111.864	0.814	< 0.0001	**5**	**104.122**	**0.856**	**<0.0001**
Carolina wren	2	120.159	0.629	0.0060	**6**	**83.845**	**0.893**	**< 0.0001**	7	83.734	0.904	<0.0001
Chipping sparrow	4	127.143	0.755	< 0.0001	4	126.789	0.748	< 0.0001	**3**	**124.152**	**0.761**	**<0.0001**
Common yellowthroat	3	122.402	0.714	< 0.0001	3	111.637	0.762	< 0.0001	**3**	**109.918**	**0.783**	**<0.0001**
Downy woodpecker	-	-	-	-	**2**	**102.772**	**0.561**	**0.0243**	-	-	-	-
Eastern towhee	3	78.089	0.971	< 0.0001	4	74.114	0.897	< 0.0001	**4**	**63.624**	**0.923**	**<0.0001**
Field sparrow	5	88.171	0.915	< 0.0001	5	78.733	0.923	< 0.0001	**5**	**74.137**	**0.927**	**<0.0001**
Hooded warbler	3	93.815	0.845	< 0.0001	3	90.418	0.848	< 0.0001	**4**	**90.059**	**0.906**	**<0.0001**
Indigo bunting	3	36.133	0.946	< 0.0001	3	33.419	0.871	< 0.0001	**4**	**21.759**	**0.992**	**<0.0001**
Mourning dove	4	121.100	0.761	< 0.0001	**4**	**118.306**	**0.806**	**< 0.0001**	4	124.723	0.753	<0.0001
Northern cardinal	4	96.881	0.807	< 0.0001	3	93.822	0.789	< 0.0001	**5**	**69.237**	**0.932**	**<0.0001**
Ovenbird	**4**	**70.441**	**0.915**	**< 0.0001**	3	89.888	0.845	< 0.0001	5	71.745	0.914	<0.0001
Pileated woodpecker	-	-	-	-	**4**	**100.306**	**0.783**	**< 0.0001**	-	-	-	-
Prairie warbler	6	80.125	0.927	< 0.0001	4	92.861	0.872	< 0.0001	**7**	**73.754**	**0.942**	**<0.0001**
Red-eyed vireo	3	54.951	0.914	< 0.0001	3	60.235	0.895	< 0.0001	**4**	**45.886**	**0.955**	**<0.0001**
Scarlet tanager	**4**	**102.621**	**0.821**	**< 0.0001**	3	112.441	0.749	< 0.0001	5	104.784	0.821	<0.0001

Table 14. (continued)

Species	Site-specific				Landscape				Mixed			
	K	**AICc**	**ROC**	**P**	**K**	**AICc**	**ROC**	**P**	**K**	**AICc**	**ROC**	**P**
Tufted titmouse	3	127.765	0.718	< 0.0001	3	127.086	0.714	0.0006	**4**	**124.874**	**0.750**	**0.0002**
White-eyed vireo	3	104.094	0.742	0.0004	5	101.850	0.809	0.0001	**4**	**98.846**	**0.802**	**<0.0001**
Wood thrush	2	109.268	0.794	< 0.0001	4	105.342	0.839	< 0.0001	**4**	**93.047**	**0.872**	**<0.0001**
Yellow-breasted chat	3	105.559	0.821	< 0.0001	4	98.206	0.839	< 0.0001	**5**	**86.980**	**0.909**	**<0.0001**

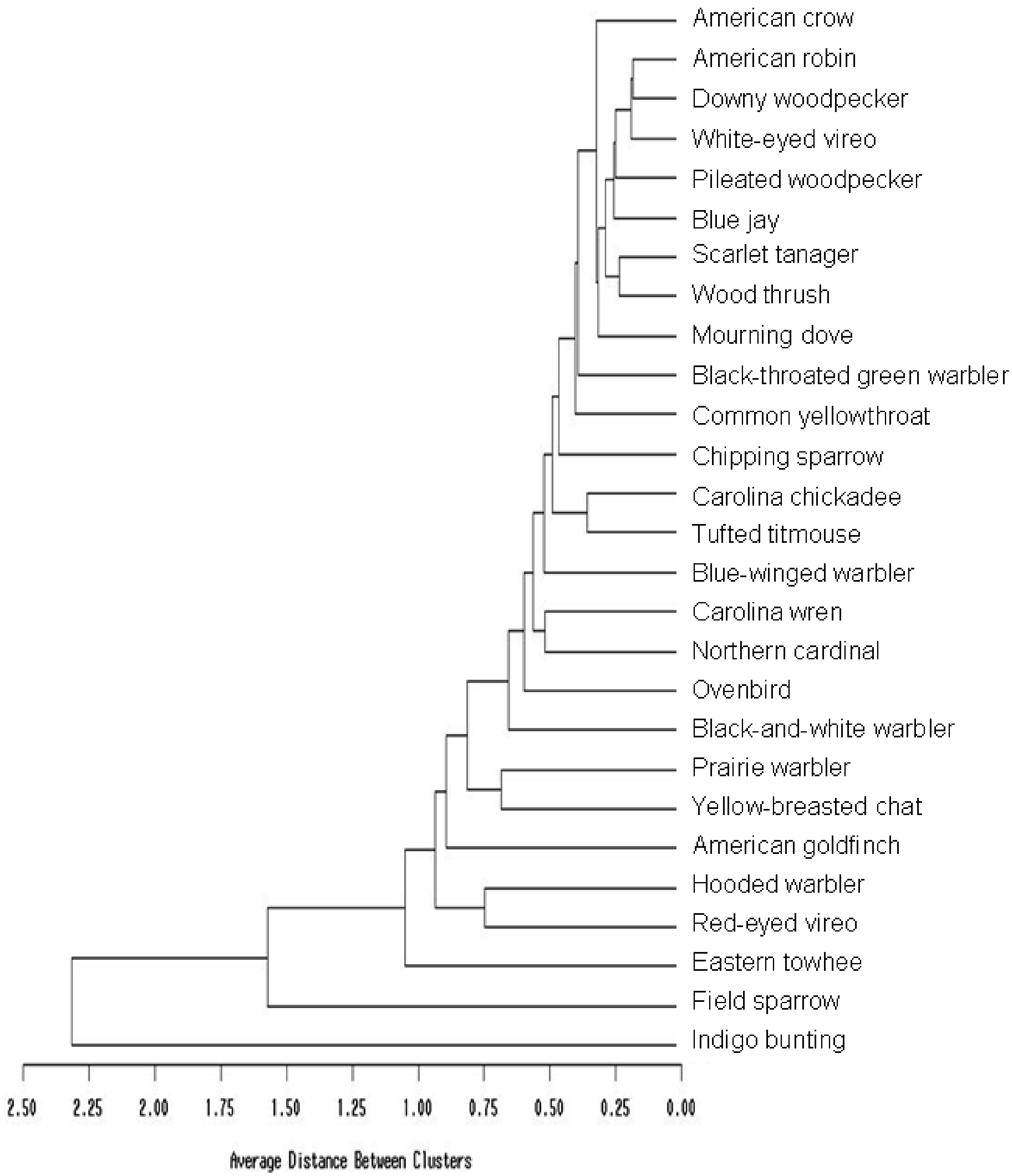

Figure 8. Dendrogram of the 27 most common bird species observed in 2007-2008 at PRP and PALS, southwestern Virginia. Relationships are based on relative abundance of each species. Euclidean distance and average linkage method were used.

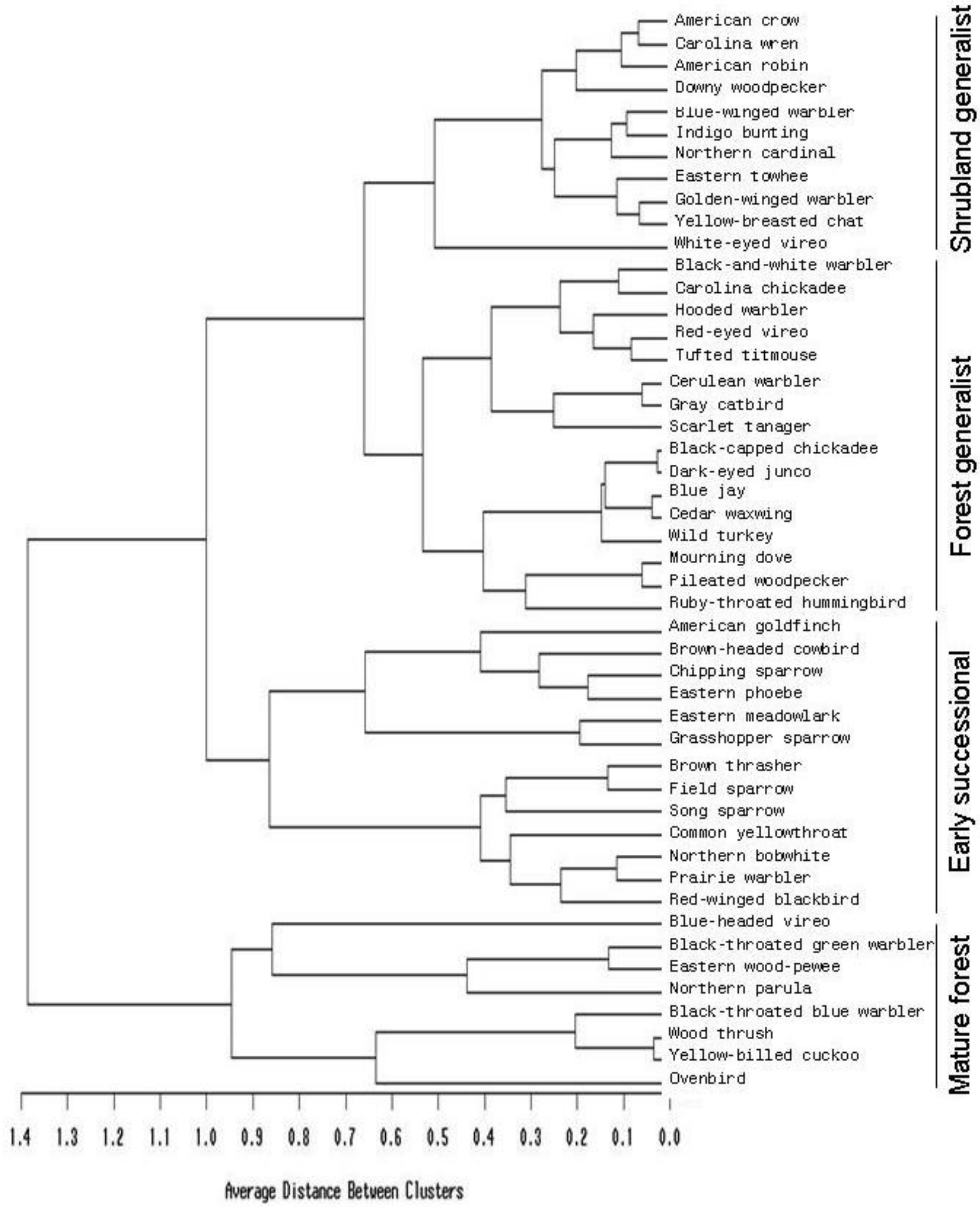

Figure 9. Dendrogram of 48 most common bird species sampled in 2007-2008 at PRP and PALS, southwestern Virginia, identified 4 general assemblages. Relationships were derived using principal components based on habitat characteristics. Euclidean distance and average linkage method were used.

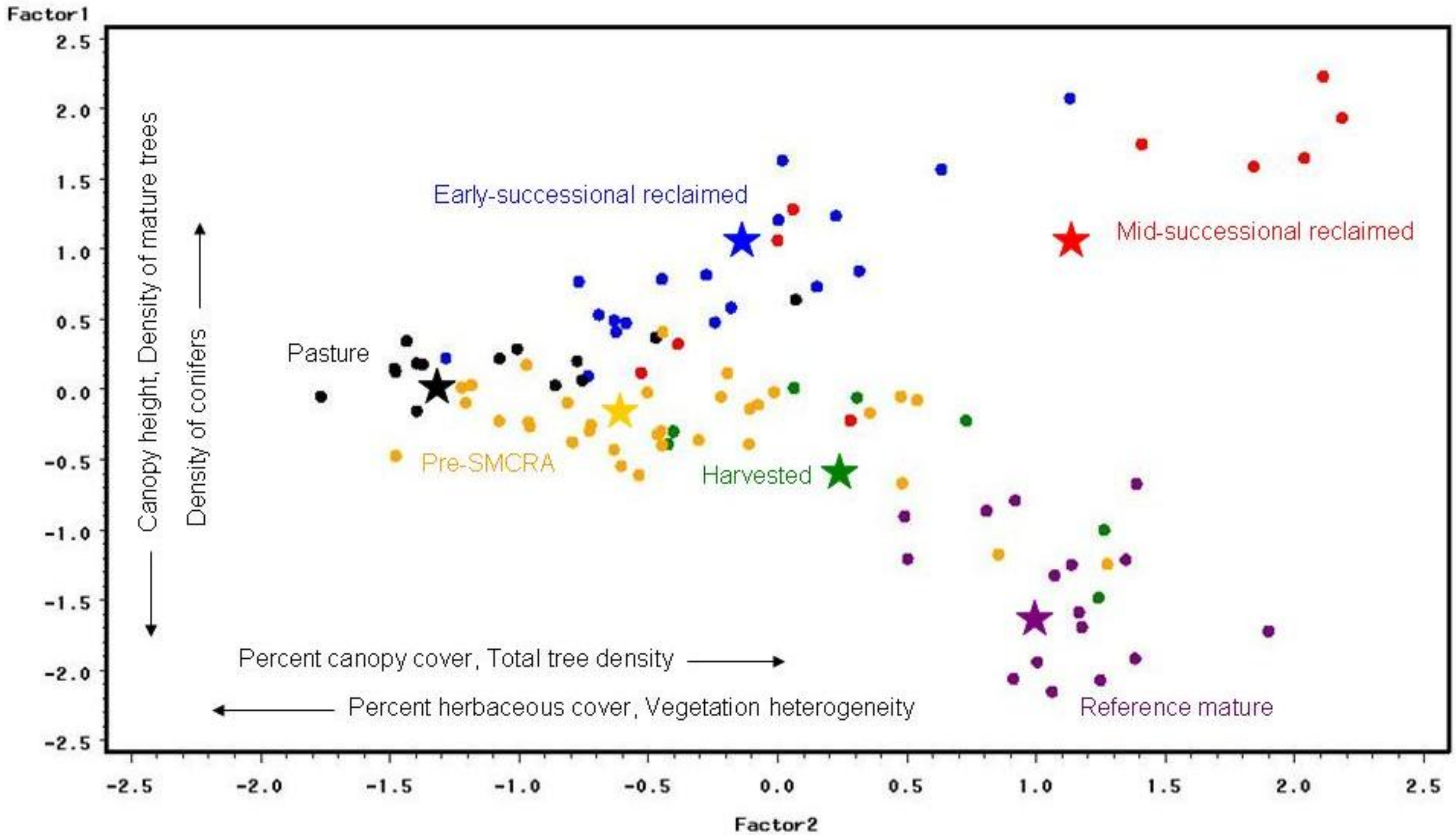

Figure 10. Distribution of sampling points (N=102) based on the first two principal components derived from analysis of habitat characteristics. Color of points indicates cover types (n=6), and mean principal components for each cover type are indicated by stars. Cover type names are labeled next to stars in matching color.

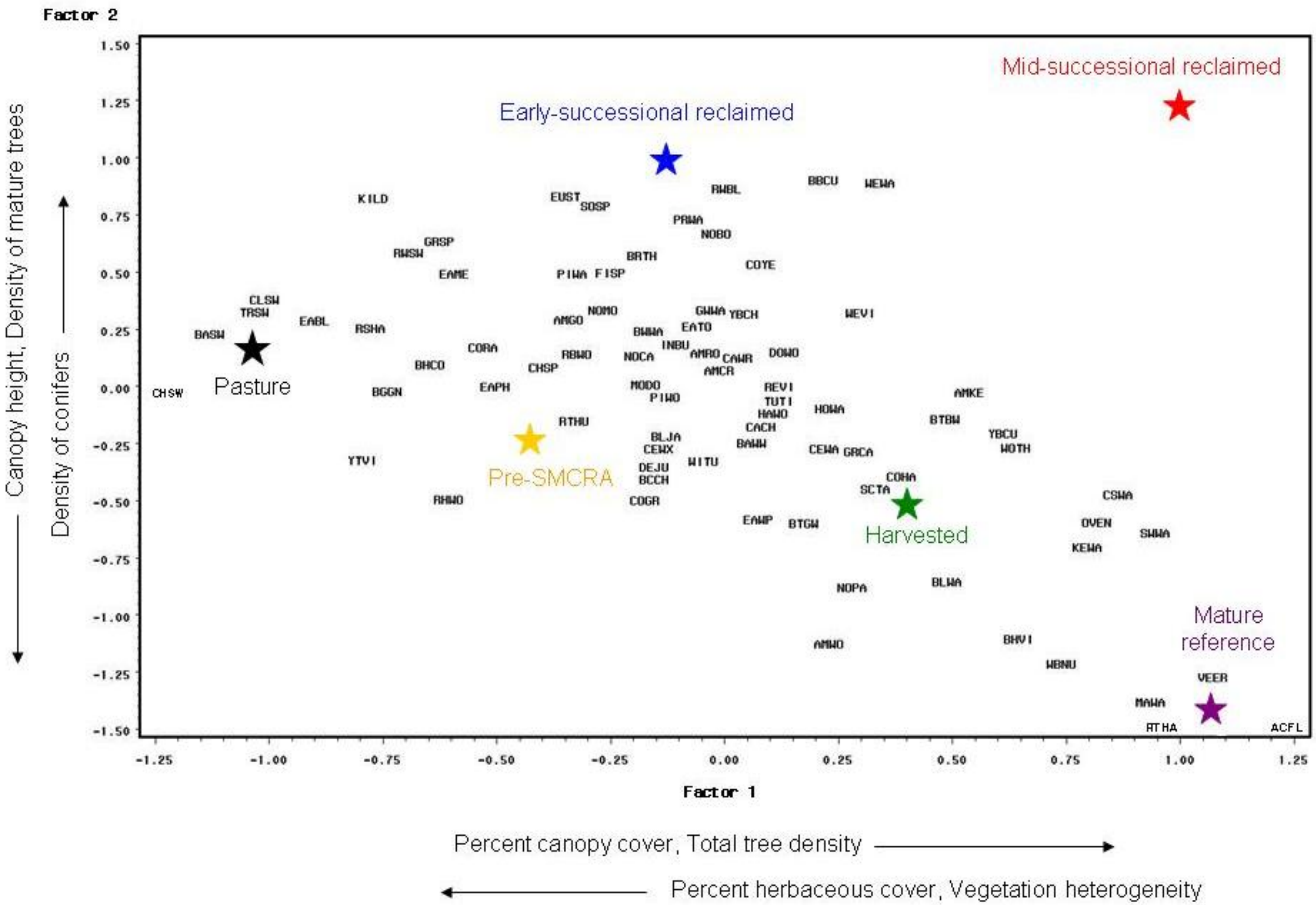

Figure 11. Plot of average PCA scores of the sampling points where each of 80 bird species were observed. The stars represent the average score on the first 2 components of sampling points from each of 6 cover types. Species codes can be found in Appendix A.

Discussion

Habitat

The 6 cover types identified for this study on reclaimed, harvested, and reference sites were somewhat different in structure (Table 4). Mature forest tended to be most structurally different from the mined and harvested sites. Mature forest specifically had more canopy cover and a higher canopy height when compared to other cover types. Mature forest also had a significantly higher density of large hardwoods (> 15 cm DBH).

The results of this study indicate functional and structural differences among early successional mined areas, pasture, and clearcuts. Bulluck and Buehler (2006) found that early successional reclaimed sites and clearcuts were not equivalent in the Cumberland Mountain region "with regard to vegetation structure, avian abundance, and avian species composition" (p.82). There are also key differences between early successional thickets and young regenerating forest (Askins 2001); both types of habitat are dominated by low, woody vegetation, but differ in structure. For example, young saplings typically grow densely in regenerating clearcuts, whereas vegetation may be patchy in early successional reclaimed habitat (Bulluck and Buehler 2006). In my study, the density of deciduous stems was significantly higher on harvested sites than mined cover types (Table 4). Lower stem densities suggest that new tree growth may be reduced on reclaimed sites as compared to mature forest or harvested sites. Patchiness of trees and stems was also higher on reclaimed sites than in mature forest or harvested sites, indicating the heterogeneous nature of the mined landscape. The resulting differences in structure between clearcuts and early successional reclaimed cover types supported unique bird communities.

The principal components analysis provided useful information that described relationships among cover types (Table 10, Fig. 10). Pasture sites tended to have the most herbaceous cover and highest vegetation patchiness. Based on habitat characteristics, sampling points located in mature forest were most distinct from the alternate disturbed cover types. Mature forest had the highest canopy height and density of mature trees, and lowest density of conifers. Mature forest and mid-successional reclaimed areas had the most canopy cover and highest tree density of all the cover types. Many of the mid-successional patches included in the study were pine plantations > 20 years old. Although mid-successional reclaimed sites are much younger than mature forest, the typical planting scheme leads to a pine monoculture with high tree density and dense canopy cover in a relatively short time. Because of pine plantings on reclaimed sites, early and mid-successional areas had high densities of conifers.

Birds

I observed 80 bird species using reclaimed mine sites, adjacent mature forests, and regenerating clearcuts. Bird observations were dependent on cover type as well as site-specific and landscape-level habitat characteristics. Some bird species were observed in all cover types, such as the American crow and Carolina chickadee, yet others were seen in only one cover type, such as the barn swallow (pasture) and magnolia warbler (mature forest) (Table 6).

Although early successional landscapes included in this study were similar in age, some species were selective in the cover types they used. The eastern bluebird, eastern meadowlark, field sparrow, grasshopper sparrow, northern bobwhite, and common yellowthroat readily used early successional reclaimed areas and pastures, but were never sighted in clearcuts. Swallows and swifts were observed using pastures exclusively and not any other form of early successional habitat. The European starling, a non-native species frequently consider a pest, was observed almost exclusively in pasture and was more common at PRP, suggesting a tie to human disturbance and livestock grazing. The brown-headed cowbird, a nest parasite, was frequently observed in pastures and clearcuts, but rarely seen in early successional reclaimed areas. Early successional reclaimed habitat may be less attractive to nest parasites because of the configuration (i.e., expansive areas with relatively little forest-open edge interface).

The results from cluster analysis on relative abundance of birds (Fig. 8) and on habitat characteristics (Fig. 9) were quite different. The dendrogram based on relative abundance of birds showed a chaining effect with few clear clusters that could be identified. Grouping species by relative abundance was not very effective in identifying bird associations. The cluster analysis based on PCA scores did result in clear and logical clusters based on habitat characteristics. Species clustered into shrubland generalists (e.g., blue-winged warbler, yellow-breasted chat), forest generalists (e.g., scarlet tanager, hooded warbler), early successional species (e.g., American goldfinch, prairie warbler), and mature forest species (e.g., northern parula, wood thrush).

Because distinct groups were identified through cluster analyses of habitat gradients defined by PCA, habitat appears to be a good descriptor of relationships within the bird community on the study areas. These guilds can be managed as a group since they respond similarly to habitat characteristics. Mature forest species responded to characteristics of undisturbed habitat, such as canopy cover and canopy height. Early successional species required more open areas with scattered vegetation and small trees. Generalists (forest and shrubland) were loosely associated with characteristics similar to those of the mature forest species and early successional, respectively. However, discrete or specific habitat characteristics were more difficult to identify, indicating a more “generalist” approach to habitat selection by these species.

Although species assumed to be native forest obligates were generally uncommon in the survey (e.g., blue-headed vireo, Northern parula, veery), there were several avian species of concern (USFWS 2008) found on the study areas. The cerulean warbler was observed using PALS forestland in 2007 and the golden-winged warbler was observed on both study areas in 2007 and 2008. Both birds are long-distance Neotropical migrants considered species of great concern in the eastern U.S. because of steady population declines since the 1960s (Cerulean & Golden-winged Warbler Summit 2008). Both species are facing similar threats including habitat loss due to landscape changes on their wintering grounds, relatively small estimated population sizes, and restricted breeding and non-breeding distributions (Cerulean & Golden-winged Warbler Summit 2008).

The cerulean warbler is typically associated with mature forest, but is known to favor canopy openings that provide low, dense vegetation (Askins 2001). In addition to forests with tree-fall gaps that may provide suitable conditions, the cerulean warbler also occupies mature forest adjacent to roadways, such as the habitat found along the Blue Ridge Parkway in Virginia and North Carolina (Hunter et al. 2001). The golden-winged is frequently found in areas that mimic natural disturbances, such as beaver meadows and frequently burned areas (Hunter et al. 2001). Reclaimed mine lands often consist of open grasslands with patchy vegetation, which may benefit the golden-winged warbler. With proper planning, we can provide breeding habitat for cerulean and golden-winged warblers by: (1) providing some early successional habitat and openings to attract insects for both species, (2) maintaining some early successional shrubland for the golden-winged warbler, through varied age structure of forest stands or treatment such as burning or herbicide, and (3) protecting mature forested areas for the cerulean warbler, along with some treatment (e.g. group selection cuts) to retain an open understory and provide canopy gaps (Hunter et al. 2001).

The Virginia Department of Game and Inland Fisheries (VDGIF) identified "species of greatest conservation need" in the 2005 Virginia Wildlife Action Plan. Species of concern observed frequently on or near reclaimed surface mines during the breeding season included black-and-white warbler, prairie warbler, yellow-breasted chat, and eastern towhee. Although an increasing number of birds warrant conservation attention, the most effective conservation activity should focus on entire communities (Hunter et al. 2001). Most species, especially those dependent on disturbance, are not restricted to a single habitat type. In addition, many species are associated with or depend on early successional habitat, such as grassy fields, shrub-scrub conditions, open woodlands, or gaps in mature forest. Several studies have found that newly reclaimed areas can provide benefits similar to native grasslands as long as they are relatively large in size (>10 ha), disturbance is reduced, and planting of invasive species is discouraged (Bajema et al. 2001, DeVault et al. 2002). With proper planning and site management, managers can minimize the negative impacts of surface mining by creating habitat to benefit these species.

Bird-habitat relationships

Although there was a 15-year age difference in stands, both the lowest and highest species richness per point was observed in clearcuts. Only 8 species were observed in the 1990 PRP clearcut and 23 species were observed in the 2005 Rasnick clearcut at PALS. New clearcuts provide habitat for a variety of species, but there may be a decline in richness in the "young forest" stage (~15-20 years) as the canopy begins to close while trees are still small in size and densely distributed. Because of the homogeneity of the vegetation, lack of understory, and relatively low canopy cover, young forests may not provide adequate conditions for forest obligates. Clearcuts also may serve as post-fledgling habitat for some juvenile and adult late-successional forest species (Bulluck and Buehler 2006, Marshall et al. 2003, Vega Rivera et al. 1998). Some hypotheses for why birds associated with mature forest use early successional habitats include: (1) increased food abundance, especially insects, (2) dense vegetation to provide cover from predators, and (3) passive dispersal leads to use of early successional habitat (Marshall et al. 2003).

Another important cover type was pre-SMCRA, which supported the highest overall species richness among the cover types. Pre-SMCRA areas consist of open, early successional areas (bench) alongside young (outslope) and mature (above highwall) forests that provide a diversity of habitat for birds. This unique edge interface is not likely to be the result of unreclaimed mining operations today, as the pre-SMCRA landscape is indicative of the mining technology available in the mid-1900s. This interface provides habitat for “edge-loving” species, such as eastern towhees and indigo buntings. Although these sites may appear attractive to some birds, it is still unclear as to whether reproduction and survival is occurring successfully. Because of increased disturbance, lack of natural food items, or the attraction of predators or nest parasites (Wray et al. 1982), pre-SMCRA sites may function as ecological traps. An ecological trap occurs when an organism makes a poor habitat choice based on cues that were formerly reliable indicators of habitat quality (Schlaepfer et al. 2002). Often, ecological traps occur when a drastic anthropogenic change, like coal mining and reclamation, alters the environment in a relatively short amount of time and breaks the normal cue-habitat quality correlation (Schlaepfer et al. 2002). The conflict could lead to nest failure or reduced survival for the individual. A study at the Savannah River Site in South Carolina showed that indigo buntings consistently chose to nest in patches with 50% more edge than the control rectangular open patches, and there individuals fledged significantly fewer young (Weldon and Haddad 2005). Other species that are sensitive to edge effects and isolation associated with forest fragmentation, such as ovenbirds and wood thrushes, may also be impacted negatively by the pre-SMCRA landscape.

Logistic regression models

Because variables such as canopy cover, canopy height, and herbaceous cover were identified frequently as important predictors in the best site-specific models, managers may want to focus on these characteristics while working with reclaimed surface mines. Some species responded positively to these variables (e.g. field sparrow to herbaceous cover), and other responded negatively (e.g., hooded warbler to herbaceous cover; Table 11). Large expanses of grasslands may be effective for some species, but integration of native woody cover and herbaceous species is important for many other species (Brenner and Kelly 1981). Although management for multiple songbird species with different natural histories is inherently difficult, canopy cover and height seem to be the most limiting on reclaimed sites, especially those < 20 years of age. Early successional habitat is frequently occupied by mature forest species during the post-fledgling period (Bulluck and Buehler 2006, Marshall et al. 2003, Vega Rivera et al. 1998), suggesting the importance of this cover type for a broad range of avian species and life stages.

No significant site-specific models could be developed for American crow, American robin, downy woodpecker, and pileated woodpecker (Table 11). Some species, such as the American crow, may be generalist in nature and not dependent on site-specific characteristics. Larger birds with expansive home ranges, such as the pileated woodpecker, may rely more on forested patch characteristics at the landscape level. For ovenbird and scarlet tanager, the best model identified based on AIC_c out of the 3 possible model sets included only site-specific variables (Table 14). Site-specific models including variables such as canopy height, canopy cover, and tree density may best describe presence of species that are typically associated with large expanses of mature forest (MacFaden and Capen 2002). Although ovenbirds and scarlet tanagers are frequently associated with large patches of mature forest, they have been present consistently in smaller patches (< 5 ha) in the Mid-Atlantic Region (Robbins et al. 1989).

High ROC values identify models with "acceptable discrimination" (0.7-0.8) or "excellent discrimination" (>0.8), describing good quality models with high predictive power (Hosmer and Lemeshow 2000). There were 11 of 23 best models at the site-specific level that had a ROC > 0.8, and 22 of 23 best models with a ROC > 0.7 (Table 11). The high number of best models identified within the acceptable or excellent discrimination range indicates that these models are likely to be useful for describing presence of a species when applied in a management situation.

Analysis of landscape-level variables generated from GIS provided more descriptive information for some species. Because of the patchiness of reclaimed landscapes, the consideration of landscape characteristics was particularly important for this study. Mitchell et al. (2001) found that fit of logistic regression models on the landscape level was highest for habitat specialists, like mature forest obligates, and lowest for generalists on a managed forest in South Carolina. Also, models developed for Neotropical migrants and short-distance migrants had the best fit with field data, whereas the models for resident species tended fit poorly (Mitchell et al. 2001). Resident species also tend to be relatively insensitive to landscape characteristics as compared to migratory birds that depend more on broad scale cues for habitat selection (Flather and Sauer 1996). Managers should consider how the broader scale context of the landscape may interact with site-specific habitat characteristics to influence avian habitat selection (MacFaden and Capen 2002, Taylor and Krawchuk 2005).

I was able to develop significant models for all birds at the landscape level. At the landscape level, 17 of 27 best models had a ROC > 0.8 and 25 of 27 had a ROC > 0.7 (Table 12). For 7 bird species (American crow, American robin, black-throated green warbler, blue-winged warbler, downy woodpecker, mourning dove, and pileated woodpecker), the landscape-level model best predicted their presence compared to site-specific and mixed models (Table 14). Typically these species were larger in size and have larger home ranges, such as crows and woodpeckers (MacFaden and Capen 2002). The black-throated green warbler and blue-winged warbler are long-distance migrants that tend to be specialists, and may depend more on landscape-level cues for habitat selection. Variables that were commonly included in the best models for these species included the proportion of open, shrub, and mature forest cover in the surrounding landscape matrix (Table 12).

For 18 of 27 species some combination of site-specific and landscape level information best predicted their presence (Table 14). The mixed-scale models were better than the site-specific and landscape-level models for most species, suggesting important habitat information is available at both scales (MacFaden and Capen 2002, Mitchell et al. 2001). At the mixed scale, 19 of 23 models had a ROC >0.8 and all 23 had ROC values >0.7 (Table 13). The highest proportion of best models with acceptable or excellent discrimination occurred when both site-specific and landscape level variables were included. I could not develop mixed models for species that did not respond to site specific variables (American crow, American robin, downy woodpecker, pileated woodpecker) (Table 13). For most bird species, it is likely that factors beyond the scale of the territory influence habitat preferences during the breeding season. Therefore, it is important to use a multi-scale approach to modeling avian distribution as many species are sensitive to broad scale and local resources (MacFaden and Capen 2002, Taylor and Krawchuk 2005).

Although species in similar clusters (Fig. 9) did not consistently have the same variables in their best models (Table 14), there were some general trends. Most of the species in the forest generalist cluster had a variable related to mature forest (i.e., distance to mature forest, proportion mature forest) in the best model at the landscape level and mixed scale. For the early successional cluster, common trends included a positive relationship to herbaceous cover and a negative relationship to mature forest. Many of the landscape level models for the shrub generalists included a variable related to shrub habitat (i.e., distance to shrub, proportion shrub habitat). For the mature forest obligates, most of the models included a variable related to mature forest. Most of the variable trends were observed at the landscape scale.

Conclusions

From this study, it is clear that a variety of bird species can use reclaimed sites and the surrounding habitat during the breeding season. By identifying important variables and developing reliable models to describe the presence of these species, we can provide information for land managers to customize the reclamation processes to fit the management goals for the property. For example, if managers are provided with information indicating that some Neotropical migrants prefer areas with conifers and small woody stems (e.g. common yellowthroat), these habitat characteristics can be provided on reclaimed sites to attract the desired species. This type of active management will be particularly important to provide habitat for species of concern, such as the golden-winged warbler.

Along with the potential to design habitat on reclaimed surface mines there is the opportunity to provide habitat for game birds. Several game species including the northern bobwhite and wild turkey were observed during bird surveys on both study areas. Ruffed grouse were also observed in mature forest adjacent to mined land, suggesting that they could be hunted successfully around reclaimed sites, especially on larger areas such as the PALS site. The presence of these species along with proper management could allow landowners to continue to profit from their property by leasing hunting privileges. Hunting, wildlife viewing, and conservation opportunities can continue to benefit the landowner following a mining operation.

Because of the profound environmental impacts of mining, there are limited analogous systems with which to make direct comparisons. I chose to compare mined sites to both relatively undisturbed reference forests and to sites impacted by current silvicultural practices (clearcuts). Although reference forests were treated as "relatively undisturbed" for this study, the history of logging and farming in the Appalachian region (Yarnell 1999) suggests that all sampling locations have been disturbed since the 1800s. There are extreme differences in post-disturbance treatments and vegetative properties of reclaimed sites, clearcuts, and mature forest. However, it is important to make general comparisons between these cover types to further understand how mining influences wildlife communities and determine what can be done to reduce these impacts.

The methods developed in this study could be used to assess wildlife communities on reclaimed sites in other parts of the Appalachian region, and are adaptable to evaluating other forms of disturbed wildlife habitat. Amphibians are particularly sensitive to habitat degradation and can act as indicators of environmental quality. Birds are early founders of wildlife communities on reclaimed land because of their mobility and higher tolerance of disturbance (Brändle et al. 2003). Birds also disperse seeds to aid in the establishment of vegetation in new areas (Walker and del Moral 2003). Long-term monitoring of these wildlife communities, along with vegetation and environmental considerations, will serve to further assess the restoration of reclaimed coal mines in Appalachia.

Although my study serves as a significant step to understanding wildlife use on reclaimed surface mines, data collected represent visual and auditory observations and do not include any information about reproductive success or survival. Without this important demographic information, we cannot fully relate the presence or density of species to the habitat quality on these sites (Van Horne 1983, Vickery et al. 1992). It is possible that these disturbed areas may appear attractive to bird species, but reproduction and survival are severely reduced because of increased disturbance, lack of natural food items, or the attraction of predators or nest parasites (Wray et al. 1982). More studies are needed to focus on survival and reproduction of birds on reclaimed mine lands.

Amphibians

Introduction

Amphibians are an ecologically sensitive group, frequently serving as important early indicators of poor environmental quality (Hyde and Simons 2001). Because amphibians are preyed upon by a variety of other species, they are believed to play an essential role in the cycling of nutrients into the food chain. Often these organisms are considered to be indicators of forest biodiversity (Welsh and Droege 2001), which illustrates the importance of understanding and considering anthropogenic impacts upon this species group. In the past 20 years, there have been substantial amphibian declines due to habitat disturbance and other anthropogenic influences (Alford and Richards 1999, Beebee and Griffiths 2005). Because of strong site fidelity and limited dispersal capacity, even small disturbances that result in fragmentation could isolate amphibians from important breeding or foraging habitat necessary for survival (Krishnamurthy 2003).

According to Virginia's Wildlife Action Plan developed by the Virginia Department of Game and Inland Fisheries (2005), there are numerous species of concern that inhabit the Northern Cumberlands Region of Virginia. In this plan, species found in Virginia are identified and ranked in a tiered list (I-IV) according to their conservation need; species identified as Tier I are those with the greatest conservation needs. Four species of amphibians, including 3 salamanders are identified as species of concern in the Northern Cumberlands Region of Virginia (Table 15).

Because of variations in surface activity and subsequent detectability of salamanders with topography, season, humidity, climate, and other landscape variables, salamanders are inherently difficult to sample (Hyde and Simons 2001). Since sampling was constrained to only one season (late spring-early summer), I chose to use two different methods to assess the salamander community. Artificial cover surveys provided a consistent, repeatable method for capturing salamanders at the sampling points already defined for bird sampling. Cover boards are particularly useful in more open habitats (Heyer et al. 1994), since natural cover is typically rare. The cover board method is effective at counting a variety of species, but is more likely to attract adults rather than juveniles (Marsh and Goicochea 2003). However, night searching and natural cover object surveys have been shown to be more efficient for capturing salamanders than artificial cover boards or leaf litter searches due to lower sampling variability, reasonable capture success, and ease of implementation (Hyde and Simons 2001). In addition, salamanders captured using natural cover or during night surveys were generally larger than those captured by other methods. Hyde and Simons (2001) found that no sampling method provided adequate power (>90%) to detect population trends in 5 or fewer years of sampling.

Some research suggests that amphibian populations are initially devastated by large scale disturbances, such as mining, but habitat can be provided for them through the development of wetlands and retention ponds (Bradley 1987, Lacki et al. 1992). The establishment of water treatment structures that are naturally designed and relatively free of toxins can provide excellent habitat for anurans and aquatic salamanders.

Methods

Salamander sampling

In May 2007, a series of wooden boards were placed in cover types of interest to act as artificial habitat structures for salamanders. We began sampling in June 2007 (2 weeks after boards were set). Boards were placed in arrays of 6 (with individual boards at least 1m apart) at

18 sampling points in 3 different cover types (Table 16). Cover board arrays were located at a subset of the bird sampling points, but were representative of the various cover types targeted for surveying. Boards were constructed of rough sawn timber and about 5 cm thick to retain moisture and provide adequate habitat for salamanders. Dimensions of each board were approximately 5 x 20 x 60 cm. All leaf litter and debris was removed from beneath the board to make it flush with the ground. These boards were searched weekly during the 2007 field season from June 5 through July 11, and then once in August, for a total of 6 visits. During the 2008 season, boards were checked every 10 days from May 10 through July 10, and then once in August and in September, for a total of 8 visits. Daily searching could potentially reduce salamander counts because of disturbance of the area under and around the cover boards (Marsh and Goicochea 2003).

In addition to cover board surveys, I also completed constrained time searches on appropriately rainy, humid evenings in the summer months when salamanders would be actively foraging on the surface. Because night sampling was only done on evenings favoring terrestrial activity of salamanders, we cannot directly compare these data to the cover board sampling method (Hyde and Simons 2001). This procedure consists of 2-3 observers actively searching for a constrained amount of time (20 minutes) in each cover type of interest. This method of area searching is particularly useful in heterogeneous habitat where multiple species are of interest (Heyer et al. 1994). Based on accessibility, a series of 4 points representative of multiple cover types (early and mid-successional reclaimed, pre-SMCRA, and reference) was sampled each visit during a rain event. In 2007 we conducted one night search for salamanders, and in 2008 we performed 2. I also recorded salamander encounters, or incidental observations of species, while conducting other work on the study areas. Natural cover objects, such as logs and rocks, were sampled opportunistically for salamanders when available.

When salamanders were captured, we weighed them using a battery-operated digital scale and measured both the length from snout to vent, and from vent to the tip of the tail. We also identified these individuals to species and noted the conditions of capture (under cover board, under natural woody debris, in leaf litter, etc.). The place where they were found was marked with a numbered pin flag and the individuals were returned to exactly where they were found immediately after data collection.

Frog Sampling

In addition to salamander sampling, I completed anuran call surveys during wet evenings at established water bodies at the Powell River Project site. Call surveys were conducted twice during June-July 2007, and 4 times during May-July 2008. Anurans were identified to species and were given call intensity scores according to the number of individuals calling and loudness of the call or chorus (i.e., 1 indicated few individuals, 3 indicated a full chorus) based on the North American Amphibian Monitoring Program (NAAMP) protocol (2009). The survey lasted for about 15 minutes each at 5-6 water bodies identified prior to sampling.

Results

I observed 6 species of salamanders (Table 17) using cover objects and actively foraging on the surface. None of the species of conservation concern identified by the Virginia Wildlife Action Plan in the Cumberland Plateau region were found on the study sites. Because of the need for appropriate weather conditions and time constraints, few surveys were conducted over the study period resulting in a low sample size.

Because of the difficulty of salamander detection and the drought conditions encountered in both 2007 and 2008, the number of salamanders detected was very low. The species captured most frequently were red-spotted newt (n=39) and slimy salamander (n=18; Table 17). A spotted salamander was observed during a night search, but we were unable to capture the individual for measurement. Fifteen salamanders were found under cover boards, and all other observations were made incidentally or during night searches. Most salamanders were found in mature forest (n=42) and on pre-SMCRA (n=21) sites, with only one individual found in pine cover on a mid-successional reclaimed site (Table 18). For slimy salamanders, ANOVA indicated that there were no significant differences in weight and length between reference and pre-SMCRA cover types (weight: $F_{1,16}$=0.04, P=0.8419; snout-vent length: $F_{1,16}$=0.55, P=0.4682; vent-tail length: $F_{1,16}$=0.10, P=0.7595). For the red spotted newt, which was observed in three cover types, there was a difference in weight and length among cover types (weight: $F_{2,36}$=4.38, P=0.0198; snout-vent length: $F_{2,36}$=6.66, P=0.0035; vent-tail length: $F_{2,36}$=8.57, P=0.0009). Red-spotted newt weight and length was significantly higher in the mid-successional reclaimed cover type, although this estimate may be biased because only one individual was found there (Table 18).

I identified 8 anuran species during frog call surveys or when encountered while on site for other work (Table 19). Spring peepers were heard most frequently near water bodies and calling from wet highwalls. I often heard spring peepers in full chorus, where calls are constant, continuous, and overlapping. I also frequently heard bullfrogs and green frogs at a lower call intensity (i.e. individual calls could be distinguished).

Conclusions

One factor impacting detection of amphibians may have been the weather in southwest Virginia during the study period. Both 2007 and 2008 were considered drought years in the region, with less precipitation than the average in the months of May through August (NCDC 2009). The NOAA weather station in Wise, Virginia reported that precipitation was less than average during every month in 2007 except for April, leading to an annual precipitation deficit of 8.29 inches. Although data are currently only available through November 2008, lower than average precipitation was reported for 7 of 11 months in 2008 (NCDC 2009) including May, June, August and September during amphibian sampling. Rainfall remained low through the summer months during both years, except for the month of July in 2008 (Fig. 12). Because of the lack of precipitation, the leaf litter and ground surface remained mostly dry, especially during the warmer spring and summer months. Without adequate moisture, many amphibians were limited in the time they were able to spend on the surface without the risk of desiccation. Soil moisture was found to be the most important microhabitat variable useful in predicting salamander abundance in Great Smoky Mountains National Park (Hyde and Simons 2001). The lack of ground moisture could be another factor contributing to the low numbers of salamanders observed during both years.

We also only surveyed amphibians from May or June through August or September and did not include earlier spring months. In my study, temperatures were higher during the 2007 field season than in 2008 (Fig. 13). In the Central Appalachians, forest salamanders are most active in the spring prior to the loss of soil moisture that occurs as the temperature warms into the summer. When temperatures are high and soil moisture is low, salamanders are often inactive and difficult to detect (Hyde and Simons 2001). In a multi-year study completed at the Selu Conservancy in Montgomery County, Virginia, the highest number of observations were consistently made in March and April when soil moisture was relatively high and temperatures were moderate (Francl et al. 2009). It is also likely that we did not detect some of the earlier anuran breeders, such as wood frogs (*Rana sylvatica*), during frog call surveys at the Powell River Project. Wood frogs are known to be present in shallow wetlands or shallow ponds on mine lands in southwestern Virginia and eastern Tennessee as early as February (Vicars 2009, Office of Surface Mining Reclamation Specialist, personal communication).

Cover boards provide a cool, moist refuge for salamanders, but they only attract active salamanders on the surface (Houze and Chandler 2002) and exclude those spending time underground. Cover board size may cause bias in the size of salamanders captured, and could result in territoriality issues with other salamanders (Mathis 1990, Hyde and Simons 2001). Cover boards are a good way to sample the salamander community as they tend to attract the same species that use natural cover objects, although cover board searches produce fewer salamanders and are more variable (Houze and Chandler 2002). It is possible that natural cover objects and artificial cover boards provide different microclimates for salamanders (Marsh and Goicochea 2003) and are not preferred equally.

Hyde and Simons (2001) found that salamanders in Great Smoky Mountain National Park were more abundant on "undisturbed, mid-elevation sites adjacent to streams, and on sites with higher soil moisture and more ground cover (p.630)." Because of the drastic environmental impacts inflicted on the study sites, young reclaimed areas may not be suitable for salamanders. The lack of adequate ground cover, soil moisture, and canopy cover on young sites may prevent early colonization by amphibians. Outslopes on pre-SMCRA sites may have adequate canopy cover and woody debris for salamanders, but the loose, rocky soil has a low water retention capacity which reduces the soil moisture. Earlier findings suggest that habitat disturbance associated with logging or agriculture may have long-term effects on salamander populations, potentially resulting in at least 60 years of post-disturbance differences in salamander diversity and abundance (Hyde and Simons 2001, Homyack and Haas 2009).

My results suggest that reclaimed sites may require long periods of time and extensive vegetation recovery before they can provide adequate habitat for sensitive amphibians such as salamanders. More extensive surveys throughout all seasons of the year are needed to support this result. Additional work should also include more in-depth analysis of survival and reproduction of amphibians on reclaimed sites. Determining presence of an amphibian species, as I did as part of this study, does not confirm effective reproduction (Freda 1986) or survival in adverse conditions. Mature trees are needed to provide adequate canopy cover, leaf litter, and downed woody debris for salamander refugia (Hyde and Simons 2001). If given enough time and adequate habitat management, reclaimed sites will likely support a diversity of amphibians. However, it is possible that amphibian diversity on highly disturbed sites may never reach that of relatively undisturbed sites.

Table 15. Herptile species of greatest conservation need requiring forested habitat in the Northern Cumberlands Region of Virginia, as identified by Virginia's Wildlife Action Plan (VGDIF 2005).

Tier	Common Name	Scientific Name	Special habitat needs
II	Mountain chorus frog	*Pseudacris brachyphona*	Wooded hillsides near wet areas
II	Green salamander	*Aneides aeneus*	Damp crevasses in mesophytic hardwoods
IV	Jefferson salamander	*Ambystoma jeffersonianum*	Shallow ponds within woodlands
IV	Cumberland Plateau salamander	*Plethodon kentucki*	Beneath logs or other debris

Table 16. Coverboard sampling locations (n=18) and associated cover types surveyed in 2007 and 2008 at PRP and PALS, southwestern Virginia. Each sampling location contained an array of 6-5 x 20 x 60 cm boards. Boards were spaced at least 1 m apart.

Cover type (N)	Study area	Number of coverboard arrays
Mid-successional (6)	PALS	1
	PRP	5
Pre-SMCRA (5)	PALS	3
	PRP	2
Mature reference (7)	PALS	3
	PRP	4
TOTAL		18

Table 17. Salamander species detected in 2007 and 2008 at PRP and PALS, southwestern Virginia We searched in 4 cover types (early successional reclaimed, mid-successional reclaimed, pre-SMCRA, and mature forest) equally but we captured salamanders in only 2 (except for 1 newt).

Species	Scientific name	Cover type	Total # of captures	Night search captures	Cover board captures	Encounter captures
Longtail salamander	*Eurycea longicauda*	Pre-SMCRA	4	2	2	
		Reference	1			1
Northern red salamander	*Pseudotriton ruber*	Pre-SMCRA	1	1		
Red-spotted newt	*Notophthalmus viridescens*	Mid-successional reclaimed	1		1	
		Pre-SMCRA	10	1	1	8
		Reference	28	1	1	26
Northern slimy salamander	*Plethodon glutinosus*	Pre-SMCRA	5	1	4	
		Reference	13	7	5	1
Southern two-lined salamander	*Eurycea cirrigera*	Pre-SMCRA	1		1	
Spotted salamander	*Ambystoma maculatum*	Reference	0	1		

Table 18. Mean weight and lengths [SE] for all salamander captures by cover type at PRP and PALS in June-August 2007 and May-September 2008. Values for each species within each variable with the same letter were not significantly different (P >0.05) based on Tukey's Studentized Range (HSD) test.

Species	Cover type	No. observed	Mean weight (g)	Mean snout-vent length (mm)	Mean vent-tail length (mm)
Red-spotted newt	Mid-succesional reclaimed	1	2.90 [0] A	47.00 [0] A	54.00 [0] A
	Pre-SMCRA	10	1.07 [0.21] B	27.03 [1.84] B	26.03 [2.54] B
	Mature reference	28	1.41 [0.11] B	31.35 [1.03] B	30.73 [1.14] B
Slimy salamander	Pre-SMCRA	5	4.92 [2.28] A	44.77 [10.58] A	43.97 [12.82] A
	Mature reference	13	5.32 [0.89] A	51.26 [3.73] A	47.56 [5.29] A
Longtail salamander	Pre-SMCRA	4	4.15 [0.55] A	53.30 [2.87] A	89.00 [4.71] A
	Mature reference	1	2.30 [0] A	27.80 [0] B	41.00 [0] B
Northern red salamander	Pre-SMCRA	1	13.60 [0]	85.00 [0]	61.00 [0]
Two-lined salamander	Pre-SMCRA	1	1.50 [0]	35.00 [0]	45.00 [0]

Table 19. Frog species encountered or detected during frog call surveys near water bodies during May-July 2007 and 2008 at PRP and PALS, southwestern Virginia.

Species	**Scientific name**	**Both years**	**2007 only**	**2008 only**
American toad	*Bufo americanus*	E[a]		
Bullfrog	*Rana catesbeiana*	1[b]		
Fowler's toad	*Bufo woodhousei fowleri*		1, 2	
Gray treefrog	*Hyla versicolor*		E	
Green frog	*Rana clamitans*	1, 2		
Pickerel frog	*Rana palustris*			1, 2, 3
Spring peeper	*Pseudacris crucifer*	1, 2, 3		
Upland chorus frog	*Pseudacris feriarum*		2, 3	

[a] Species was encountered on site and not heard during call surveys.

[b] Indicates the North American Amphibian Monitoring Program call intensity score.
1= Individuals can be counted; there is space between calls.
2= calls of individuals can be distinguished by there is some overlapping of calls.
3= full chorus, calls are constant, continuous, and overlapping.

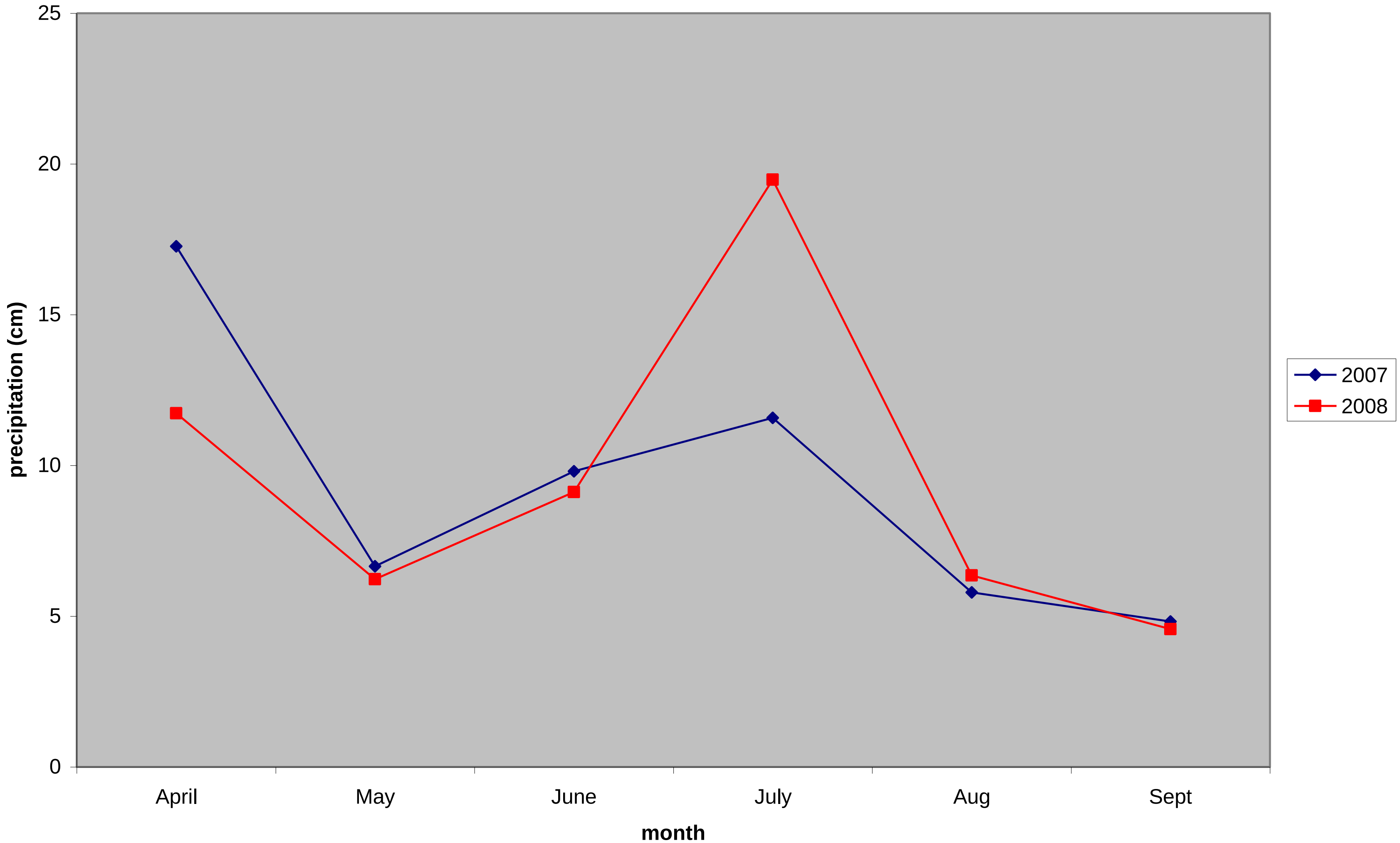

Figure 12. Average monthly precipitation in centimeters in 2007 and 2008 recorded in Wise County, southwestern Virginia by the NOAA National Climatic Data Center (2009).

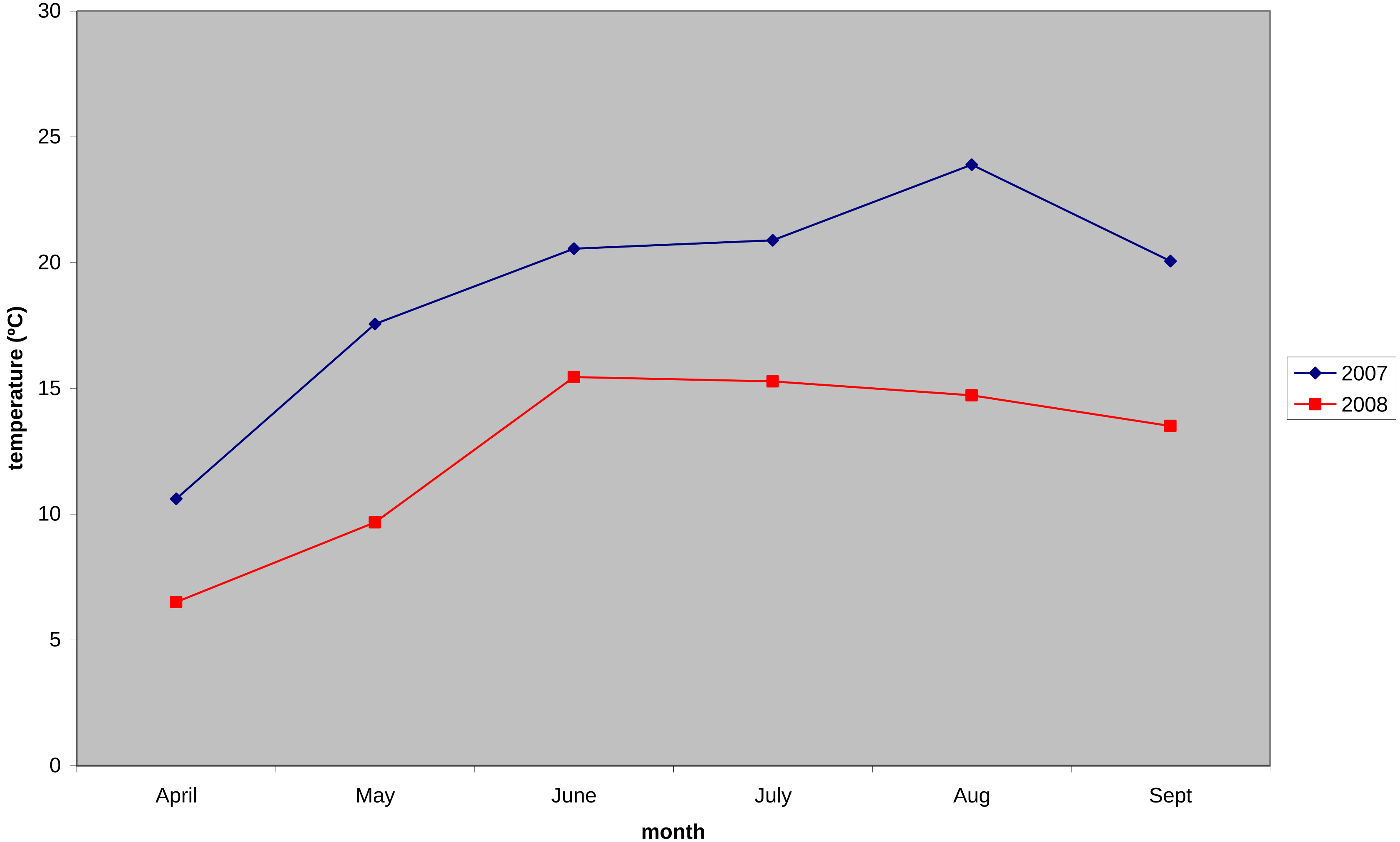

Figure 13. Average monthly temperature in degrees Celsius in 2007 and 2008 recorded in Wise County, southwestern Virginia by the NOAA National Climatic Data Center (2009).

Management Implications and Recommendations

Although mining disturbances can have many negative impacts on wildlife populations, the reclamation process may provide habitat management opportunities for some species. Through various reclamation techniques and procedures, mine lands can be manipulated to attract and support desired wildlife species through proper management (Scott and Zimmerman 1984). The following recommendations may improve the condition of wildlife habitat on reclaimed mine sites:

1. Reduce continued disturbance. This includes continued disturbance from mining operations, road traffic, and human impacts, as well as disturbance from cattle grazing. Several of the reclaimed sites included in this study were heavily impacted by grazing in a short time because of the poor quality food items available to livestock. Heavy cattle grazing can cause increased erosion and depletion of vegetation, reducing cover available to birds.

2. Diversify cover types. Although large expanses of reclaimed grasslands may provide habitat for some area-sensitive grassland birds (e.g., grasshopper sparrow, eastern meadowlark), many birds will benefit from a variety of cover types. The diversity of birds observed on the study areas also supports the necessity for providing a variety of cover types. Species abundances were found to be greater in more heterogenous landscapes; in other words, many birds are associated with a fragmented distribution of habitat (McGarigal and McComb 1995). On the other hand, preservation or creation of small representative patches, referred to as the "living museum approach," may not provide large enough home ranges for some species (Askins 2001).

In addition to different reclamation practices, attempting to maintain cover types of various ages since reclamation will help to produce heterogenous cover, and maintain early successional habitat on the site even as other patches age. This can be done by reclaiming smaller areas as mining is completed rather than reclaiming expansive areas to a single cover type.

3. Diversify vegetation species. Including a variety of less-competitive herbaceous vegetation will allow for effective tree establishment. Species such as foxtail millet (*Setaria italica*), annual rye *(Secale cereal*e), perennial ryegrass (*Lolium perenne*), redtop (*Agrostis gigantea*) , and birdsfoot trefoil (*Lotus corniculatus*) can provide effective erosion control after the first year and are less competitive than traditional herbaceous species used in reclamation (Holl et al. 2001). If soils are treated properly following mining, a multitude of native hardwoods can be established on non-compacted grounds, rather than the typical monocultures of pines and black locust. Although these monocultures grow quickly and survive well on acidic or impoverished soils, hardwood diversity would provide additional habitat complexity to the system. Structural diversity of vegetation on mine sites has been shown to be strongly related to bird species diversity (Karr 1968). In addition to wildlife diversity, many native commercially viable hardwood species can be planted effectively on reclaimed sites (Torbert and Burger 2000). Because of the higher value of some native hardwoods, these species may provide significant income for the landowner over the long term.

4. Reduce the establishment of invasive and non-native vegetation. Although some vegetation species typically planted on reclaimed sites may provide similar structural habitat as natural early successional habitat, native food sources are unavailable. Non-native grasses such as Kentucky-31 tall fescue, sericea lespedeza (*Lespedeza cuneata*), and red, white, and sweet clover (*Trifolium* spp.) are frequently planted during reclamation. Even though these species may provide erosion control and establish quickly, they can prevent the seeding of trees and other more desirable native herbaceous species (Burger and Zipper 2002). Autumn olive (*Eleagnus umbellata*), a species commonly planted on reclaimed sites, can provide food for wildlife and excellent escape and nesting cover. However, autumn olive can quickly overtake some areas because of seed transfer by birds (Miller and Miller 2005).

5. Encourage the establishment of native vegetation. Native woody vegetation is particularly important for birds that depend on food sources such as berries and seeds. Serviceberry (*Amelanchie*r spp.), dogwood (*Cornus* spp.), blueberry (*Vaccinum* spp.), and raspberry (*Rubus* spp.) are all native species that provide fruits for wildlife. Also mast producing trees like oaks (*Quercus* spp.), hickories (*Carya* spp.), beech (*Fagus* spp.) and walnuts (*Juglans* spp.) can provide nuts and seeds for wildlife.

If given time, native herbaceous species have been shown to establish themselves on mine sites, suggesting that diversification can occur as a natural process (Strong 2000). However, these indigenous species typically represent a very low percentage of the overall herbaceous coverage, which may be due to suppression from planted non-natives or unsuitable microhabitat conditions (Strong 2000).

6. Introduce native wildflowers or flowering shrubs where possible. On some sites where acidic soils are not a problem or have been treated with liming agents, the introduction of some hearty native wildflowers or flowering shrubs would greatly benefit some birds. Many wildflowers have been identified for conservation and restoration uses in Virginia (Department of Conservation and Recreation 2006) and could also be used as seasonal herbaceous cover. Flowering plants would provide nectar and seeds, and would attract insects eaten by many bird species.

7. Encourage tree establishment and growth. By reducing the intensity of heavy equipment use on mined sites during reclamation activities, soil compaction can be decreased. Uncompacted soil provides a better rooting medium for native or planted trees. Even if sites are not planted with trees during reclamation, native trees can establish themselves as long as compaction does not prevent successful rooting.

Canopy cover was included in many of the best logistic regression models, suggesting the importance of at least some canopy cover to many bird species. Canopy cover will also improve habitat for salamanders that require leaf litter to retain soil moisture and as foraging habitat. Even in relatively open areas, the establishment of some trees will provide cover and nesting sites for many early successional species.

8. Retain remnant patches of forest/shrubland between mine sites. Retaining some native vegetation between mine spoils, around equipment storage areas and along haul roads can provide some wildlife habitat as well as erosion control during the project (Schaid et al. 1983). Native vegetation can also provide a seed source for the re-establishment following reclamation.

Remnant forested patches in areas that cannot be safely or effectively used for coal extraction can provide important refugia for many species. They also can continue to provide ecosystem services during and following nearby mining operations, such as erosion control. Although we observed few salamanders using remnant forested patches, these areas may provide both important refugia and sources for recolonization for salamanders because of increased canopy cover, leaf litter, and soil moisture. Forested birds can also benefit from remnant patches spared from disturbance.

9. Use treatment ponds and wetlands to provide wildlife habitat. Wetlands established for water quality treatment can provide habitat for reptiles and amphibians, given that water quality in the wetland and/or surrounding bodies of water can support the annual reproductive life cycle for herptiles (Lacki et al. 1992). Amphibians are known to be somewhat tolerant of slightly acidic waters (Freda 1986), although tolerance varies with species and individuals. Generally embryos and larvae are most susceptible to acidity (Freda 1986). However, if ponds and wetlands are treated for pH issues and vegetation is planted to aid in sedimentation and the uptake of heavy metals, these water bodies can provide habitat and allow the invasion of herptiles (Bradley 1987). Some birds may also benefit from wetland habitat as a hunting ground for insect or amphibian prey. Wetlands also provide multiple ecosystem services, such as removing harmful toxins from the water supply, permitting slow groundwater recharge, preventing erosion following heavy rains, increasing organic matter in the soils, and attracting wildlife to the site (Atkinson et al. 1997).

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