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Avifauna associated with ephemeral ponds on the Cumberland Plateau, Tennessee

Brett R. Scheffers,[1] J. Berton C. Harris, and David G. Haskell

Department of Biology, The University of the South, 735 University Avenue, Sewanee, Tennessee 37383 USA

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ABSTRACT. Although ephemeral ponds act as small hotspots of plant, invertebrate, and salamander diversity, the importance of such ponds for birds has been little studied. We hypothesized that ephemeral ponds on the Cumberland Plateau in Tennessee would support a greater abundance, richness, and diversity of birds than the surrounding hardwood forests. In 2004, we recorded all birds seen or heard in 10 min within 50-m radius circles at 25 ephemeral ponds. We repeated the counts at control sites located 150 m from each pond in the surrounding forest. To quantify potential food availability, we captured aerial invertebrates using sweep nets at four points around a subsample of eight ephemeral ponds and at an equal number of control sites. We found significantly greater bird abundance, richness, and species diversity at ephemeral ponds than at control sites, and that pond area was not associated with either bird abundance or richness. Bird community composition at pond and control sites was similar. Aerial invertebrates were significantly more abundant at ephemeral ponds than at adjacent forest sites, providing one possible explanation for greater bird abundance at ephemeral ponds.

SINOPSIS. **Investigación sobre la avifauna asociada a charcas efímeras en Cumberland Plateau, Tennessee**

Aunque las charcas efímeras actúan como lugares claves para plantas, invertebrados y vertebrados como salamandras, la importancia de estas no ha sido objeto de estudio para aves. Pusimos a prueba la hipótesis de que charcas efímeras, sostendrían una mayor abundancia, riqueza y diversidad de aves que unos bosques secundarios encontrados en Cumberland Plateau, Tennessee. Durante el 2004 contabilizamos las aves observadas o escuchadas, durante un periodo de 10 minutos en círculos con radio de 50 m en 18 charcas efímeras. Como control, repetimos los conteos en los alrededores del bosque a distancias de 150 m de las charcas. Para cuantificar la disponibilidad potencial de alimentos, capturamos invertebrados aéreos utilizando redes de barrido en cuatro lugares como sub-muestras en ocho de las charcas y en un número similar de áreas con bosques. Encontramos un número significativo mayor de abundancia de aves, riqueza y diversidad de especies en las charcas efímeras que en los bosques. El área ocupada por las charcas no estuvo asociada ni a la riqueza o abundancia de aves. La composición de la comunidad de aves en las charcas y en los bosques resultó similar. La cantidad de invertebrados aéreos fue significativamente más abundante en las charcas que en los bosques adyacentes, lo que provee una explicación posible para la mayor abundancia de aves en las charcas.

Key words: aerial invertebrates, avian diversity, hardwood forest, point count, vernal pool, wetland

Ephemeral or vernal ponds are seasonally dry wetlands that provide important habitat for plants, invertebrates, and salamanders (Mahoney et al. 1990, Haig et al. 1998, Semlitsch 1998, Russell et al. 2002, Colburn 2004) and act as small foci of biodiversity for these taxa (Colburn 2004). However, birds associated with ephemeral ponds have been little studied. Colburn (2004) reviewed the literature on vernal pools and found no "systematic surveys of avian uses of vernal pool habitats." In perhaps the only study on the use of vernal pools by birds to date, Silveira (1998) found that vernal pools in central California provided important habitat for resident and migratory birds, particularly waterfowl. However, ephemeral ponds in other areas, such as the Cumberland Plateau in Tennessee, differ from those in California in geographic location, hydrogeomorphology, hydroperiod, and invertebrate communities, making it difficult to draw general conclusions about the importance of these ponds to birds.

Ephemeral ponds on the Cumberland Plateau are long-cycle pools that are generally inundated from November to July (Colburn 2004). The Cumberland Plateau is a primarily sandstone plateau, which extends from northeast Alabama to eastern Kentucky. Soils are generally shallow, sandy, and acidic. The plateau is dominated by oak–hickory hardwood forests.

[1] Current address: P.O. Box 669, Scottsville, Virginia 24590 USA. Email: schefbr0@hotmail.com

The forest around ephemeral ponds, however, can include sweet gum (*Liquidambar styraciflua*) and black gum (*Nyssa sylvatica*) trees. The water in ephemeral ponds and the adjacent wet soil may promote a greater abundance and richness of invertebrates than the surrounding hardwood forests (Anderson and Smith 2000). Many insects associated with ephemeral ponds have aquatic larval stages that emerge into aerial adults, for example, caddisflies (*Trichoptera*), dragonflies and damselflies (*Odonata*) and several *Dipterans*. These aerial adults may serve as food for insectivorous birds.

Considering that many taxa use ephemeral ponds, but little is known about their importance to birds, we proposed the following hypotheses: (1) ephemeral ponds have greater bird abundance, richness, and diversity than the surrounding forests, (2) ephemeral pond bird communities differ in species evenness and community composition from bird communities of the surrounding forest, (3) larger ephemeral ponds have more birds than smaller ephemeral ponds, and (4) ephemeral ponds have greater abundance of aerial invertebrates than the surrounding forests.

METHODS

From 19 February to 15 May 2004, in Franklin and Grundy County on the southern Cumberland Plateau, Tennessee, USA (35°13′00″N, 85°55′00″W), we recorded all birds seen or heard in 10 min within a 50-m radius circle at ephemeral ponds ($N = 25$). A control point count for each pond was conducted 150 m from the pond in the surrounding forest. The distance of 150 m between ponds and controls was selected to locate control sites in areas close to ponds, but without overlap of point count radii. Point counts for pond and control sites were always conducted on the same day within 20 min of each other. Each pond and control site was sampled once. To eliminate temporal bias, point counts alternated between pond and control sites from sampling site to sampling site. We selected control sites that were similar in extent of canopy cover to associated pond sites. Forest cover similarities between pond and control pairs were determined using aerial photographs and visual observations in the field. All counts were conducted between 06:00 and 09:00 hours.

During our bird surveys in 2004, we observed many more flying insects at ponds than in the surrounding forests. Therefore, in 2005, we performed a preliminary assessment of flying insect abundance during 2 weeks in April. We quantified aerial invertebrate abundance at a subsample of eight ephemeral ponds and control sites. This subset was arbitrarily chosen based on accessibility of pond and control sites. Invertebrates were captured in sweep nets from 4 to 19 April 2005. Control sites were located 150 m away from ponds in areas previously surveyed for birds. Each survey consisted of four points at the north, east, west, and south edges of each pond, and we reconstructed the same orientation for all control points. We captured insects by conducting figure-eight motions with sweep nets, for 15 revolutions at each point. The number of invertebrates captured in nets was determined in the field. These counts therefore quantify the number of individual prey items, but not their biomass. Each paired pond and control site was sampled once and on the same day. All samples were collected between 12:00 and 16:00 hours. Sampling between pond and control sites was alternated.

We located ephemeral ponds on 1:12,000-scale 3.75-min black-and-white Digital Orthophoto Quarter Quadrangles (DOQQ) at a 1-m ground resolution (DOQQ photographs were taken under leaf-off conditions during the winter of 1997). We then used these aerial images to determine the area of each pond. To ensure that 1997 contained comparable water volume to 2004 and therefore similar pond areas, we compared data on total precipitation in the years 1997 and 2004. The total precipitation between the months of September 1996 and March 1997 was 92.5 cm. In comparison, the precipitation between the months of September 2003 and March 2004 was 93.5 cm (Domain Management Office, unpubl. data, Sewanee, TN).

We calculated three summary statistics to describe the avian community at each point: (1) abundance of individuals, (2) species richness, and (3) diversity (Shannon–Weiner index; Krebs 1989). In addition, we quantified species evenness and community composition for the pooled data from both pond and control sites. We tested normality of both bird and invertebrate data sets with a Kolmogorov–Smirnov test. All data sets were normally distributed. We conducted two-tailed t-tests to compare the means of the bird species richness and Shannon–Weiner diversity index values between pond and control sites. We report means ± 1 SE for all measures of abundance and diversity. We used linear regression to test whether pond area and date of sampling were associated with avian presence at ephemeral ponds. To summarize species evenness at pond and control sites, we constructed rank-abundance and species-accumulation curves. Community composition was analyzed using a principal components analysis in MVSP (v.3.1; Kovach 2005). We performed a two-tailed *t*-test to compare the abundance of invertebrates between ephemeral ponds and forest controls. All analyses other than the principal components analysis were conducted using SPSS (v.12.0, SPSS Inc. 2003).

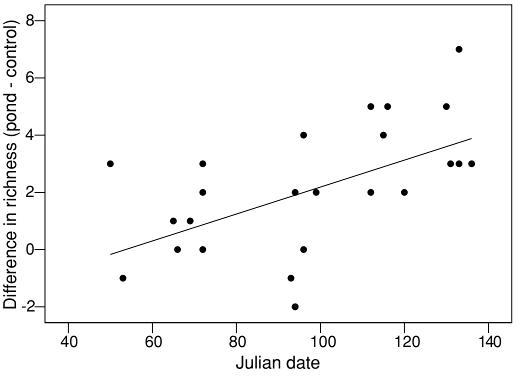

Fig. 1. The difference in species richness between ephemeral ponds and control (adjacent forest) sites increased as the season progresses from winter (mid-February) to spring (mid-May). Each point represents a pair of point counts (species richness at the pond site minus species richness at the control site). Positive points therefore represent pairs of point counts where pond sites had greater species richness than control sites.

RESULTS

We recorded 210 individual birds representing 42 species at pond sites ($N = 25$) and 126 individuals of 31 species at control sites ($N = 25$). Tufted Titmice (*Baeolophus bicolor*), Red-eyed Vireos (*Vireo olivaceus*), and Downy Woodpeckers (*Picoides pubescens*) were the most common birds found at both ponds and control sites. The mean area of the ephemeral ponds ($N = 25$) was 930 m^2 (range 230–2307 m^2), and area was not related to bird abundance (linear regression $R^2 = 0.001$, $F_{1,24} = 2.15$, $P = 0.43$), species richness ($R^2 = 0.038$, $F_{1,24} = 0.92$, $P = 0.41$), or diversity ($R^2 = 0.007$, $F_{1,23} = 0.16$, $P = 0.69$).

Mean abundance (number of individuals), species richness, and diversity were significantly higher at ponds than at control sites (Table 1). In addition, the abundance and richness of Neotropical migrants were greater at ponds than at control sites, and aerial invertebrates were more abundant at ponds than in the adjacent forest (Table 1). Most insects caught at ponds were midges (*Diptera: Chironomidae*), but we did not quantify taxa.

The difference between pond and control sites in species richness (i.e., richness of pond minus richness at control, calculated for each pair of point counts) increased as migration progressed (from mid-February to mid-May; $R^2 = 0.29$, $F_{1,24} = 9.39$, $P = 0.005$; Fig. 1). Species evenness did not differ between pond and

Table 1. Summary of measures of bird and aerial invertebrate abundance and diversity at ephemeral ponds and at adjacent hardwood forest control sites.

	Mean ± SE			
	Ponds[a]	Controls[a]	*t*-value	*P*
Bird abundance	8.40 ± 1.03	5.04 ± 0.56	−3.89	0.001
Bird species richness[b]	5.64 ± 0.68	3.60 ± 0.40	4.40	0.001
Shannon–Weiner index (birds)	1.40 ± 0.16	1.08 ± 0.12	2.69	0.013
Neotropical migrant abundance[c]	3.20 ± 0.79	2.04 ± 0.41	−2.12	0.044
Neotropical migrant richness[b]	2.32 ± 0.54	1.52 ± 0.31	−2.22	0.036
Aerial invertebrate abundance[c]	8.19 ± 2.17	1.19 ± 0.38	6.44	0.001

[a]$N = 25$ for birds and $N = 8$ for invertebrates.
[b]Number of species.
[c]Number of individuals.

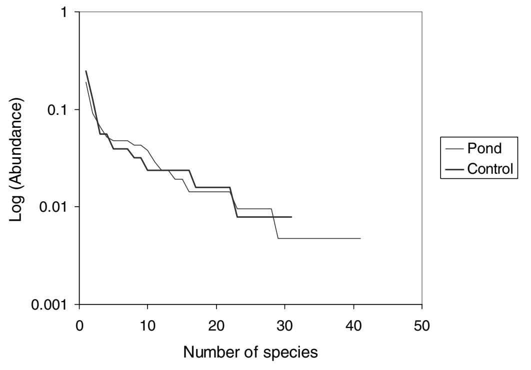

Fig. 2. Rank-abundance curve for ephemeral ponds and control (adjacent forest) sites. Species evenness was similar at ephemeral ponds and control sites.

control sites, with one dominant species, Tufted Titmouse (*B. bicolor*), comprising >19% of all individuals at both types of sites and a similar number of rare species at pond and control sites (Fig. 2). In addition, species-accumulation curves for pond and control sites were similar in shape and slope (Fig. 3), and ponds did not cluster separately from controls in a principal component analysis (Fig. 4).

DISCUSSION

Our data indicate that ephemeral ponds on the Cumberland Plateau support a greater abundance, richness, and diversity of birds (including Neotropical migrants) than the surrounding forests. The magnitude of this difference in diversity and abundance increased from mid-February through mid-May, with ponds hosting relatively more birds and more bird species. However, species evenness and community composition were similar at pond and control sites, suggesting that ephemeral ponds provide a general focus of resources that can be used by bird species from the surrounding forests. Species-accumulation curves for pond and control sites were similar in shape and slope, again suggesting that greater richness at ponds is a result of increased abundance and not the presence of a specialized subcommunity.

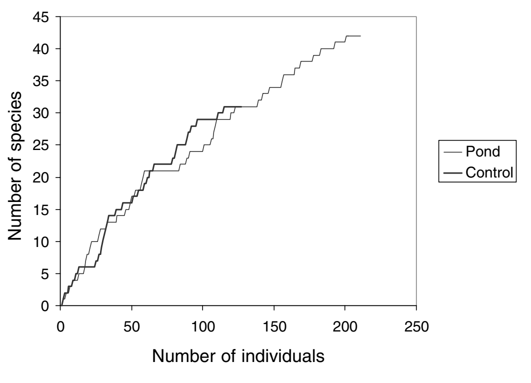

Fig. 3. Species-accumulation curves for ephemeral ponds and control (adjacent forest) sites. Species richness increased at similar rates as a function of increasing numbers of individuals sampled at the two sites.

There are several possible explanations for the higher densities of birds around ponds. Ponds may provide a water source and food resources in the form of insects emerging from ponds, fruits from black gum trees, insects and other organisms in the pond water, or insects in the dead trees and thick layers of leaf litter that line the edges of ponds. Ephemeral ponds might also provide thermoregulatory advantages through the thermal inertia of the water. Because ponds create a small opening or thinning in the canopy, ponds may also provide better views for birds monitoring potential predators. Most of these hypotheses are highly speculative and await further testing. Indeed, some of these hypotheses could reasonably be reversed, for example, ponds might be cooler than the surrounding forests and the canopy opening might increase, rather than decrease, the risk of predation.

Our data do suggest that the relationship between ponds and bird densities may be due in part to the increased availability of aerial invertebrates, with greater numbers of aerial insects (mostly midges, *Diptera, Chironomidae*) at ponds than in adjacent forests. Our examination of aerial insect abundances was conducted during the middle (April) of our previous bird-sampling period (February–May); so additional work is needed concerning the abundance of insects both earlier and later in the season. However, other investigators have reported that large mating swarms of midges may be an important source of food for migratory warblers (Smith et al. 1998, 2004). Migrating warblers often alter their foraging behavior by concentrating their foraging efforts along shorelines with high

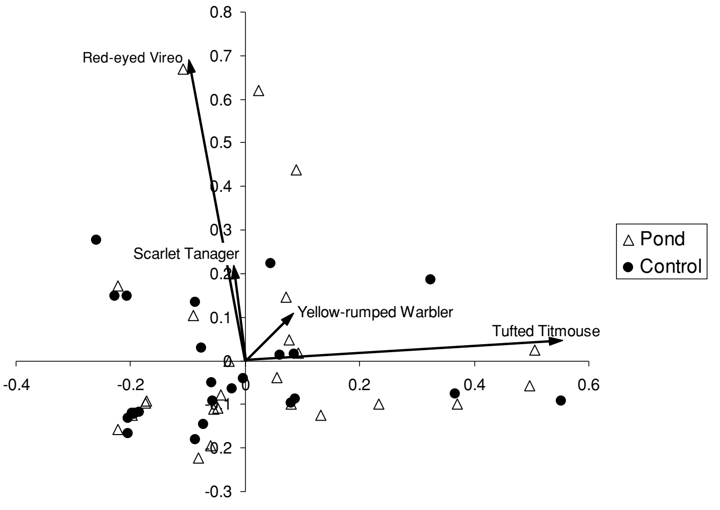

Fig. 4. Principal component analysis (PCA) revealed that for ephemeral ponds and control (adjacent forest) sites, bird community composition was similar. Points represent individual point counts. Vectors show the contributions of the four species that had the greatest effect on the PCA.

abundances of insects (Smith et al. 1998, 2004), and a similar phenomenon may occur around ephemeral ponds.

Flying insects are not the only potential food source at these ponds. Moister soils such as those around ephemeral ponds often support more diverse terrestrial invertebrate faunas (Anderson and Smith 2000). Periodic drying of ephemeral wetlands limits vertebrate predator populations, further increasing invertebrate abundance (Anderson and Smith 2000). In addition, layers of organic deposits at ponds promote more water retention than the surrounding sandy plateau soils. Thus, moist soils near pond margins may support more terrestrial invertebrate food sources than the surrounding forest. We observed birds foraging for insects on the ground along pond margins on several occasions. For example, Louisiana Waterthrushes (*Seiurus motacilla*) foraged along a pond margin when a large swarm of midges had aggregated along the pond edge. Similarly, we observed Golden-crowned Kinglets (*Regulus satrapa*) consuming springtails (Collembola) on the ground near a pond margin in February. In addition, moist soils along the pond margins result in the growth of trees that are rare in the rest of the forest, including sweet gum (*L. styraciflua*) and black gum (*N. sylvatica*). These trees may provide seeds and fruits that are unavailable elsewhere in the forest.

Some birds may be able to forage directly on aquatic organisms living within the ponds. For example, we observed Wood Ducks (*Aix sponsa*) consuming spotted salamander (*Ambystoma maculatum*) eggs. Similarly, local landowners have observed Red-shouldered Hawks (*Buteo lineatus*) preying on *Ambystoma* salamanders near ponds (E. Kirven, pers. comm.). These hawks often build their nests in trees along pond margins, suggesting that the ponds provide a favorable nesting habitat.

Ephemeral ponds provide important habitat for amphibians and plants (Russell et al. 2002, Semlitsch 1998), and our results and those of Silveira (1998) suggest that these wetlands are also important for birds. Because we found that avian abundance, richness, and diversity were not related to pond size, both small and large ephemeral ponds are likely ecologically important. Presently, federal regulatory oversight on ephemeral ponds is limited, primarily due to their small size and isolation from other surface waters (Russell et al. 2002, Calhoun et al. 2003). Many states have proposed legislation to preserve isolated wetlands, but Tennessee has not passed such a legislation (Christie and Hausmann 2003, Colburn 2004). Our study and those of previous investigators (Haig et al. 1998, Semlitsch 1998, Semlitsch and Bodie 1998) document the importance of ephemeral ponds to a variety of taxa, and strengthen the case for the implementation of incentives or regulations that protect their ecological integrity.

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