Nesting Habitat Characteristics of Bank Swallows and Belted Kingfishers on the Connecticut River

Mara Silver[1,2,*] and Curtice R. Griffin[1]

Abstract - *Ceryle alcyon* (Belted Kingfisher) and *Riparia riparia* (Bank Swallow) rely on vertical eroded banks for nesting. We inventoried Belted Kingfisher and Bank Swallow nesting banks along a 91.6-km section of the Connecticut River in Massachusetts, New Hampshire, and Vermont, including stretches where bank stabilization projects are completed, under construction, or planned. In the case of Bank Swallows, we also assessed the availability of potential nesting habitat in the study area. Forty-four Belted Kingfisher nesting sites and 12 Bank Swallow colonies were detected in the study area. Both species used banks with a low percentage of vegetative cover and a steep slope. Belted Kingfishers used high narrow banks. Bank Swallows used wide banks composed of well-drained, fine sandy loam soils. Potential Bank Swallow nesting sites were limited and in comparison to the sites actually used by Bank Swallows, they were narrower, more vegetated, and composed of more coarse soils. The impact of bank stabilization on Belted Kingfishers is probably minimal. However, bank stabilization eliminated three of twelve Bank Swallow colony sites that served as habitat for ≈20% of nesting pairs in the study area between 1999 and 2005.

Introduction

Riverine systems are dynamic, resulting in bank erosion and deposition of eroded sediment. In North America, steeper portions of eroded banks provide nesting sites for several species of burrow-nesting birds, including solitary-nesting *Ceryle alcyon* (L.) (Belted Kingfishers) and colonial-nesting *Riparia riparia* (L.) (Bank Swallows).

Brooks and Davis (1987) reported that bank height, slope, soil composition, and availability of prey were important factors in habitat selection for Belted Kingfishers in southwestern Ohio. There is little information on the characteristics of banks used by Belted Kingfishers in New England.

Information on the characteristics of banks used by Bank Swallows is also limited. Most studies were at artificial sites, (e.g., road cuts, quarries, and gravel pits) where swallows typically occupy steep banks with well-drained, sandy soils (John 1991, Peterson 1955, Spencer 1962). Garrison described the physical characteristics of banks used by Bank Swallows along the Sacramento River in California, where bank stabilization projects alter and threaten their nesting habitat (Garrison 1999, Garrison et al. 1987).

Notwithstanding the lack of data on the nesting habitats of resident Belted Kingfishers and Bank Swallows along the Connecticut River, bank

[1]Department of Natural Resources Conservation, University of Massachusetts Amherst, Holdsworth Hall, Amherst, MA 01002. [2]Current address - 93 North Street, Shelburne Falls, MA 01370. [*]Corresponding author - silver@sinauer.com.

stabilization projects are occurring in some areas. In light of ongoing stabilization of riverbanks in our locale, our objectives were to: (1) inventory eroding riverbanks used by Belted Kingfishers and Bank Swallows, (2) characterize the habitat features of eroding river banks important to these two species, and (3) identify riverbanks that have potential as Bank Swallow colony sites. To reach these objectives we measured: (1) characteristics of actively used nesting banks for both species, (2) a random sample of unused banks, and (3) potential Bank Swallow nesting banks.

Methods

Study area

The Connecticut River, New England's largest river, originates at the Connecticut Lakes (45°14'N, 71°12'W) in northern New Hampshire, and flows south 650 km to Old Saybrook, CT (41°16'2N, 72°20'W), where it empties into Long Island Sound. The river forms much of the boundary between Vermont and New Hampshire, and continues through Massachusetts and Connecticut to the Sound.

We conducted our fieldwork by boat on the main stem of the Connecticut River from the Vernon Dam (42º46'N, 72º31'W, about 425 km south of the Connecticut Lakes), in Vernon, VT and Winchester, NH, to the Holyoke Dam (42º12'N, 72º36'W), Holyoke, MA, a river distance of 91.6 km. The Turners Falls Dam (42º36'N, 72º32'W), Turners Falls, MA, lies 34.0 km south of the Vernon Dam, 57.6 km north of the Holyoke Dam, and separates our river study area into two sections (designated pools by the conventions of hydroelectric generation). The northern pool, (the Turners Falls Pool) extends from the Vernon Dam to the Turners Falls Dam. The southern pool (the Holyoke Pool), extends from the Turners Falls Dam to the Holyoke Dam. Electrical generation capacities of the Vernon, Turners Falls, and Holyoke dams, all of which have been in place for at least a century, are 21MW, 6MW, and 44MW, respectively. There are 12 additional functioning dams on the main stem of the river; all of these are north of the Vernon Dam. To augment the peak hydroelectric capacity of the river, a 1000 MW pumped-storage hydroelectric station (Northfield Mountain Station [42°37'N 72°25'W], about 9.0 km north of Turners Falls Dam) began operation in the Turners Falls Pool in 1972.

The interaction between the flowing river and physical features of the land results in various bank types in the study area. These range from ledges to steep eroded faces, terraces, beaches, and gently sloping floodplain forests. Factors contributing to erosion include natural fluvial processes, hydroelectric generation, recreational motorboat use, and high run-off from storm events.

In the Turners Falls Pool, hydroelectric generation results in water level fluctuations of up to 0.9 m over 24 hours, and 2.4 m over a one-week cycle. As of 1991, approximately one-third of the banks of this pool were actively eroding (US Army Corps of Engineers 1991).

The rate and magnitude of water-level fluctuations in the Holyoke Pool are lower than in the Turners Falls Pool, and erosion is variable. During our study (1997–1999), water levels in the Holyoke Pool fluctuated by 0.3 m. Erosion rates are low in the first 40 km of the Holyoke Pool below the Turners Falls Dam. Erosion rates increase along the next 7.4 km. South of this, to the Holyoke Dam (10.2 km), the banks on both the east and west sides of the river are composed primarily of ledge, and erosion rates are minimal.

For both Belted Kingfishers and Bank Swallows, after initial investigation revealed the pattern of erosion in the two pools, fieldwork was concentrated in the two stretches of the river with high bank erosion rates, where the two species were found to nest: the entire Turners Falls Pool (34.0 km), and the 7.4-km area of high erosion in the Holyoke Pool. To maintain consistency, however, all results were considered relative to the 96.1-km river study area. Fieldwork investigating Belted Kingfisher nesting sites was conducted in both pools in the 1999 season. For Bank Swallows, we worked the three seasons 1997–1999 in both pools.

Belted Kingfisher nest-burrow inventory

After the nesting season (i.e., after 31 July) in 1999, daily surveys were conducted for 21 days to identify Belted Kingfisher nest burrows throughout both pools. Belted Kingfisher nest burrows are unique in our study area. Although *Stelgidopteryx serripennis* (Audubon) (Northern Rough-winged Swallows), a secondary cavity nester, will use abandoned kingfisher burrows for nesting, no other species in our region constructs nests with the same appearance. Thus, we assumed that even if a kingfisher burrow was not fresh, it was active within the past two years. The locations of recent burrows were recorded, while locations of older burrows were not. Burrows with partially-closed entrances (by either soil or vegetation) and with sediment (i.e., sand) in the entrance hole were considered older (constructed prior to 1998). Multiple recent nest burrows were present in some banks. However, because Belted Kingfishers vigorously defend individual territories, it is unlikely that two pairs would nest in the same bank. A second or third burrow would more likely be last season's or a partially excavated burrow.

Bank Swallow colony inventory

Surveys to locate active Bank Swallow colonies were conducted in both pools during the nesting seasons in 1997–1999. Large colonies are usually composed of smaller subcolonies that are often separated by bare bank face, vegetation, or fallen trees. We considered one bank with multiple subcolonies to be one colony.

Bank habitat characteristics

Bank height, width, slope, aspect, vegetative cover, and soil type were determined at all banks used by Belted Kingfishers and Bank Swallows, at potential Bank Swallow nest sites, and at a random sample of bank sites. Potential colony sites were identified based on the following criteria: 5–20 m height (i.e., we did not find active nests in banks <5 m tall), 10–150 m wide, 70–90° slope, and ≤10% vegetative cover. Potential sites were considered a single site if vegetation between them was ≤20 m wide and/or <1 m high. These criteria were chosen based on characteristics of active sites observed in 1997. Random sites were chosen by dividing each power pool into 11-km long segments. In each segment, 11 bank sites (one per km) were selected for measurement using a random numbers table without replacement.

Bank height was measured from the base to the top of the bank at the approximate center of the bank. Base of bank was (considered to begin) at the high water mark; height included both the vertical portions of the bank and any material that had slumped. Little slumped material was present in the measured sites, probably due to strong intermittent currents and rapid depth fluctuations resulting from hydroelectric generation as well as recreational boating. Height was measured via triangulation for banks >6 m high and with a 2 m-long pole for those <6 m high.

For used banks, width was considered the entire vertical bank face, not just the bank face where nest holes were present. For potential banks, width included the total area with a slope ≥70°, and vegetative cover ≤10% at the onset of the breeding season (late April–early May). We used the same criteria at random sites that we used for potential banks if the site occurred on an eroded bank. If the random site was part of a long section of uniform bank, bank width was truncated at 300 m. Bank width was measured with a 2 m-long pole across the base of shorter banks, and visually estimated for long banks.

Slope of all banks was measured as the angle of the bank from the top of the bank to the high water mark across the entire width of the bank face. For each 5 m of bank width, one randomly chosen point was taken for slope measurement, and an average slope was calculated from multiple measurements. Slope was measured with an inclinometer attached to a 2 m-long pole. For random banks that were part of a long, uniform stretch of bank, slope was visually estimated.

For banks facing in one direction, aspect was determined from the center of the bank. For banks on river bends, aspect was the angle of most of the bank. Aspect was determined with a compass.

Vegetative cover on the bank face was estimated via visual surveys using cover classes (1–5% [midpoint = 3.0], 6–15% [midpoint = 10.5], 16–25% [midpoint = 20.5], 26–50% [midpoint = 38.0], 51–75% [midpoint = 63.0], 76–95% [midpoint = 85.5], and 96–100% [midpoint = 98.0] total vegetative cover). Vegetative cover surveys were conducted in late July–August when most vegetation had fully leafed out. Soil type was determined using USDA county soil maps (USDA Soil Conservation Service 1967, 1978, 1981, 1987, 1989). Given the parent material of the soils along the Connecticut River in our study area, the textural composition is of a fairly narrow range, and generally composed of silts, fairly fine sand, and very fine sand. Additionally, the soils developed in alluvium, which has a range in texture and composition that is fairly limited; thus, we assumed soil maps were of a fine enough scale for this study.

Data analyses

Data from both the Turners Falls and Holyoke pools were combined after preliminary statistical analysis indicated no significant differences among measured variables between pools ($P \geq 0.1$). To determine which variables described Belted Kingfisher and Bank Swallow nesting habitat, a regression model was built for each. Additionally, a third model was built to determine the best predictor(s) of swallow presence at used versus potential sites. We tested for variables with high Pearson's pair-wise correlation ($P > 0.75$), and none met this criterion. Thus, all variables were entered into the models separately. We used forward selection (SAS Institute 1990). Our observation/predictor ratio (12 observations and 6 predictors) violates that recommended by Steyerberg et al. (1999). Thus, univariate analysis may be a more comprehensive measure of results for the swallow models, whereas the logistic regression models serve as an exploratory investigation. In the model-building phase, we first examined the effects of each independent variable separately. Independent variables were bank height, width, slope, aspect, vegetative cover, and soil type. Bank width, vegetative cover, and soil type had bimodal distributions; each was divided into two categories for analysis (Table 1). The variable soil type was categorized from an original 30 soil types. To determine which variables would be included in the logistic model, we conducted univariate screening using χ^2 and *t*-tests. Variables were retained if significant ($P < 0.1$).

The overall goodness-of-fit of the Belted Kingfisher model was assessed with the Hosmer-Lemeshow statistic (Hosmer and Lemeshow 1989). This statistic indicates whether the model produces estimates that are significantly different than observed values. For swallow models, the goodness-of-fit could not be determined due to the low sample size and consequent low number of groups (6) required for calculation of the goodness-of-fit (Hosmer and Lemeshow 1989). Thus, as already stated, the univariate analysis may be a more comprehensive measure of results for the swallow models.

Table 1. Bank characteristics measured at Belted Kingfisher nest sites, used and potential Bank Swallow colony sites, and random sites along the Connecticut River, 1997–1999 and used in regression models.

Variable	Type	Description
Height	Continuous	Height of bank (m)
Width	Categorical	Width of bank (0–150 m versus >150 m)
Slope	Continuous	Average slope of bank
Aspect	Continuous	Aspect of bank face
Vegetative cover	Categorical	Percent of vegetation covering bank face (0–11% versus >11%)
Soil type[A]	Categorical	Category 0; Category 1

[A]Category 0 = very deep (1.5 m) well to moderately well drained, textures ranging from silt loam through sand with <5% coarse fragments. Category 1 = wetter than moderately well drained, coarse fragments >5% or shallow (<1.5 m) to bedrock.

The logistic regression model to predict the presence of Belted Kingfishers included height, width, slope, and vegetative cover of banks. The Bank Swallow model included width, slope, vegetative cover, and soil type. The used/potential Bank Swallow model included width and vegetative cover. A probability cut point of 0.5 was used to classify observations as events or non-events (Hosmer and Lemeshow 1989).

Results

Belted Kingfisher inventory and bank habitat characteristics

We found 44 Belted Kingfisher nest sites along 96.1 km of river, or 0.5 nests/km overall (Fig. 1). There were 0.4 nests/km in the 34-km Turners Falls Pool, and 1.0 nests/km in the 7.4-km focus area of the Holyoke Pool. In the Holyoke Pool, we did not find kingfisher nests outside of this 7.4-km stretch of river. Nesting sites were distributed evenly in both stretches of river in which they were found.

We compared the bank characteristics of nest sites (Table 2) to those of 90 random sites (Fig. 2, Table 3). Height, width, slope, and vegetative cover were included and remained in the logistic model (Table 4), providing 93% correct classification. Bank slope and vegetative cover were the best predictors of bank use (highest Wald χ^2 values). However, bank use was negatively related to width and vegetative cover, and positively related to height and slope. The odds ratio indicated that kingfishers were 1.4 times as likely to use higher banks per unit height increase (per meter), and 1.2 times as likely to use vertical banks per unit slope increase (per degree). According to these data, kingfishers selected banks that were both higher and narrower than

Figure 1. Active Belted Kingfisher nest site.

unused banks. Average widths of banks used for kingfisher nesting were narrower than those used by Bank Swallows (mean = 25.8 m and mean = 128.3 m, respectively).

Bank Swallow inventory and bank habitat characteristics

We located 12 active Bank Swallow colonies in the study area over three seasons (Fig. 3). In 1999, there were 1007 total nesting pairs in 11 banks (one bank was discovered late in the nesting season in 1999, and total nesting pairs could not be determined for that colony). Colony size ranged from 1 to 250 pairs (mean = 92 pairs). There were five colonies (11% of total nesting pairs) with 1–49 nesting pairs, one colony (5% of total nesting pairs) with 50–99 pairs, three colonies (36% of total nesting

Table 2. Average measures of bank characteristics at Belted Kingfisher nest sites, active and potential Bank Swallow colony sites, and random sites along the Connecticut River, 1997–1999.

Variable	Used (kingfishers) $n = 44$	Used (swallows) $n = 12$	Potential (swallows) $n = 31$	Random $n = 90$
Height (m)	7.6	7.3	7.0	5.7
Width (m)	25.8	128.3	32.6	257.7
Slope (degrees)	89.0	88.0	89.0	55.0
Aspect (compass)	187.2	180.0	133.4	185.7
Vegetative cover (%)	7.5	7.3	24.5	84.9
Soil type[A]				
% in Cat 0	77.0	100.0	77.0	74.0
% in Cat 1	23.0	0.0	23.0	26.0

[A]See Table 1 for definitions of soil categories.

Figure 2. Random site. Random sites were variable; this one depicts a non-ideal nesting site for Belted Kingfishers and Bank Swallows.

pairs) with 100–149 pairs, no colonies with 150–199 pairs, and two colonies (48% of total nesting pairs) with 200–250 pairs. Eighty-four percent of all birds in the study nested in banks with ≥100 active nests, and 48% nested in banks with ≥200 active nests. Eleven of 12 colonies were occupied all three years of the study.

Width, slope, vegetative cover, and soil type differed between active colony sites and random sites (Table 5). Banks with active colonies were wider, steeper, less vegetated, and had deeper, better-drained soil with fewer coarse fragments than random sites. In the stepwise logistic procedure, only vegetation remained in the model (parameter estimate = -4.25, SE = 0.89, Wald χ^2 = 23.18, odds ratio = 0.01, P = 0.0001) as the single best predictor of nesting Bank Swallows at a site, providing 92% correct

Table 3. Bank habitat characteristics at used Belted Kingfisher nest sites (n = 44) and random sites (n = 90) along the Connecticut River, 1997–1999.

	Used	Random	Used vs. Random		
			df	χ^2	*P*
Vegetative cover					
0–11%	38	6	1	85.11	8.81E-21
>11%	6	84			
Soil type					
Cat. 0	34	67	1	0.13	0.832
Cat. 1	10	23			
Width					
0–150 m	41	15	1	71.12	2.49E-18
>150 m	3	75			
	Used	Random	Used vs. Random		
			t	*P*	
Height (m)					
Mean	7.6	5.7	-3.51	0.0006	
SE	0.3	0.4			
Slope (degrees)					
Mean	89.0	55.0	-14.10	0.0001	
SE	0.7	2.3			
Aspect (degrees)					
Mean	187.2	185.7	-0.08	0.935	
SE	16.3	9.9			

Table 4. Results of logistic regression for predicting nesting Belted Kingfisher nest sites along the Connecticut River 1997–1999.

Variable	Parameter estimate	SE	Wald χ^2	Odds ratio	*P*
Average slope	0.18	0.07	6.85	1.2	0.009
Vegetative cover	-2.20	0.95	5.37	0.1	0.021
Height	0.34	0.17	3.97	1.4	0.046
Width	-1.96	1.05	3.95	0.1	0.062
Goodness-of-fit statistic = 3.94, df = 6, P = 0.684					

classification. Slope and vegetative cover were highly related (t = 3.97, P = 0.001). Banks that had 0–11% vegetative cover had a mean slope of

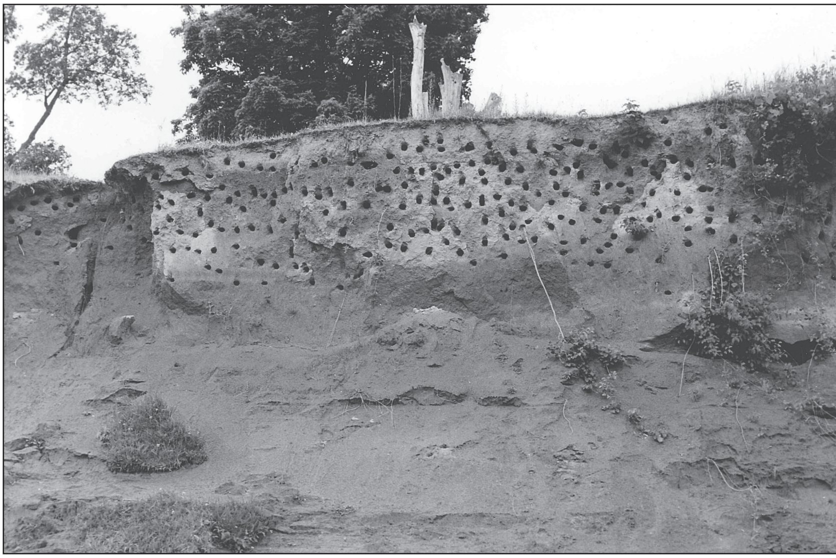

Figure 3. Active Bank Swallow colony showing nesting burrows.

Table 5. Bank habitat characteristics at used (n = 12) and potential (n = 31) Bank Swallow colonies, and random sites (n = 90) along the Connecticut River, 1997–1999.

				Used vs. Potential			Used vs. Random		
	Used	Potential	Random	df	χ^2	P	df	χ^2	P
Vegetative cover									
0–11%	10	14	6	1	5.11	0.039	1	47.06	2.19E-08
>11%	2	17	84						
Soil type									
Cat. 0	12	24	67	1	3.24	0.163	1	3.96	0.063
Cat. 1	0	7	23						
Width									
0–150 m	5	30	15	1	17.35	17.3E-04	1	4.20	0.055
>150 m	7	1	75						

				Used vs. Potential		Used vs. Random	
	Used	Potential	Random	t	P	t	P
Height (m)							
Mean	7.3	7.0	5.7	-0.23	0.820	-1.27	0.210
SE	1.2	0.5	0.4				
Slope (degrees)							
Mean	88.0	89.0	55.0	0.38	0.710	-13.51	0.0001
SE	0.8	1.4	2.3				
Aspect (degrees)							
Mean	180.1	133.4	185.7	-1.25	0.220	0.19	0.847
SE	30.7	19.9	93.6				

79°, whereas banks with >11% vegetation had a mean slope of 56°. The parameter estimate indicates that as vegetation increases, the probability of nesting swallows decreases.

Thirty-one potential sites (Fig. 4) were identified and compared to used sites. In the univariate analysis (Table 5), width and vegetative cover differed between used and potential sites. These two variables were included and remained in the logistic model (Table 6), providing 81% correct classification. The parameter estimate indicates that as bank width increases, the probability of nesting swallows increases; yet as vegetation increases, the probability of nesting Bank Swallows decreases. These results were reinforced by our finding that 82% of the swallows in our study nested in banks >150 m wide. Thus, potential banks were consistently narrower, with more vegetative cover than used banks. Using these criteria, we considered 11 (five in the Turners Falls Pool and six in the Holyoke Pool) of the 31 potential sites to be suitable for Bank Swallow nesting. If we combine these 11 suitable potential sites with our 12 active colonies, we arrive at a site occupancy of about 50%.

Figure 4. Potential nesting site for Bank Swallow colony.

Table 6. Results of logistic regression comparing used and potential Bank Swallow sites along the Connecticut River 1997–1999.

Variable	Parameter estimate	SE	Wald χ^2	Odds ratio	*P*
Width	3.94	1.34	8.62	51.4	0.003
Vegetative cover	–2.07	1.18	3.08	0.1	0.080

Discussion

Belted Kingfishers

Our count of 1.0 nest/km in the focus area (higher erosion) of the Holyoke Pool is similar to that reported in Colorado (Shields and Kelly 1997). In contrast, Belted Kingfisher nests were found at a lower density (0.4 nest/km) in the Turners Falls Pool, where there was more fluctuation of water levels and higher river bank erosion rates than in the Holyoke Pool. It is unlikely that there were no kingfisher nests in the remainder of the Holyoke Pool; however, we were unable to locate them with the techniques that we had developed. In this respect, we feel justified in the conclusion that kingfisher nesting sites were rare outside of the 7.4-km high erosion area of the Holyoke Pool. The nest density over the entire 96.1-km study area, 0.5 nests/km, appears to reinforce this interpretation.

Belted Kingfishers select nesting banks that are vertical, free of vegetation, and consist of sandy soils with variable clay content (Hamas 1994). Brooks and Davis (1987) argued that higher banks afforded kingfisher nests protection from predators, fluctuating water levels, and floods along stream habitats in Pennsylvania and Ohio. They reported that the average slope of kingfisher nesting banks was 88.0° (± 5°) in Pennsylvania and 89.0° (± 2°) in Ohio. In Colorado, Shields and Kelly (1997) found that kingfishers selected high banks that sloped uniformly to the waterline (without a decrease in slope at the base) and had a lower sand content than those reported by Brooks and Davis. Our results were similar to these two studies regarding slope and height, but soil characteristics were not significant in our investigation.

Bank Swallows

We located 12 colonies along 91.6 km of the Connecticut River, whereas 60 colonies were found along 256 km of the Sacramento River (Garrison et al. 1987) and 211 colonies were found along a 586-km segment of the River Tisza in Hungary (Szép 1991). However, our ≈50% site occupancy is approximately twice the site occupancy (between 20% and 30%) observed in mid-1990s on the Sacramento River by B.A. Garrison (Rancho Cordova, CA, 2006 pers. comm.). Our relatively high occupancy rate may indicate that nesting habitat is limited, which may also explain the persistence of colonies at the same sites throughout the three years of our study.

Although there were more colonies with 1–49 pairs, most individuals in our study nested in banks with over 100 pairs. Similarly, 60% of Bank Swallow colonies in Michigan had 1–50 active nests, but 71% of swallows were in colonies with ≥100 active nests, and 47% inhabited colonies ≥200 nests (Hoogland and Sherman 1976). In Hungary, average colony size was 158 pairs, and 67% of the birds nested in colonies with >200 pairs (Szép 1995).

Bank Swallows prefer a freshly eroded bank face for nesting, even though new burrows must be excavated annually (Hickling 1959). Banks relatively free of vegetative cover probably facilitate the excavation of burrows by swallows, and reduce access by predators.

Steep slopes probably facilitate excavation of the swallows' long horizontal burrows and, again, deter predators. Previous studies reported that areas highest on the vertical bank face are more easily defended against threats and evictions from conspecifics during burrow-excavation (Peterson 1955). John (1991) found that swallows only nested in banks with sufficient stability to maintain a 3-m vertical face. Although slope did not remain in our stepwise regression model, this was most likely due to its high correlation with vegetative cover.

Bank Swallows typically prefer sandy, silty, loamy soils, characterized by small particle size (Garrison 1999). Along the Sacramento River, Garrison et al. (1987) found that 68.6% of swallows nested in fine sandy loam, loam, and silt-loam. Similarly, Spencer (1962) found that the birds preferred loamy sands or sandy loams with low clay and high sand content. Peterson (1955) reported that swallows prefer sand to clay or chalk, and that nest burrows were deeper when excavated in sand (92% sand) than sandy loam (65% sand). In accord with these investigators, we found colonies in deep, fine, uniform, river-deposited sediments.

Our observation that 82% of swallows nested in banks that were >150 m wide was consistent with Garrison et al.'s (1987) study on the Sacramento River where nesting bank width averaged 454.6 m. Although Spencer (1962) reported an average bank width of only 57.1 m (range = 9.1–304.8), 24 of 25 sites in his study were human-made; these artificial banks tend to be narrower than banks along rivers and streams. Larger colonies are located on wider banks, and these larger colonies tend to persist longer than smaller colonies (Garrison 1999). We suspect that the Connecticut River probably provides important Bank Swallow nesting habitat in the study area because of the presence of wide banks.

Petersen (1955) suggested that social forces play a role in keeping Bank Swallow burrows concentrated, and some researchers noted a surplus of unused bank habitat (Spencer 1962). Similarly, there appeared to be sufficient suitable potential habitat in our study area that was unused. However, based on characteristics of used sites, we found a shortage of wide banks or vegetation-free banks for nesting. One explanation for the high number of potential banks with high vegetative cover may be related to vegetation phenology. We identified many of the potential sites early in the growing season before vegetation had leafed out. Many of these sites were covered with vegetation by mid- to late-summer when vegetative cover was measured. This was not the case with used sites, which remained vegetation-free. Further, a higher percentage of potential sites were composed of coarser soils than used sites. Thus, width, vegetative cover, and soil type may differentiate used from potential sites, thereby limiting the utility of potential sites for nesting swallow colonies along this stretch of the Connecticut River.

Conservation

Although we did not find published records, Bank Swallows have always nested in some numbers along the length of the river (S. Kellogg, Springfield, MA, 2007 pers. comm.), and a colony has been observed nesting in one particular section of riverbank in Holyoke Pool of the study for the last 45 years (T. Gagnon, Amherst, MA, 2007 pers. comm.).

Nest-site characteristics of Belted Kingfishers and Bank Swallows differed in our study area. Although both species used steep eroding banks with little vegetation, kingfishers tended to use narrow banks, whereas swallows used wide banks. Considering there are relatively fewer suitable wide banks, swallow nest-sites are probably more limited than kingfisher nest sites in our study area. This limited number of suitable nest sites in combination with their moderate levels of nest site tenacity (Bergstrom 1951, Stoner 1941) makes Bank Swallows vulnerable to bank stabilization programs along the Connecticut River.

As bank stabilization continues, fewer sites erode and additional habitat is not created (Fig. 5). Further, the most highly eroded and widest banks are typically chosen for stabilization projects; yet, these banks are the most important for nesting swallows in our study area. During our study, two of six active swallow colony sites in the Turners Falls Pool were lost to stabilization projects. Observations made after our study and information provided by The Franklin Regional Council of Governments revealed that at least five banks, with a total width of 1798 m, were stabilized within the Turners Falls Pool by 2000. Additionally, between 2000 and 2005, another 2171 m of riverbank were stabilized in our study area, eliminating one more active colony

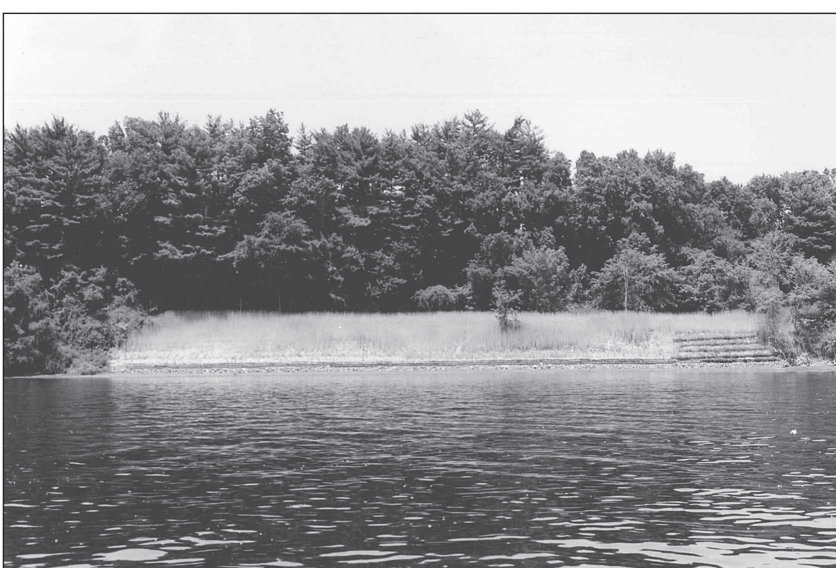

Figure 5. Stabilized bank. Current stabilization efforts in the Turners Falls Pool are done using a method called "bioengineering"; the banks are graded, creating a shallow slope, and a stone toe is installed. The bank is then covered with "fabric" and further stabilized with plantings.

site and four of five sites we considered suitable potential sites. Thus, three of six active colonies in the Turners Falls Pool were eliminated between 1997 and 2005. Stabilization of an additional 299 m was scheduled to occur by the end of 2005, with 518 m more by the end of 2007, and additional work is planned beyond 2007.

The three Bank Swallow colonies in the Turners Falls Pool that were lost to stabilization between 1997 and 2005 accounted for ≈20% of the nesting pairs of birds recorded in 1999 in our 96.1-km study area. One of these sites was a larger site (135 pairs). It is not known if the birds that nested at this site moved to another nesting site in the study area in the subsequent year. For the six years following our study, we have not received any casual reports indicating that the birds have been able to exploit new habitat (comparable to the size of the large site that was eliminated) elsewhere in the Turners Falls Pool.

The size and impact of the pumped-storage hydroelectric facility at Northfield Mountain Station has contributed to the decision favoring intensive soil conservation efforts in the Turners Falls Pool. The energy of the moving water must, however, be somehow dissipated; the future effects of these projects with respect to our study species, even if these effects are largely confined to the Turners Falls Pool, are unknown. It seems likely that habitat availability in this pool will diminish as the river is increasingly channelized. Garrison et al. (1987) reported that erosion control projects on the Sacramento River threatened over 50% of that river's Bank Swallow population. By 1996, Schlorff (1997) reported that the number of nesting pairs on the Sacramento River had declined by 66% since 1986. Our work suggests a similar effect over a much shorter stretch of river than that of the Sacramento. A greatly expanded effort, encompassing a much greater portion of the 650-km main stem of the river, is necessary to help bring perspective to our work.

Although erosion is a natural fluvial process that provides nesting habitat for Belted Kingfishers and Bank Swallows along the Connecticut River, human activities also affect erosion rates both positively (i.e., water fluctuation for hydropower generation), and negatively (i.e., bank stabilization). To conserve nesting Bank Swallows in our study area of the river, the wide banks currently used for nesting and erodable areas adjacent to these sites should not be stabilized. Additionally, wide banks that we consider to have high potential as future swallow nest sites should also be protected from stabilization. The long-term conservation of Belted Kingfishers and Bank Swallows on the Connecticut River depends on maintenance of dynamic erosive processes of the river.

Acknowledgments

For helpful comments on early drafts of the manuscript, we thank P. Vickery and T. Litwin. We thank P. Kuzeja, C. Silver, and G. LeBaron for help with fieldwork, and we are indebted to Trina Hosmer for her assistance with data analyses. Funding for this project was provided by Northeast Utilities Corporation, the Sweetwater Trust, and the Charles Blake Fund. We also acknowledge B.A. Garrison and two anonymous reviewers, whose comments greatly improved the manuscript.

Literature Cited

Bergstrom, E.A. 1951. The South Windsor Bank Swallow colony. Bird-Banding 22:54–63.

Brooks, R.P., and W.J. Davis. 1987. Habitat selection by breeding Belted Kingfishers (*Ceryle alcyon*). American Midland Naturalist 117:63–70.

Garrison, B.A. 1999. Bank Swallow (*Riparia riparia*). *In* A. Poole and F. Gill (Eds.). The Birds of North America, No. 414. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, DC.

Garrison, B.A., J.M. Humphrey, and S.A. Laymon. 1987. Bank Swallow distribution and nesting ecology on the Sacramento River, California. Western Birds 18:71–76.

Hamas, M.J. 1994. Belted Kingfisher (*Ceryle alcyon*). *In* A. Poole and F. Gill (Eds.). The Birds of North America, No. 84. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, DC.

Hickling, R.A.O. 1959. The burrow-excavation phase in the breeding cycle of the Sand Martin *Riparia riparia*. Ibis 101:497–500.

Hoogland, J.L., and P.W. Sherman. 1976. Advantages and disadvantages of Bank Swallow (*Riparia riparia*) coloniality. Ecological Monographs 46:33–58.

Hosmer, D.W., Jr., and S. Lemeshow. 1989. Applied Logistic Regression. John Wiley and Sons, Inc. New York, NY.

John, R.D. 1991. Observations on soil requirements for nesting Bank Swallows, *Riparia riparia*. Canadian Field-Naturalist 105:251–254.

Petersen, A.J. 1955. The breeding cycle in the Bank Swallow. Wilson Bulletin 67:235–286.

SAS Institute, Inc. 1990. SAS/STAT User's Guide. Version 6.12. SAS Institute. Cary, NC.

Schlorff, R.W. 1997. Monitoring Bank Swallow populations on the Sacramento River: A decade of decline. Transactions of the Western Section of the Wildlife Society 33:40–48.

Shields, S J., and J.F. Kelly. 1997. Nest-site selection by Belted Kingfishers (Ceryle alcyon) in Colorado. American Midland Naturalist 137:401–403.

Spencer, S.J. 1962. A study of the physical characteristics of nesting sites used by Bank Swallows. Ph.D. Dissertation, Pennsylvania State University, University Park, PA.

Steyerberg, E.W., Eijkemans, M.J.C., and J.D. Habbema. 1999. Stepwise selection in small data sets: A simulation study of bias in logistic regression analysis. Journal of Clinical Epidemiology 52:935–942.

Stoner, D. 1941. Homing instinct in the Bank Swallow. Bird-Banding 12:104–109.

Szép, T. 1991. Number and distribution of the Hungarian Sand Martin [*Riparia riparia* (L.), 1758] population breeding along the Hungarian reaches of the River Tisza. Aquila 98:111–124.

Szép, T. 1995. Relationship between west African rainfall and the survival of central European Sand Martins *Riparia riparia*. Ibis 137:162–168.

United States Army Corps of Engineers. 1991. General investigation study, Connecticut River streambank erosion. US Corps of Army Engineers, New England Division, Concord, MA.
United States Department of Agriculture, Soil Conservation Service (USDA SCS). 1967. Soil survey, Franklin County Massachusetts. US Government Printing Office, Washington, DC.
USDA SCS. 1978. Soil survey, Hampden County Massachusetts. US Government Printing Office, Washington, DC.
USDA SCS. 1981. Soil survey, Hampshire County Massachusetts. US Government Printing Office, Washington, DC.
USDA SCS. 1987. Windham County, Vermont. US Government Printing Office, Washington, DC.
USDA SCS. 1989. Cheshire County, New Hampshire. US Government Printing Office, Washington, DC.