

# Riparian and Riverine Wildlife Response to a Newly Created Bridge Crossing

Joshua A. Vance<sup>1</sup>, Norse B. Angus<sup>2</sup>, James T. Anderson<sup>1\*</sup>

<sup>1</sup>West Virginia University, Division of Forestry and Natural Resources, Morgantown, USA; <sup>2</sup>West Virginia Department of Transportation, Division of Highways, Charleston, USA.

Email: [jim.anderson@mail.wvu.edu](mailto:jim.anderson@mail.wvu.edu)

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## ABSTRACT

Construction of man-made objects such as roads and bridges can influence wildlife presence and abundance. We investigated waterbirds, songbirds, anurans, turtles, small mammals, and furbearers along the Ohio River, WV, at a new bridge crossing, a 45-year-old bridge, and 1 or 2 islands with no bridge and at 3 distances from the bridge or center point at each site (0 m, 100 m, and 300 m). We sampled 19 waterbird, 60 songbird, 7 anuran, 5 turtle, 9 small mammal, and 4 furbearer species. Great blue heron (*Ardea herodias*) abundances were greater at the site with no bridge. Songbird composition differed among sites and between transects under and away from the bridge with higher abundances or association of rock pigeon (*Columba livia*) and cliff swallow (*Petrochelidon pyrrhonota*) under the bridges and lower abundances of Carolina wren (*Thryothorus ludovicianus*) and common yellowthroat (*Geothlypis trichas*) under the bridges. Total small mammal abundance, diversity, and richness were lower under the new bridge compared to other sites and distances. We conclude that overall the new bridge is causing minimal relative abundance impacts to wildlife. However, great blue heron abundance may be altered due to noise and activity from the presence of the bridge and minor short-term impacts to some songbirds and small mammals directly under the bridge in the form of habitat conversion, fragmentation, and loss due to removal of vegetation is apparent.

**Keywords:** Great Blue Heron; Road Effects; Small Mammals; Songbirds; Waterbirds

## 1. Introduction

Humans today are affecting natural ecosystems at extraordinary rates through conversion of land and resource consumption [1], alteration of habitat and species composition [2], disruption of hydrological processes [3], and modification of energy flow and nutrient cycles [4]. Since the 1940s, the human population of the United States has become increasingly urbanized [5]. Urbanization dramatically alters landscapes through habitat fragmentation and increased human presence. Urbanization and the construction of roads and bridges can alter wildlife habitat, and is cited as the second most frequent cause of species endangerment, behind agriculture, in the United States [6]. Construction of these man-made objects may have temporary or permanent effects on wildlife and vegetation. Historically, relatively few published studies have evaluated these effects. Recently, more attention has been directed toward the effects of bridges and roads upon wildlife and vegetation [7,8].

Bridges can potentially affect mammals, birds, amphibians, and reptiles either positively, negatively, or have no

effect depending on species or location. Bridges have positive effects on wildlife by providing habitat for nesting, roosting, and resting as well as providing corridors for movement. Cliff swallows (*Petrochelidon pyrrhonota*) and barn swallows (*Hirundo rustica*) are species that use bridges for nesting and perching [9,10]. Additionally, peregrine falcons (*Falco peregrinus*) have been well documented as using bridges and skyscrapers for nesting sites and hunting perches [11]. Other research shows that bridges provide roosting and resting habitat for bats [12]. Edge created by roads and bridges may provide habitat for certain songbirds and increase their population [13].

There is a lack of published literature on the ecological impacts of bridges on wildlife. However, the presence of a bridge may have direct negative impacts on wildlife similar to those of highway impacts which have been studied in much greater detail. Some of these negative impacts include: increased mortality from vehicle collisions [14,15], noise [16], barrier effects [17,8], and attraction of undesirable or non-native species [18]. Bridges and highways also can impact the landscape causing habitat fragmentation [19], habitat loss [20], and habitat alteration [21] which in turn are negative for some wild-

\*Corresponding author.

life. This can lead to species declines and disruption of continuous population distributions, limit movements, and cause potential genetic problems.

The purpose of this study was to evaluate the short-term impacts and effects of the Blennerhassett Island Bridge as it crosses over the Ohio River and Blennerhassett Island near Parkersburg, West Virginia, USA. The Blennerhassett Island Bridge is a tied-arch style single-span bridge [22] about 1220 m in length and about 24 m above the island and water with 3 piers on the island. Construction of the bridge began in May 2005 and it was opened to the public 13 June 2008. This study investigated waterbird, songbird, anuran, turtle, small mammal, and furbearer relative abundance and overall wildlife mortality and compared results to 2 other islands (1 with an old bridge crossing and 1 with no bridge crossing) and also at 0, 100, and 300 m from the bridge. Comparisons for anurans and turtles also were made to an additional island with no bridge crossing.

## 2. Materials and Methods

### 2.1. Field-Site Description

This study was conducted along the Ohio River in Wood County and Pleasants County, West Virginia and Washington County, Ohio, USA (39°16'12"N, 81°, 38'47"W). There were 4 sites (Blennerhassett Island, Buckley Island, Muskingum Island, and Grape Island) and surveys were conducted on both the islands and the adjacent mainland. Blennerhassett and Buckley both had bridge crossings, but Muskingum and Grape did not and one or the other was used as a control site for some surveys. These islands occur between km markers 244.0 and 305.6 (mi markers 151.6 and 189.9). Blennerhassett, Buckley, and Muskingum are located in the Belleville Navigational Pool, and Grape Island is located in the Willow Island Navigational Pool [23].

Blennerhassett Island is owned by Dupont Corporation and is leased to the state of West Virginia as a state historical park. Buckley, Muskingum, and Grape islands are owned by the U.S. Fish and Wildlife Service and are part of the Ohio River Islands National Wildlife Refuge. Precipitation occurs throughout the year, totaling about 106 cm/year [24]. The elevation of the study area ranges from 184 - 198 m. The primary cover types for these islands are: bottomland hardwood forest, late old-field, and early old-field [23]. Additionally, both Blennerhassett and Grape islands contain a palustrine unconsolidated bottom wetland. All islands in this study area have been historically used for agriculture and the river channels around them may have been historically dredged [23]. The adjacent mainland has been characterized by disturbance from urbanization, agriculture, commercial development, and industrial expansion. Both back and main channels

of Ohio River islands provide critical riparian wildlife habitat for many species of birds, aquatic mammals, frogs, and turtles [25].

### 2.2. Study Design

Waterbirds, songbirds, anurans, turtles, small mammals, and furbearers were sampled at Blennerhassett Island (new Rt. 50 bridge), Buckley Island (existing I-77 bridge), and Muskingum Island (no bridge). Anurans and turtles were sampled at Grape Island (no bridge) due to the presence of a wetland, but due to the island's small size, other taxa were not sampled. Songbirds, anurans, small mammals, and furbearers were sampled along 100 m transects placed under the bridge or island center, if there was no bridge (0), and at 100 and 300 m from the central transect with transects starting at the shorelines on both sides of the bridge on the mainland and on the island. Ideally our study would have had transects on both shores of the island as well as on the West Virginia and Ohio mainland ( $n = 20$  at each site). Because of site constraints (e.g., size of island, industry, agriculture, rock quarry, commercial and residential development) only 37 of the 80 proposed transects among the 4 sites could be sampled for all taxa except turtles: Blennerhassett Island ( $n = 15$ ), Buckley Island ( $n = 12$ ), Muskingum Island ( $n = 7$ ), and Grape Island ( $n = 3$ ). Because turtle trapping occurred at the terminal ends of the transects in the main river, all 20 transects could be sampled at each site. Additionally, turtle trapping was conducted in the slough on Blennerhassett Island, and was planned in the slough on Grape; however, water levels were not deep enough to trap. This provided 85 trap locations for turtles ( $n = 25$  at Blennerhassett,  $n = 20$  at Buckley,  $n = 20$  at Muskingum, and  $n = 20$  at Grape). Comparisons were made among sites (waterbirds, songbirds, anurans, small mammals, furbearers, mortality) and/or distance from bridge (songbirds, anurans, turtles, small mammals, and furbearers).

### 2.3. Waterbirds

Waterbird surveys were conducted by a single observer during 90 minute complete scan counts while sitting on the mainland facing the island and monitoring the river, air, riparian zones, and part of the island in a 39.25 ha area (semicircle with a 500 m radius from the observation point) using 8 × 42 power binoculars and a 15 to 60 power, 60 mm zoom, Bausch and Lomb® spotting scope. Surveys were conducted from 1 hour before sunset to 30 minutes after sunset (dusk) and then 30 minutes before sunrise to 1 hour after sunrise (dawn) at the same location the following morning [26]. The dusk survey and the dawn survey the following morning were combined into one single survey and the maximum count for each species between the two times was used. During these

counts, all waterbirds observed were enumerated and recorded [27,28] and flyovers were categorized by whether the individuals flew over or under the bridge. Waterbirds were considered waterfowl, seabirds, shorebirds, wading birds, and belted kingbirds (*Megasceryle alcyon*) [29]. The distance from the observer to the bird was measured with a Nikon Laser™ 1200 7 × 25 power range finder to make accurate estimations on whether the birds were within the 39.25 ha area.

Waterbird counts were conducted twice a month during October, November, and December 2007 and 2008, as well as March, April, and May 2008 and 2009. Dusk and dawn surveys were conducted from the West Virginia mainland once a month and then from the Ohio mainland later in the month because each side of the island had a different 39.25 ha area to be surveyed and to ensure the entire river channel around the island was surveyed monthly. Observation points were placed at suitable locations with clear viewing of the river, air, riparian zones, and the bridge (where applicable), but were not correlated to transects. Counts were not recorded if the wind speeds exceeded 16 km/hr or during high flow conditions and were made up at the next available time [30].

## 2.4. Songbirds

Breeding bird surveys for songbirds were conducted along each of the 100 m transects using the dependent double observer method [31]. This method involved 2 observers recording data together on a single data sheet with 1 observer designated as the primary observer and the other designated as the secondary observer. The primary observer verbally dictated the number of each species detected while the secondary observer recorded the information. The secondary observer verified observations and also recorded birds that the primary observer did not detect [31]. This technique was not used to calculate detection probabilities due to low number of observations, but to verify accuracy of species identifications and counts.

Songbirds were sampled by walking along each transect for a total of 15 minutes each, pausing to identify and record all birds observed or heard. Only songbirds detected within a 1 ha area ( $\leq 50$  m perpendicular to the transect) were included in transect data. Those species detected outside or as flyovers were recorded but not included in any estimates. There were 3 scheduled stops of 3 minutes each at the beginning, middle, and end of each transect. The species, sex, age, and estimated distance of all birds detected by sight and sound was recorded. Estimated distances were recorded perpendicular to the transect using a Nikon Laser™ 1200 7 × 25 power range finder. Surveys were conducted from 600 to 1000, but were not conducted during rainy or windy weather.

Surveys were conducted during the breeding season in May and June 2008 and 2009.

## 2.5. Anurans

Anuran communities were evaluated using nocturnal call count surveys to evaluate species and relative abundance [32]. To account for temporal breeding differences among species, surveys were conducted over 3 periods (period 1:25 February-25 March 2008 and 2009, period 2:8 April-6 May 2008 and 2009, and period 3:27 May-24 June 2008 and 2009) based on recommended temperature ranges for different survey periods (period 1:  $\geq 5.6^{\circ}\text{C}$ ; period 2:  $\geq 10^{\circ}\text{C}$ ; period 3:  $\geq 12.8^{\circ}\text{C}$ ) [32]. Surveys were conducted between 30 minutes after sunset to midnight because calling activity is generally greater before midnight. Surveys were conducted along the 100 m transects by slowly walking each transect for 15 minutes with 3 scheduled stops of 3 minutes at the beginning, middle, and end of each transect. There was a 1 - 2 minute settling period for disturbance caused while walking to the transects before surveys began.

Anurans were identified to species and abundances were evaluated by assigning a Wisconsin Index (WI) value of intensity of each species' call [33]. The WI ranked species from 0 - 3 based on overlap of calls and determination of individuals. A value of 0 indicated that no individuals of that species were heard. A value of 1 indicated that calling individuals could be counted and there were no overlapping calls. A value of 2 indicated that calls could be distinguished but there was some overlap. A value of 3 indicated a full chorus with continuous calling and overlapping calls. For values of 1 or 2, the number of calling individuals was estimated. If a WI value of 3 was assigned to a species, a mandatory abundance estimate of 50 was used because numbers were impossible to estimate [32]. The date, time, temperature, and weather conditions were recorded before each survey. Surveys were not conducted if winds exceeded 20 km/hr or if temperatures were below the minimum for each period. Estimated distance from the transect to the calling anurans also was recorded and mapped to lessen the chances of double-counting.

## 2.6. Turtles

Turtle trapping was conducted using turtle hoop nets [25]. Hoop nets were nylon, 1.5 m long × 0.9 m diameter with 5 cm mesh (Memphis Net and Twine Company, Inc., Memphis, TN). Traps were baited each day with chopped fish (either canned or frozen) contained in nylon mesh bags and suspended from the center hoop of each trap. If possible, traps were placed in areas suitable for turtles such as sand or gravel bars, areas of emergent vegetation, or areas of woody debris. Traps were set for 3 consecu-

tive nights and checked each morning. A trap night was considered as 1 trap found completely intact the day after being set. Traps with bait missing also were considered as 1 trap night, since the opportunity to capture a turtle by scent remained. A trap found with a hole torn in it  $\leq 18$  cm in diameter was considered 0.5 trap night, since the potential to capture larger turtles ( $>18$  cm carapace width) remained. Missing traps, those found to be collapsed, and those with holes  $>18$  cm were all considered 0 trap nights. All turtles captured were identified, measured, weighed, and released at the capture site. Hard-shell turtles were marked by shell notching [34], and softshell turtles were marked along the edge of the carapace using a leather punch [35]. Turtle trapping was conducted during July and August 2008 and June and July 2009.

### 2.7. Small Mammals

Small mammal trapping was conducted by using Sherman live traps (small folding galvanized,  $5 \times 6.4 \times 16.5$  cm; H. B. Sherman Traps, Tallahassee, FL) to capture small mammals such as mice, voles, moles, chipmunks, and shrews. Sherman traps were placed along the 100 m transects at 10 stations located 10 m apart [36]. Three Sherman live traps were set at each station. Each trap was baited with a peanut butter rolled oats mixture wrapped with wax paper [37]. Traps were set and opened for 3 consecutive nights and were checked each morning. We deducted 0.5 trap nights for each trap tripped without a capture [37]. Corresponding transects of each site were trapped simultaneously to account for temporal variation. Each mouse, vole, chipmunk, rat, or squirrel captured was ear-tagged with a #1005-1 monel ear tag (National Band and Tag Company, Newport, Kentucky, 41072-0430) and shrews were toe-clipped for identification [38]. Other information such as trap location, species, new or recapture, age, gender, mass, and reproductive condition also were recorded. Small mammal trapping was conducted during May, June, and July 2008 and 2009.

### 2.8. Furbearers

Scent stations were constructed and monitored to measure medium-sized mammals, carnivores, and large rodent occurrence [39]. Scent stations were established along the river banks at the terminal end of each transect. Scent stations were 1 m  $\times$  1 m and made from scraped, sifted, and smoothed alluvial soil at a depth of 3 - 5 cm to make tracks more visible. Scent stations were baited with a fatty acid scent tablet placed in the center of the station. Stations were operated for 3 consecutive nights and checked every morning. Identification of all animals investigating the scent station was made by the tracks left in the scent station. Scent stations were monitored in

conjunction with small mammal traps during May, June, and July 2008 and 2009.

### 2.9. Statistical Analysis

Waterbird abundance (number/39.25 ha plot) of combined waterbirds and those species representing 2% or more of detections, species richness, and Shannon Diversity Index (diversity) (dependent variables) were rank transformed [40] and compared among sites (independent variable) using a repeated measures single-factor analysis of variance (ANOVA) with an alpha level of 0.05. A Tukey's honest significance difference multiple comparison post hoc test was used for pairwise comparisons of significant variables. Flyovers were excluded from analyses. For the islands with bridges, data on whether the birds flew over or under the bridge also were summarized to investigate response to bridge.

Songbird abundance (individuals/ha) for all species combined and for any species representing 2% or more of observations, species richness, and diversity (dependent variables) were rank transformed [40] and compared by site, distance, and the interaction term (independent variables) using a repeated measures 2-way ANOVA ( $\alpha = 0.05$ ). Because the levels of distance had no physical meaning for Muskingum, a partial analysis was conducted to examine distance only for Blennerhassett and Buckley islands. In the case where there was no significant interaction, a contrast for the effect of distance pooled across both islands was estimated and, if necessary, follow up pairwise comparisons between levels of distance were estimated. If there was a significant interaction, then the effect of distance was examined for the 2 islands on an individual basis (*i.e.*, a simple effects analysis). A model allowing for heterogeneous variance was fitted for all variables due to nonconstant variance. Residual diagnostics were then used to verify the assumptions of the model. The test of interaction was done using untransformed data to obtain a more approximate analysis [41]. When subsequently testing main effects or contrasts, rank transformed data were used.

We initially evaluated the uniqueness of species composition by site and distance from bridge (independent variables) with PERMANOVA [42] using the Vegan package in Program R. A subsequent one at a time analysis was done using multi-response permutation procedures (MRPP) in PC-ORD version 5.10 software [43]. MRPP is a non-parametric multivariate procedure for testing the hypothesis of no differences in species composition of 2 or more *a priori* groups of plots [44]. For these analyses, all species that occurred less than 3 times were deleted. Individuals/ha (dependent variable) were calculated for abundance data and were relativized using a general column relativization. A Sorensen (Bray-Curtis) distance measure was used with a rank transformed dis-

tance matrix and an alpha level of 0.05. A Sorensen community similarity index, which compares pairwise similarities, was used to evaluate songbird overlap among sites and distances.

Lastly, the affinity of species occurrence by site and by distance from bridge were calculated using indicator species analysis [45]. Indicator species analysis combines information on the species abundance at a particular treatment and the faithfulness of occurrence of a species at a particular treatment. First, an indicator value for each species was calculated with a value between 0 and 100. A value of 0 showed no indication (*i.e.*, no association) of the species and a value of 100 showed perfect indication of the species. Second, the statistical significance of the highest indicator value ( $IV_{\max}$ ) for each species was tested using a Monte Carlo test using 4999 permutations with an alpha level set at 0.05.

Combined anuran abundances, combined call index codes (CIC), abundances and CIC of those species representing 2% or more of all detections, species richness, and diversity (dependent variables) were rank transformed [40] and compared among sites and distances (independent variables) using a single-factor ANOVA with an alpha level of 0.05. Due to anurans not being detected at Buckley or Muskingum, only Blennerhassett and Grape were used in analyses. Site comparisons for Blennerhassett and Grape used transects only in which anurans were detected. Because Grape did not have sufficient distances, distance comparisons were made only at Blennerhassett.

Turtle relative abundance (captures/100 trap nights) for combined turtles and any species representing 2% or more of all captures, species richness, and diversity (dependent variables) were rank transformed [40] and compared among sites, distances, and the interaction term (independent variables) using a 2-way ANOVA with an alpha level of 0.05 and proceeded in the same fashion as the songbird analysis with a partial analysis for distance using only Blennerhassett and Buckley islands. Data were combined over each 3 day trapping interval and over the 3 trapping periods for each individual trap giving each trap a potential of 9 trap nights. Each trapping location was counted as a replicate. Recaptures were excluded from abundance analyses.

Small mammal relative abundance (captures/100 trap nights) of combined small mammal captures and individual species representing at least 2% of total captures, species richness, and diversity (dependent variables) were rank transformed [40] and compared by site, distance, and the interaction term (independent variables) using a repeated measures 2-way ANOVA ( $\alpha = 0.05$ ) in the same fashion as the songbird and turtle analyses. Abundance data were combined over each 3 night interval as 1 total trapping period. Deer mice (*Peromyscus maniculatus*)

and white-footed mice (*Peromyscus leucopus*) were combined into a single species (*Peromyscus* spp.) to account for identification biases. All recaptures were excluded from analyses.

Scent station data for furbearers were analyzed based on presence or absence by *G*-tests of independence with William's correction factor. Data were combined for each scent station over the 3 consecutive nights each station was operated and over the 6 survey periods in 2 years. Data were then combined by distance for each site. Analyses were run for all furbearer species combined (whether any furbearer tracks were present) and for each individual species representing 2% or more of furbearer species identified. Analyses compared both site and distance from bridge by combining total presences and absences for each site or distance. Each adjusted *G*-statistic was tested and an alpha level of 0.05 was set. Pair wise comparisons (among sites or distances) of significant tests were analyzed similarly. Transects at Muskingum Island were not used in the distance comparison due to no bridge being present at that site.

### 3. Results

#### 3.1. Waterbirds

A total of 19 waterbird species ( $n = 11$  at Blennerhassett,  $n = 8$  at Buckley, and  $n = 17$  at Muskingum) was observed during surveys (see [46] for a complete list). Additionally, 15 other waterbird species were observed within the study area but not during survey hours [46]. Combined waterbird abundance (individuals/39.25 ha plot) was not significantly higher at Blennerhassett compared to Buckley or Muskingum although Blennerhassett had 4 times as many waterbirds as Buckley (**Table 1**).

Only Canada goose (*Branta canadensis*) ( $n = 1007$ , 73.6%), double-crested cormorant (*Phalacrocorax auritus*) ( $n = 28$ , 2.1%), great blue heron (*Ardea herodias*) ( $n = 36$ , 2.6%), mallard (*Anas platyrhynchos*) ( $n = 124$ , 9.1%), and wood duck (*Aix sponsa*) ( $n = 54$ , 3.9%) had enough observations to analyze separately. Canada goose, double-crested cormorant, and wood duck abundances did not differ significantly among sites (**Table 1**). Great blue heron abundances were greater at Muskingum than at Blennerhassett or Buckley, which were similar. Mallard abundances were similar between Blennerhassett and Muskingum, but were significantly lower at Buckley.

Overall species richness was significantly lower at Buckley than the other 2 sites (**Table 1**). Overall diversity differed among all 3 sites with Muskingum having the highest diversity and Buckley having the lowest. At Blennerhassett, 185 of 239 (77.4%) observations of waterbirds flew over the bridge and 54 of 239 (22.6%) flew under the bridge. At Buckley, 138 of 191 (72.3%) observations

**Table 1. Summary of waterbird variables (abundances in the form of individuals/39.25 ha plot) with their means and standard errors for Blennerhassett, Buckley, and Muskingum islands, West Virginia, USA for 2007-2009 with same letters indicating no significance among sites (bolded means are significant at  $\alpha = 0.05$ ).**

Common Name <sup>a</sup>	Blennerhassett		Buckley		Muskingum		$F_{2,9}$	$p$
	Mean	SE	Mean	SE	Mean	SE		
Canada Goose	28.59a	8.12	6.86a	2.46	10.32a	2.52	1.51	0.272
Double-Crested Cormorant	0.09a	0.09	0.00a	0.00	1.18a	1.00	1.44	0.286
Great Blue Heron	<b>0.32b</b>	<b>0.12</b>	<b>0.09b</b>	<b>0.06</b>	<b>1.23a</b>	<b>0.39</b>	<b>5.33</b>	<b>0.030</b>
Mallard	<b>2.50a</b>	<b>0.81</b>	<b>0.64b</b>	<b>0.29</b>	<b>2.50a</b>	<b>0.57</b>	<b>5.24</b>	<b>0.031</b>
Wood Duck	0.91a	0.35	0.91a	0.35	0.64a	0.30	0.58	0.579
All Waterbirds	33.77a	7.99	8.82a	2.53	19.59a	4.20	3.38	0.080
Species Richness	<b>2.50a</b>	<b>0.31</b>	<b>1.31b</b>	<b>0.20</b>	<b>3.50a</b>	<b>0.35</b>	<b>5.54</b>	<b>0.027</b>
Shannon Diversity Index	<b>0.49b</b>	<b>0.10</b>	<b>0.19c</b>	<b>0.06</b>	<b>0.85a</b>	<b>0.09</b>	<b>8.64</b>	<b>0.008</b>

<sup>a</sup>Scientific names are found in Appendix 1.

of waterbirds flew over the bridge and 54 of 191 (27.7%) flew under the bridge.

### 3.2. Songbirds

Songbird surveys detected a total of 60 species ( $n = 48$  at Blennerhassett,  $n = 53$  at Buckley, and  $n = 42$  at Muskingum) [46]. A total of 17 species resulted in enough observations to analyze separately by sites and distances (Table 2). Three of these species had a significant site by distance interaction with Carolina chickadee (*Poecile carolinensis*) having higher abundances at the 0 m transect at Muskingum than at the 0 m transects at Blennerhassett and Buckley, while house wrens (*Troglodytes aedon*) had higher abundances at the 0 m transects at Blennerhassett compared to the 0 m transects at Buckley and Muskingum, and rock pigeon (*Columba livia*) was only found at the 0 m transects at Blennerhassett and Buckley causing an interaction and indicating an overall bridge effect.

Seven species differed significantly by site. Red-winged blackbird (*Agelaius phoeniceus*) and song sparrow (*Melospiza melodia*) were higher at Blennerhassett, gray catbird (*Dumetella carolinensis*) and red-eyed vireo (*Vireo olivaceus*) were lower at Blennerhassett, Carolina wren (*Thryothorus ludovicianus*) and tufted titmouse (*Baeolophus bicolor*) were higher at Muskingum, and European starling (*Sturnus vulgaris*) and yellow warbler (*Dendroica petechia*) were higher at Buckley (Table 2). Three species significantly differed by distances. Common yellowthroat (*Geothlypis trichas*) and Carolina wren were lower at 0 m transects and European starling was higher at 0 m transects (Table 2). No other species significantly differed among sites, distances, or interaction.

All species that occurred less than 3 times were removed from the total species composition matrix reducing the 60 to 46 for the site analysis and 44 for the dis-

tance analysis for MRPP [46]. Results of the PERMANOVA showed no evidence of a site by distance interaction ( $F_{4, 25} = 0.98$ ,  $p = 0.53$ ). Results of the MRPP suggest that all 3 islands have different songbird communities and that the 0 m transects have significantly different songbird communities than 100 m and 300 m transects ( $p \leq 0.005$ ). The Sorensen community similarity index comparing songbird composition among sites (0.402) and distances (0.456) further indicated different communities ( $p \leq 0.016$ ).

Results from indicator species analysis suggest certain species were more likely to occur on particular sites and at particular distances from the bridge [46]. Song sparrow was indicative of Blennerhassett, house finch (*Carpodacus mexicanus*) was indicative of Buckley, and 12 species were indicative of Muskingum. Two species cliff swallow (*Petrochelidon pyrrhonota*) and rock pigeon were indicative of 0 m transects.

### 3.3. Anurans

A total of 7 anuran species were detected at Blennerhassett Island and 5 anuran species at Grape Island: spring peeper (*Pseudacris crucifer*), Fowler's toad (*Anaxyrus fowleri*), eastern American toad (*Anaxyrus americanus americanus*), American bullfrog (*Lithobates catesbeianus*), Cope's gray treefrog (*Hyla chrysoscelis*), pickerel frog (*Lithobates palustris*), and northern green frog (*Lithobates clamitans melanota*). Only observations of spring peeper ( $n = 674$ , 88.5%), Cope's gray treefrog ( $n = 39$ , 5.1%), American bullfrog ( $n = 19$ , 2.5%), and northern green frog ( $n = 18$ , 2.4%) resulted in enough detections to analyze separately.

Combined anuran abundances (individuals/transect) were similar between Blennerhassett and Grape islands and at 0, 100, and 300 m transects ( $p = 0.400$ ) [46]. Likewise, spring peeper, American bullfrog, Cope's gray

**Table 2. Summary of songbird variables (abundances in the form of individuals/ha) with their means and standard errors for Blennerhassett, Buckley, and Muskingum islands, West Virginia, USA and at 0, 100, and 300 m from the bridge for 2008-2009 with same letters indicating no significance among sites or distances (bolded means are significant at  $\alpha = 0.05$ ).**

Common Name <sup>a</sup>	Island						Distance					
	Blennerhassett		Buckley		Muskingum		0 m		100 m		300 m	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
American Goldfinch	0.38a	0.08	0.60a	0.12	0.42a	0.16	0.35a	0.13	0.52a	0.11	0.53a	0.12
American Robin	0.82a	0.14	0.94a	0.16	0.67a	0.20	0.83a	0.17	1.00a	0.20	0.76a	0.16
Carolina Chickadee	<b>0.33b</b>	<b>0.10</b>	<b>0.21b</b>	<b>0.07</b>	<b>1.13a</b>	<b>0.28</b>	0.17a	0.08	0.36a	0.12	0.24a	0.08
Carolina Wren	<b>0.84a</b>	<b>0.13</b>	<b>0.73a</b>	<b>0.15</b>	<b>1.33b</b>	<b>0.14</b>	<b>0.35b</b>	<b>0.16</b>	<b>1.05a</b>	<b>0.17</b>	<b>0.76a</b>	<b>0.14</b>
Common Yellowthroat	0.58a	0.10	0.23a	0.07	0.33a	0.13	<b>0.13a</b>	<b>0.07</b>	<b>0.36ab</b>	<b>0.10</b>	<b>0.66a</b>	<b>0.12</b>
European Starling	<b>0.25a</b>	<b>0.14</b>	<b>1.15b</b>	<b>0.49</b>	<b>0.04a</b>	<b>0.04</b>	<b>1.48a</b>	<b>0.57</b>	<b>0.14a</b>	<b>0.08</b>	<b>0.76a</b>	<b>0.55</b>
Gray Catbird	<b>0.78b</b>	<b>0.11</b>	<b>1.38a</b>	<b>0.17</b>	<b>1.50a</b>	<b>0.21</b>	0.87a	0.21	1.24a	0.19	0.97a	0.12
House Wren	<b>0.82a</b>	<b>0.15</b>	<b>0.31b</b>	<b>0.09</b>	<b>0.29b</b>	<b>0.13</b>	0.74a	0.26	0.67a	0.15	0.39a	0.10
Indigo Bunting	0.55a	0.10	0.60a	0.10	0.96a	0.15	0.52a	0.16	0.74a	0.12	0.42a	0.09
Mourning Dove	0.15a	0.05	1.25a	0.85	0.08a	0.06	0.30a	0.15	0.40a	0.20	1.16a	1.05
Northern Cardinal	0.62a	0.10	0.90a	0.16	1.21a	0.19	0.52a	0.15	0.67a	0.11	0.97a	0.19
Red-Eyed Vireo	<b>0.16b</b>	<b>0.06</b>	<b>0.54a</b>	<b>0.09</b>	<b>0.79a</b>	<b>0.13</b>	0.26a	0.11	0.31a	0.09	0.42a	0.10
Red-Winged Blackbird	<b>1.35b</b>	<b>0.31</b>	<b>0.15a</b>	<b>0.05</b>	<b>0.21a</b>	<b>0.10</b>	0.17a	0.08	0.64a	0.29	1.32a	0.33
Rock Pigeon	<b>0.29b</b>	<b>0.12</b>	<b>0.90a</b>	<b>0.29</b>	<b>0.00c</b>	<b>0.00</b>	<b>2.57a</b>	<b>0.51</b>	<b>0.00b</b>	<b>0.00</b>	<b>0.00b</b>	<b>0.00</b>
Song Sparrow	<b>2.91a</b>	<b>0.21</b>	<b>1.79b</b>	<b>0.20</b>	<b>1.83b</b>	<b>0.26</b>	2.26a	0.33	2.33a	0.26	2.53a	0.24
Tufted Titmouse	<b>0.20b</b>	<b>0.05</b>	<b>0.29b</b>	<b>0.07</b>	<b>1.13a</b>	<b>0.23</b>	0.09a	0.06	0.29a	0.07	0.29a	0.07
Yellow Warbler	<b>0.25b</b>	<b>0.07</b>	<b>0.65a</b>	<b>0.13</b>	<b>0.17b</b>	<b>0.08</b>	0.48a	0.14	0.50a	0.13	0.34a	0.10
All Songbirds	<b>14.60b</b>	<b>0.61</b>	<b>16.83a</b>	<b>1.22</b>	<b>18.13a</b>	<b>1.01</b>	15.57a	1.44	15.12a	0.82	16.26a	1.29
Species Richness	<b>9.04b</b>	<b>0.38</b>	<b>9.77b</b>	<b>0.63</b>	<b>12.58a</b>	<b>0.67</b>	8.22a	0.72	9.74a	0.57	9.68a	0.59
Shannon Diversity Index	<b>2.01b</b>	<b>0.04</b>	<b>1.98b</b>	<b>0.08</b>	<b>2.40a</b>	<b>0.06</b>	1.86a	0.07	2.04a	0.08	2.02a	0.07

<sup>a</sup>Scientific names are found in Appendix 1.

treefrog, and northern green frog abundances did not show significant difference between sites or among distances ( $p \geq 0.623$ ). Call index codes for combined anurans also were similar between Blennerhassett and Grape and among 0, 100, and 300 m transects at Blennerhassett ( $p \geq 0.400$ ). Similarly, spring peeper, American bullfrog, Cope's gray treefrog, and northern green frog call index codes did not differ between sites or among distances ( $p \geq 0.560$ ). Species richness and diversity also were similar between sites and among distances ( $p \geq 0.402$ ).

### 3.4. Turtles

A total of 728 trap nights were attempted with 651 total trap nights occurring after deductions. We had 96 captures of 88 individuals from 5 species: eastern spiny softshell (*Apalone spinifera spinifera*), common snapping turtle (*Chelydra serpentina*), northern map turtle (*Graptemys geographica*), Midland painted turtle (*Chry-*

*semys picta marginata*), and stinkpot (*Sternotherus odoratus*). Of these 88 individuals, a total of 11 common snapping turtles and 4 Midland painted turtles were captured in the slough on Blennerhassett Island.

Combined abundances (captures/100 trap nights) were not different among sites, distances from the bridge, or by the interaction term (**Table 3**). Eastern spiny softshell ( $n = 46$ , 52.3%), common snapping turtle ( $n = 31$ , 35.2%), northern map turtle ( $n = 6$ , 6.8%), and Midland painted turtle ( $n = 4$ , 4.5%) occurred in large enough numbers to analyze separately. Eastern spiny softshell, common snapping turtle, and northern map turtle abundances did not differ significantly among sites, distances, or by the interaction term (**Table 3**). Midland painted turtle abundances significantly differed among sites due to that species only being captured at Blennerhassett (**Table 3**). Species richness did not differ among sites, distances, or by the interaction term (**Table 3**). Diversity differed significantly among sites due to Blennerhassett and Grape

**Table 3. Summary of turtle variables (abundances in the form of captures/100 trap nights) with their means and standard errors for Blennerhassett, Buckley, Muskingum, and Grape islands, West Virginia, USA and 0, 100, and 300 m from the bridge for 2008 and 2009 with same letters indicating no significance among sites or distances (bolded means are significant at  $\alpha = 0.05$ ).**

Common Name <sup>a</sup>	Island								$F_{3,72}$	$p$	Distance						$F_{2,72}$	$p$	Interaction	
	Blennerhassett		Buckley		Muskingum		Grape				0 m		100 m		300 m				$F_{6,72}$	$p$
	Mean	SE	Mean	SE	Mean	SE	Mean	SE			Mean	SE	Mean	SE	Mean	SE				
Eastern Spiny Softshell	9.00a	2.60	7.81a	3.53	6.25a	3.90	4.67a	1.32	0.73	0.537	6.90a	3.87	12.59a	3.85	7.53a	2.96	1.47	0.236	0.70	0.653
Common Snapping Turtle	5.94a	3.05	0.70a	0.70	3.30a	1.68	7.01a	2.27	2.06	0.114	5.17a	4.17	6.06a	3.74	3.08a	1.52	0.11	0.900	0.24	0.963
Northern Map Turtle	2.22a	1.57	0.70a	0.70	0.00a	0.00	0.00a	0.00	0.59	0.624	0.00a	0.00	1.85a	1.85	1.98a	1.40	0.98	0.382	0.27	0.948
Midland Painted Turtle	<b>1.83a</b>	<b>1.07</b>	<b>0.00b</b>	<b>0.00</b>	<b>0.00b</b>	<b>0.00</b>	<b>0.00b</b>	<b>0.00</b>	<b>2.75</b>	<b>0.049</b>	1.39a	1.39	0.00a	0.00	1.93a	1.38	1.57	0.215	0.83	0.554
All Turtles	19.00a	3.77	9.92a	3.46	9.55a	3.98	11.69a	2.74	1.88	0.140	12.46a	6.04	20.24a	4.80	13.52a	3.54	1.65	0.199	0.75	0.608
Species Richness	0.80a	0.14	0.47a	0.12	0.40a	0.11	0.80a	0.16	2.56	0.062	0.50a	0.27	0.78a	0.13	0.61a	0.16	1.43	0.247	0.94	0.474
Shannon Diversity Index	<b>0.10a</b>	<b>0.04</b>	<b>0.00b</b>	<b>0.00</b>	<b>0.00b</b>	<b>0.00</b>	<b>0.10a</b>	<b>0.05</b>	<b>3.13</b>	<b>0.031</b>	0.07a	0.07	0.03a	0.03	0.07a	0.05	0.20	0.820	1.50	0.190

<sup>a</sup>Scientific names are found in Appendix 1.

differing from Buckley and Muskingum, but did not differ by distance, or by the interaction term (**Table 3**).

### 3.5. Small Mammals

A total of 16,448 trap nights were attempted with 14,625 total trap nights calculated after deductions yielding a total of 1124 captures of 733 individuals. A total of 9 small mammal species were encountered during trapping surveys [46]. *Peromyscus* spp. ( $n = 495$ , 67.5%), meadow vole (*Microtus pennsylvanicus*) ( $n = 183$ , 25.0%), and eastern chipmunk (*Tamias striatus*) ( $n = 24$ , 3.3%) occurred in enough observations to analyze separately. Three variables, *Peromyscus* spp., species richness, and diversity, had a significant interaction effect (**Table 4**). These 3 variables had a significant interaction effect due to the 0 m transects at Blennerhassett having lower abundances, richness, and diversity under the bridge compared to 100 and 300 m transects. Also, the 100 and 300 m transects at Blennerhassett differed from the 100 and 300 m transects at Buckley and Muskingum due to higher abundances, richness, and diversity at the 100 and 300 m transects at Blennerhassett.

Combined small mammal abundances differed significantly by distances due to lower abundances at the 0 m transects, but did not differ among sites or by the interaction term (**Table 4**). Meadow vole abundances differed by sites due to this species not being sampled at Muskingum, but did not differ among distances or by the in-

teraction term. Eastern chipmunk abundances did not differ among sites, distances, or by the interaction term.

### 3.6. Furbearers

A total of 4 furbearer species were encountered in scent station surveys: raccoon (*Procyon lotor*) represented 82.8% of all occurrences, red fox (*Vulpes vulpes*) 8.2%, Virginia opossum (*Didelphis virginiana*) 7.5%, and American beaver (*Castor canadensis*) 1.5%. Occurrences of all furbearer species combined and Virginia opossum did not differ by site or by distance (**Table 5**). Raccoon occurrences differed by site and by distance with transects at 0 m at Blennerhassett having lower occurrences. Red fox occurrences differed by site with Blennerhassett having the highest occurrences, but not by distance (**Table 5**). American beaver occurrences were not tested due to too few observations.

## 4. Discussion

### 4.1. Waterbirds

Of the 5 species analyzed, only great blue heron and mallard differed among sites. Great blue heron densities were 3.84 times higher at Muskingum than Blennerhassett and 13.67 times higher at Muskingum than Buckley. This could be attributed to great blue herons being negatively impacted by the highway bridge crossings at the other 2 islands. Great blue herons prefer remoteness and

**Table 4. Summary of small mammal variables (abundances in the form of captures/100 trap nights) for Blennerhassett, Buckley, and Muskingum islands, West Virginia, USA and 0, 100, and 300 m from the bridge for 2008 and 2009 with same letters indicating no significance among sites or distances (bolded means are significant at  $\alpha = 0.05$ ).**

Common Name <sup>a</sup>	Island						Distance						Interaction								
	Blennerhassett		Buckley		Muskingum		0 m		100 m		300 m		F	df	P	F	df	P			
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE									
<i>Peromyscus</i>	<b>5.67a</b>	<b>0.67</b>	<b>0.89b</b>	<b>0.15</b>	<b>3.09b</b>	<b>0.45</b>	<b>2, 47.9</b>	<b>6.94</b>	<b>0.002</b>	1.17a	1.18	4.10a	0.71	3.96a	0.69	2, 48.1	0.66	0.519	<b>4, 48.1</b>	<b>2.96</b>	<b>0.021</b>
Meadow Vole	<b>1.56a</b>	<b>0.30</b>	<b>1.43a</b>	<b>0.32</b>	<b>0.00b</b>	<b>0.00</b>	<b>2, 53.8</b>	<b>4.60</b>	<b>0.014</b>	0.75a	1.67	1.50a	0.29	1.97a	0.45	2, 53.9	1.71	0.191	4, 47.4	0.41	0.803
Eastern Chipmunk	0.06a	0.03	0.30a	0.10	0.07a	0.05	2, 61.2	1.90	0.159	0.21a	0.66	0.19a	0.08	0.14a	0.10	2, 61.3	0.20	0.822	4, 68.8	0.11	0.980
All Small Mammals	7.37a	0.86	2.97a	0.36	3.35a	0.49	2, 65.6	2.45	0.094	<b>2.29b</b>	<b>2.16</b>	<b>5.99a</b>	<b>0.83</b>	<b>6.33a</b>	<b>0.93</b>	<b>2, 65.5</b>	<b>6.34</b>	<b>0.003</b>	4, 45.7	2.40	0.064
Species Richness	1.57a	0.11	1.07a	0.10	1.28a	0.12	2, 69.9	1.91	0.156	1.06a	0.16	0.93a	0.12	1.37a	0.13	2, 70.3	1.23	0.297	<b>4, 70.3</b>	<b>5.88</b>	<b>&lt;0.001</b>
Shannon Diversity Index	0.36a	0.04	0.20a	0.04	0.23a	0.05	2, 67.8	1.08	0.345	0.22a	0.06	0.29a	0.05	0.30a	0.05	2, 68.2	0.39	0.676	<b>4, 68.2</b>	<b>3.99</b>	<b>0.005</b>

<sup>a</sup>Scientific names are found in Appendix 1.

**Table 5. Summary of scent station data for furbearers with their presence (P) and absence (A) percentages (%) for Blennerhassett, Buckley, and Muskingum islands, West Virginia, USA and 0, 100, and 300 m from the bridge for 2008 and 2009 with the same letters indicating no significance among sites or distances (bolded species are significant at  $\alpha = 0.05$ ).**

Common Name <sup>a</sup>	Island						$G_2$	$p$	Distance						$G_2$	$p$
	Blennerhassett		Buckley		Muskingum				0 m		100 m		300 m			
	P	A	P	A	P	A			P	A	P	A	P	A		
<b>Raccoon</b>	50.0b	50.0	70.8a	29.2	69.4a	30.6	7.39	0.025	40.6ab	59.4	63.8ab	36.2	69.2a	30.8	7.00	0.030
Red Fox	15.7a	84.3	2.8b	97.2	0.0b	100.0	13.14	0.001	15.6a	84.4	8.6a	91.4	5.8a	94.2	2.08	0.354
Virginia Opossum	4.3a	95.7	8.3a	91.7	2.8a	97.2	1.67	0.433	6.3a	93.7	5.2a	94.8	7.7a	92.3	0.27	0.873
American Beaver	0.0	100.0	2.8	97.2	0.0	100.0	-	-	6.3	93.7	0.0	100.0	0.0	100.0	-	-
All Furbearers	60.0a	40.0	75.0a	25.0	49.9a	50.1	3.66	0.161	59.4a	40.6	67.2a	32.8	73.1a	26.9	1.66	0.436

<sup>a</sup>Scientific names are found in Appendix 1.

lack of human disturbance [47,48]. Noise can disrupt heron breeding and nesting patterns [49]. Additionally, great blue heron nesting patterns and nest success can be altered by other human disturbances including: increased human presence, land development, and destruction of habitat [50]. Mallard abundance was lower at Buckley Island possibly indicating that over time bridges impact mallards, but because mallard abundances were similar at Blennerhassett and Muskingum, we believe the Blennerhassett Island Bridge has no current impacts to mallards. There was no evidence that the Blennerhassett Island Bridge caused negative impacts to abundances of any other waterbird species.

We found waterbird species richness and diversity were lower at Buckley compared to the other 2 islands. This may be the result of the bridge at Buckley, but this is difficult to determine due to low abundances of 6 species found only at Muskingum. Lower species richness and diversity at Buckley are more easily explained by natural variation in observations rather than from the presence of a bridge.

Waterbirds do collide with bridges, which create barriers to movement and causes mortality and population declines. Our data, however, shows no indication that the bridge was a barrier or cause of mortality to waterbirds during diurnal time periods. Waterbirds more often flew over the bridge as opposed to under the bridge; however, waterbirds did not hesitate to fly under the bridge when flying low over the water. We had direct observations of many species including: belted kingfisher (*Megaceryle alcyon*), Canada goose, double-crested cormorant, great blue heron, mallard, spotted sandpiper (*Actitis macularia*), and wood duck flying under the bridge. The bridge does not seem to be a major barrier for waterbirds during flight, likely due to its relatively low height (24 m above the surface). There were no observations or documentations of waterbirds colliding with the bridge during diurnal flight.

## 4.2. Songbirds

Our study indicates that the Blennerhassett Island Bridge has some, albeit minor impacts to songbirds that resulted in a decrease in overall songbird abundance and changes in species composition most likely due to the area directly under the bridge being highly disturbed and lacking woody vegetation. This effect was mostly due to the removal of all trees, snags, and coarse woody debris and may be responsible for decreases in forest interior songbirds. Rock pigeon, cliff swallow, and European starling had high affinity for transects under bridges as these are all generalist species that use bridges and other man-made structures for nesting, roosting, and perching [12]. House wrens had high abundances under the Blennerhassett Island Bridge due to the placement of songbird nest boxes under the bridge after construction.

Songbird species composition is closely related to habitat structure [51,52]. Our study echoes this as songbirds observed were closely related to known habitat preferences with habitat generalist species using the areas directly under the bridges. Muskingum Island had higher species richness and diversity, different composition, and higher abundances of forest interior songbirds than the other 2 sites. This is largely due to all transects at Muskingum Island being located in bottomland hardwood forest [46] which harbor high species richness of passerines [53] while transects at Blennerhassett and Buckley islands varied across cover types with transects in old-field habitat having lower species richness.

Changes in songbird communities found in our study follows previously documented findings on the changes in species composition following a disturbance. Songbird communities vary among successional stages and forest types, and a diversity of landscapes maintains songbird diversity. Community changes of songbirds similar to those under the bridge have been documented for many types of natural and anthropogenic disturbances including: fire, blow downs, timber harvests, mowing, agricul-

ture, residential development, and urbanization [51,54-57].

### 4.3. Anurans

Anurans are commonly depicted as ecologically sensitive to anthropogenic disturbance [58,59]. However, we found anuran abundances, richness, and diversity were not different between a site with a large bridge crossing and a site without a bridge. Also, anuran abundances, richness, and diversity were no different at the different distances at Blennerhassett Island. Species were found calling throughout the wetland complex on the island and also in the wetland vegetation under the bridge on the West Virginia mainland. This indicates that the bridge had no negative effect on anuran relative abundance. Calling indices did not differ between sites or among distances further indicating the Blennerhassett Island Bridge has no negative effect on abundance or richness.

All anuran species encountered in this study had been previously documented on the Ohio River Islands National Wildlife Refuge and are common along the Ohio River [60]. Habitat was the determining factor of anuran presence [61], and anuran abundance and richness in relation to the bridge indicated the bridge had no negative effect. Other research has indicated that anurans respond positively or neutrally to disturbance. Two endangered anuran species responded favorably or neutrally to ground disturbance on a military training area in Germany [62]. Populations of anurans in floodplain wetlands were similar in abundance and richness compared to less dynamic wetlands not in floodplains [63]. Also, anuran abundance and richness was stable at a suburban wildlife refuge despite large amounts of development in close proximity to wetlands [64].

### 4.4. Turtles

Turtles are tolerant of urbanization and anthropogenic changes in the landscape [65,66]. Our study indicated that turtle abundance and richness were no different among sites or at the different distances from the bridges indicating that the new bridge has no negative effect on these metrics. Additionally, the difference in diversity among sites had no attribution to the new bridge. Eastern spiny softshell and common snapping turtle represented the majority of captures which is comparable to other studies on the Ohio River [25]. Eastern spiny softshells were encountered only in the main river which coincides with habitat preferences for this species [67]. Common snapping turtles were found readily in the main river at each of the study islands but more frequently in back channels [25]. We believe the Ohio River supports a large population of these 2 species around the study areas due to quality and quantity of habitat in the form of sand and

gravel bars, emergent vegetation, and woody debris.

The other 3 species (northern map turtle, Midland painted turtle, and stinkpot) were all encountered in low numbers. Each species is associated with slow bodies of water with soft bottoms and abundant basking sites [60] which are plentiful around Ohio River islands and in the slough on Blennerhassett, and we do not believe the bridge is affecting their abundances. Aquatic turtles are disturbance tolerant animals unlike many other taxa of wildlife. Spiny softshell turtle survival in Arkansas was not negatively affected when creek beds were bulldozed and woody debris was removed which decreased habitat quality and quantity [66]. Painted turtle nesting ecology showed no changes with increases of human recreation at a major nesting beach [68]. Species of freshwater turtles, including those found in this study, persist following disturbances in the form of urbanization [65] and in some cases may even be more abundant in urban habitats than they are in more undisturbed natural areas [69,70].

### 4.5. Small Mammals

Small mammals are typically depicted as disturbance tolerant [71,72]. However, we found that combined small mammal abundance and abundances of *Peromyscus* spp. were lower under the new bridge indicating that it has impacts. Species richness and diversity also were lower under the new bridge compared to other distances indicating that the disturbance from construction of the bridge may result in a decrease in small mammal richness and diversity. We believe these impacts are due to the amount and type of vegetative cover, and preferences of microhabitat by certain species [73]. We suggest these impacts are temporary and that abundance, richness, and diversity under the bridge will increase to levels similar to other distances as shown at the older Buckley Island Bridge making it consistent with other studies following a disturbance [74,75].

Total abundances of small mammals were highest at Blennerhassett, which is most likely due to more quality, quantity, and diversity of habitat. Lack of grasslands, old fields, and brushy areas at Muskingum Island [46] may be causing lower abundances [76], while possible reasons for lower abundance at Buckley Island include high numbers of raccoons preying on small mammals [77] or high intensity disturbance from agriculture, residential development, and urbanization. Also, all 3 sites may be experiencing variation due to cyclical fluctuations of small mammal populations [78,79].

The vegetation under the new bridge was of low coverage and consisted of herbaceous, disturbance tolerant plants typically used for reclamation making it similar to roadsides and may be the reason why abundances, richness, and diversity was low. However, capture rates and diversity increased under the bridge as vegetative cover

increased during the study. We hypothesize that the low abundances, richness, and diversity under the bridge is temporary and will increase as vegetative coverage increases. Also, there was only one detection of a small mammal moving from transect to transect at all of the sites (one *Peromyscus* spp. moved from a 100 m transect to a 0 m transect at Blennerhassett) possibly indicating that small mammal populations were impacted under the bridge during construction and are slowly increasing as habitat is restored.

#### 4.6. Furbearers

We found that combined furbearer detections did not differ among sites or distances. However, 2 species, raccoon and red fox, did vary. Raccoon detections were much lower at 0 m transects at Blennerhassett. These impacts could possibly be from habitat fragmentation and loss, most notably disturbance of natural shorelines caused by construction of the bridge. However, increased urbanization and habitat modification and fragmentation result in higher raccoon densities [79]. Raccoons respond well and use wildlife passages and underpasses [80] and we assume they use the area under the bridge similarly. We hypothesize that raccoons commonly frequent the area beneath the bridge, but may be patrolling around the wetland instead of the shorelines, thus avoiding our scent stations. Raccoon populations within the study area appear to be high due to high presence shown in scent station surveys, large amounts of tampering of small mammal traps during small mammal trapping periods, abundant quality and quantity of habitat (proximity to water, proximity to urban areas, and multiple cover types), lack of hunting and minimal trapping on the islands, and abundant food sources [77,81].

Red fox occurrences were highest at Blennerhassett and this species did not occur at Muskingum which is the reason for variation among sites and indicates the new bridge has no negative impacts. Personal observations suggest red fox populations are high on Blennerhassett as this island has preferred habitats including: forest, open areas, and grasslands and mixed vegetation communities such as edge habitats and mixed scrub and woodland [82].

#### 4.7. Conclusion

Any disturbance is likely to have impacts on some species, either negatively or positively. Species adapted to man-made structures such as rock pigeons responded favorably to the bridge and some such as Carolina wrens responded negatively. However, most songbird and waterbird species displayed no effect. Indeed, variation among islands was greater than variation among distances for almost all taxa. The more aquatic taxa such as turtles and anurans showed no relative density effects from the bridge.

Overall, the new bridge had little significant impact on relative density of wildlife, but the bridge did impact community composition and relative abundance of some species. It is possible that more impacts would have been seen if the island did not have a long history of human impacts. Continued monitoring of this and other bridges is necessary to determine potential long-term impacts.

### 5. Acknowledgements

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**Appendix 1. Common and Scientific Names of Species in Tables**

Songbirds		Mammals		Waterbirds		Turtles	
Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name	Common Name	Scientific Name
American Goldfinch	<i>Spinus tristis</i>	Peromyscus	<i>Peromyscus</i> spp.	Canada Goose	<i>Branta canadensis</i>	Eastern Spiny Softshell	<i>Apalone spinifera spinifera</i>
American Robin	<i>Turdus migratorius</i>	Meadow Vole	<i>Microtus pennsylvanicus</i>	Double-crested Cormorant	<i>Phalacrocorax auritus</i>	Common Snapping Turtle	<i>Chelydra serpentina</i>
Carolina Chickadee	<i>Poecile carolinensis</i>	Eastern Chipmunk	<i>Tamias striatus</i>	Great Blue Heron	<i>Ardea herodias</i>	Northern Map Turtle	<i>Graptemys geographica</i>
Carolina Wren	<i>Thryothorus ludovicianus</i>	Raccoon	<i>Procyon lotor</i>	Mallard	<i>Anas platyrhynchos</i>	Midland Painted Turtle	<i>Chrysemys picta marginata</i>
Common Yellowthroat	<i>Geothlypis trichas</i>	Red Fox	<i>Vulpes vulpes</i>	Wood Duck	<i>Aix sponsa</i>		
European Starling	<i>Sturnus vulgaris</i>	Virginia Opossum	<i>Didelphis virginiana</i>				
Gray Catbird	<i>Dumetella carolinensis</i>	American Beaver	<i>Castor canadensis</i>				
House Wren	<i>Troglodytes aedon</i>						
Indigo Bunting	<i>Passerina cyanea</i>						
Mourning Dove	<i>Zenaidura macroura</i>						
Northern Cardinal	<i>Cardinalis cardinalis</i>						
Red-Eyed Vireo	<i>Vireo olivaceus</i>						
Red-Winged Blackbird	<i>Agelaius phoeniceus</i>						
Rock Pigeon	<i>Columba livia</i>						
Song Sparrow	<i>Melospiza melodia</i>						
Tufted Titmouse	<i>Baeolophus bicolor</i>						
Yellow Warbler	<i>Dendroica petechia</i>						