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RESEARCH ARTICLE

A BASELINE INVENTORY OF WATERFOWL FROM SURFACE MINE WETLANDS IN THE VIRGINIA COALFIELDS

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ABSTRACT

Surface mining activities result in multiple changes to the structure and function of ecosystems across the Appalachian Mountains of the eastern United States, including the creation of numerous wetlands via the construction of artificial retention ponds and flattened topography that alters surface runoff. While past work has assessed the impacts of such wetland creation on native Appalachian wildlife, little is still known about if and how wetlands created on active and former surface mines are used by waterfowl taxa. We performed a seasonal study of wetlands on two former surface mine complexes in Wise County, Virginia in 2016 and 2017 to assess waterfowl species' use of such wetland habitats. We found substantial waterfowl diversity at wetlands on former surface mines, encompassing 16 species and including both native residents and passage migrants. Nearby unmined wetlands had similar diversity, with 19 species inventoried over the same period. Several of these species are uncommon within the Appalachian region and seem to be tied to the passage of high-latitude storm systems in winter months. Our results suggest that wetland creation on former surface mines may supplement available habitat for both resident and migratory waterfowl across the Virginia coalfields, and we provide a preliminary inventory of such taxa that can guide future work.

Keywords: Appalachia, coal, ecology, pond, wildlife.

INTRODUCTION

The Appalachian Mountains of the eastern United States have experienced extensive landscape change as a result of surface coal extraction, with an estimated 5900 km^2 of surface-mined and reclaimed habitats created as a result of mineral extraction to date (Townsend et al., 2009; Pericak et al., 2018). These activities have had pronounced impacts on habitats within the Appalachian region, particularly with respect to the conversion of temperate hardwood forest

ecosystems to grassland or shrubland habitats on reclaimed surface mines. Reduced forest cover and replacement by grasslands, for example, is a driver of altered ecosystem dynamics on mined sites (Zipper et al., 2011; Gurung et al., 2018), while altered topography and fragmented ridgetop forests exert substantial control over the ecology of terrestrial taxa (Wickham et al., 2013; Hinkle et al., 2018; Maigret et al., 2019; Margenau et al., 2019).

Surface mining activities also result in the widespread creation of wetland habitats on formerly steeply-sloped terrain. Many wetlands on surface mines are formed incidentally from topographic changes that reduce surface runoff and enhance the pooling of water following precipitation events, while others are intentionally constructed as retention or settling ponds to mitigate water quality concerns related to sedimentation and runoff (Wieder, 1989; Atkinson & Cairns, 1994; Atkinson, 2010). While few estimates exist in the literature of how much new wetland area has been created due to surface mining regionwide, mining practices have likely driven the large-scale creation of new wetland habitats in physiographic regions that were not historically characterized by a high density or number of wetland habitats due to steep terrain (Tiner, 1986; Thompson et al., 2007).

Past research has shown that surface mine-associated wetlands increase habitat availability for a number of taxa, including herpetofauna (Lacki et al., 1992; Lannoo et al., 2009), mammals (Brenner & Hofius, 1990; Lacki et al., 1991), and birds (Rumble, 1989; McKinstry & Anderson, 2002). However, little information currently exists related to the use of mine-associated wetlands by waterfowl in the central Appalachian region, particularly from the coalfields of the Cumberland Mountains in eastern Kentucky and southwestern Virginia. Nevertheless, this region is located between two major waterfowl flyways (Lincoln, 1935; Nichols et al., 1995), with presumably a diverse regional species pool that may make use of wetlands formed on former surface mines. Understanding this habitat use will be critical to both managing wetlands on former surface mines as wildlife habitat and understanding the regional dynamics of waterfowl populations across the broader landscape.

From November 2016 to April 2017, we performed a survey of waterfowl at wetlands on two former surface mine complexes in Wise County, Virginia—the most heavily surface mined county in Virginia and one of the most mining impacted counties in the Appalachian region. Our goal was to produce the first formal inventory of waterfowl taxa using mine-associated wetlands across the Virginia coalfields. We also examined waterfowl diversity at two naturally occurring wetland complexes across the same area to compare waterfowl use of natural habitats with those artificially created on former surface mines.

METHODS

We selected two wetland habitats for study from two large surface mine complexes in Wise County, Virginia: a 120 ha surface mine on Dale Ridge near Coeburn, Virginia and a 100 ha surface mine encompassing the headwaters of Yellow Creek near Wise, Virginia (Fig. 1). Wetlands on both sites were large (>0.5 ha) impoundments constructed for sediment retention and erosion control and were surrounded primarily by large monocultures of planted, non-native vegetation (*Elaeagnus umbellata* and *Lespedeza sericea*), with *Typha* spp. as the predominant emergent vegetation in the wetlands proper. All wetlands were of similar age, being constructed in the 1980s-1990s, and none were associated with any inventoried locations experiencing acid mine drainage or related water quality issues (Virginia DMME, 2020), due to their reliance primarily on surface runoff.

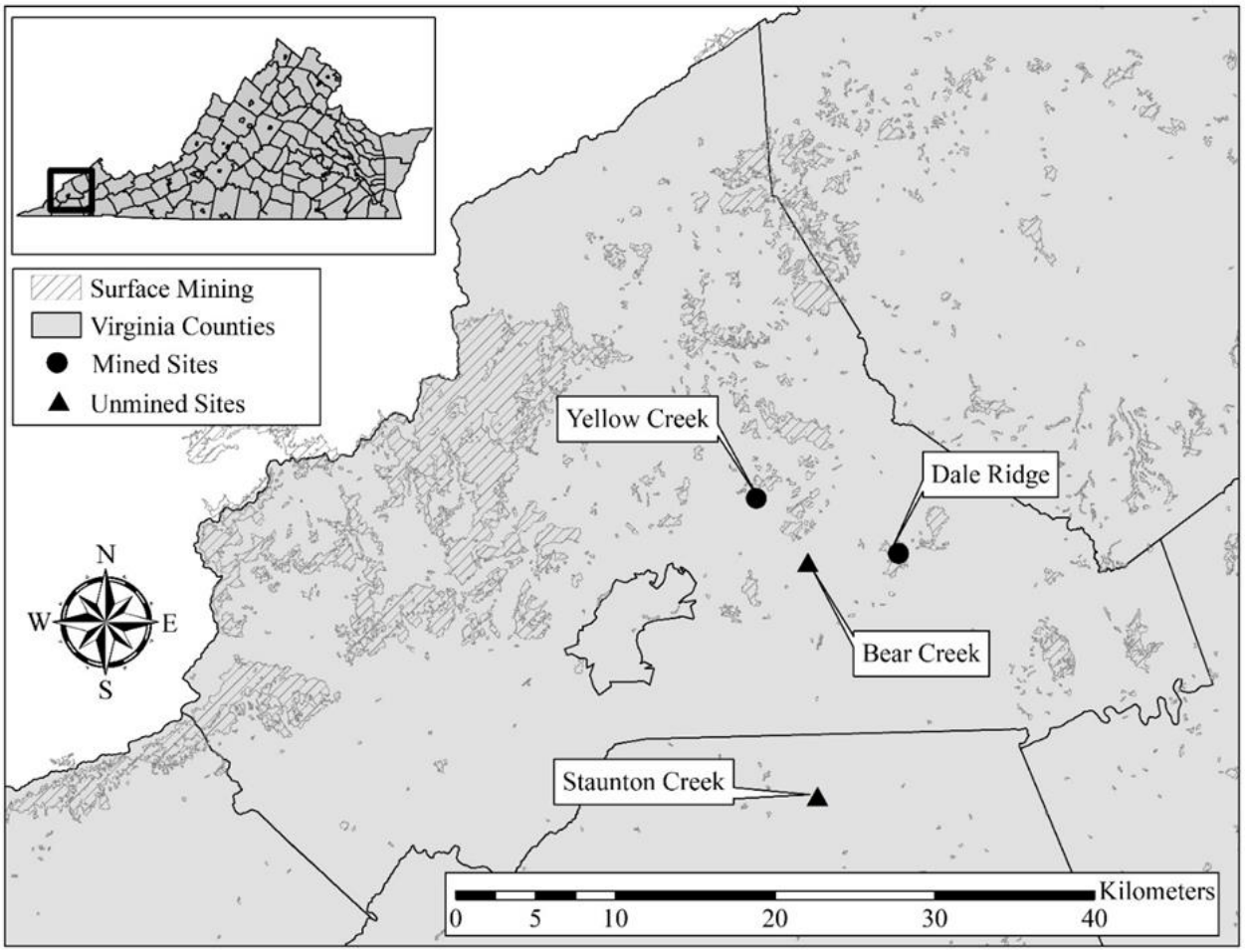

Figure 1. Map of study sites. Highlighted area in inset map denotes location of the study area relative to the rest of Virginia. Surface mining polygons were derived from data originally published by Pericak et al. (2018).

In addition to mine-associated wetlands, we also performed waterfowl inventories at two wetland habitats not associated with surface mines (Fig. 1). The first was a 1.42 ha wetland formed due to beaver impoundments on Staunton Creek on the south slope of Stone Mountain. This site is surrounded by dense mixed hardwood forest, with predominantly open water and emergent vegetation in the wetland proper. The second site was a 2.42 ha wetland located near the headwaters of Bear Creek near Wise, Virginia. This site is surrounded by mixed hardwood forest interspersed with planted White Pine (*Pinus strobus*) and is characterized by predominantly open water. We estimated the wetland area, canopy cover, and proportion of open water at all sites using 0.3 km pixel resolution orthophotography (Virginia Geographic Information Network, 2017) in ArcGIS v.10.1 and field visits to each wetland. General wetland habitat characteristics were similar across all sites, with the exception of the mined/unmined context of each wetland (Table 1).

Table 1. Habitat characteristics of four wetlands used for waterfowl inventories in 2016 and 2017.

Wetland	**Type**	**Size** (ha)	**Elevation** (m asl)	**Canopy Cover** (%)	**Open Water** (%)	**Predominant upland vegetation**
Dale Ridge	Mined	1.61	1990	8.1	71.4	Scrub/Shrub
Yellow Creek	Mined	0.94	2500	0	70.6	Scrub/Shrub
Bear Creek	Unmined	2.42	2550	8.7	73.6	Mixed Hardwood Forest
Staunton Creek	Unmined	1.42	1670	59.2	38.0	Mixed Hardwood Forest

Accessibility restrictions imposed by a high regional rate of private landownership precluded a fully random selection of wetlands from the broader region as study sites, although we selected individual wetlands at random from available public lands and accessible surface mines.

We inventoried waterfowl by way of automated surveys using a Bushnell eight-megapixel Trophy Cam motion-sensitive game camera (Overland Park, Kansas) installed at each site. Game cameras were installed on 1 November 2016 and sampled until 1 April 2017, with visits made approximately every other week during this time period to check camera operation and download photographs. While it was not possible to place the entirety of each wetland within each camera's field of view, we chose locations for camera installation at each site along the wetland margin that provided the maximum viewable extent of both the wetland and adjacent vegetation along its margin.

We supplemented automated sampling with regular vantage-point surveys at each site. Vantage-point surveys were performed by selecting a location above the wetland that provided the best view of the habitat, with weekly surveys (also from 1 November 2016 to 1 April 2017) conducted at one-hour intervals randomized within the constraints of site accessibility. We then recorded the species seen in both vantage-point surveys and automated game camera observations, pooling these data to create a list of detected species at each site. We used species accumulation curves (Gotelli & Caldwell 2001) following the completion of the sampling period to assess species richness against overall sampling effort across mined and unmined sites. We also grouped species inventoried during our surveys into classifications reflecting their regional status (native breeding, native non-breeding, or passage migrant) using distributional data provided by the IUCN Red List for Birds (BirdLife International 2019).

RESULTS

We recorded 23 total waterfowl species at the wetland sites inventoried for this study (Table 2) across 875 game camera observations and 19 hours of vantage point surveys. While overall species richness was similar between mined and unmined wetlands (16 versus 19 species, respectively), there was some turnover in species between these general types of sites. Specifically, we recorded three species (*Anas crecca, Mareca americana*, and *Anser rossii*) at mined sites but not from unmined sites in the same general vicinity. By contrast, we recorded seven species (*Anas rubripes, Aythya collaris, Oxyura jamaicensis, Mergus merganser, Anser caerulescens*, and *Anser albifrons*) at unmined sites that were not observed at wetlands on nearby mined sites. Species accumulation curves approached an asymptote across both mined and unmined wetland groups (Fig. 2), suggesting adequate sampling of local waterfowl fauna across these wetland types.

Table 2. Waterfowl taxa detected across wetlands on mined and unmined sites in the Virginia coalfields in 2016-2017. Plus signs denote detection; species statuses reflect those defined by the IUCN Red List for Birds (BirdLife International 2019). "Unknown/Not Inventoried" denotes species lacking regional coverage in the aforementioned dataset.

Species Name	Common Name	Mined Sites	Unmined Sites	Regional Status
Aix sponsa	Wood Duck	+	+	Native Resident
Anas acuta	Northern Pintail	+	+	Passage Migrant
Anas crecca	Green-Winged Teal	+		Passage Migrant
Anas platyrhynchos	Mallard	+	+	Native Resident
Anas rubripes	American Black Duck		+	Native Non-Breeding
Anser albifrons	Greater White-Fronted Goose		+	Unknown/Not Inventoried
Anser caerulescens	Snow Goose		+	Unknown/Not Inventoried
Anser rossii	Ross's Goose	+		Unknown/Not Inventoried
Aythya affinis	Lesser Scaup	+	+	Passage Migrant
Aythya americana	Redhead	+	+	Passage Migrant
Aythya collaris	Ring-Necked Duck		+	Passage Migrant
Aythya marila	Greater Scaup	+	+	Unknown/Not Inventoried
Branta canadensis	Canada Goose	+	+	Native Non-Breeding
Bucephala albeola	Bufflehead	+		Passage Migrant
Fulica americana	American Coot	+	+	Passage Migrant
Lophodytes cucullatus	Hooded Merganser	+	+	Native Resident
Mareca americana	American Wigeon	+		Unknown/Not Inventoried
Mareca strepera	Gadwall	+	+	Unknown/Not Inventoried
Mergus merganser	Common Merganser		+	Unknown/Not Inventoried
Mergus serrator	Red-Breasted Merganser		+	Passage Migrant
Oxyura jamaicensis	Ruddy Duck		+	Passage Migrant
Podilymbus podiceps	Pied-Billed Grebe	+	+	Native Resident
Spatula discors	Blue-Winged Teal	+	+	Passage Migrant

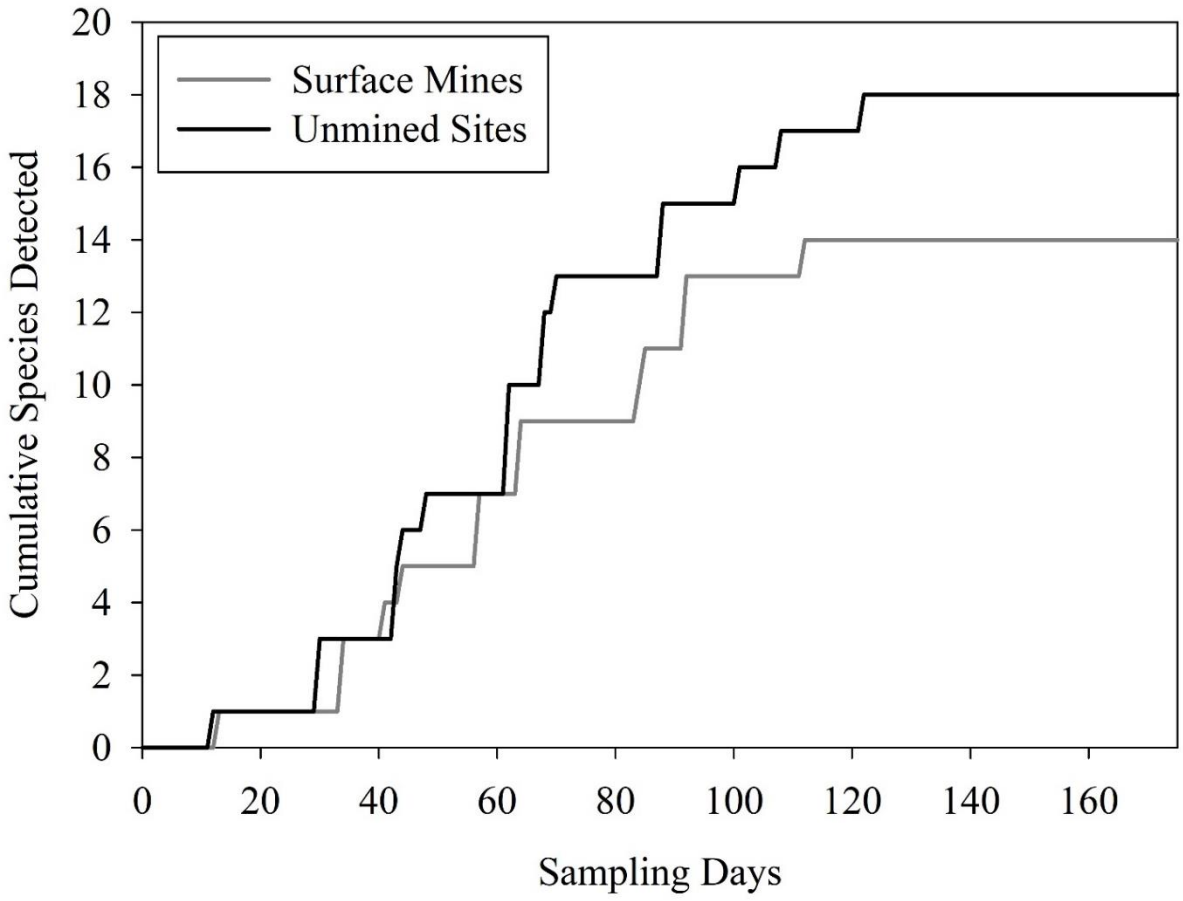

Figure 2. Species accumulation curves for unmined (black line) and mined (gray line) sites during automated waterfowl sampling in 2016 and 2017.

Waterfowl recorded across all wetlands were primarily passage migrants that were generally observed following the passage of large storm systems during winter and early spring. Most initial observations of species were recorded in December and January (Table 3), particularly in the 24-48 hours following the passage of such weather systems. Waterfowl observations recorded by automated game cameras peaked during early morning, particularly just prior to and after local sunrise, with a secondary peak in late afternoon and evening (Fig. 3). Most species recorded during surveys are known from the larger physiographic context of the study area, although three species (*Anser caerulescens, Anser rossii*, and *Anser albifrons*) are considered uncommon across this region and form, to our knowledge, the first recorded observations of these species from the Virginia coalfields in the peer-reviewed literature.

Table 3. Waterfowl detections by month at four study sites across southwest Virginia in 2016-2017. Dale Ridge and Yellow Creek are wetlands formed on former surface mines; Bear Creek and Staunton Creek are naturally-occurring wetlands not associated with surface mines. Shaded months for a species indicate detection during that month.

	Dale Ridge					Yellow Creek					Bear Creek					Staunton Creek				
Species	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar	Nov	Dec	Jan	Feb	Mar
Aix sponsa	■	■	■	■	■												■	■	■	■
Anas acuta			■															■		
Anas crecca			■	■																
Anas platyrhynchos	■	■	■	■	■	■	■	■	■	■						■	■	■	■	■
Anas rubripes																		■		
Anser albifrons																		■		
Anser caerulescens																		■		
Anser rossii			■																	
Aythya affinis			■															■		
Aythya americana		■															■			
Aythya collaris													■							
Aythya marila			■															■		
Branta canadensis		■	■	■	■											■	■	■		
Bucephala albeola			■																	
Fulica americana		■															■			
Lophodytes cucullatus		■	■				■	■					■							
Mareca americana									■											
Mareca strepera									■					■						
Mergus merganser																		■		
Mergus serrator														■						
Oxyura jamaicensis														■						
Podilymbus podiceps		■	■				■	■				■	■							
Spatula discors								■										■	■	

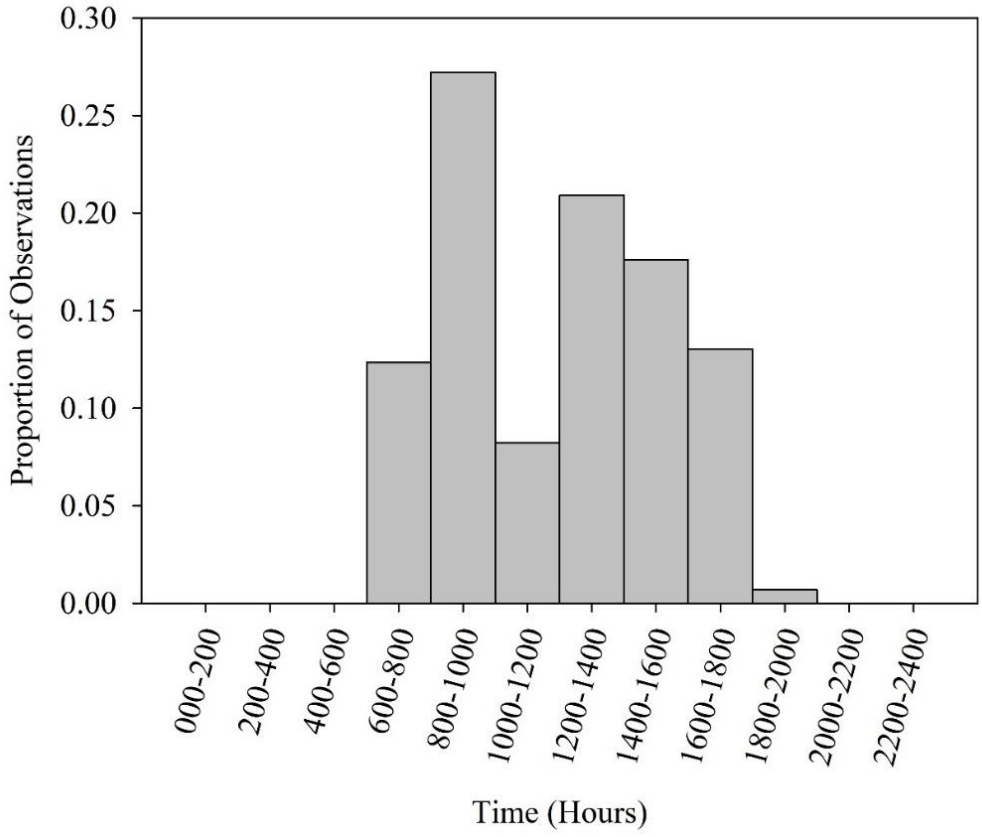

Figure 3. Proportion of game camera images collected at various times of day across all sites during 2016 and 2017.

DISCUSSION

To our knowledge, our work provides the first survey of waterfowl from surface mine associated wetlands in the Virginia coalfields region and from the Cumberland Mountains region of southwest Virginia, in general. We found substantial waterfowl diversity within this region, both at artificial wetlands on former surface mines and wetlands not associated with mined lands. Our overall inventory of waterfowl taxa is indicative of species known from both the Mississippi and Atlantic Flyways (Bellrose, 1968; Heusmann & Sauer, 2000), with most taxa being passage migrants inventoried during and shortly after the passage of major storm systems during winter months. Such storm systems – which typically occur as low pressure systems passing to the north or south of the central Appalachian region, leading to winter weather conditions following a frontal passage – are one of the predominant weather scenarios leading to prolonged cold air and snowfall across the southern and central Appalachians (Perry et al., 2007; Perry et al., 2010). Past studies have found that such storm systems and related measures of winter severity (consecutive days of cold temperatures, snow depth, and snow cover duration) are a major factor influencing the timing and intensity of North American waterfowl migrations (Notaro et al., 2014; Schummer et al., 2014).

We noted many of our observations of passage migrants, particularly those species consisting only of observations of one or a few individuals on a single survey visit, co-occurring with the passage of strong storm systems and associated outbreaks of cold temperatures and snowfall across our study area. In fact, the majority of our waterfowl observations occurred during December and January, when such storm systems were most active during our study period. By contrast, we did not observe dramatic changes in observations of more year-round wetland residents, such as Wood Ducks, Canada Geese, and Mallards, corresponding with these same storm systems. While this suggests that significant winter storm systems may facilitate the movement of some migratory waterfowl species into the Cumberland Mountains, our small number of sampled wetlands and a lack of context data in the form of past waterfowl surveys within our study area precludes a definitive link between the passage of weather systems and waterfowl movements within the region. Our observations, however, present opportunities for future, hypothesis-driven work seeking to investigate a link between weather conditions and waterfowl movements within the central Appalachians, similar to those observed in other states (Schummer et al., 2010).

We found highly similar waterfowl species at wetlands on both mined and unmined sites, despite some variability in species composition across individual wetlands. Wood Ducks and Mallards both appeared to be especially abundant at wetlands on former surface mines and unmined reference sites. Both species are common at naturally-occurring wetlands in the broader Appalachian region and have been inventoried in multiple previous studies (Boynton, 1994; Bulluck & Rowe, 2006; Zimmerman et al., 2015). However, we additionally recorded seven species that we found exclusively at wetlands associated with unmined sites and three species exclusively associated with wetlands formed as a result of surface mining activities.

One outstanding question not addressed by our dataset is whether such taxa inventoried solely at mined or unmined sites are reflective of an actual preference for particular habitat types. Because our survey methodology primarily used automated survey methods that did not allow for a comprehensive assessment of the entirety of each site nor information regarding the frequency of recaptures in game camera images, we did not feel confident using count data to make inferences about the relative abundance of waterfowl species at each site. This is especially relevant since our game cameras likely captured multiple images of the same individuals moving throughout

wetlands during particular days. Similarly, it is likely that we may have missed observations of uncommon species, despite species accumulation curves suggesting a relatively thorough sampling effort.

Similarly, our mined and unmined sites were located within substantially different landscape contexts related to the history of surface mining (or lack thereof) at a given site. The typical forest types across our study region are generally mixed mesophytic forests interspersed with more xeric hardwood forests on upland ridges (Braun, 1942). However, surface mining activities replace these forest types with grass or shrub-dominated environments that often are characterized by exotic or invasive vegetation and facilitate changes to ecosystem services following mining (Zipper et al., 2011; Gurung et al., 2018). These differences ultimately result in more open-canopy wetlands and may also influence wetland plant assemblages and other structural characteristics of wetlands that may be key to resident fauna (Branduzzi et al., 2020), although little work has been performed in our immediate study region to gauge these specific impacts. Disentangling if and how the landscape contexts of wetlands on surface mines impact waterfowl presence and abundance differently from local-scale wetland features may be especially crucial for future work expanding on our data.

As a result of the aforementioned limitations, we are cautious about making inferences about the relative rarity of particular species, as well as inferences about the apparent absence of particular species from general groupings of wetlands within a mined or unmined context. Our data are instead best viewed as a preliminary checklist of waterfowl using mine-associated wetlands across the Virginia coalfields rather than a definitive assessment of differences between waterfowl assemblages on mined and unmined sites. Future researchers may want to build upon this preliminary inventory to perform a more robust assessment of the detection of waterfowl taxa and their relative abundances at wetlands on both mined and unmined sites. Such a comparison may shed light on individual species' preferences for types of sites, as well as associations between those species and particular habitat variables at the local or landscape scale that are influenced by mineral extraction activities.

Nevertheless, our surveys detected several species, including the Greater White-Fronted Goose, Snow Goose, and Ross's Goose, that are more commonly encountered in regions well west (Prevett & MacInnes, 1972; Alisauskas, 1998; Abraham et al., 2005) and east (Hill &Frederick, 1997; Gauthier et al., 2005) of the Cumberland Mountains and, to our knowledge, have never been inventoried from the Virginia coalfields in the scientific literature. One of these species (Ross's Goose) was present at constructed wetlands associated with a former surface mine, and our encounters with each species were constrained to a single observation during vantage point surveys, most following the passage of major storm systems. These observations were likely the result of migratory behavior associated with such storm systems (Smith & Hayden, 1984), and all of these species have been informally reported in separate citizen science datasets from the larger region surrounding our study sites in past years (eBird, 2019). However, the use of artificial wetlands on former surface mines by Ross's Goose appears to be a novel habitat report for the central Appalachian region.

More broadly, our data suggest that the creation of artificial wetlands on surface mines across central Appalachia has not been inconsequential to waterfowl taxa—a factor that may be of interest to land and wildlife managers. We found evidence of substantial use of mine-associated wetlands by waterfowl, including by passage migrants and year-round residents. Wetlands on surface mines are often located in high-elevation environments that are typically not predisposed to natural wetland formation, given the proclivity for upland wetlands in the Cumberland

Mountains to form infrequently and be relatively small in size (Thompson et al., 2007, 2012). Beyond the general increase in the number and density of wetlands as a result of surface mining, an examination of the elevational and structural differences in wetland habitats between mined and unmined sites in the central Appalachian coalfields may help researchers gain further insight into if and how wetlands on former surface mines are influencing habitat availability for waterfowl and other wetland-associated taxa.

Our data also were limited to the presence of waterfowl species and did not address parameters related to the health or demography of waterfowl populations. The selection of wetland habitats by waterfowl at any given site may be driven by factors such as food availability and water quality (Longcore et al., 2006; Kaminski & Elmberg, 2014) - features that may be influenced by mineral extraction and subsequent reclamation activities and were not addressed by our presence-only dataset. Past work, for example, has found that some mine-associated wetlands, such as tailings ponds and retention basins, may present a toxicity risk to waterfowl when acidity and metal levels are high (Isanhart et al., 2011). Our study sites did not contain any such known contamination issues, although it is plausible that some wetland sites throughout the Appalachian coalfields may present similar risks. While our inventory provides a foundation for addressing the management of regional waterfowl populations on wetlands associated with former surface mines, these questions will be crucial for appropriately designing management guidelines for such taxa in future work.

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