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WILDLIFE HABITAT AND COMMUNITIES IN STREAMSIDE MANAGEMENT ZONES: A LITERATURE REVIEW FOR THE EASTERN UNITED STATES

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ABSTRACT

Streamside management zones (SMZs) are strips of forest vegetation maintained along waterways for many reasons, including enhancement of wildlife habitat. Retention of SMZs has become a common practice where forest management is implemented intensively on private and public timberlands. SMZs generally are considered to contribute to the maintenance of diverse wildlife communities in managed forests because they often contain habitat features not usually found in intensively managed stands. Despite this widely accepted perception, there are few data available describing the wildlife values of SMZs or the relationships between wildlife values and SMZ characteristics. An understanding of these relationships is important because regulatory agencies are increasingly promulgating regulations regarding SMZ width and other characteristics to protect wildlife communities. In this paper, we summarize available literature pertaining to wildlife communities in SMZs in the Eastern United States (especially reported relationships between SMZ characteristics and wildlife values), discuss the suitability of extant studies for regulatory purposes, and identify topics needing additional research.

INTRODUCTION

Under sections 208 and 319 of the Clean Water Act, states are mandated to develop procedures for addressing potential nonpoint sources of pollution, including forestry. The Act requires states to seek approval from the U.S. Environmental Protection Agency for their forestry-related programs. In response to these requirements, several states have approved forestry practices acts and rules that address water quality issues. Other states have developed voluntary best management practices (BMPs).

Buffer strips or streamside management zones (SMZs) often are required or recommended in state water quality programs to mitigate potential impacts of forestry practices on adjacent surface waters (Comerford et al. 1992). Streamside management zones are strips of forest vegetation maintained along waterways, and may include both riparian and upland habitats. State forestry practices acts and BMPs sometimes contain recommendations regarding minimum width of SMZs, usually based on the ability of the SMZ to protect water quality (e.g., Comerford et al. 1992).

Increasingly, however, states also are considering the potential of SMZs to protect biological diversity when recommending SMZ characteristics such as width. Some western states have been using SMZs for several years to address wildlife habitat or biological diversity concerns. In Washington, for instance, concerns about riparian management led to the development of the Timber/Fish/Wildlife (TFW) agreement (Ice 1990). More recently, eastern states such as Florida and North Carolina included wildlife habitat considerations when developing guidelines for SMZs or forested wetlands.

SMZs generally are considered to contribute to the maintenance of diverse wildlife communities in managed forests. Several authors have recommended their use in landscapes managed intensively for southern pines (*Pinus* spp,) (e.g., Buckner 1982, 1983; Owen 1994; Wigley 1986; Melchiors 1991). Intensive silviculture provides habitats suitable for many early- and mid-succession wildlife species, but can reduce habitat features (e.g., mature deciduous trees, den trees, snags) used by species often associated with older, less intensively managed forest habitats. Thus, intuitively, SMZs may be a logical place to provide habitat features that sometimes are less abundant in intensively managed stands.

SMZs also are considered by many to function as travel corridors, connecting habitats dissected by other forest types, non-forest land uses, or other barriers. Simberloff et al. (1992) note that a Aremarkable publicity campaign, much of it outside the bounds of mainstream science, has promoted corridors for conservation". In truth, there are few data regarding the efficacy of forested corridors or whether SMZs function as such. Simberloff et al. (1992), however, observed that the utility of riparian habitats, such as those contained within SMZs, often is important independent of their importance for movement.

In the humid U.S. where stream densities may be high, significant proportions of commercial forests can be in SMZs. And, opportunity costs of maintaining SMZs can be high. Thus, regulations and recommendations regarding SMZs, such as width and stand characteristics, should have a sound statistical basis to ensure cost-effectiveness. The purpose of this paper is to review extant literature from the eastern United States that describe SMZ characteristics and their relationship to wildlife habitat quality or wildlife communities. We also will discuss needs for future research, the appropriateness of existing studies for use in developing guidelines for SMZ characteristics, and present considerations for policymakers.

THE STUDIES

We are aware of 19 studies of SMZs or streamside habitats in the eastern U.S. which have yielded 30 documents or publications (Table 1). Most studies have been in the southern Coastal Plain (8) and Piedmont (2). Eleven studies have investigated use of SMZs or streamside habitats by birds, both nongame (9) and game (2), i.e., wild turkeys (*Meleagris gallopavo* L.). Mammals, including small mammals, squirrels (*Sciurus* spp. L.), and white-tailed deer (*Odocoileus virginianas* [Zimmerman]) have been the subject of nine studies. Other studies have addressed herpetofauna (3), habitat (1), and economics (1). Many of the studies compare wildlife communities in SMZs with communities in adjacent habitats or older forests. However, few studies have addressed SMZ characteristics such as width. A variety of statistical approaches has been used, ranging from case studies to more rigorous techniques such as principal components analysis, logistic models, and cluster analysis.

Table 1. Studies of wildlife habitat and communities in streamside management zones (SMZS) in the eastern United States.

State	Physiographic Province[1]	Habitat	Taxonomic groups studied	Publications
Alabama	Coastal Plain	hardwood leave strips in even-aged pine and mixed pine-hardwood stands	squirrels	Fischer and Holler (1991)

Arkansas	Ouachita Mountains	riparian and upland forests (not SMZS)	trees	Melchiors and Cicero (1987)
Arkansas	Ouachita Mountains	SMZs in pine plantations	birds small mammals	Tappe et al. (1993)
Georgia	Coastal Plain	SMZs in pine plantations	birds small mammals	Thurmond (1993)
Iowa	Inter Plains (Central Lowlands)	riparian habitat in agricultural landscape (not SMZS)	birds small mammals	Stauffer and Best (1980) Geier and Best (1980)
Kentucky	Interior Low Plateau	SMZ in pine plantation	birds herpetofauna	Triquet et al. (1990) Pais et al. (1988)
Maine	New England Plateau	lakefront adjacent to clearcut hardwood-spruce stand	birds	Johnson and Brown (1990)
Maine	New England Plateau	streamside and upland forests (not SMZs)	birds	Hooper (1991)
Mississippi	Coastal Plain	SMZS in pine plantation	squirrels	Warren and Hurst (1980)
Mississippi	Coastal Plain	SMZS in pine plantation	wild turkey	Burk (1989) Burk et al. (1990)
New Hampshire	New England Plateau	streamside and upland forests (not SMZs)	herpetofauna	DeGraaf and Rudis (1990)
Southern U.S.	Coastal Plain	SMZs in pine plantations	economics	McKee (1981)
Texas	Coastal Plain	SMZs in pine plantations	birds small mammals squirrels herpetofauna	Unpublished Dickson and Williamson (1988) Dickson (1989) Dickson and Huntley (1985, 1987) Dickson (1989) Rudolph and Dickson (1990) Dickson (1989)
Texas	Coastal Plain	SMZs in pine plantations	white-tailed deer	Poteet (1990)
Texas	Coastal Plain	streamside habitat in pine plantations	white-tailed deer	Kroll (1991)

Texas	Coastal Plain	SMZs in pine plantations	squirrels	McElfresh et al. (1980)
Virginia	Blue Ridge Mountains	riparian and upland forests (not SMZS)	birds	Murray (1992)
Virginia	Piedmont	SMZS in pine plantations	birds	Tassone (1981)
Virginia	Piedmont	streamside and upland leave strips in pine plantations	wild turkey	Holbrook (1984) Holbrook et al. (1985, 1987)
[1]Based on maps in U.S. Geological Survey (1970:60).				

Nongame Birds

Four of the nine studies of nongame birds in SMZs or riparian habitats are either unreplicated case studies or have not yielded a document/publication. Triquet et al. (1990) is a case study from Kentucky comparing bird communities in one clearcut with a 15- to 23-m-wide SMZ (ABMP clearcut@), one clearcut without a SMZ, and a mature forest control. It is unclear whether the SMZ was 15 to 23 m wide on each side of the stream or in total. Depending upon which case is accurate, the SMZ was one to two acres in size, and represented only about 3 to 6% of the area within the BMP clearcut. Triquet and his co-authors found that the clearcut with the SMZ probably Aprovide[d] habitat for some species of mature-forest and edge-dwelling songbirds that otherwise would [have been] absent.@ The authors do not present information about birds found only within the SMZ and do not address SMZ characteristics.

Another case study by Johnson and Brown (1990) censused birds along two lakeshores in Maine. One lakeshore had a 80-m-wide buffer strip along the shore adjacent to a recent clearcut. The other lakeshore was forest that had not recently been harvested. Johnson and Brown found that AAlthough there were differences in breeding bird composition [along the two lakeshores]...the composition of regularly occurring species of the buffer strip was similar to the undisturbed forest.@ Additionally, they thought that vegetative structure within the buffer strip and the undisturbed forest greatly influenced the bird community.

Two studies of birds in SMZs have not yet yielded a publication. One study was conducted by J. G. Dickson in Texas in the same study area described by Dickson and Williamson (1988). Tappe et al. (1993) describe a study of birds in SMZs in Arkansas. That study, however, remains in progress, and results presented by Tappe et al. (1993) are preliminary.

There are five documented studies of bird communities in SMZs or streamside habitats that have applied statistical analyses. Four of the studies (Tassone 1981, Hooper 1991, Murray 1992, Thurmond 1993) have yielded unpublished theses. The fifth, Stauffer and Best (1980), is the only study of nongame birds that applied statistical analyses and has been published in a peer-reviewed journal. Best et al. (1979) presented a summary of methodology used by Stauffer and Best (1980), but presented no results. The study by Stauffer and Best (1980) is often cited by authors recommending width of SMZs, e.g., Howard and Allen (1989).

Over a two year period, Stauffer and Best (1980) studied 28 stream segments in Iowa, 23 of which were wooded. The stream segments were surrounded by agricultural land, and were not SMZs associated with forestry operations. Thus, results likely do not apply directly to SMZs in forested landscapes.

Stauffer and Best (1980) found that ABird species richness increased with the width of wooded riparian habitats@ (Figure 1). Bird species richness, however, did not increase linearly. The relationship depicted in Figure 1 appears linear because values for riparian forest width were mathematically converted (natural logarithm). If the unconverted values for SMZ width are used (Figure 2), it is evident that the relationship is curvilinear with most of the gains in species richness occurring in the narrower riparian width classes. In fact, 70-78 percent of the breeding bird species occurred in riparian strips that were 17 percent of the maximum width sampled of about 250 m.

Species gained as width of forest area increases are sometimes typified as Aarea-sensitive@ or Aforest-interior@ species. Some species gained with increased riparian width in the study by Stauffer and Best (1980), however, may have been dependent upon microhabitat variables that varied among sampled sites. In fact, Stauffer and Best (1980) found that microhabitat variables, i.e., snag size, number of canopy layers, sapling/tree size, and species richness, were important determinants of the bird community. Thus, altering stand characteristics within the riparian forests altered the bird community.

In Virginia, Tassone (1981) studied 12 SMZs ranging from 20 to 200 m wide. The SMZs were in pine plantations from two to 23 years old. He found that Amany forest interior species were most common at [SMZ] widths above the mean value of 62 m..@ Thus, he recommended that AUntil more extensive research is done, strips should be left 60 or more meters in width...@ Not surprisingly, other authors, e.g., Howard and Allen (1989), have cited Tassone as the basis for retaining SMZs at least 60 m wide.

Tassone, however, noted that A...data from this study are inadequate to make definitive recommendations regarding optimal buffer widths required to provide viable breeding habitat for forest-breeding birds. Data cover only a single breeding season, and samples are only from a small number of occasions. Sample size for many species are quite small...@ Additionally, Tassone (1981) did not consider plantation age-class or stand characteristics within the SMZs during statistical analyses.

Also in Virginia, Murray (1992) sampled bird densities and habitat characteristics along gradients perpendicular to 16 second-order stream in the Appalachian Mountains. His sampling points were located 4, 154, 304, and 454 m upland from the streams in natural second-growth hardwood stands. In this unpublished thesis, Murray used cluster analysis, logistic models, and regression models to group species into five assemblages, to predict the number of species in each assemblage, and to predict the relative abundance of each assemblage and species.

Murray (1992) found that total bird density and species richness showed no riparian influence. The riparian assemblage, consisting of acadian flycatchers (*Empidonax virescens* [Viedllot]) and Louisiana waterthrushes (*Seiurus motacilla* [Vieillot]), used habitats new streams having well-developed overstory and understory canopy layers with relatively open ground layers. Distance from the stream was the most important variable defining areas used by this assemblage. Carolina wrens (*Thryothorus ludovicianus* [Latham]), American robins (*Turdus migratorius* L.), and red-eyed vireos (*Vireo olivaceous* [L.]) showed weaker positive associations with stream and several other species demonstrated negative associations.

In a discussion of streamside management practices, Murray (1992) stated that in some cases SMZs of a specified width may be narrower or wider than the functioning riparian ecosystem. Also, he noted that if management zone delineation were based on some characteristics of the riparian biota, these systems could be better managed and protected. He could not determine a SMZ width necessary to minimize the effect of forestry on either the acadian flycatcher or Louisiana waterthrush, and stated that further research is needed to provide reliable and sound recommendations.

Similar to Murray (1992), Hooper (1991) surveyed birds in 42 riparian sites in Maine to evaluate the relative influence of distance from streams and vegetation structure on songbird distribution. Half of the sites were Aupland@ or well-drained, deciduous or coniferous forests; the other half were poorly-drained, floodplain forests. All of the floodplain forests were deciduous. At each site, she censused birds and sampled vegetation at points 25, 75, 125, 175, 225, and 275 m from the

streams.

Using a variety of statistical analyses, Hooper (1991) found that songbird communities differed between upland and floodplain forests. In upland forests, where interior species dominated the bird community, neither total abundance nor species richness were associated with distance from streams. In floodplain forests, however, edge species were dominant and their total abundance decreased with distance from streams. In this unpublished thesis, Hooper (1991) concluded that her data demonstrated a Ariparian effect@ for species richness or total abundance of songbirds, but only in floodplain forests. She noted, however, that the increase in birds near streams in floodplain forests was primarily generalist species responding to the presence of open, shrubby deciduous vegetation. Hooper also concluded that a 200-m-wide buffer strip would be needed to retain all songbirds of undisturbed riparian forests if that was the desired objective of SMZs in central Maine. She further noted, however, that regulations requiring SMZs that wide might restrict timber harvest on substantial amounts of land. Thus, she suggested that the surrounding landscape could Abe managed to provide sufficient habitat for these species.@

Thurmond (1993) also is an unpublished thesis; she studied bird communities in six SMZs and a mature forest control in Georgia. The SMZs were in one 450-ha, pre-canopy-closure pine plantation. Thurmond used an ANOVA approach, dividing the SMZs into three width-classes: narrow (15-18 m), medium (28-30 m), and wide (49-53 m).

Generally, winter birds in SMZs were more abundant, rich, and diverse than in the pine plantation. However, the abundance, richness, and diversity of winter birds generally did not differ between SMZs and mature forest. Breeding birds in SMZs were more abundant than in the pine plantation, but less abundant than in mature forest. Breeding bird richness and diversity were not different among the pine plantation, SMZs, or mature forest control. However, forest-interior neotropical migratory birds were much less diverse and abundant in the SMZs than in mature forest. Abundance, richness, and diversity of breeding and winter birds did not differ among the three width-classes of SMZs.

Thurmond's (1993) study may be limited in two aspects. First, she used only one age-class of plantation: pre-canopy closure. While studies of SMZs adjacent to pre-canopy closure plantations are important, it cannot be assumed that results from those studies also apply to SMZs in plantations with closed or thinned canopies (Tappe et al. 1993). Thurmond's (1993) study also is limited in the range of SMZ widths evaluated; the maximum width studied was about 50 m.

In summary, only five documents/publications have used statistical analyses to evaluate relationships between bird communities and SMZ characteristics such as width. Only one publication (Stauffer and Best 1980) was peer-reviewed, but it was conducted in an agricultural setting. One of the five studies did not consider adjacent habitats during analyses (Tassone 1981), and another used just one age-class of plantation (pre-canopy closure) (Thurmond 1993). Two of the five studies (Hooper 1991, Murray 1992) accounted for streamside stand characteristics (i.e., basal area, canopy closure, tree species composition) during statistical analyses, but they were conducted in natural forest settings.

Wild Turkeys

We found two studies that investigated wild turkey use of SMZs; five documents/publications have resulted from the studies. Burk (1989) and Burk et al. (1990) used radiotelemetry and counts of sign to study turkeys in the interior flatwoods of Mississippi. In this 2.5-year-long project, they classified SMZs on the study area as narrow (30-45 m), medium (84-104 m), or wide (170-179 m). The SMZs were in pine plantations $\leq$ 20 years old. Each season, the authors compared the number of radio locations within each SMZ width-class to the number that would be expected, based on the proportion of the study area in each SMZ width-class. Thus, there were 30 opportunities to compare observed versus expected use (3 SMZ width-classes and 10 seasons [4 seasons per year for 2.5 years]).

Burk and his co-authors found that turkey hens used all widths of SMZs more than or equal to expected in 29 of the 30 cases. Turkey hens did not use SMZs for nesting or brood rearing; rather, they used the pine plantations. Gobblers used all widths of SMZs more than or equal to expected in 27 of 30 cases. Unexpectedly, the four cases of SMZs being used less

than expected (one for hens and three for gobblers) were for wide SMZs.

Despite this evidence from > 14,000 radio locations for 108 turkeys that there was no preference for medium or wide SMZs, Burk et al. (1990) recommended that AForest managers ... should plan for establishment of medium to wide SMZs. @ Apparently this recommendation was based on less turkey sign being found in narrow SMZs than in medium and wide SMZs. Yet, the authors acknowledged that AHigh use of narrow SMZs by radio-equipped turkeys but low amounts of turkey sign in the three narrow SMZs was probably due to differences in sampling methods@ among the SMZ width-classes. Therefore, the principal management recommendation from this study is not clearly supported by data presented within the publication.

A second study of turkeys has yielded one unpublished thesis (Holbrook 1984) and two publications by Holbrook et al. (1985, 1987). This one-year telemetry study of 32 turkeys in Virginia also compared observed and expected use of Ahardwood leave strips@ along drainages and steep slopes. Expected use was based on proportion of the study area in leave strips. Leave strips were 20 to 200 m wide and were in plantations two to five years old. It is unclear how many of the leave strips were SMZs.

Holbrook and his coauthors (1987) found that observed and expected use did not differ for any stand type, including hardwood leave strips. Also, AIntensity of [leave strip] use did not vary by stand width@ during any season. Holbrook did document use of leave strips for nesting and brood rearing. The authors recommended retaining hardwood leave strips between plantations to provide cover for use during early brood rearing and other habitat attributes for use year-round. But, no recommendations addressed characteristics of the strips such as width or stand structure. The authors acknowledged that AResearch over a complete cutting cycle would provide a better understanding of wild turkey responses to intensive pine management.@

Small Mammals

We are aware of four studies of small mammal communities within SMZs. All four studies used or are using a statistical design and analyses. One of the four studies (Tappe et al. 1993) is still in progress and has yielded only preliminary results. Another of the four studies (Geier and Best 1980), used the same 28 stream segments studied by Stauffer and Best (1980). This two-year study in Iowa reported the effects of microhabitat features on small mammal communities. Macrohabitat characteristics such as average SMZ width were not investigated. The authors found that altering vegetation altered small mammal communities. AMicrohabitat features most frequently related to [small mammal] species abundance were plant-species richness and percentage forb cover.@ Small mammal diversity was highest in highly disturbed habitats. Best et al. (1979) summarized methodology used by Geier and Best (1980), but reported no results.

In addition to birds, Thurmond (1993) studied small mammal communities in SMZs. In her Georgia study, she found that the winter abundance, richness, and diversity of small mammals were not different among SMZs, adjacent pine plantation, or mature forest. During summer, however, small mammals were more abundant in mature forests than in SMZs or plantation. Species richness and diversity during summer were higher in the mature forest than the SMZs, but not different between mature forest and plantation. Three species of small mammals trapped in the SMZs were not trapped in the pine plantation. Apparently, no species were unique to the mature forest. Abundance, richness, and diversity of small mammals did not differ among the three width-classes of SMZs during either season. However, Thurmond concluded that only 49- to 53-m-wide SMZs supported a small mammal community similar to the mature forest control.

In Texas, Dickson and Williamson (1988) studied small mammals In three width-classes of SMZs: narrow (<25 m), medium (30-40 m), and wide (>55 m). Two replications of each width-class were sampled; all were in pine plantations two to five years old. In contrast to Thurmond's (1993) results, Dickson and Williamson found that ASignificantly more small mammals were captured in the narrow SMZ[sl than were captured in the medium or wide SMZ[s].@ No species were unique to the wide zones; all species caught in the wide SMZs also were caught in either the narrow or medium zones. The authors thought that the abundance of small mammals in narrow zones was related to microhabitat features of those habitats

such as an abundance of low, dense vegetation; ample forage, fruits, and seeds; and down logs and logging slash. Dickson and Williamson (1988) made no recommendations regarding SMZ width. Dickson (1989) also presented some results from this study of small mammals.

At present, only two studies (Thurmond 1993, Dickson and Williamson 1988) have evaluated the relationship between small mammal communities and SMZ width. The results of the two studies seem inconclusive. One of the studies (Thurmond 1993) was limited in the range of SMZ widths evaluated, and neither study accounted statistically for microhabitat differences among study plots. In Thurmond's study, narrow SMZs had more grass cover than other SMZs, and shrub and sapling cover varied among SMZ width-classes. In the study by Dickson and Williamson (1988), habitat also differed among width-classes; apparently the canopies in narrow SMZs were more open than in wider zones. Both studies were in SMZs within only one age-class of plantation (pre-canopy closure).

Squirrels

We found four studies of squirrels in SMZs-one in Alabama, one in Mississippi, and two in Texas. All four studies used statistical designs and analyses and all were studies of SMZs in pine plantations.

In Alabama, Fischer and Holler (1991) studied habitat use and estimated relative abundance of squirrels in three habitats: even-aged pine, mixed pine-hardwood, and hardwood stands. The even-aged pine and mixed pine-hardwood stands were about 40 to 45 years old; SMZs were < 100 m wide. Three stands of each habitat type were used. Relative abundance was estimated through capture-recapture techniques and radio-telemetry was used to evaluate habitat use.

Squirrel abundance did not differ between hardwood and mixed pine-hardwood habitats, but was lowest in the even-aged pine stands. The only microhabitat variable correlated with squirrel abundance was shrub cover. The authors also found that ANarrow bands of hardwoods along ephemeral streams (i.e., hardwood stringers) were an important component of gray squirrel habitat in even-aged pine and mixed pine-hardwood stands." Squirrels used the stringers more than expected (based on the proportion of the stands in that habitat) in both even-aged pine and mixed pine-hardwood stands. Thus, they concluded that AForest management should include the retention of hardwood stringers within pine and mixed pine-hardwood stands." Although no data on stringer width were presented, the authors recommended that Ahardwood stringers should be maintained at their naturally occurring width.@

In Mississippi, Warren and Hurst (1980) compared time-area counts of squirrels between two SMZs and two pine-hardwood stands. The SMZs were 40 to 141 m wide. In their study, SMZs had higher squirrel densities than did pine-hardwood stands. But, the SMZs had older and larger hard mast-producing trees, and probably more cavities than the pine-hardwood stands. Warren and Hurst (1980) did not evaluate SMZ width.

In Texas, McElfresh et al. (1980) live-trapped squirrels in three 50- to 100-m-wide SMZs that were in pine plantations 15 to 20 years old. They also trapped squirrels in three pine-hardwood stands. McElfresh and his co-authors found that, where squirrels occurred in the SMZs and pine-hardwood stands, density was similar. Thus, they suggested that SMZs 50 to 100 m wide would Aprovide adequate habitat for squirrels." However, this study was not designed to evacuate SMZ width, statistical analyses apparently were not conducted, and there appears to have been unequal amounts of Asuitable@ habitat within SMZs and other treatments.

Dickson and Huntley (1987) studied squirrels on the same Texas SMZs used by Dickson and Williamson (1988). They conducted time-area counts and counts of leaf nests. Squirrels were observed Aregularly@ (24 times) in wide SMZs (> 50 m), Avery rarely@ (one time) in medium SMZs (30-40 m), and never in narrow SMZs (< 25 m). Leaf nest counts showed a similar trend. Therefore, they suggested a minimum width of 55 m to support squirrels. As with Dickson and Williamson (1988), this study included only one age-class of plantation and the narrow SMZs may have had fewer large trees per unit area than did wider SMZs. Dickson and Huntley (1985) and Dickson (1989) also present information about this study.

White-tailed Deer

Two studies were found that addressed white-tailed deer use of SMZs. In Texas, a telemetry study by Poteet (1990) compared observed use of SMZs by 19 deer to use expected on the basis of habitat availability. The author calculated availability two ways: (1) using all habitats within the study area and (2) using only habitats within the home ranges. When all habitats within the study area were considered as available, SMZs were significantly preferred during fall and winter. However, when considering only habitats within the home ranges, ANo significant selectivity was exhibited during any season for [SMZ] habitat." The author interpreted his results as indicating that deer established home ranges with large amounts of SMZ and other interplantation habitats, but then used those habitats in proportion to their availability within the home ranges. No data were presented that address potential relationships between deer habitat use and SMZ characteristics such as width.

In his management guide, Kroll (1991:121-124) describes deer preference for habitats near drainages. He reports that studies he has conducted In Texas demonstrate a tendency of deer to remain closer to drainages in summer and fall than in other seasons. Thus, his data address proximity to streams rather than use of SMZs. Kroll (1991:122) advocates variable-width SMZs with width based on local site characteristics. Because no citations are provided for the telemetry studies, however, it is not possible to ascertain the basis for his recommendations regarding SMZ width. Several other investigators in Texas and Oklahoma (e.g., Ockenfels 1980, Tucker 1981, Rayburn 1983) have found seasonal preferences of deer for riparian habitats or stands near open water.

Herpetofauna

We found three studies of herpetofauna in streamside forests and SMZs in the eastern U.S. One of the studies (Pais et al. 1988) is an unreplicated case study. In this 6-month project in Kentucky, herpetofauna were sampled in one clearcut with a 15-m-wide SMZ, one clearcut without a SMZ, permanent wildlife openings, and a mature forest control. Pais and his co-authors found that herpetofaunal species richness was highest in the wildlife clearings while mature forest supported the fewest species. The same number of species was caught on the clearcuts with and without a SMZ. The authors reported that richness of herpetofauna was most affected by the biomass of nonwoody vegetation and closeness to water. SMZ width was not addressed in the study.

DeGraaf and Rudis (1990) sampled herpetofauna communities in streamside and upland forests of New Hampshire. One streamside and one upland stand were sampled in three form types-red maple, northern hardwoods, and balsam fir. Generally, abundance, richness, and diversity of herpetofauna were greater in the red maple and northern hardwood stands than in the balsam fir stand. Herpetofauna were most abundant in streamside stands, but richness and diversity did not differ between upland and streamside stands. This study was not conducted in SMZs, and may not be directly applicable. However, it demonstrates how stand characteristics can affect wildlife communities in streamside forests and how wildlife communities can differ between upland and streamside habitats.

In Texas, Rudolph and Dickson (1990) studied herpetofauna on the sites used by Dickson and Huntley (1987) and Dickson and Williamson (1988). The investigators relied mostly on visual observations of herpetofauna rather than trapping. They found Afewer amphibians and reptiles in narrow (< 25 m) SMZs than in wider zones (30 to 95 m)." In contrast to Pais et al. (1988), they concluded that AAbundance seemed related to the closed canopy conditions of the medium and wide zones." Narrow zones apparently were Amore brushy@ than wider zones and had more insolation. Rudolph and Dickson recommended Aretaining streamside zones of mature trees at least 30 m wide and preferably wider when forest stands are harvested.@ Dickson (1989) also presented an overview of this project.

Habitat

In the Ouachita Mountains of Arkansas, Melchiors and Cicero (1987) sampled stand characteristics along nine streams. Their findings demonstrate that habitat quality of riparian forests can vary geographically even within the same mountain

range. For example, they found that the hardwood component of stands varied among regions within the Ouachita Mountains. Melchiors and Cicero (1987) also found that presence of cavities and dens in live trees was correlated with tree diameter and was associated with particular hardwood species, i.e., blackgum (*Nyssa sylvatica* Marshall), American sweetgum (*Liquidambar styraciflua* L.), and white oak (*Quercus alba* L.). Thus SMZs dominated by hardwoods may be logical sites for providing den trees. They recommended that Astreamside management practices should consider landowner objectives, differences in forested habitats related to physiography and landform, and variation in floodplain width.@ And, they felt that variable-width SMZs would be most appropriate in the Ouachita Mountains.

Literature Review

We found three publications that reviewed literature pertaining to wildlife communities and/or habitats in SMZs. Howard and Allen (1989) reviewed literature from the South. Although their paper focused primarily on bottomland hardwood forests, they did summarize some data pertaining to SMZs. They Arecommended for fish and wildlife management purposes that protected zones along perennial streams [< 10 m wide] be at least 60 m wide.@ This recommendation appears to be based on Tassone (1981).

Furthermore, Howard and Allen suggested that AOn streams or rivers wider than about 10 meters, ideally 60 meters should be left along both banks.@ The technical basis for recommending double-width SMZs along larger stream is unclear. For Aintermittent streams, small sloughs, and isolated wetlands,@ Howard and Allen recommended a total width of 30 meters. And, they suggested that AThere does not appear to be any reason why occasional limited selection cuts should not be made in streamside forests.@ AIt is possible,@ they argued, Athat partial removal of the overstory may actually enhance the water quality protection function of streamside forests by allowing a denser cover of herbaceous plants, shrubs, and tree seedlings.@ They also observed that Aperiodic thinning encourages tree crown development, which favors increased mast production.@

Howard and Allen (1989) cited four publications as the basis for their recommendations (Simpson 1969, Stauffer and Best 1980, Tassone 1981, Dickson and Huntley 1987). Simpson (1969) is an anecdotal account of field work and bird observations along river system in North and South Carolina. The author did not observe prothonotary warblers (*Prothonotaria citrea* [Boddaert]) in riparian habitats that were less than about 30 m wide. However, this was not a statistically designed study, and the author describes neither the riparian nor adjacent habitats. Limitations and considerations for interpreting the results of Stauffer and Best (1980), Tassone (1981), and Dickson and Huntley (1987) may be found earlier in this document. Early in their review, Howard and Allen (1989) acknowledged that the AQuantitative bases for ... recommendations are generally lacking, and recommended widths ... [are] largely an intuitive factor.@

Small and Johnson (1986) summarized literature describing the importance of riparian habitats and SMZs for wildlife in the northeast, primarily Maine. They cited Banasiak (1961) as evidence that 85% of deer yards in Maine are in riparian conifer stands. Small and Johnson observed that ASpecies diversity within the riparian zone or buffer strip may be enhanced by small cuts.@ However, they also stressed not creating excessively large openings in the riparian forest canopy, largely for the benefit of bobcats (*Felis rufus* [Schreber]) (May 1981). And, Small and Johnson stated that many furbearers concentrate their activity within 100 m of the water's edge (DiBello 1984).

Small and Johnson (1986) recommended no harvesting within 25 m of any stream, including Asmall streams.@ Furthermore, they suggested retaining an additional 50-m-wide buffer strip beside Alarger@ stream, rivers, and lakes (for a total width of 75 m on each side). They did not provide a definition of Asmall@ or Alarger@ streams. Small and Johnson (1986) advocated allowing group selection harvesting of $\leq$40% of the basal area or $\leq$50% of the canopy cover within the outer 50 m of 75-m wide SMZs. They acknowledged, however, that AThese recommendations are based primarily upon studies of unharvested riparian areas@ and that additional research is needed to address characteristics of SMZs (such as width) that are important to wildlife.

Hooper (1989) also reviewed literature from Maine describing wildlife/riparian relationships and described some of her unpublished field work. On the basis of her field work, she concluded that Ahabitat management within riparian zones may result in minimal change in the number of breeding songbirds, but a more substantial change in species composition in favor of more common edge species.@ Overall though, she observed, Aour knowledge of the importance of eastern riparian zones to birds and mammals is lacking. This does not mean the importance of eastern riparian systems to wiIdlife is not an issue, only that we do not yet understand how close the interactions are.@

Hooper (1989) also critically reviewed many of the papers cited by Small and Johnson (1986). She observed that no data are presented in Banasiak (1961) to support the statement that 85% of deer yards occur in riparian forests, and Athe case for buffer zones is based on just a single sentence.@ She argues that Dibello's (1984) results Acannot be reliably used to justify or identify buffer zones.@ Therefore, she notes that AA critical review of the literature available for eastern riparian zones reveals that many of the conclusions frequently cited are not adequately supported by data.@

DATABASE LIMITATIONS

The existing database describing wildlife communities within SMZs is limited and not adequate for devising policy. There are several reasons why the database is limited. First, there are few papers related to wildlife communities in SMZs. We found only 19 studies that have resulted in 30 papers. Second, even fewer studies have evaluated SMZ characteristics such as width; only 7 studies and 15 documents or publications have addressed width. Third, the quality of studies in true SMZs is highly variable. Some studies did not apply statistical tests because they were case studies or sample size was small. Most studies were short-term, with data being collected over a period of six months to two years. Most studies used SMZs surrounded by only one age-class of pine plantation, usually pre-canopy closure. Study results sometimes conflict possibly due to geographical differences, study designs, or sampling methods. No studies published to date have statistically accounted for stand characteristics within the SMZs or other factors such as SMZ length or the character of upstream/ downstream habitats. And, conclusions in some documents/publications do not appear to be supported by data presented in the papers.

CONSIDERATIONS FOR POLICY MAKERS

We believe that there are several questions that policymakers should address if guidelines are being considered for SMZ characteristics. First, policy makers should identify why wildlife-related SMZ characteristics are being considered. Are SMZ characteristics being recommended or required to provide habitats for forest-interior species? Are the characteristics intended to ensure that the SMZs can function as a movement corridor? Or, is there some other objective for the proposed characteristics?

Second, policymakers should consider whether SMZs are the only way to meet their intended objectives. For example, there may be disadvantages to providing SMZs as habitats or movement corridors for forest-interior species. Among potential disadvantages, SMZs and other corridors could function as sinks or ecological traps for interior species (Simberloff et al. 1992). If so, interior species might best be provided for elsewhere in the landscape. Unfortunately, field data describing the value of SMZs as productive habitats for forest-interior species or as movement corridors remain inconclusive. Other habitats such as unconnected patches of forest potentially could serve as movement corridors for many species. Thus, there may be alternative strategies for achieving the intended conservation objectives at less cost to the public and/or landowners.

Third, policymakers should consider what SMZ characteristics will be required to achieve the intended objectives. They should consider the desired vegetative condition within the SMZs and the desired macrohabitat and landscape characteristics. Desired vegetative condition probably will determine what management practices will be appropriate within SMZs. In many cases, SMZs with a substantial component of hard mast-producing oaks may be the desired future

condition. Therefore, to achieve this condition policymakers may wish to encourage timber harvesting to favor shade-intolerant oaks. If policymakers deem that timber harvesting is desirable, other questions will follow. For example, what type of regeneration and intermediate treatments will most likely yield the desired vegetative condition?

Unfortunately, there are few data upon which to base decisions about larger-scale SMZ characteristics such as width. Tappe et al. (1993) reported that Aincreasing width of SMZs does not necessarily result in greater abundance, more species, or increased diversity.@ Therefore, we suggest that any such recommendations be temporary until more technical data can be gathered. In many cases, variable-width SMZs may be more desirable. In areas where topography and/or habitats are variable, fixed-width SMZs may not always encompass important habitat features. And, flexibility in width probably is important from an operational perspective.

Fourth, policymakers should consider whether a reasonable balance can be achieved between the costs and benefits of SMZs. For example, retaining unharvested SMZs or severely restricting timber harvesting in SMZs would cost landowners money and may yield undesirable habitat conditions. McKee (1981 and personal communication) indicated that SMZs cost $13.16/acre/year in 1981 dollars. The impact of costs and benefits likely will vary among different categories of public and private landowners. Thus, there may be a basis for differential SMZ practices on private versus public lands.

Policymakers should decide whether such costs would be worth the resulting benefits. Many conservationists argue that restrictions should be implemented regardless of the cost. However, enforcing expensive guidelines that are marginally beneficial or even counterproductive, and are not based on sound data, may dilute support for more scientifically-based guidelines and restrict opportunities to achieve specific wildlife objectives.

RESEARCH NEEDS

Developing technically sound recommendations for SMZs in managed forests requires a considerable amount of information. Research is needed both in riparian areas of unharvested stands as well as in actual SMZ. Information needs related to wildlife habitats and communities in SMZs include the following.

1. The relationships of SMZ stand characteristics (e.g., basal area, tree species composition, tree diameter distribution) and landscape-scale characteristics (e.g., landscape pattern [O'Neill et al. 1988] characteristics of forests upstream/downstream) to wildlife communities. These are important variables that can be managed and will affect the value of SMZs for wildlife.

2. Wildlife values of SMZs throughout the rotation of adjacent, managed forest stands. Most research to-date has looked only at SMZs surrounded by young, open-canopy plantations. The value of SMZs to wildlife communities likely will change as the age, structure, and species composition of adjacent habitats change.

3. Wildlife values of SMZs through versus between stands. Many SMZs are located between stands which differ in age, structure, etc. Yet, most research has focused on SMZs in one stand or between similar types of stands.

4. Use of forest management in and adjacent to SMZs to help meet specific wildlife-related objectives. Management offers opportunities to alter stand- and landscape-scale characteristics that will affect the value of SMZs to wildlife communities.

5. Evaluation of SMZs as movement corridors among stands. Despite many hypotheses about the value of SMZs as corridors, little field work to test those hypotheses has been initiated.

6. Evaluation of the Aecological trap@ theory. What is the effectiveness of managing for Aforest interior@ or Aupland@ species in riparian habitats or SMZs? Are wildlife communities in SMZs productive? Are SMZs the right place in the landscape to manage for all species?

7. The economic costs and benefits of SMZs and the role of SMZs in meeting timber and wildlife objectives on private versus public forest lands.

CONCLUSIONS

As many studies cited in this paper demonstrate, SMZs contain diverse habitat and wildlife communities. Yet, we urge caution in considering or developing guidelines for SMZs when wildlife benefits are the primary objective. At present, there is little technical basis for doing so. Few studies have examined relationships between wildlife communities and SMZ characteristics, and much more data are needed before sound policy or management recommendations can be devised. Policymakers are encouraged to recognize that many factors other than width potentially influence the value of SMZs as wildlife habitat.

LITERATURE CITED

Banasiak, C. F. 1961. Deer in Maine. Game Div. Bull. No. 6. Maine Dept. of Inland Fish. and Game, Augusta. 159pp.

Best, L. B., D. F. Stauffer, and A. R. Geier. 1979. Evaluating the effects of habitat alteration on birds and small mammals occupying riparian communities. Pages 117-124 *In* Proc. symp. on strategies for protection and management of floodplain wetlands and other riparian ecosystems. USDA For. Serv. Gen. Tech. Rep. WO-12.

Buckner, J. L. 1982. Integration of forestry and wildlife management in the loblolly pine type. Pages 297-305 *In* Proceedings of the symposium on the loblolly pine ecosystem (east region). School For. Resour. N.C. State Univ., Raleigh.

Buckner, J. L. 1983. Wildlife concerns in the managed slash pine ecosystem. Pages 369-374 *In* E. L. Stone, ed. The managed slash pine ecosystem. School For. Resour. and Conserv., Univ. Fla., Gainesville.

Burk, J. D. 1989. Use of streamside management zones within midrotation-aged loblolly pine plantations by wild turkeys. M.S. Thesis. Miss. State Univ., Miss. State. 73pp.

Burk, J. D., G. A. Hurst, D. R. Smith, B. D. Leopold, and J. G. Dickson. 1990. Wild turkey use of streamside management zones in loblolly pine plantations. Natl. Wild Turkey Symp. 6:84-89.

Comerford, N., R. Mansell, and D. Neary. 1992. The effectiveness of buffer strips for ameliorating offsite transport of sediment, nutrients, and pesticides from silvicultural operation. NCASI Tech. Bull. No. 631. 48pp.

DeGraaf, R. M., and D. D. Rudis. 1990. Herpetofaunal species composition and relative abundance among three New England forest types. For. Ecol. and Manage. 32:155-165.

DiBello, F. J. 1994. Furbearer use of waterways in Maine. Unpubl. Rep. Maine Coop. Wildl. Res. Unit. 4pp.

Dickson, J. G. 1989. Streamside management zones and wildlife in southern forests. Pages 131-133 *In* Gresswell, R. E., B. A. Barton, and J. L. Kershner, eds. Practical approaches to riparian resource management: an educational workshop. May 8-11, Billings, Mont.

Dickson, J. G., and J. C. Huntley. 1985. Streamside management zones and wildlife in the southern Coastal Plain. Pages

263-264 *In* R. R. Johnson, C. D. Ziebell, D. R. Patton, P. F. Pfolliott, and R. H. Hamre, tech. coords. Riparian ecosystems and their management: reconciling conflicting uses. USDA For. Serv. Gen. Tech. Rep. RM-120.

Dickson, J. G., and J. C. Huntley. 1987. Riparian zones and wildlife in southern forests: the problem and squirrel relationships. Pages 37-39 *In* J. G. Dickson and O. E. Maughan, eds. Managing southern forests for wildlife and fish - a proceedings. USDA For. Serv. Gen. Tech. Rep. SO-65.

Dickson, J. G., and J. H. Williamson. 1988. Small mammals in streamside management zones in pine plantations. Pages 375-378 *In* R. C. Szaro, K. E. Severson, and D. R. Patton, tech. coords. Management of amphibians, and small mammals in North America: proceedings of the symposium. USDA For. Serv. Gen. Tech. Rep. RM-166.

Fischer, R. A., and N. R. Holler. 1991. Habitat use and relative abundance of gray squirrels in Southern Alabama. J. Wildl. Manage. 55(1):52-59.

Geier, A. R., and L. B. Best. 1980. Habitat selection by small mammals of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:16-24.

Holbrook, H. T. 1984. Wild turkey responses to intensive pine management in Virginia's central Piedmont. M.S. Thesis. Virginia Polytechnic Inst. and State Univ., Blacksburg. 65pp.

Holbrook, H. T., Vaughan, M. R., and P. T. Bromley. 1985. Wild turkey management on domesticated pine forests. Proc. Nat. Wild. Turkey Symp. 5:253-258.

Holbrook, H. T., Vaughan, M. R., and P. T. Bromley. 1987. Wild turkey habitat preferences and recruitment in intensively managed Piedmont forests. J. Wildl. Manage. 51(l):182-187.

Hooper, S. T. 1989. Wildlife and riparian zones in Maine: a review. Pages 171-177 *In* Briggs, R. D., W. B. Krohn, J. G. Trial, W. D. Ostrofsky, and D. B. Field, eds. Forest and wildlife management in New England - what can we afford? Maine Agric. Expt. Sta. Misc. Rep. 336.

Hooper, S. T. 1991. Distribution of songbirds in riparian forests of central Maine. M.S. Thesis. Univ. Maine, Orono. 90pp.

Howard, R. J., and J. A. Allen. 1989. Streamside habitats in southern forested wetlands: their role and implications for management. Pages 97-106 *In* D. D. Hooks and R. Lea, eds. Proc. symp. the forested wetlands of the southern United States. USDA For. Serv. Gen. Tech. Rep. SE-50. 168pp.

Ice, G. G. 1990. Guidelines and approaches for forest riparian management: state forest practice rules. Pages 94-98 *In* Proc. 1989 Soc. Am. For. Conv. Spokane, Wa.

Johnson, W. N., Jr., and P. W. Brown. 1990. Avian use of a lakeshore buffer strip and an undisturbed lakeshore in Maine. North. J. Appl. For. 7:114-117.

Kroll, J. C. 1991. A practical guide to producing and harvesting white-tailed deer. Center for Applied Studies in Forestry, Stephen F. Austin State Univ., Nacogdoches, TX. 590pp.

May, D. W. 1981. Habitat utilization by bobcats in eastern Maine. M.S. Thesis. Univ, Maine, Orono. 36pp.

McElfresh, R. W., J, M. Inglis, and B. A. Brown. 1980. Gray squirrel usage of hardwood ravines within pine plantations. La. State Univ, Annu. For. Symp. 29:79-89.

McKee, C. W. 1981. The economics of forest management for softwood sawlogs. Pages 95-103 *In* P. T. Bromley and R. L. Carlton, eds. Habitat requirements and habitat management for the wild turkey in the Southeast. Proc. Symp. Va. Wild. Turkey Found., Elliston, Va.

Melchiors, M. A. 1991. Wildlife management in southern pine regeneration system. Pages 391-420 *in* M. L. Duryea and P. M. Dougherty, eds. Forest regeneration manual. Kluwer Academic Publ., Dordrecht, The Netherlands.

Melchiors, M. A., and C. Cirero. 1987. Streamside and adjacent upland forest habitats in the Ouachita Mountains. Proc. Annu. Conf. SE. Assoc. Fish and Wildl. Agencies 41:385-393.

Murray, N. L. 1992. Habitat use by nongame birds in central Appalachian riparian forests. M. S. Thesis. Va. Poly. Inst. and State Univ., Blacksburg. 140pp.

Ockenfels, R. A. 1980. Habitat requirements of white-tailed deer in the post oak-blackjack oak habitat. M.S. Thesis. Arizona State Univ., Tempe. 73pp.

O'Neill, R. V., J. R. Krummel, R. H. Gardner, G. Sugihara, B. Jackson, D. L. DeAngelis, B. T. Milne, M. G. Turner, B. Zygmunt, S. W. Christensen, V. H. Dale, and R. L. Graham. 1988. Indices of landscape pattern. Landscape Ecology 1 (3):153-162.

Owen, C. N. 1994. Integrating wildlife and loblolly pine management. Pages 233-245 *In* B. L. Karr et al., eds. Proceedings of the symposium on loblolly pine ecosystem (west region). Miss. Coop. Extension Serv., Mississippi State Univ.

Pais, R. C, S. A. Bonney, and W. C. McComb. 1988. Herpetofaunal species richness and habitat associations in an eastern Kentucky forest. Proc. Annu. Conf. Southeast. Assoc. Fish and Widl. Agencies 42:448-455.

Poteet, M. L. 1990. White-tailed deer use of riparian zones and adjacent pine plantations in east Texas. M.S. Thesis. Stephen F. Austin State Univ., Nacogdoches, TX. 69pp.

Rayburn, R. L. 1983. Foraging activities of white-tailed deer in East Texas. M.S. Thesis. Stephen F. Austin State Univ., Nacogdoches, Tex. 76pp.

Rudolph, D. C., and J. G. Dickson. 1990. Streamside zone width and amphibian and reptile abundance. Southwest. Naturalist 35(4):472-476.

Simberloff, D., F. A. Farr, J. Cox, and D. W. Mehlman. 1992. Movement corridors: conservation bargains or poor investments? Conserv. Biol. 6(4):493-504.

Simpson, M. B., Jr. 1969. The prothonotary warbler in the Carolina Piedmont. Chat 33:31-37.

Small, M. F., and W. N. Johnson, Jr. 1986. Wildlife management in riparian habitats. Pages 69-79 *in* Is good forestry good wildlife management? Maine Agri. Expt. Sta. Misc. Publ. No. 689.

Stauffer, D. F, and L. B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:1-15.

Tappe, P. A., R. E. Thill, M. A. Melchiors, and T. B. Wigley. 1993. Wildlife values of streamside management zones in the Ouachita Mountains, Arkansas. Proc. conf. riparian ecosystems in the humid U.S.: functions, values, and manage. In press.

Tassone, J. 1981. Utility of hardwood leave strips for breeding birds in Virginia's central Piedmont. M.S. Thesis. Va. Polytechnic Inst. and State Univ., Blacksburg. 83pp.

Thurmond, D. P. 1993. Effect of streamside management zone width on wildlife abundance and diversity in young pine plantations. M.S. Thesis. Univ. Ga., Athens. 57pp.

Triquet, A. M., G. A. McPeek, and W. C. McComb. 1990. Songbird diversity in clearcuts with and without a riparian buffer strip. J. Soil and Water Conserv. 45(4):500-503.

Tucker, R. L. 1981. Home range and habitat selection of white-tailed deer in East Texas. M. S. Thesis. Stephen F. Austin State Univ., Nacogdoches, Tex. 160pp.

U.S. Geological Survey. 1970. National atlas of the United States. U.S. Department of Interior. 417pp.

Warren, R. C., and G. A. Hurst. 1980. Squirrel densities in pine-hardwood forests and streamside management zones. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 34:492-498.

Wigley, T. B. 1986. Wildlife and shortleaf pine management. Pages 222-234 *in* P. A. Murphy, ed. Symposium on the shortleaf pine ecosystem. Ark. Coop. Extension Serv., Little Rock.

Figure 1. Relationship of species richness of breeding birds to width (natural log) of wooded streamside habitat in Iowa. Data taken from graph presented in Stauffer and Best (1980).

Figure 2. Relationship of species richness of breeding birds to width of wooded streamside habitat in Iowa (untransformed data). Data taken from graph presented in Stauffer and Best (1980).