The impact of wetlands on avian diversity and species richness at Brookhaven National Laboratory (Long Island, New York)

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Abstract

Wetlands perform important ecological functions and provide heterogeneity in the landscape. The destruction of wetlands throughout the United States has drastically impacted biodiversity and ecosystem health. Our objectives were to investigate the bird diversity and species richness in wetland and upland areas of Brookhaven National Laboratory (BNL). Bird point counts with a 150-meter buffer were performed at 32 stations located at various distances from wetlands between 2000 and 2016. 128 bird species were present at BNL, with 18 of these species found only in wetland areas and 11 of these species found only in upland areas. We found a negative trend in bird diversity and species richness along the wetland to upland gradient. Bird diversity and species richness was significantly higher in areas with wetlands compared to areas without wetlands. Bird point count stations located between 150 to 500 meters from a wetland had significantly higher bird diversity and species richness than stations located between 500 meters and 2200 meters. Wetlands provide crucial habitat, shelter, resources, and nesting sites for birds. Many birds also rely on uplands and waterfowl prefer wetlands with larger forest area surrounding them. It is important to conserve wetland networks throughout Long Island as climate change and other anthropomorphic factors impact birds and the landscape.

Introduction

Wetlands perform important ecological functions such as, carbon sequestration,[1] water filtration,[2] and hydrologic stabilization, which can minimize the effects of flood and drought periods.[3] They also support uniquely adapted species and high biodiversity by providing crucial wildlife habitat and high productivity.[4,5,6] Many migrating and resident bird species rely on wetlands and their adjacent uplands for breeding, food, and shelter.[7] In fact, approximately 80 percent of the breeding bird population in the United States are dependent on wetland ecosystems.[8] The destruction of wetlands through drainage, dredging, degradation, and filling in the United States has drastically impacted crucial bird habitat.[8] In New York, between the 1780s and 1980s, approximately 60 percent of wetlands were destroyed primarily for agriculture and other land uses.[9,10]

Wetlands that are considered as navigable waters or within significant distance of navigable waters received protection in 1977 from Section 404 of the Clean Water Act which required the Army Corps of Engineers to obtain a permit before dredging or filling a wetland.[8] In 1975, New York implemented the Freshwater Wetlands Act which stated that wetlands must be at least five hectares to be considered protected (with exceptions for small wetlands considered to have special importance) and that a buffer of 30.5 meters around the wetland must be regulated.[11] These protections may not be sufficient because small, isolated wetlands and large areas of adjacent upland habitat must also be protected to adequately conserve biodiversity and ecosystem health.[12,13,14,15] In 2001, the federal court ruled that isolated intrastate waters were protected if they provided migratory bird habitat in the case of Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers (SWANCC).[16] Furthering our understanding of

wetland ecology and the influence that wetlands have on bird diversity will be important for policy-making and for their conservation.

We investigated bird diversity and richness at wetland and upland sites at Brookhaven National Laboratory (BNL) in Long Island, NY. Research indicates that wetlands in many regions have high bird abundance and diversity including the deciduous forested freshwater wetlands in Massachusetts[17] and the depressional marshes of the Prairie Pothole Region of Iowa.[18] At BNL, the pitch pine (*Pinus rigida)* / oak-dominated (*Quercus* spp.), fire-dependent ecosystem has been degraded by fire suppression, resulting in homogeneity of old growth forest and risk of crown fires. D.I. King et al. found that managing fuel loads through thinning pitch pine forest increases the abundance of scrub-shrub birds, but reduces the abundance of mature forest birds.[19] Therefore, a healthy mosaic of ecosystems and habitat heterogeneity may optimize bird diversity and evenness in the pine barrens. We hypothesize that wetlands support higher bird diversity than upland areas in the pine barrens and contain unique bird species that are not found in upland areas.

Study Area

Brookhaven National Laboratory (BNL) is a research site of 2,153 hectares located on Long Island, New York and funded by the U.S. Department of Energy.[20] One-tenth of the total land area has been dedicated to the Upton Ecological and Research Reserve for conservation purposes.[21] About 1,394 hectares are part of the pine barrens region,[22] and about 688 hectares of the site have been developed.[23] The three primary habitat types at BNL are pitch pine / white oak (*Quercus alba),* scarlet oak (*Quercus coccinea*) / heath (Ericaceae) forest, and pitch pine / mixed oak-heath.[22] BNL is home to over 350 plant species, 33 mammal species, 13 amphibian species,

12 reptile species,[23] and 131 avian species.[22] As of 2014, 34% of plant species found at BNL were not native.[24] The U.S. Fish and Wildlife Service's National Wetland Inventory classifies BNL's wetlands as palustrine freshwater ponds that flood for short time periods and palustrine freshwater forested/shrub wetlands that flood seasonally.[25] As of 2004, the Peconic River, which flows through the property, was considered by the National Wetland Inventory to be a lower perennial system with an unconsolidated bottom.[25] Because BNL stopped discharging wastewater into the Peconic River in 2015, the river is now dry for much of the year.[22] Although the pine barrens are a fire-maintained ecosystem, the reigning fire management practice for the past 75 years has been suppression.[22] The Southern Pine Beetle was first documented on Long Island in 2014, and is now considered to be widespread.[22] The Environmental Protection Division has plans to continue to monitor the forests for the presence of the Southern Pine Beetle and to consider appropriate responses to an infestation.[22]

Methods

Migratory bird monitoring at BNL began in the summer of 2000 with five transects. Bird point counts took place at stations spaced approximately 300 meters from each other, positioned to reduce the likelihood of counting the same individual twice. The original five transects were the Biology Field Transect (BF) consisting of five stations, the East Transect (ET) consisting of three stations, the North Transect (NT) consisting of three stations, the Peconic River Transect (PRB) consisting of four stations, and the South Transect (ST) consisting of five stations. In 2010, the location of the last station in the BF transect was changed due to the construction of the Long Island Solar Farm. The Z-Path Transect (ZP) was implemented in March 2002 and consists

of eight stations. The Solar Farm Transect (SF) was created in May 2010 and consists of three stations. The total number of stations used from 2000 to 2016 is 32 (Figure 1).

Point counts were conducted in a double approach, similar to the one described by Nichols et. al.[26] Two observers performed a bird point count approximately five times per station per year from 2000 to 2016 between March and October. The bird point count at the first transect each day began between 5:00 AM to 8:00 AM. The observers spent five minutes at each point. Any bird that vocalized or came into view was counted. During the bird point counts, each individual detected within a 152.4 meter (500 feet) buffer was recorded.

An ArcMap™ Geographic Information System (Version 10.1, ESRI, Redlands, CA) was used to map all of the stations and their 152.4 meter buffers, to clip wetlands within each buffer, and to determine how far each station was from the nearest wetland. We used a previously-generated map that contained all of the points and buffers used throughout the years of bird point counts at BNL as well as a wetland layer. The "Clip" function was used to measure the area of each wetland that fell within each buffer. We added a field to each new attribute table corresponding to the clipped shapefiles and calculated the area of the clipped polygons. Using the "Near" function, we calculated the distance from each point to the nearest wetland.

We used the package "vegan" in Program R (The R Foundation, Vienna, Austria) to calculate the Shannon-Wiener diversity indices[27] and species richness values for each bird point count since May 2000. We used an unequal-variance *t* test to compare the mean species richness and the mean Shannon-Wiener diversity index of birds in areas that contain wetlands to areas that do not contain wetlands. To investigate the effects of the wetland to upland gradient on mean Shannon-Wiener diversity index and mean species richness of birds, we calculated a regression line, goodness of fit (R^2), and Pearson correlation coefficient (r) for each, using the

bird point count stations' distance to the nearest wetland. We performed ANOVAs with a 95% confidence interval and Tukey's HSD test to compare Shannon-Wiener diversity index and species richness at stations that contain a wetland in their buffer, stations that are located within 500 meters from the nearest wetland, and stations that are located over 500 meters from the nearest wetland. We also counted species that were unique to areas that contained wetlands, species unique to uplands (with no wetlands), and species found in both wetland and upland habitats.

Results

A total of 128 avian species were documented in the past 17 years of point counts at BNL. Of these, 18 species were only found in buffers that contained a wetland, while 11 were only found in buffers that were solely composed of upland habitat (Table 1). Mean Shannon-Weiner diversity indices per station ranged from 1.35 (±0.06) to 2.00 (±0.04) (Figure 2) and species richness averages ranged from 5.04 (±0.24) to 9.78 (±0.28) per station (Figure 3). Bird point count stations that contain wetlands within their buffer had a significantly higher mean Shannon-Wiener diversity index compared to those without wetlands, which had a mean diversity index of 1.80 (±0.01) and 1.59 (±0.01) respectively ($p: <0.001$, df: 2867, t: 10.5) (Figure 4). Mean bird species richness at stations containing wetlands is 7.95 (±0.09), which is significantly higher than stations without wetlands, which have a mean bird species richness of 6.50 (±0.07) ($p: <0.001$, df: 2673, t: 12.7) (Figure 5). Stations that contain wetlands within their buffer had the highest mean Shannon-Wiener diversity index and stations that had a center point located within 500 m from the nearest wetland had a higher mean Shannon-Wiener diversity index than stations that had a center point located farther than 500 m from the nearest wetlands

(Figure 6). These means are statistically significant from each other (p: <0.001, df: 2, f: 62.0). Stations containing wetlands had significantly higher bird species richness than stations within 500 m from wetlands, which had significantly higher bird species richness than stations farther than 500 m from wetlands (p: <0.001, df:2, f: 91.2) (Figure 7). Shannon-Wiener diversity indices are negatively correlated with distance from wetland (R^2: 0.30, r: -0.55) (Figure 8). Bird species richness values are also negatively correlated with distance from wetland (R^2: 0.30, r: -0.55) (Figure 9).

Discussion

Our hypothesis of a negative correlation between bird diversity and proximity to wetlands was supported. Our second hypothesis was also supported. A number of shorebirds, geese, warblers, and other songbirds were only found in wetland areas, while a number of songbirds and a few waterfowl were only found in upland areas (Table 1). A few of these species have a special conservation status. The Greater Yellowlegs, which was only found in wetland areas, is recognized as a species of greatest conservation need.[22] The Eastern Whip-poor-will and the Glossy Ibis, also of greatest conservation need, were only found in upland areas.[22]

While our results suggested that wetland proximity impacted bird diversity, there are many other factors that could be influencing diversity as well. According to Riffell et al., forest patch area has an impact on species richness, but the size of a wetland does not.[28] Roads taken into account on their own merit did not influence bird diversity, but they did have an impact when coupled with forest patch area.[28] The National Wetland Inventory classifies most of BNL's wetlands as being forested/shrub wetlands.[25] We did not take forest patch area into account for this study. However, it is possible that it also had a bearing on species richness, even for upland

species. Riffell et al. found that upland species were more likely to utilize wetlands that were similar to uplands in vegetative structure.[28] This could explain the use of wetlands by upland birds in our study, since the wetlands at BNL tend to be forested. After also observing upland species on or near a wetland, Petersen et al. concluded that wetlands are not only of importance to species that nest in wetlands, but also to other species that may nest elsewhere, yet still benefit from the ecosystem services that wetlands provide.[29]

The negative correlation of diversity and distance from a wetland suggests that there are stratifications in wetland use by birds at BNL. While the differences in the diversity indices were statistically significant, they were not strikingly different from each other. Diversity was not high at any distance from a wetland. It could be that diversity is not what it could be due to prolonged fire suppression and perhaps even to some degree, the introduction of the Southern Pine Beetle. It is becoming increasingly important to preserve the wetlands we have left. For adequate bird conservation, our diversity indices suggest that it may be important to protect both wetlands and their adjacent uplands for adequate bird conservation.

Wetland protection is crucial for conserving birds because they utilize this habitat for shelter, resources, and breeding. Even birds that can adapt to anthropogenic sites, such as mallards, preferentially select protected wetland areas during the nonbreeding season.[30] Beatty et al. also found that these mallards prefer wetlands with larger protected areas, which suggests that adjacent upland forests are important for maintaining high bird diversity.[30] Protecting wetland networks throughout Long Island will be important for bird conservation as climate change and other human-induced factors have significant impacts on the landscape.[30,31]

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Figures & Tables

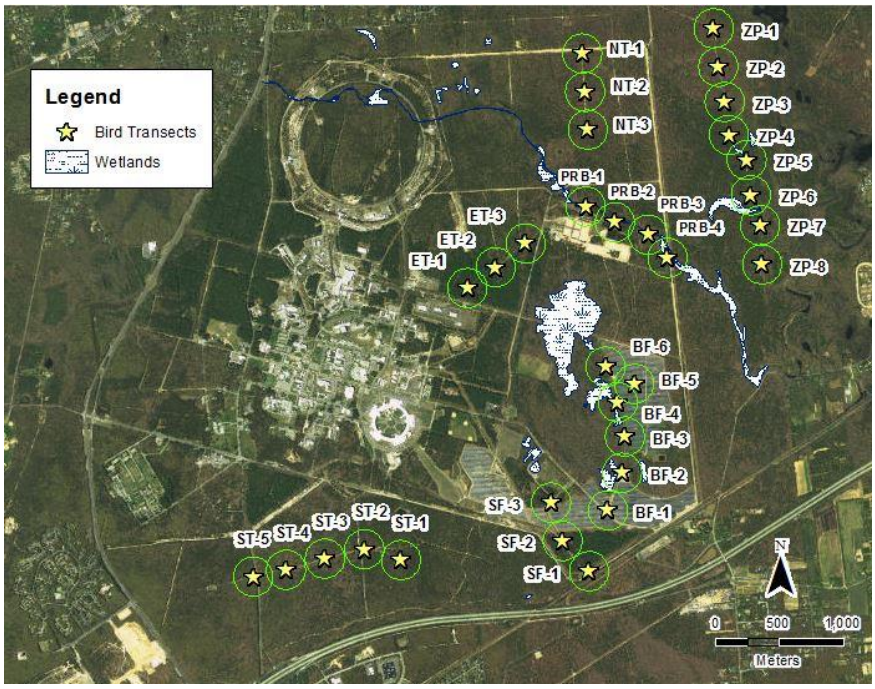


Figure 1. Map of the seven point count transects and the wetlands at Brookhaven National Laboratory

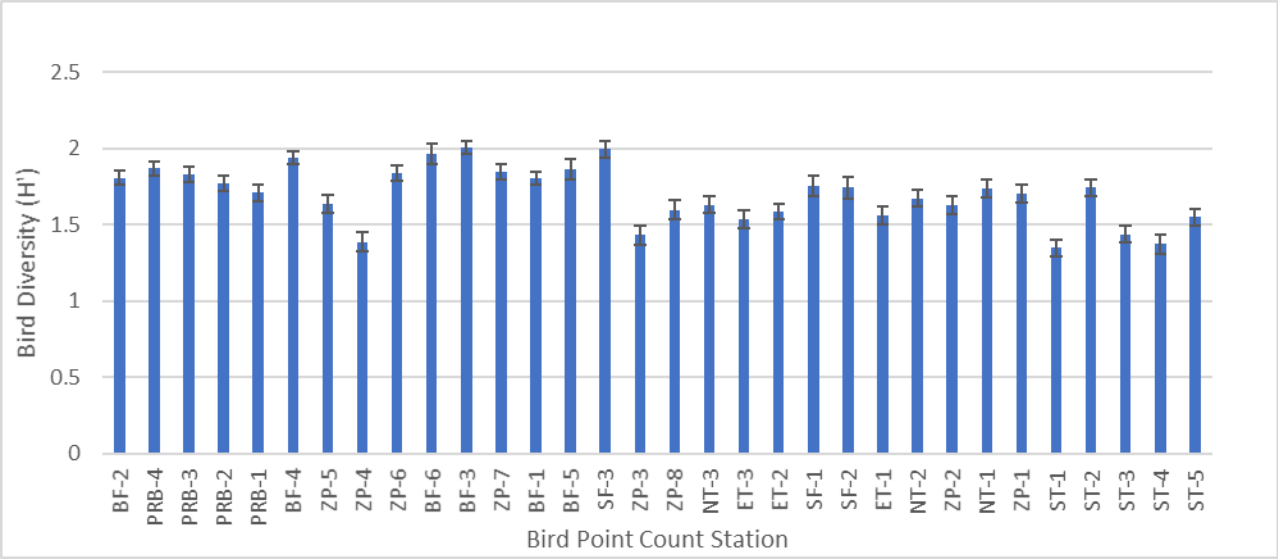


Figure 2. Bird diversity per bird point count station using the mean Shannon-Wiener Diversity Index (H') for each station. Stations are ordered by those closest to the nearest wetland and those farthest from the nearest wetland. Error bars represent the standard error of each mean. Data taken at Brookhaven National Laboratory, April through August of 2000-2016 with 32 point count stations and seven transects (number of stations and transects varied by year).

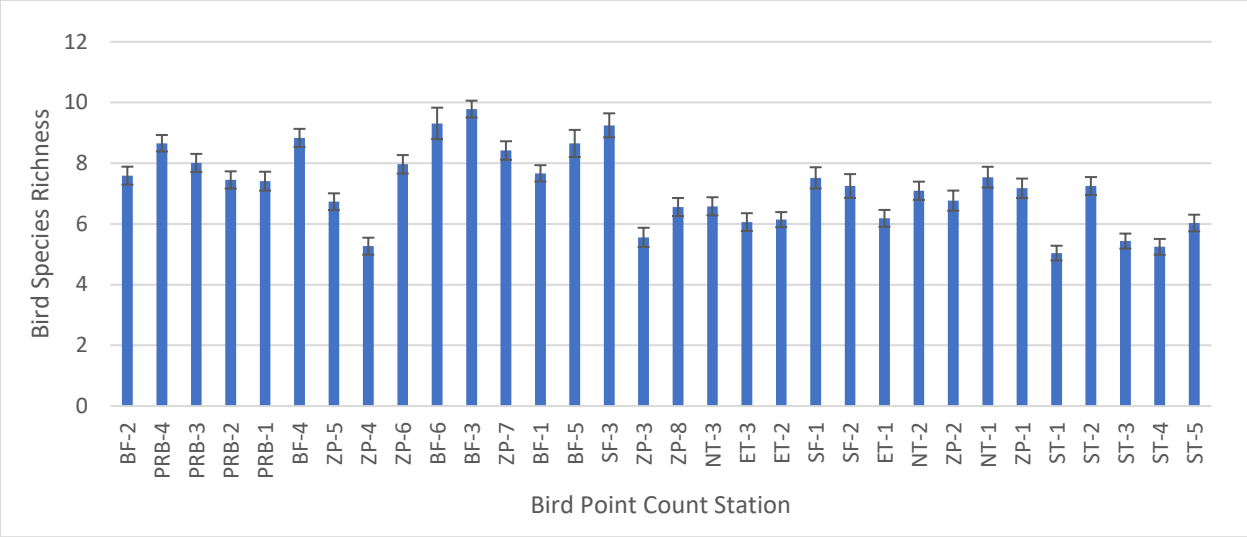


Figure 3. Bird species richness per bird point count station using the mean number of bird species counted for each station. Stations are ordered by those closest to the nearest wetland and those farthest from the nearest wetland. Error bars represent the standard error of each mean. Data taken at Brookhaven National Laboratory, April through August of 2000-2016 with 32 point count stations and seven transects (number of stations and transects varied by year).

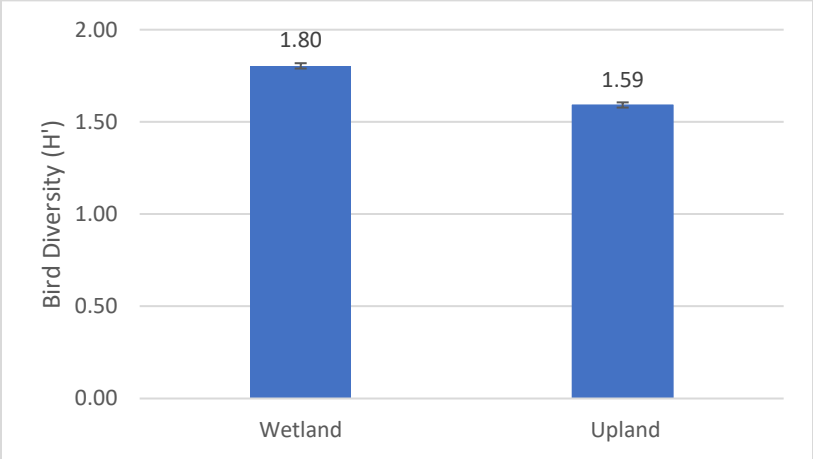
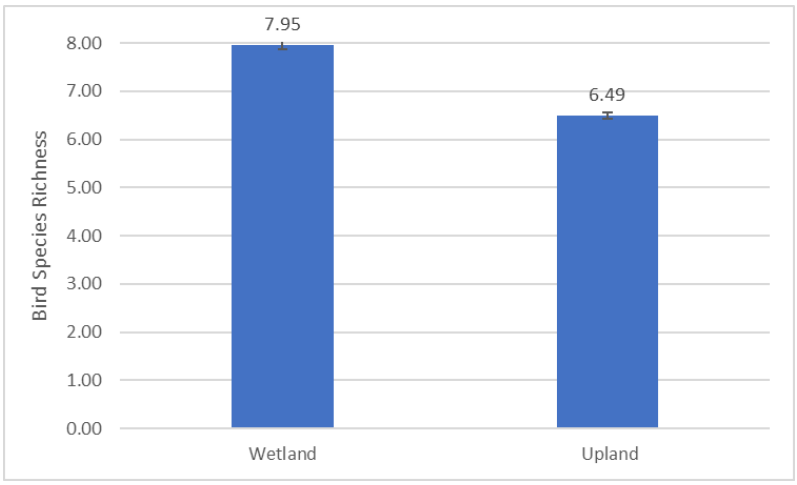


Figure 4. Mean bird diversity at bird point count stations that contain wetlands within their 150 meter buffer and stations that do not contain wetlands (upland stations). Error bars represent the standard error of each mean. Data taken at Brookhaven National Laboratory, April through August of 2000-2016 with 32 point count stations and seven transects (number of stations and transects varied by year).



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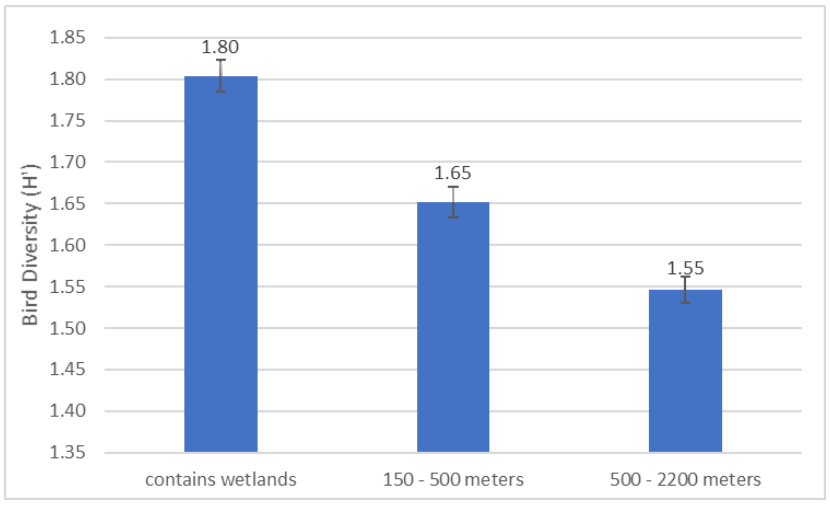
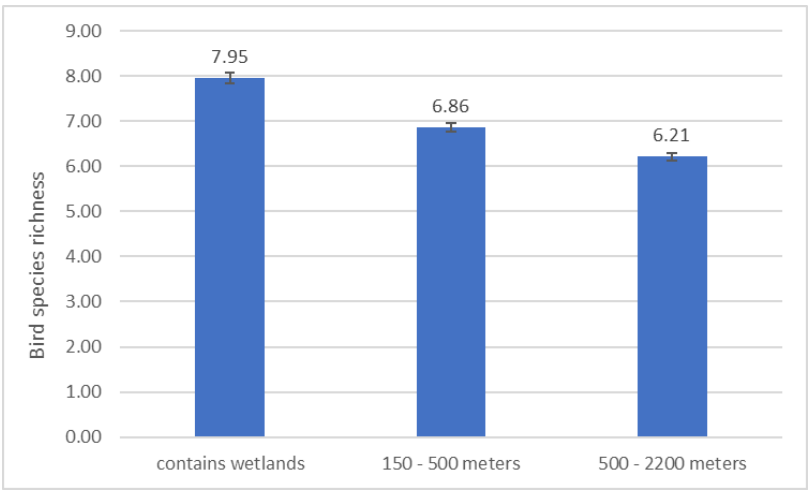


Figure 6. Mean bird diversity at bird point stations that contain wetlands within their 150 meter buffer, stations that are within 150 to 500 meters to the nearest wetland, and stations that are within 500 to 2200 meters from the nearest wetland. Error bars represent the standard error of each mean. Data taken at Brookhaven National Laboratory, April through August of 2000-2016 with 32 point count stations and seven transects (number of stations and transects varied by year).



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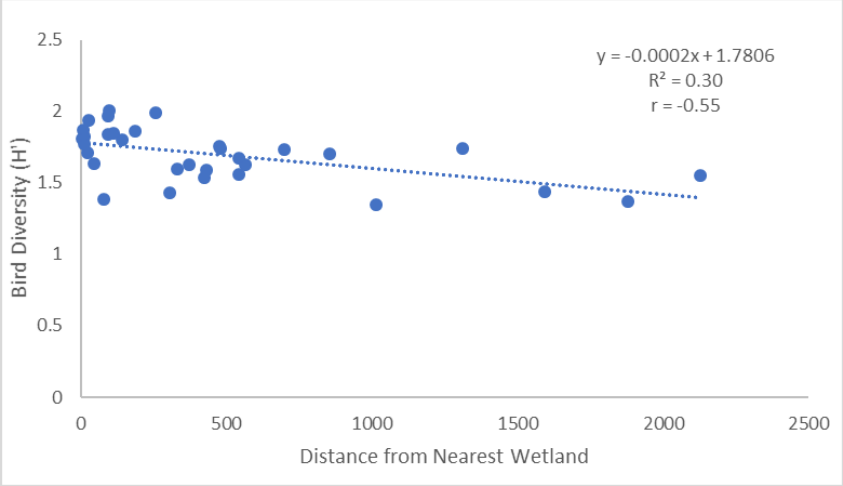

Figure 8. Bird diversity along a wetland to upland gradient using the mean Shannon-Wiener Diversity Index (H') for each station. Data taken at Brookhaven National Laboratory, April through August of 2000-2016 with 32 point count stations and seven transects (number of stations and transects varied by year).

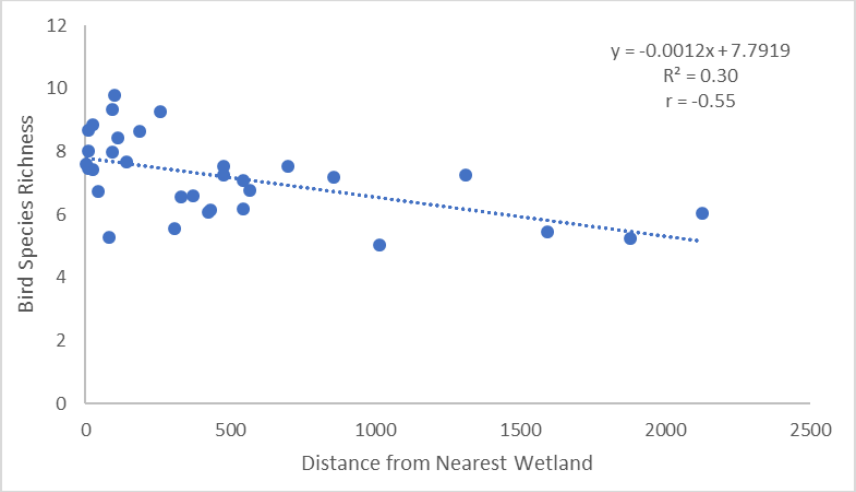

Figure 9. Bird species richness along a wetland to upland gradient using the mean number of bird species counted for each station. Data taken at Brookhaven National Laboratory, April through August of 2000-2016 with 32 point count stations and seven transects (number of stations and transects varied by year).

Table 1. List of the 128 bird species found during point counts performed from 2000 to 2016 at 32 point count stations at Brookhaven National Laboratory. (W: Species found in wetlands, U: Species found in uplands, SGCN: Species of greatest conservation need, SC: Special concern)

Common Name	Species	Habitat	Status
Greylag Goose	Anser anser	W	
Green Heron	Butorides virescens	W	
Pectoral Sandpiper	Calidris melanotos	W	
Canada Warbler	Cardellina canadensis	W	
Snow Goose	Chen caerulescens	W	
Yellow-throated Warbler	Dendroica dominica	W	
Magnolia Warbler	Dendroica magnolia	W	
Chestnut-sided Warbler	Dendroica pensylvanica	W	
Black-throated Green Warbler	Dendroica virens	W	
Acadian Flycatcher	Empidonax virescens	W	
Northern Waterthrush	Parkesia noveboracensis	W	
Bay-breasted Warbler	Setophaga castanea	W	
Blackburnian Warbler	Setophaga fusca	W	
Yellow-bellied Sapsucker	Sphyrapicus varius	W	
Bewick's Wren	Thryomanes bewickii	W	
Greater Yellowlegs	Tringa melanoleuca	W	SGCN
Nashville Warbler	Vermivora ruficapilla	W	
White-eyed Vireo	Vireo griseus	W	
Eastern Whip-poor-will	Antrostomus vociferus	U	SGCN
Mute Swan	Cygnus olor	U	
Alder Flycatcher	Empidonax alnorum	U	
Ring-billed Gull	Larus delawarensis	U	
Common Merganser	Mergus merganser	U	
Savannah Sparrow	Passerculus sandwichensis	U	
Blue Grosbeak	Passerina caerulea	U	
Common Peafowl	Pavo cristatus	U	
Summer Tanager	Piranga rubra	U	
Glossy Ibis	Plegadis falcinellus	U	SGCN
Blackpoll Warbler	Setophaga striata	U	
Cooper's Hawk	Accipiter cooperii	U, W	
Sharp-shinned Hawk	Accipiter striatus	U, W	
Red-winged Blackbird	Agelaius phoeniceus	U, W	
Wood duck	Aix sponsa	U, W	
Grasshopper Sparrow	Ammodramus savannarum	U, W	SC
Mallard	Anas platyrhynchos	U, W	
Ruby-throated Hummingbird	Archilochus colubris	U, W	
Great Egret	Ardea alba	U, W	SGCN
Great Blue Heron	Ardea herodias	U, W	

Tufted Titmouse	Baeolophus bicolor	U, W	
Cedar waxwing	Bombycilla cedrorum	U, W	
Canada Goose	Branta canadensis	U, W	
Great Horned Owl	Bubo virginianus	U, W	
Red-tailed Hawk	Buteo jamaicensis	U, W	
Broad-winged Hawk	Buteo platypterus	U, W	
Northern Cardinal	Cardinalis cardinalis	U, W	
Goldfinch	Carduelis tristis	U, W	
Veery	Catharus fuscescens	U, W	
Hermit Thrush	Catharus guttatus	U, W	
Brown Creeper	Certhia americana	U, W	
Chimney Swift	Chaetura pelagica	U, W	
Killdeer	Charadrius vociferus	U, W	
Yellow-billed Cuckoo	Coccyzus americanus	U, W	
Black-billed Cuckoo	Coccyzus erythropthalmus	U, W	SGCN
Northern Flicker	Colaptes auratus	U, W	
Northern Bobwhite	Colinus virginianus	U, W	SGCN
Plain Pigeon	Columba livia	U, W	
Eastern Wood Peewee	Contopus virens	U, W	
American Crow	Corvus brachyrhynchos	U, W	
Common Raven	Corvus corax	U, W	
Fish Crow	Corvus ossifragus	U, W	
Blue Jay	Cyanocitta cristata	U, W	
Palm Warbler	Dendroica palmarum	U, W	
Pine Warbler	Dendroica pinus	U, W	
Grey Catbird	Dumetella carolinensis	U, W	
Horned Lark	Eremophila alpestris	U, W	SC
Merlin	Falco columbarius	U, W	
American Kestrel	Falco sparverius	U, W	SGCN
Common Loon	Gavia immer	U, W	SGCN
Red-throated Loon	Gavia stellata	U, W	
Common Yellowthroat	Geothlypis trichas	U, W	
House Finch	Haemorhous mexicanus	U, W	
Barn swallow	Hirundo rustica	U, W	
Wood Thrush	Hylocichla mustelina	U, W	SGCN
Baltimore Oriole	Icterus galbula	U, W	
Orchard Oriole	Icterus spurius	U, W	
Dark-eyed Junco	Junco hyemalis	U, W	
Herring Gull	Larus argentatus	U, W	
Great Black-backed Gull	Larus marinus	U, W	
Red Crossbill	Loxia curvirostra	U, W	
Belted Kingfisher	Megaceryle alcyon	U, W	
Red-bellied Woodpecker	Melanerpes carolinus	U, W	

Red-headed Woodpecker	Melanerpes erythrocephalas	U, W	SC
Wild Turkey	Meleagris gallopavo	U, W	
Song Sparrow	Melospiza melodia	U, W	
Northern Mockingbird	Mimus polyglottos	U, W	
Black-and-white Warbler	Mniotilta varia	U, W	
Brown-headed Cowbird	Molothrus ater	U, W	
Great Crested Flycatcher	Myiarchus crinitus	U, W	
Eastern Screech Owl	Otus asio	U, W	
Osprey	Pandion haliaetus	U, W	
Indigo Bunting	Passerina cyanea	U, W	
Double-crested Cormorant	Phalacrocorax auritus	U, W	
Rose-breasted Grosbeak	Pheucticus ludovicianus	U, W	
Downy Woodpecker	Picoides pubescens	U, W	
Hairy Woodpecker	Picoides villosus	U, W	
Eastern Towhee	Pipilo erythrophthalmus	U, W	
Scarlet Tanager	Piranga olivacea	U, W	SGCN
Black-capped Chickadee	Poecile atricapillus	U, W	
Blue-gray Gnatcatcher	Polioptila caerulea	U, W	
Purple Martin	Progne subis	U, W	
Common Grackle	Quiscalus quiscula	U, W	
Ruby-crowned Kinglet	Regulus calendula	U, W	
Golden-crowned Kinglet	Regulus satrapa	U, W	
Eastern Phoebe	Sayornis phoebe	U, W	
Ovenbird	Seiurus aurocapillus	U, W	
Northern Parula	Setophaga americana	U, W	
Yellow-rumped Warbler	Setophaga coronata	U, W	
Prairie Warbler	Setophaga discolor	U, W	SGCN
Yellow Warbler	Setophaga petechia	U, W	
American Redstart	Setophaga ruticilla	U, W	
Eastern Bluebird	Sialia sialis	U, W	
Red-breasted Nuthatch	Sitta canadensis	U, W	
White-breasted Nuthatch	Sitta carolinensis	U, W	
Chipping Sparrow	Spizella passerina	U, W	
Field Sparrow	Spizella pusilla	U, W	
Northern Rough-winged Swallow	Stelgidopteryx serripennis	U, W	
European Starling	Sturnus vulgaris	U, W	
Tree Swallow	Tachycineta bicolor	U, W	
Carolina Wren	Thryothorus ludovicianus	U, W	
Brown Thrasher	Toxostoma rufum	U, W	SGCN
House Wren	Troglodytes aedon	U, W	
American Robin	Turdus migratorius	U, W	
Eastern kingbird	Tyrannus tyrannus	U, W	
Blue-winged Warbler	Vermivora cyanoptera	U, W	SGCN

Red-eyed Vireo	Vireo olivaceus	U, W
Blue-headed Vireo	Vireo solitarius	U, W
Mourning Dove	Zenaida macroura	U, W
White-throated Sparrow	Zonotrichia albicollis	U, W

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