# The Relationship of Wood Duck Brood Density to River Habitat Factors

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*Abstract*: To better understand habitat features on rivers that are important to wood ducks (*Aix sponsa*), I measured brood density for sections of 12 rivers (329 km) in Tennessee nightlighting during spring 1990 and 1991. Sixteen habitat variables were evaluated for each river and the relationship to brood density was tested. Brood density ranged from 0 to 1.8/km ($\bar{x}$ = 0.7 on unchannelized rivers). No broods were found on 61 km of channelized rivers. Brood density was positively correlated to aquatic vegetation, mud flats, logs and limbs in the water, large overhanging trees, rapids, and islands and was negatively correlated to exposed mud banks and small trees. River channelization and certain agricultural practices degraded riparian habitat and had a negative effect on brood density. Where habitat for wood duck broods is to be maintained or improved, streams should be protected from channelization and from land management practices which remove tree cover and destabilize riverbanks.

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The importance of understanding the ecological requirements of the wood duck were underscored in the 1965 wood duck symposium (Jahn 1966, McCabe 1966, Webster and McGilvrey 1968). Yet, few studies have focused on habitat since then (Frederickson and Graber 1990). The value of river habitat for wood ducks and concern for its loss due to human activities has been stressed (Bellrose 1966, Minser 1968, Barstow 1970, Prokop 1989, Cottrell et al. 1990). River habitats continue to be impacted by construction of reservoirs, channelization, agriculture, and urbanization. My objective was to identify habitat features on rivers which may influence wood duck brood production.

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## Methods

Wood duck brood density and habitat characteristics of rivers were surveyed on 12 rivers distributed throughout Tennessee (Table 1). The rivers studied were recommended by regional waterfowl biologists of TWRA and were mostly the same rivers used in TWRA's annual wood duck brood surveys. These rivers vary from cold, fast flowing rivers with many shoals and islands in the mountains and valleys of the east to warm, slow-moving, meandering rivers of western Tennessee. Representative segments of each river were selected for evaluation. Segment length ranged from 8.5 to 32.8 km ($\bar{x}$ = 27) and the combined length of all segments was 329 km. Two of the 12 rivers, the Obion River and the South Fork of the Forked Deer River, were channelized in 1915–1917 and all but segment 1 of the South Fork of the Forked Deer were rechannelized in 1972–1977. The Hatchie River was the only river in the study that traversed a functioning wetland. Assistants and I used the nightlighting technique described by Minser and Cole (1991) as an index to brood density. Two boats were used in nightlighting streams >50 m wide, and 1 boat on streams <50 m wide. Where 1 boat was used, we traveled down the center of the river shining both banks simultaneously. Where 2 boats were used, each bank was shined from a distance of 10–20 m from the respective boats. Nightlighting teams consisted of 2 people per boat. Each stream segment was surveyed 1 time during the peak of brood-rearing season (Minser 1968), the last week of May to the third week of June in 1990 and 1991. Earlier studies showed that results on consecutive nights were consistent (Minser and Dabney 1973, Minser and Cole 1991) and so only 1 survey per river segment was made.

We characterized and compared river and riparian habitat variables ($N$ = 16) using a method modified from Prokop (1989) (Table 2). We conducted habitat surveys from late May to late June from a boat during daylight on the same river segment where we conducted nightlighting surveys. Habitat surveys were done on different days than brood surveys. We judged habitat variables of both banks subjectively by visual observations (scans) of each bank ($\bar{x}$ = 6.1/km). Scans were made every 1.5 minutes as the boat moved downstream and habitat characteristics were recorded. Brood use and habitat variables were compared between rivers using Pearson Correlation Coefficients. However, since there was more variation in rivers with higher brood densities than rivers with low brood densities, the natural log of brood use plus 0.0001 was used. This had the effect of stabilizing this different variation for analysis.

## Results

Numbers ($N$ = 191; range = 0 to 1.8/km) of roosting wood duck broods were counted on segments ($\bar{x}$ = 27 km) of 12 rivers ($N$ = 329 km) in Tennessee using the nightlighting surveys. Mean number of broods found on unchannelized rivers was 0.7/km. No broods were found on 61 km of channelized rivers. Sixteen habitat variables were evaluated along each river at a rate of 6/km for a total of 1,936

**Table 1.** Wood duck brood density observed by nightlighting of 12 rivers in Tennessee, 1990 and 1991.

| River | County location | Origin and Termination points (river mile markers or descriptions) | Length (km) | Broods/km | *N* Broods |
|---|---|---|---|---|---|
| Buffalo | Perry | Heath Canoe Rental on Highway 13 to I-40 bridge (21–11.5) | 15.2 | 0.49 | 8 |
| Duck | Humphreys | S.R. 6357 water gaging station to Highway 13 bridge (26–16) | 16.1 | 0.25 | 4 |
| Harpeth | Cheatham | Newsom Station Rd. bridge to Kingston Sprs. rec. park (n/a) | 24.1 | 0.33 | 8 |
| Red | Montgomery | 1.6 km upstream from I-24 bridge to US 79 bridge (n/a) | 19.3 | 0.31 | 6 |
| Hiwassee | Polk, McMinn | Highway 411 bridge to 22.5 river mile marker (42.5–22.5) | 32.8 | 0.61 | 20 |
| Sequatchie | Marion | Ketner Mill dam to mouth of Town Creek | 21.7 | 0.41 | 9 |
| Little | Blount | Davis Ford to Highway 33 bridge (19.5–9.5) | 17.4 | 1.44 | 25 |
| Clinch | Hancock | Kiles Ford to Hwy 33 bridge in Sneedville | 20.9 | 1.40 | 30 |
| Holston No.1 | Hawkins | Confluence of North and South forks, Holston R. Kingsport to Church Hill Bridge | 8.5 | 1.53 | 13 |
| Holston No.2 | Hawkins | Church Hill Bridge to Surgoinsville Bridge | 21 | 1.57 | 33 |
| Holston No.3 | Hawkins | Surgoinsville Bridge to south end Bureum Island | 10.8 | 2.41 | 26 |
| Holston | Hawkins | Total survey area | | $\bar{x} = 1.84$ | 72 |
| Obion No.1[a] | Obion | U.S. Hwy 45 to state Hwy 211 bridge | 13 | 0 | |
| Obion No.2[b] | Obion | U.S. Hwy 51 bridge to the Hwy bridge at Lane | 15.5 | 0 | |
| Hatchie No.1 | Hardeman | U.S. Hwy 64 bridge at Bolivar to State Hwy 18 bridge | 17 | 0.06 | 1 |
| Hatchie No.2 | Haywood | State Hwy 54 bridge to U.S. Hwy 51 bridge at Hatchie Nat. Wildl. Refuge | 18 | 0.22 | 4 |
| Hatchie No.3 | Haywood | Pilljerk Rd. boat landing to Club Rd., Tipton Co. | 26 | 0.15 | 4 |
| Hatchie | Haywood | Total survey area | | $\bar{x} = 0.14$ | 9 |
| South Fork, Forked Deer No.1[a] | Madison | U.S. Hwy 70 bridge in Jackson to Roberts Station Bridge | 15 | 0 | |
| South Fork, Forked Deer No.2[b] | Haywood | State Hwy 54 bridge to State Hwy 88 bridge, Haywood Co. | 17.5 | 0 | |
| | | | 329 | $\bar{x} = 0.65$[c] | 191 |

[a] This river segment was channelized about 1917.
[b] This river segment was channelized about 1917 and rechannelized 1972–77.
[c] The mean number of broods for all channelized rivers was 0.7/km.

**Table 2.** River habitat evaluation key (to be used with river habitat evaluation data form).

| Habitat type | Description |
|---|---|
| Trees | |
| None | no trees present along river bank |
| Big trees | trees ≥0.3m dbh den trees possible |
| Small trees | trees <0.3m dbh |
| Overhanging trees | leaning or spreading over riverbank |
| Flooded | base of trees under water |
| Mud flats | exposed, fairly flat, muddy edge of banks |
| Overhanging shrubs | overhanging shrubs or tree limbs offering overhead protection |
| Without overhanging shrubs | exposed, fairly flat, muddy edge riverbank without overhanging tree limbs or shrubs |
| Flooded shrubs | Partially or totally flooded areas dominated by woody vegetation <6m tall and has a dbh <30cm |
| Aquatic vegetation | rooted, or freely floating aquatic vegetation |
| Logs & Limbs in water | downed trees and limbs and woody debris piles in river edge |
| Exposed stream bed | (sand, gravel, or silt bar) irregularly exposed portion of the river channel composed of unconsolidated material |
| Eroded bank | eroded portions of the river bank frequently occurring on the concave side of the river channel |
| Rapids | swift moving water usually accompanied with shallow water and a rocky bottom |
| Wooded island | river island with trees |
| Steep bank | bank steeper than 60° |
| Exposed mud bank | bank stable, without erosion but without vegetation on the banks or low shrub, overhead cover |

habitat evaluations ($\bar{x}$ = 161/river). Big trees (> 0.3 m, dbh), overhanging trees, mud flats with overhanging shrubs, aquatic vegetation, logs and limbs in water, rapids, and islands were all positively correlated ($P >$ R = 0.10) with the log of brood use. River segments with small trees and exposed mud banks were negatively correlated with the log of brood use ($P >$ R = 0.10).

## Discussion

Sixteen habitat variables of rivers in Tennessee were evaluated and the relationship of them to the number of roosting wood duck broods observed per km was determined. I suggest there was a direct relationship between numbers of broods observed and the river's productivity for broods and, because all but 1 of the rivers examined had little or no associated wetlands, I assumed that number of broods observed roosting was a reflection of brood habitat use on each river. Variables examined are discussed as they relate to broad categories of habitat needs of wood ducks during reproduction and include: nesting cover, food and cover for broods, and wetlands influence.

### Nesting Cover

Wood ducks need large trees with cavities for nesting. Rivers with large trees were positively correlated with the natural log of brood density (big trees, R = 0.51, $P = 0.03$; overhanging trees, R = 0.60, $P = 0.006$). Not only do large trees provide dens for nesting but those that overhang or droop into the water provide seclusion, roosting, loafing, escape, and feeding cover that broods need (McGilvery 1968, Minser 1968, Cottrell et al. 1990). These needs and preferences help explain the positive correlation of large overhanging trees to rivers with high brood use and the negative correlation (R = –0.52, $P = 0.03$) of brood use to rivers with higher proportions of river banks with small trees and/or treeless areas. Rivers characterized by small trees (≤0.3 m dbh) provided fewer denning opportunities and had less seclusion and loafing cover for broods. Lack of trees with suitable nesting cavities is sometimes the limiting factor for wood duck brood production. Wood duck production on Puget Sound, Washington, was increased following initiation of a nesting box program (Fielder et al. 1990). However, nesting box placement is not a cure-all to low numbers of wood ducks. Factors other than nesting cavities were believed to be more limiting on the lower Holston River and French Broad River in Tennessee; addition of nesting boxes did not result in population increase, and a lack of aquatic foods was believed to be more limiting (Schacher and Minser 1988). On the channelized South Fork of the Forked Deer and Obion rivers in this study, trees along the riverbanks had been removed and had been replaced by small second growth hardwoods. No broods were observed on 61 km of channelized rivers. Reduced nesting habitat was likely part of the reason.

### Food and Cover for Broods

Juvenile wood ducks feed extensively on insects their first few weeks of life (Hocutt and Dimmick 1971) shifting to mostly plant foods before flight (Hawkins and Bellrose 1940, McGilvrey 1968, Minser 1968, Schacher and Minser 1988, Prokop 1989, Cottrell et al. 1990). Brood use of both aquatic and terrestrial insects and vegetation (Hocutt and Dimmick 1973) demonstrates the importance of aquatic and riparian habitats for feeding. The upper Holston River in this study was reported as the most productive river in North America for aquatic macrophytes (Young and Dennis 1983). The 2.7 broods/km found on the Holston River (Minser and Dabney 1973) was also described by F. C. Bellrose (pers. commun.) as the most productive river for wood duck broods reported for North America. Many believe the dense growth of aquatic vegetation with associated aquatic insects was responsible for high brood production (Minser 1968, Watts 1968, Hocutt and Dimmick 1973, Cottrell et al. 1990). It was not surprising then that there was a positive correlation (R = 0.47, $P = 0.06$) between the natural log of brood density and aquatic vegetation on rivers in this study. The 2 most producing rivers for wood duck broods in this study, the Holston and Little rivers also had more aquatic vegetation than other rivers. The Hatchie River had the lowest brood density (0.14 broods/km) of any other unchannelized river sampled. The Hatchie had good cover components, i.e., large overhanging trees, flooded trees, shrubby mud flats, and good brood roosting cover and was better than other rivers for those features. However, no aquatic vegetation was observed on the Hatchie, and this may have been the habitat feature which resulted in lower brood density. The Hatchie River flows through some of the most fertile farmland in Tennessee, but it also flows through some of the most erosive land in the United States. Erosion rates of 15–19 tons/ac/year are among the worst in the United States (U.S. Dep. Agric. 1977, U.S. Dep. Agric. 1990). As a result, the stream bottom is ladened with silt and the water is often muddy. Rivers with unstable bottoms and turbid water restrict light penetration and have low production of plankton, algae, and moss-like plants (Wharton and Brinson 1978), all of which are important in the food chain of wood duck broods.

There are several important components of brood cover. Cover provided by downed trees in the water's edge, where woody debris often accumulates by the current, apparently is an important component of wood duck brood habitat. This cover is particularly useful to broods for roosting, loafing, and escape when leafy limbs droop on it and the water surrounding it. Broods swim into this cover and remain relatively secure from most predators and the hot summer sun. Broods could be regularly found roosting in these aquatic brush-piles. As many as 4 broods were found in 1 brush-pile. Farmers often cut down trees along the riverbank to prevent shading of crops, allowing trees to fall into the river. If not done extensively so as to eliminate all den trees and overhanging cover, this practice likely improves brood habitat by providing feeding, escape, loafing, and roosting cover. Brushy aquatic cover for escape, loafing, and feeding (McGilvrey 1968, Minser 1968, Watts 1968, Hocutt and Dimmick 1971, Cottrell et al. 1990, Heitmeyer and Frederickson 1990) and for roosting (Minser 1968, Minser and Dabney 1973, Parr et al. 1979, Minser and Cole 1991) has been identified in previous studies as important to wood duck broods. Prokop (1989) found that wood duck broods in Oklahoma also selected log jams for cover, and that log jams are reservoirs for invertebrates upon which ducklings feed. We observed fewer aquatic brush piles in channelized rivers likely because accelerated stream velocity in those straight ditches scoured river banks during heavy rains and flushed organic matter downstream (Barclay 1978). Broods make use of vegetation on wooded shorelines for loafing, escape, and feeding (McGilvery 1968, Minser 1968, Cottrell et al. 1990). I observed in this study and others (Minser 1968) that muskrat and beaver bank dens and overhanging tree rootcaps were also used by broods for escape and roosting.

There was a positive correlation with the natural log of brood density and mud flats (mud flats with overhanging shrubs, R = 0.52, $P = 0.03$, mud flats without overhanging shrubs, R = 0.44, $P$ = 0.07). This cover provides broods easy access to riparian habitat while offering overhead cover from sun and predators. Broods were sometimes found roosting in this habitat and it likely is used for loafing and feeding. Loafing areas for wood duck broods and river ducks in general are an important habitat component (Hochbaum 1944, Sowls 1955, McGilvrey 1968, Minser 1968, Cottrell et al. 1990) and is likely why this habitat feature was positively correlated to brood production in this study. The Hatchie River had more loafing habitat than all other rivers but low brood use indicated other factors, i.e., food resources, were more limiting.

The natural log of brood density was positively correlated to frequency of islands (R = 0.56, $P$ = 0.02): the greater the number of km of islands per km of river, the more broods were found. An island doubles the linear amount of shoreline per unit length of river and likewise increases wood duck habitat. Islands may also provide an added amount of seclusion and security that wood ducks seem to favor. Seclusion is due to the unfarmed, undisturbed, wild nature of most islands and the narrowing of channels around islands. Narrow channels often allow trees from opposing banks to touch forming a shadowy canopy. Islands on the Holston River were found to be important to wood duck broods in a previous study where 53% of broods were found along islands although islands constituted only 24% of the length of the study area (Minser 1968). The Holston and Little rivers had the highest frequency of islands of all rivers sampled. Habitat added by islands was probably another reason they also had the highest brood densities.

Curiously, the natural log of brood density was positively correlated to rivers with rapids (R = 0.57, $P$ = 0.01). This correlation was probably associated with the food base. Streams in eastern Tennessee were characterized by alternating pools and rapids, clearer water, and had low to high amounts of aquatic vegetation. Slow moving rivers studied in western Tennessee have few rapids and because erosion and siltation rates are high, light penetration in the water is low, reducing photosynthesis and aquatic vegetation in those streams. I believe that lack of aquatic vegetation is an important reason wood duck brood use was low on river channels in western Tennessee.

Exposed mud banks were negatively correlated to the natural log of brood density (R = 0.85, $P$ = 0.0001), a finding shared by Prokop (1989). Streams with no cover on the riverbanks offer little or no protection for broods to roost, feed, loaf, or escape from predators. Exposed mud banks are largely a result of human activities and were seen primarily in 3 situations: First, where farmers had apparently persistently removed tree cover on riverbanks until tree root systems were eliminated, bank erosion resulted, leaving exposed mud banks devoid of vegetation. Second, cattle from farms adjoining the river often caused serious bank erosion by trampling the bank where they watered. Finally, river channelization eliminated all vegetation leaving steep exposed mud banks. The Obion and South Fork of the Forked Deer River were channelized in 1917 and the Obion and segment 2 of the South Fork of the Forked Deer River were rechannelized in the 1970s. No wood duck broods were observed on 61 km of these streams. Even though the banks of segment 1 of the South Fork of the Forked Deer River had been stabilized by new tree growth, it is believed that even after 75 years since channelization, habitat conditions needed by wood ducks had not recovered (Minser, unpubl. data). The banks of channelized streams are high, steep, and trough-like. High stream flow scours the banks above normal water levels leaving exposed mud banks. The exposed mud banks virtually eliminate feeding, loafing, roosting, and escape cover for broods. In addition, any resulting bank erosion problems worsen habitat problems in that aquatic food resources are diminished by increased siltation. The Duck River had the lowest brood density of the 9 unchannelized rivers outside the west Tennessee region. Trees and root systems were absent from the riverbank along several portions of the Duck River. I assumed that farmers had cleared the trees to protect the crops from shading. Serious bank erosion occurred where trees were absent leaving vertical mud banks 3 to 4 m high in some cases.

### Wetlands Influence

The influence of wetlands adjoining rivers on use of rivers by wood ducks in this study has been considered. Wood ducks favor dense forested wetlands and swamps where they are available (Kortright 1967, Heitmeyer and Frederickson 1990). It has been suggested that rivers may serve primarily as travel lanes and are otherwise little used (Hepp and Hair 1977, Heitmeyer and Frederickson 1990). Wood duck broods likely prefer swamps and flooded woodlands over rivers because of superior food and cover availability (Heitmeyer and Frederickson 1990), but in much of the range of the wood duck, there are no wetlands. Nine of the 12 rivers in this study flow through mountains or uplands. On those 9 rivers, rivers were practically the only aquatic habitat available. The Hatchie River was the only river in this study that flowed through a functioning wetland, but it had the lowest brood density (0.14 broods/km) of all unchannelized rivers studied. Lack of aquatic foods may have been one reason for brood scarcity as discussed. Another major reason few broods were seen on the Hatchie River was likely because the Hatchie flows through a major wetland and wood ducks may be drawn from rivers to adjacent wetlands (Hardister et al. 1962, Hein and Haugen 1966, Prokop 1989, Heitmeyer and Frederickson 1990). The remaining 2 rivers in this study, the Obion and South Fork of the Forked Deer, flowed through what were formerly wetlands but those watersheds have been extensively channelized. Channelization not only negatively altered instream habitat structure but also significantly reduced the associated wetlands. The Obion and Forked Deer rivers before channelization were highly meandered and were characterized by broad wooded floodplains attaining widths of up to 5 km (Parsons 1983). Lowland forested habitats, like the Obion floodplain (Bellrose 1966) and Mingo Swamp in Missouri (Heitmeyer and Frederickson 1990), have been described as extremely important to wood ducks. Following channelization, swamps and sloughs in the Obion and Forked Deer watershed were drained and floodplain forests were replaced with crop fields. Wood duck nesting, brood rearing, and feeding habitat were reduced or eliminated. Only 15% of bottomland hardwood forests remain on private lands in the 100-year floodplain of the Obion-Forked Deer basin following 75 years of channelization, wetland drainage, and clearing for agriculture (Parsons 1983). The longterm negative effect of channelization on wetlands was also documented in Oklahoma where 100% of 54 wetlands were eliminated 50 years following channelization (Barclay 1978). So, considering the debilitated condition of the river channels and associated wetlands of the Obion and Forked Deer River systems, the absence of wood ducks on these rivers was not surprising. Wood duck brood use of rivers can be high without associated wetlands as was illustrated by the high numbers of broods found on the Holston, Little and upper Clinch rivers where river habitat features were excellent. Although rivers do provide a ribbon of habitat that may be productive for wood duck broods, rivers undoubtedly produce only a small fraction of the numbers of broods that were once produced on the associated wetlands such as the Obion and Forked Deer. Perhaps Hankla and Carter (1966) summed it best in describing wetlands drainage and the clearing of forested bottomlands as irretrievable losses and the wood duck's worst enemy.

I conclude that river channelization has a devastating effect on wood ducks in that stream structure and riparian zones are degraded and severe habitat loss for broods and adults is the result. Even worse, most of the associated wetlands and forested lowlands are drained and converted to agricultural fields eliminating those critical habitats from most wood duck use. Other practices which I observed degrading river habitat for wood ducks include bank degradation by livestock and extensive agricultural clearing of riparian zones resulting in bank erosion.

In summary, I describe ideal river habitat for wood duck broods as a river with large overhanging trees on its banks with dense understory vegetation, numerous islands, many shrubby mud flats, many fallen trees and woody debris piles in the water, low siltation rates, and one that has an abundance of aquatic vegetation.

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