NATURAL CAVITY CHARACTERISTICS AND CAVITY BIRD ABUNDANCE ON WEST VIRGINIA FORESTED ISLANDS OF THE OHIO RIVER

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Abstract.—Wildlife habitats connected with forested islands and their back channels (areas where commercial traffic is prohibited) on the Ohio River are valuable to diverse species. However, quantitative data on the importance of these areas to cavity-nesting birds are lacking. We compared cavity-nesting bird use and habitat between back and navigational channel sides of islands in 2000 and 2001. We observed 13 species of cavity-nesting birds. Total cavity-nesting bird abundance (number per 50-m-radius plot) was similar between the back and navigational channel sides, but abundance of downy woodpeckers (*Picoides pubescens* L.) was higher on the back than the navigational channel side. The back channel side contained more cavities in living and dead trees combined per plot than the navigational side. Most cavity characteristics (entrance height, width, inside height, and volume) were similar between navigational and back channel sites. Basal area was higher on the back channel than on the navigational channel side. The back channels can support more cavity-nesting birds than the navigational channel side and this study adds to the growing literature base indicating that the more forested and isolated back channel areas are important to a variety of wildlife species.

INTRODUCTION

Bottomland hardwood forests play an important role in riverine systems. The movement of nutrients through a riparian ecosystem can alter the water quality of rivers and streams (Brinson et al. 1981). Bottomland hardwood wetlands are known for high wildlife species richness, in part because forested wetlands serve as transitional areas between uplands and bodies of water for a variety of wildlife (Wigley and Lancia 1998). The moist soil on bottomland sites increases understory vegetation, which can increase bird abundance (Dickson 1978). Dead woody vegetation serves as sites for cover, food, and breeding; and tree roots provide cover for aquatic invertebrate and fish communities (Brinson et al. 1981, Wigley and Lancia 1998).

Only 1.5 percent of the United States is composed of riparian ecosystems (Brinson et al. 1981). In 1937, bottomland hardwoods covered 4.8 million ha but decreased to 2.1 million ha by 1977 (Brinson et al. 1981). Bottomland hardwood forests were originally cleared for agriculture because of the high soil fertility (Kellison et al. 1998). The removal rate of the forests was particularly high during the 1960s and 1970s, when the price received for farm crops, particularly soybeans, increased substantially (Kellison et al. 1998). Conversion of forests to agricultural land and reservoirs causes the greatest threat to birds within bottomland hardwoods (Chapman and Chapman 1999, Dickson 1978).

Destruction and conversion of bottomland hardwoods to agriculture and development alters plant and animal communities. Removal of bottomland hardwoods may make the area susceptible to exotic

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species, parasites, predators, and diseases that affect native wildlife species (Harris and Gosselink 1990, Hoover 2005). Converting land from natural forests to tree plantations often results in lower bird species abundance and diversity (Dickson 1978). Kilgo et al. (1998) found that the narrow stands of bottomland hardwoods remaining from previous land management practices might not provide suitable habitat for forest birds that require interior habitat.

The Ohio River, flowing from Pennsylvania to Illinois, provides valuable habitats for a variety of species (Tolin and Schettig 1983). Aquatic habitats connected with the Ohio River islands and their back channels (i.e., areas behind islands without commercial boat traffic) provide some of the area's highest quality bottomland hardwood, riverine, and wetland habitats, and are used by a variety of birds, fishes, and mussels (Tolin and Schettig 1983, Zadnik et al. 2009). Specifically, the back channels are thought to be important to wildlife because they provide protection from disturbances such as wind and commercial navigation (Zadnik et al. 2009). However, quantitative data on bird populations and habitat on the islands and back channels are lacking. Resource management agencies need quantitative data on the islands and particularly the back channel areas, which are under increasing pressure for development. Our objectives were to compare breeding bird abundance and habitat characteristics for cavity-nesting birds between back channel and navigational channel sides of islands on the Ohio River to determine if the back channel areas deserved additional protection from development.

STUDY AREA

We conducted the study on 10 islands of the Ohio River Islands National Wildlife Refuge from Paden City to Vienna, West Virginia, within Wetzel, Tyler, Pleasants, and Wood Counties (Zadnik et al. 2009). The average size of the islands was 42.7 ha (SE = 9.2), and the back channels ($\bar{x}$ = 153.9 m, SE = 22.6) were generally half the size of the navigational channels ($\bar{x}$ = 341.1 m, SE = 18.5). Vegetation communities included mature and immature bottomlands, early and late old fields, and agricultural fields. Islands were located in the Western Hills avifauna region (Buckelew and Hall 1994). Long-term precipitation averages 111.8 cm (range = 65.4 - 153.2 cm) (National Climatic Data Center 2003).

METHODS

We conducted this study in spring and summer 2000 and 2001. In 2000, we established two 50-m-radius plots on each of 10 islands, with one plot on the back channel side and one plot on the navigational side. In 2001, we established two additional plots on each island, to make a total of two plots on the back channel side and two plots on the navigational side.

We established the plots in the oldest available stands, with trees >50 years old in most cases. We delineated the stands based on cover type maps from September 1993 imagery. We located the center points of the plots near the shoreline so that half of the plots covered the island and half covered the water. By using this approach, we eliminated the risk of plots touching shores on both sides of the islands, and maximized the amount of shoreline edge that could be surveyed, because this area was the focus of the study. Plots on all islands, except for two, were at least 250 m apart ($\bar{x}$ = 727.8 m; SE = 76.4; range = 129.4 - 2,470.3 m) for independent wildlife sampling (Ralph et al. 1995), unless the size of the island or availability of bottomland hardwood stands prevented this distance. Study plots, but not islands, were devoid of artificial nest boxes.

We used single observer fixed-radius point counts (Ralph et al. 1995) to quantify overall breeding bird abundance twice between May 24 and July 7 in 2000 and 2001 (Dettmers et al. 1999). This time period provided information for the breeding season of most birds. We surveyed each plot for 10 minutes between 0600 and 1030 (Rodewald and Smith 1998).

We initially conducted a prism count of trees within each plot with a 10 basal area factor prism. For trees tallied with the prism we recorded tree species, diameter at breast height (d.b.h.) (cm), presence or absence of cavities (Cline et al. 1980, Mannan et al. 1980), and tree height (m) (Raphael and White 1984, Runde and Capen 1987, Sedgwick and Knopf 1990, Swallow et al. 1986). We recorded canopy cover for the shoreline centers of each plot in 2001.

Once the prism count was completed, we searched all living and dead trees within the plot for cavities following Kahler and Anderson (2006). We surveyed trees if ≥50 percent of the trunks fell within the 50-m-radius plot boundary. For all standing trees within the plot that contained cavities, we recorded tree species, d.b.h., tree height, number of shelf fungi or conks (Dobkin et al. 1995, Raphael and White 1984, Runde and Capen 1987), decay class (Maser et al. 1979), and distance to the Ohio River. We then collected data for the number of cavities per tree, height of each cavity above ground, entrance hole width, entrance hole height, cavity volume, compass direction of cavities, and cavity origin (Oli et al. 1997, Soulliere 1988, Swallow et al. 1986). We assessed the origin of a cavity by using five categories: woodpecker-excavated holes, limb holes (due to the loss of a fallen branch), chimneys (stumps with a cavity at the top), all other cavities that do not fit the above descriptions (Carlson et al. 1998), and limb hole enlarged by woodpeckers.

We also collected data for cavity breadth and height inside the cavity. We termed the measurement from the front of the cavity to the back "cavity breadth." For cavities that could not be measured directly (i.e., trees were too unstable to climb or cavities were too high) we made estimates by using the minimum values observed for similar tree sizes. We did not measure or count cavities that were <2 cm in height and width. We also did not consider cavities suitable if they contained water or excessive debris, or if they were constructed so that a nest would not be well hidden or protected by weather (Robb 1986).

We used a randomized block analysis of variance (ANOVA) to compare basal area per plot (m^2/ha), prism tree d.b.h. (cm/plot), mean number of cavities per tree per plot, mean cavity trees per plot, and percentage canopy cover (dependent variables) between treatments (back channel side and navigational side, and years [independent variables]) in which the effects of the islands were blocked. We found particular cavity characteristics per tree (entrance height, width, inside height, and volume [dependent variables]) to be correlated (r^2 range = 0.171 - 0.805, $P < 0.05$), so we compared them between treatments (back channel side and navigational side, and years [independent variables]) with a multivariate analysis of variance.

We compared canopy cover, cavity breadth, height from ground, number of fungal conks, tree height, cavity tree d.b.h., and distance to water (dependent variables) between treatments and years (independent variables) with randomized block ANOVAs. We analyzed all variables across both living and dead trees to maintain adequate sample sizes and to include all current resources for cavity-nesting birds. We analyzed cavity origin and cavity tree decay class (dependent variables) between treatments and years (independent variables) with a *G*-test (Sokal and Rohlf 1995, Zar 1999). Cavity orientation for woodpecker-created holes was analyzed for circular uniformity by using Rayleigh's *z*-test (Zar 1999, Zwartjes and Nordell 1998). We compared differences in orientation (dependent variables) between channel sides (independent variables) for 2000 and 2001 with Watson's test (Rendell and Robertson 1994, Zar 1999). We compared tree species (dependent variables) of cavity trees between treatments and years (independent variables) with a *G*-test (Sokal and Rohlf 1995, Zar 1999). We used Friedman's nonparametric block test to compare native cavity bird abundance, total cavity bird abundance (includes European Starlings [*Sturnus vulgaris* L.]), and cavity bird species (dependent variables) between island sides, years, and the island-side interaction term (independent variables).

We considered all tests significant at $P < 0.05$. We transformed density data with square root transformation to meet normality and homogenous variance assumptions (Sedgwick and Knopf 1990, Sokal and Rohlf 1995). We log transformed cavity characteristics and tree height from ground, d.b.h., number of fungal conks, and distance to water; rank-transformed tree height and Maser decay class (Conover and Iman 1981); and arcsine transformed canopy cover (Zar 1999).

We analyzed relations between cavity and cavity tree characteristics (cavity volume, cavity breadth, height from ground to cavity, cavity tree height, cavity tree d.b.h., number of conks, and cavity tree distance to water) and cavity birds (abundance, richness, and diversity) with stepwise multiple regression ($P < 0.05$). Cavity volume was chosen to represent entrance height, width, and inside height because the variables were highly correlated (Sacilotto 2002).

RESULTS

Habitat Characteristics

The tree species that had the most importance (Spurr and Barnes 1980), or influence, on the composition of the plots were silver maple (*Acer saccharinum* L.), box elder (*Acer negundo* L.), pawpaw (*Asimina triloba* L.), black walnut (*Juglans nigra* L.), black locust (*Robinia pseudoacacia* L.), sycamore (*Platanus occidentalis* L.), and Eastern cottonwood (*Populus deltoids* Bartr.). Basal area was higher on the back channel ($\bar{x}$ = 42.03 m^2/ha, SE = 3.11) than on the navigational channel ($\bar{x}$ = 27.24 m^2/ha, SE = 1.99) side ($F_{1,9} = 43.51$, $P < 0.001$). There was no interaction between side and year ($F_{1,9} = 0.195$, $P = 0.197$) for basal area. There was an interaction between side and year ($F_{1,9} = 6.07$, $P = 0.029$) for d.b.h. of the trees located in the prism count, but treatment effects by year showed no differences in 2000 (back channel: $\bar{x}$ = 57.27, SE = 5.76; main channel: $\bar{x}$ = 53.78, SE = 3.89; $F_{1.9} = 0.001$, $P = 0.974$) or 2001 (back channel: $\bar{x}$ = 55.13, SE = 3.96; main channel: $\bar{x}$ = 44.71, SE = 3.58; $F_{1.9} = 1.84$, $P = 0.208$).

Cavity abundance (cavities/plot) was higher on the back channel ($\bar{x}$ = 19.93, SE = 2.48) than on the navigational channel ($\bar{x}$ = 11.58, SE = 1.73) side ($F_{1,9} = 35.39$, $P < 0.001$). Cavity tree abundance (trees/plot) also was higher on the back channel ($\bar{x}$ = 10.15, SE = 1.28) than on the navigational ($\bar{x}$ = 6.45, SE = 0.85) side ($F_{1,9} = 21.34$, $P = 0.001$). There was no interaction between side and year for cavity abundance ($F_{1,9} = 0.57$, $P = 0.469$) or number of cavity trees ($F_{1,9} = 0.62$, $P = 0.450$).

Table 1.—Characteristics of cavities, cavity trees, and 50-m-radius plots between back channel and navigational channel sides of islands (n=10) on the Ohio River Islands National Wildlife Refuge, West Virginia, 2000-2001

	Back channel side		Navigational side	
Variable	$\bar{x}$ †	SE	$\bar{x}$ †	SE
Cavity characteristics				
Height of entrance (cm)	10.49 a	0.62	10.16 a	0.62
Width of entrance (cm)	6.77 a	0.20	6.95 a	0.29
Height inside cavity (cm)	11.98 a	0.99	11.57 a	1.14
Volume (cm^3)	2,623.04 a	719.41	2,860.36 a	902.89
Breadth (cm)	8.16 a	0.37	8.47 b	0.51
Height from ground to cavity (m)	7.30 a	0.25	6.60 b	0.27
Cavity tree characteristics				
Cavity tree height (m)	15.97 a	0.38	14.52 a	0.44
Cavity tree d.b.h. (cm)	55.7 a	1.84	47.72 b	1.84
Conks (no.)	1.19 a	0.32	0.64 a	0.25
Cavity tree distance to water (m)	14.00 a	0.61	17.42 b	1.00
Plot characteristics				
Canopy cover (%)	95.43 a	3.42	86.60 b	4.57

† Means in a row followed by the same letter are not different (P > 0.05) between the back channel and navigational channel sides.

Table 2.—Cavity origin per 50-m-radius plot between the back channel and navigational channel sides of islands (n=10) on the Ohio River Islands National Wildlife Refuge, West Virginia, 2000-2001

		Number of Cavities					
Year	Origin†	Back channel	Navigational channel	Total	Cavities (%) ‡	G-test	P-value
2000	1	75	47	122	37.3 a	1.84	0.605
	0.5	6	4	10	3.1 a		
	2	121	55	176	53.8 a		
	3, 4	12	7	19	5.8 a		
2001	1	129	114	243	40.1 a	10.49	0.015
	0.5	25	12	37	6.1 ab		
	2	204	104	308	50.8 b		
	3, 4	11	7	18	3.0 ab		

†Index of origin: 1 = woodpecker-excavated holes, 2 = limb holes, 3 = chimneys, 4 = all other cavities not described above (Carlson et al. 1998), 0.5 = limb holes enlarged by woodpeckers.

‡The same letter following values in this column indicates no difference ($P > 0.05$) in proportion of cavities of particular origin.

Cavity characteristics (entrance height, width, inside height, and volume) were similar between back and navigational channel sides (Wilks' $\lambda = 0.485$, $P = 0.291$) and there were no interactions between side and year for any cavity or cavity tree characteristic ($P \geq 0.320$). Cavity breadth was lower on the back than the navigational channel side ($F_{1,9} = 5.55$, $P = 0.043$; Table 1). Cavity height from ground was higher on the back channel than the navigational side ($F_{1,9} = 6.32$, $P = 0.033$). Generally, the origins of most cavities were limb holes (Table 2). In 2000, types of cavities were similar between the channel sides ($G_{1,3} = 1.84$, $P = 0.605$). In 2001, there was a significant difference between the types of cavities and channel side, with a higher proportion of limb holes on the back channel side ($G_{1,3} = 10.50$, $P = 0.015$).

Table 3.—Cavity tree decay class per 50-m-radius plot between the back channel and navigational channel sides of islands (n=10) on the Ohio River Islands National Wildlife Refuge, West Virginia, 2000-2001

Year	Decay class[†]	Number of trees: Back channel	Number of trees: Navigational channel	Total	Percentage of trees[‡]	G-test	P-value
2000	1	67	28	95	55.6 a	6.75	0.080
	2, 3	36	22	58	33.9 a		
	4	2	6	8	4.7 a		
	5, 6, 7	8	2	10	5.8 a		
2001	1	139	71	210	65.4 a	23.76	< 0.001
	2	41	41	82	25.5 b		
	3	1	5	6	1.9 bc		
	4	3	14	17	5.3 cd		
	5, 6	4	2	6	1.9 bd		

[†]Maser decay classification: 1 = live, 2 = declining, 3 = dead, 4 = loose bark, 5 = clean, 6 = broken, 7 = decomposed, 8 = down material, 9 = stump (Maser et al. 1979).

[‡]The same letter following values in this column indicates no difference (P > 0.05) in proportion of trees of particular decay class.

Cavity tree height ($F_{1,9}$ = 3.10, P = 0.112), and number of fungal conks ($F_{1,9}$ = 0.73, P = 0.415) were similar between channel sides (Table 1). Cavity tree d.b.h. was higher on the back channel than the navigational side ($F_{1,9}$ = 6.68, P = 0.030), but cavity tree distance to water was shorter on the back channel than the navigational side ($F_{1,9}$ = 13.63, P = 0.005). Plot canopy cover (percent) was higher on the back channel than the navigational side ($F_{1,9}$ = 10.38, P = 0.011). Maser decay class of the cavity trees was similar between channel sides in 2000 ($G_{1,3}$ = 6.75, P = 0.080) (Table 3), but in 2001, there was a difference between the decay class and channel side, with more live healthy trees than trees showing signs of senescence ($G_{1,4}$ = 23.76, P < 0.001).

The entrances of woodpecker-created cavities were randomly distributed with respect to compass direction for both sides and years combined (z = 0.0204, n=364, P > 0.05). Orientation was similar between the back channel side (BC) and navigational side (NC) for 2000 (Watson's U^2 = 0.1779, n_{BC}=75, n_{NC}=47, P > 0.05) and 2001 (Watson's U^2 = -0.0009, n_{BC}=128, n_{NC}=114, P > 0.50).

In both years, most trees containing cavities were silver maple, box elder, and black locust (Table 4). Differences were found between tree species containing cavities in 2000 (G_{10} = 64.68, P < 0.001) and 2001 (G_{12} = 520.48, P < 0.001). In 2000, box elder, hackberry (*Celtis occidentalis* L.), sycamore, silver maple, sweet buckeye (*Aesculus octandra* Marsh.), and black cherry (*Prunus serotina* Ehrh.) contained the highest proportion of cavity trees. Black locust, black willow (*Salix nigra* Marsh.), slippery elm (*Ulmus rubra* Muhl.), and black walnut contained the lowest proportion of cavity trees. In 2001, Eastern cottonwood, sycamore, box elder, silver maple, hackberry, black locust, and black cherry contained the highest proportion of cavity trees. Tree-of-heaven (*Ailanthus altissima* P. Mill. Swingle), slippery elm, black willow, black walnut, and pawpaw contained the lowest proportion of cavities.

Table 4.—Proportion of trees containing cavities for 2000 and 2001 on islands (n=10) on the Ohio River Islands National Wildlife Refuge, West Virginia, 2000-2001

Year[†]	Species	Scientific name	Cavity trees	Total trees	Cavity trees (%)[‡]
2000	Box elder	*Acer negundo*	39	162	24.1 a
	Hackberry	*Celtis occidentalis*	6	31	19.3 a
	Sycamore	*Populus occidentalis*	7	37	18.9 ab
	Silver maple	*Acer saccharinum*	95	531	17.9 ab
	Sweet buckeye	*Aesculus octandra*	1	3	33.3 abc
	Black cherry	*Prunus serotina*	2	12	16.7 abc
	Black locust	*Robinia pseudoacacia*	11	134	8.2 bc
	Black willow	*Salix nigra*	4	67	6.0 bc
	Slippery elm	*Ulmus rubra*	1	25	4.0 bc
	Black walnut	*Juglans nigra*	5	206	2.4 cd
2001	Others[§]		8	9	88.9 a
	Eastern cottonwood	*Populus deltoides*	6	13	46.2 ab
	Sycamore	*Populus occidentalis*	15	37	40.5 b
	Box elder	*Acer negundo*	60	162	37.0 b
	Silver maple	*Acer saccharinum*	171	531	32.2 b
	Hackberry	*Celtis occidentalis*	7	31	22.6 bc
	Black locust	*Robinia pseudoacacia*	29	134	21.6 c
	Black cherry	*Prunus serotina*	2	12	16.7 cd
	Tree -of-heaven	*Ailanthus altissima*	6	47	12.8 c
	Slippery elm	*Ulmus rubra*	3	25	12.0 cde
	Black willow	*Salix nigra*	7	67	10.4 cde
	Black walnut	*Juglans nigra*	7	206	3.4 d
	Pawpaw	*Asimina triloba*	1	937	0.1 f

[†]Differences were found between tree species containing cavities in 2000 (G_{10} = 64.68, P < 0.001) and 2001 (G_{12} = 520.48, P < 0.001).

[‡] The same letter following values in this column indicates no difference (P > 0.05) in proportion of trees containing cavities between species.

[§]Includes catalpa (*Catalpa* spp.), sassafras (*Sassafras albidum* [Nutt.] Nees), sweet buckeye, and sweet cherry (*Prunus avium* L.).

Cavity Birds

We observed 13 species of cavity-nesting birds during point counts (Table 5). A total of 111 native cavity-nesting birds were recorded, 63 on the back channel side and 48 on the navigational side. Total native cavity-nesting bird abundance was similar between the back channel and navigational channel sides ($\chi^2_{1,9}$ = 1.80, P = 0.180) (Table 5). When European starlings were added to the cavity-nesting bird group, differences remained similar between sides ($\chi^2_{1,9}$ = 0.05, P = 0.823) (Table 5).

Abundance of downy woodpeckers (*Picoides pubescens* L.) was higher on the back channel than the navigational channel side ($\chi^2_{1,9}$ = 7.20, P = 0.007), but abundance of Carolina chickadees (*Poecile carolinensis* Audubon) ($\chi^2_{1,9}$ = 1.80, P = 0.180), Carolina wrens (*Thryothorus ludovicianus* Latham) ($\chi^2_{1,9}$ = 3.20, P = 0.074), European starlings ($\chi^2_{1,9}$ = 0.80, P = 0.371), great crested flycatchers (*Myiarchus crinitus* L.) ($\chi^2_{1,9}$ = 0.20, P = 0.655), hairy woodpeckers (*Picoides villosus* L.) ($\chi^2_{1,9}$ =

Table 5.—Cavity-nesting bird abundance (number of birds/plot) between the back channel and navigational channel sides of islands (n=10) on the Ohio River Islands National Wildlife Refuge, West Virginia, 2000-2001

	Back channel		Navigational channel	
Variable	$\bar{x}$ †	SE	$\bar{x}$ †	SE
Native cavity bird abundance ‡	0.91 a	0.14	0.73 a	0.15
Total cavity bird abundance §	1.10 a	0.19	1.19 a	0.21
Carolina chickadee	0.14 a	0.05	0.05 a	0.02
Carolina wren	0.13 a	0.05	0.04 a	0.02
Downy woodpecker	0.23 a	0.05	0.11 b	0.04
European starling	0.19 a	0.07	0.46 a	0.18
Great crested flycatcher	0.00 a	0.00	0.03 a	0.03
Hairy woodpecker	0.06 a	0.03	0.03 a	0.02
House wren	0.05 a	0.03	0.08 a	0.05
Northern flicker	0.11 a	0.04	0.06 a	0.04
Pileated woodpecker	0.05 a	0.03	0.01 a	0.01
Red-bellied woodpecker	0.05 a	0.03	0.01 a	0.01
Tree swallow	0.01 a	0.01	0.14 a	0.09
Tufted titmouse	0.06 a	0.03	0.11 a	0.06
White-breasted nuthatch	0.01 a	0.01	0.06 a	0.04

†Means pairs followed by the same letter are not different (P > 0.05) between the back channel and navigational channel sides.

‡ Cavity bird abundance without European starlings.

§ Cavity bird abundance with European starlings.

1.25, P = 0.264), house wrens (*Troglodytes aedon* Vieillot) ($\chi^2_{1,9}$ = 0.20, P = 0.655), northern flickers (*Colaptes auratus* L.) ($\chi^2_{1,9}$ = 3.20, P = 0.074), pileated woodpeckers (*Drycopus pileatus* L.) ($\chi^2_{1,9}$ = 0.80, P = 0.371), red-bellied woodpeckers (*Melanerpes carolinus* L.) ($\chi^2_{1,9}$ = 0.80, P = 0.371), tree swallows (*Tachycineta bicolor* Vieillot) ($\chi^2_{1,9}$ = 0.80, P = 0.371), tufted titmice (*Baeolophus bicolor* L.) ($\chi^2_{1,9}$ = 0.00, P = 1.000), and white-breasted nuthatches (*Sitta carolinensis* Latham) ($\chi^2_{1,9}$ = 0.80, P = 0.371) were similar between channel sides (Table 5). There was no interaction between year and side for any species or group ($P \geq 0.118$). Over both years, cavity characteristics had an effect on native cavity bird abundance (Y = 2.095 – 0.788[volume] + 1.566 [breadth]; $F_{2, 37}$ = 5.65, P = 0.007, R^2 = 0.234, Akaike's information criterion [AIC] = -41.39) and total cavity bird abundance (Y = -1.363 + 1.324[height from ground]; $F_{1, 38}$ = 9.54, P = 0.004, R^2 = 0.202, AIC = -15.82).

DISCUSSION

Habitat for cavity-nesting birds was better on the back channel side than on the navigational channel side, due to the greater number of cavities, cavity trees, and potentially basal area found on the back channel side. Cavity tree d.b.h. was higher on the back channel side, which indicates that the trees will remain standing longer and provide a greater variety of cavity sizes, allowing for greater species richness (DeGraaf and Shigo 1985, Newton 1994). Mannan et al. (1980) found that cavity-nesting bird density was positively correlated with d.b.h. of snags. Rosenberg et al. (1988) found that snags with larger diameters were used more often by foraging birds than were smaller snags.

The average Maser decay class (Maser et al. 1979) of the cavity trees in 2001 was lower on the back channel side than the navigational side. This finding signifies that the cavity trees on the back channel side were generally in better health (Maser et al. 1979), which could result in cavities that are more stable for nesting, and should provide better-quality habitat for a longer time (Kahler and Anderson 2006). Tree resistance to decay is partly dependent on tree species (DeGraaf and Shigo 1985, Maser et al. 1979). Sycamore and black locust trees are known for their longevity, unlike silver maple (Fowells 1965) and box elder (Manion 1981). The heartwood of sycamore is considered nonresistant to natural decay (Sheffer and Cowling 1966). It is a good cavity tree because it is susceptible to few serious diseases and is regarded as wind-firm (Fowells 1965). More silver maple and box elder cavity trees were found than sycamore and black locust, suggesting that most cavity trees on the islands are susceptible to early decomposition. However, a good variety of decay-resistant and non-decay-resistant trees will ensure adequate cavity resources over time.

There was not an overwhelming loss of cavity trees from 2000 to 2001. In the original 20 plots, there was a loss of 12 cavity trees and recruitment of 11 cavity trees between 2000 and 2001. Two of the 12 trees contained cavities that were no longer considered suitable in 2001 and 10 fell due to windthrow or erosion. Overall, there was a net loss of one cavity tree between 2000 (171 cavity trees) and 2001 (170 cavity trees), or a 0.6 percent loss of available cavity trees within the 20 original plots. Although not a significant loss, a net loss of cavity trees from one year to the next could present a problem for cavity-nesting birds over time if the rate of loss increases.

Investigating the density of cavity trees can assist in predicting populations of cavity-nesting birds (McComb and Muller 1983, Sedgwick and Knopf 1992). The combination of losing cavity trees to unavailability and erosion could create a habitat-limiting situation for cavity-nesting birds. If this trend continues, the population of cavity-nesting birds could decrease in response to fewer cavities. Availability of cavity trees is often considered a major limiting factor for a population of cavity-nesters (Brush 1983, von Haartman 1957, Zarnowitz and Manuwal 1985), especially if the quality of the cavities is low (Carlson et al. 1998).

Although the habitat appeared more favorable on the back channel side for cavity-nesters, channel side did not appear to have a strong effect on the distribution of cavity-nesting birds. Generally, the greater number of cavity trees and cavities provides the necessary environment for native cavity species to reproduce (McComb and Muller 1983, Newton 1994, Sedgwick and Knopf 1990). Furthermore, most cavities found on the back channel side were limb holes, which can have higher use by cavity-nesting birds than other cavity types (Carlson et al. 1998).

Because we found that the height of cavities from the ground was higher on the back channel side, it is possible that the cavity-nesting birds did not select cavities that high. However, this scenario is unlikely because a positive relation was found between cavity height from ground and total cavity-nesting birds. Carlson et al. (1998) found that cavity height above ground was the most important cavity characteristic connected with use by cavity-nesting birds, and that used cavities were located higher from the ground than unused cavities. Sedgwick and Knopf (1990) also found that most cavity-nesting bird species used cavities at greater heights. Li and Martin (1991) found that nest success was greater for species nesting in higher cavities, and suggested that results could be due to depredation.

Cavity breadth was lower on the back channel side, which might have deterred cavity-nesting birds from using some of the cavities there, although a positive relation was found between cavity breadth and native cavity-nesting bird abundance. Inner cavity circumference, similar to cavity breadth, also was smaller for used cavities (Carlson et al. 1998). Entrance size, entrance width, inside height, and volume were other cavity characteristics associated with native cavity-nesting bird abundance. Carlson et al. (1998) found that used cavities were associated with entrance size, volume, inner cavity circumference, and wall thickness. Sedgwick and Knopf (1990) found that cavity-nesting species selected cavities with entrance diameters that differed between species. European starlings and northern flickers selected cavities with larger diameters than did black-capped chickadees (*Poecile atricapillus* L.) and house wrens (Sedgwick and Knopf 1990). Despite these associations, cavity dimensions, with the exception of cavity breadth, were similar between channel sides and thus do not necessarily explain the distribution of cavity-nesting birds on the islands.

Primary cavity-nesters, like downy woodpeckers, would have been affected not by the cavities already created but more likely by tree characteristics such as d.b.h., which could explain why their abundance was higher on the back channel side. Runde and Capen (1987) found that downy and hairy woodpecker nests were associated with live trees, whereas black-capped chickadees selected well-decayed snags. Some cavity-nesting birds on the islands might have been nesting on the back channel side but foraging on the navigational side. Bird species may be able to obtain more of their resources, such as food and shelter, where the habitat is more diverse (Penhollow and Stauffer 2000). Habitat diversity was lower on the back channel side probably because that side mostly consisted of mature hardwood areas, whereas the navigational side also contained some immature hardwood areas. European starlings are known for their generalist behavior in choosing habitat for nesting (Ehrlich et al. 1988) and might not select one channel side over another for nesting. Another factor influencing cavity-bird distribution is territory size. Rendell and Robertson (1989) suggested that the avoidance of many tree cavities resulted from intraspecific territoriality. Furthermore, habitat quality should be measured in terms not only of density, but also of survival and reproductive potential (Van Horne 1983, Vickery et al. 1992); however, density can be a suitable predictor of habitat quality if the spatial scale is not too coarse (Maurer 1986).

Despite differences in cavity characteristics between channel sides, it is possible that cavity abundance is not actually limiting to cavity-nesters on the navigational side. Because use of cavities was not determined, we cannot ascertain if cavities are a limiting factor for cavity-nesting populations on navigational channels of the Ohio River. However, nest box use on a subset of the islands used in this study, suggests no difference in use between navigational and back channel sides (Sacilotto and Anderson 2005), but evidence suggests that habitat is more suitable for cavity-nesting species on the back channel side. We believe that the lack of significant differences in cavity-nesting songbird abundance is related to their strong territoriality (Rendell and Robertson 1989), thus limiting their densities, as back channels were more heavily used by waterfowl, turtles, and aquatic mammals (Zadnik et al. 2009). Nonetheless, islands on the Ohio River are important to cavity-nesting birds and other wildlife.

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