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Wildlife species: responses to forest harvesting and management in riparian stands and landscapes

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Summary

- Breeding birds were surveyed in five watersheds in northern Minnesota for four years. In three watersheds (Knife, Pokegama, Cloquet) 12, 6 to 10 acre plots were established. In two watersheds (Knife, Gooseberry) one large (> 40 acre) plot was established.

- Plots were established to assess breeding bird response to harvest type and harvest method in riparian forests.

- Treatments in the Pokegama watershed included removal of basal area to 25-35 ft^2 within 100 ft of either side of the stream with two different harvest methods (grapple skidding and cut-to-length systems). Uplands adjacent to riparian buffers were clearcut and three total (no harvest) plots were maintained in the watershed as well as three uncut riparian control plots. Before harvest data were collected in 1997, harvest was completed in the fall of 1997, and after harvest data collected in 1998, 1999 and 2000.

- Treatments in the Knife watershed ranged from clearcut in the riparian area to 25-35 ft^2 residual basal area within 100 feet on one side of the stream. Uplands adjacent to riparian buffers were clearcut and three total (no harvest) plots were maintained in the watershed as well as three uncut riparian control plots. Harvests were not completed on all sites because of poor winter harvest conditions in 1997, 1998 and 1999. Breeding bird data have been collected in all years and will be collected in 2001 if all sites are harvested within this time frame.

- Treatments on sites in the Cloquet watershed were designed to examine bird response to harvest in the riparian area by leaving residual basal area (40 ft^2) in either a scattered or clumped pattern. Uplands adjacent to riparian buffers were clearcut and three total (no harvest) plots were maintained in the watershed as well as three uncut riparian control plots. Harvests were not completed on all sites because of poor winter harvest conditions in 1997, 1998 and 1999. Breeding bird data have been collected in all years and will be collected in 2001 if all sites are harvested within this time frame.

- Bird surveys were also completed on two large sites in Lake County. One site, the Gooseberry was harvested, but the Knife River site was not. No statistical analyses were completed on these data and no additional studies are planned.

- In addition to breeding bird surveys, two additional tasks were completed and results were presented in the previous biennial report (Louisiana Waterthrush and riparian landscape statistics for the forested regions of Minnesota. No new information is presented in this report on those tasks.

- Here we report results of our work in three chapters. Chapter 1: Effects of riparian buffers on landscape characteristics: implications for breeding birds. Chapter 2: Associations of

breeding birds to riparian forests in northern Minnesota. and Chapter 3: Response of breeding birds to harvest level and harvest system in riparian forests in northern Minnesota, USA.

- Our objectives in Chapter 1 were to; 1) quantify landscape characteristics resulting from imposing two different buffer widths on riparian areas in northern Minnesota, 2) quantify the change in forest composition and landscape characteristics over a five year time period, and 3) discuss the pros and cons of leaving buffers in terms of potential effects this practice could have on breeding bird communities in this region.

- For the purposes of the landscape investigation we selected a 100 x 100 km area in northern Minnesota. This area was selected because it is representative of forest type, ownership, and management that occurs in this region. We quantified area of riparian habitat within individual cover types using Landsat Thematic Mapper (TM) data. We used two dates of TM data (1990 and 1995) and calculated hectares of forest types and riparian habitat for each of the dates. We then calculated the total area of forest harvested and amounts and types of riparian habitat harvested over the five year period.

- The dominant forest cover types in the study area were aspen/birch (51% of total) and lowland conifer (24% of total). Analyses of the 1995 coverage indicated that 26,978 ha (4.6%) of the forest area was harvested from 1990 to 1995. Forest types harvested were primarily white spruce, balsam fir, aspen, paper birch, jack pine, and northern hardwoods.

- A total of 113,993 ha (19.5%) of forest area was adjacent to and within 28.5 m of non-forested wetlands, intermittent or perennial streams, or lakes. A total of 214,298 ha of forest was within 57 m of these water bodies, representing 36.6% of the total forest area. Over 80% of the total amount of riparian forest was adjacent to non-forested wetlands (these areas are not currently subject to riparian guidelines). Riparian areas adjacent to perennial streams and lakes represented about 9% of the total riparian area and less than 2% was adjacent to intermittent streams.

- Landscape analyses of the study area indicated that the amount of forest edge increased by a factor of >10 (5,560 km to 92,686 km) in the five year period from 1990 to 1995. In addition, about 6% less interior forest existed in the study area in 1995 than in 1990.

- When we surrounded all water bodies with a 28.5 m buffer, the amount of edge on the landscape in 1995 increased ten-fold and there was a slight increase in amount of interior forest area. When water bodies were buffered with a 57 m forest strip, there was a slight increase in forest edge compared to the non-buffered riparian area and this buffer width resulted in the largest amount of interior forest.

- The significant increase in amount of edge in this landscape from 1990 to 1995 is likely due to the small size of harvests that are currently prescribed by landowners in this region. From a basic geometry comparison, more edge will be created with several small versus one large harvest area that total the same number of acres.

- Our objectives in Chapter 2 were to: 1) identify breeding bird relationships to stream riparian areas along a stream width gradient in northern Minnesota, 2) quantify the relative importance of riparian areas to breeding bird species and communities along this gradient in this region and 3) identify riparian-dependent bird species use of stream riparian forest.

- For these analyses, we used 36 study sites in three watersheds in northern Minnesota to examine relationships of breeding birds to streamside riparian areas (Knife, Pokegama, Cloquet). Before-harvest data were examined on all sites.

- Results from analyses of breeding bird community parameters indicated slightly different responses of the bird community to the stream edge forest habitat in each watershed. Bird communities varied more among transects in the Pokegama watershed than in the Cloquet or Knife watershed transects and bird communities in the Cloquet watershed study sites varied more in the distance categories from the stream edge than did bird communities in the Knife and Pokegama watersheds.

- In the Pokegama watershed, the Winter Wren, Blackburnian Warbler, Northern Parula and Blue Jay were positively associated with the 0-50 m transect block closest to the stream. Similarly, in the Knife River both the Winter Wren and Blackburnian Warblers were associated with the 0-50 m transect block as well as the Ruffed Grouse, White-throated Sparrow, and Veery. In the Cloquet watershed sites, the White-throated Sparrow and Northern Parula had positive associations with the 0-50 m segment along with the Common Yellowthroat and Swamp Sparrow. In contrast, the Ovenbird, Red-eyed Vireo, and Black-throated Green Warbler were all associated with distance blocks greater than 50 m from the stream edge.

- We found a significant relationship between species richness and distance from stream in the Cloquet watershed sites but not in the other two watersheds. Richness was greater in the first 50 m adjacent to the stream in the Cloquet watershed.

- Patterns for total numbers of individuals observed relative to stream position were similar to the pattern found for species richness. In these tests, significantly more individuals were observed in the block closest to the stream in the Cloquet watershed sites, but fewer individuals were observed in the block closest to the stream in the Pokegama watershed sites.

- We also found more edge-associated individuals within the first 50 m of the stream in the Cloquet and Knife watershed sites. The Pokegama sites showed a pattern opposite to the other two watersheds; more forest bird individuals were observed at distances greater than 50 m from the stream.

- Abundance patterns for ground nesting birds relative to the stream edge indicated a significant positive relationship for sites in the Cloquet and Knife watersheds.

- The distribution of permanent resident individuals to the stream edge was different in each watershed. In these tests, a significant effect was found for the Cloquet watershed, where more permanent residents were found in the area closest to the stream edge.

- Only two riparian-dependent bird species were observed in our study sites. One Northern Waterthrush observed in May on the Pokegama site was likely a migrant individual because no individuals were recorded in June or July. The Common Merganser observed on the Cloquet site was likely a breeding individual.

- There are several factors that may explain the lack of riparian-dependent bird species in our study areas. First, many of the larger-bodied species likely require wider streams, rivers or lakes for foraging activities. Second, the forest adjacent to streams that we studied were all second-growth stands that were less than 70 years in age. Current forests lack tall, super-canopy trees, large snags, and older trees with heartrot suitable for cavity excavation in the area adjacent to the stream that are more common in older forests. In general, habitat characteristics of forests adjacent to streams (other than a higher density of under-story shrubs and conifer species) was not different from the adjacent upland forest. This hypothesis is supported by the observation that bird species associated with upland deciduous forests were evenly distributed across the study areas. Given these conditions, we would not expect to find unique bird species or riparian-dependent bird species in these types of riparian forests.

- The objective of the third portion of the study was to describe riparian breeding bird response to harvest level and harvest system in the riparian area. The harvest systems used here were the traditional harvest method using whole-tree grapple skidding (GPL) and the new cut-to-length (CTL) harvest equipment. Our working hypothesis was that removal of basal area to an average of 25-35 ft^2 and type of harvest system used to remove trees would not affect breeding bird communities in riparian forests. In addition, if we found an affect of forest harvest, we expected that the difference would be larger with the traditional harvest system (GPL) because this practice results in a greater amount of disturbance to the understory and forest floor vegetation than the CTL harvest system.

- The experimental design in the Pokegama watershed for this portion of the study consisted of a randomized block design. The treatment combinations consisted of one level of over-story manipulation combined with two types of harvesting operations. Over-story treatments within riparian area were designed to test best management practices (BMP) for water quality in Minnesota. This included leaving an average of 25 ft^2/ac basal area within 100 feet of either side of the stream. These guidelines supercede the current guidelines recommended for forest management in Minnesota (MN Forest Resources Council 1999). A block of uncut riparian control sites was retained in the experimental design as well as a total control (no harvest in the study plot).

- We found that bird community composition changed in response to harvest and harvest system in forests adjacent to small (1-3 m in width) streams in this watershed. As expected, bird communities in the CTL and GPL treatment groups changed more relative to the control sites than sites where the riparian forest was left uncut. Significant changes in species composition on the treatment sites did not occur in the first year after harvest. However, the composition of bird communities, even three years after harvest continued to diverge, especially on the harvested sites (both CTL and GPL).

- The breeding bird composition of the harvested riparian sites included more early-successional species than both the control and uncut plots as time since harvest increased. Although the trajectory patterns of the bird communities in the statistical analyses were not identical on the CTL and GPL sites, overall, the type of harvest system used did not appear to have a significant impact on breeding bird community composition.

- Total number of individual birds and numbers of species increased on all treatment plots relative to the control areas in all years after treatment. Numbers of birds and species on our treated sites continued to increase two years after treatment and then slightly decreased in the third year after harvest. This result is likely due to two contributing factors. First, although we did not mark individuals, it is likely that forest dependent individuals occupying these treated sites before harvest returned to the sites the first year after harvest. In addition, individuals that were displaced by the clearcut harvest of mature forest in the surrounding upland forest, likely occupied remaining forest patches left in these riparian strips.

- This "species-packing" effect was likely evident in our study sites the first year after harvest. After this time, the increase in numbers of individuals and species in the harvested riparian and uncut plots was likely due to an increase in both early-successional individual and species in the CTL and GPL sites and edge species in the uncut riparian sites.

- The Ovenbird was the only species that showed a significant response to harvest in the riparian area. Because this species is forest dependent and also suggested to be a forest interior dependent species, this is a response that would be expected given that little residual forest cover was left in the CTL and GPL study sites.

- The power of our statistical tests to detect treatment effects for five bird species that had large enough numbers to conduct univariate tests was quite low (0.10 to 0.64). It is not surprising that no significant treatment by time interactions were detected. However, while we did not find significant differences for these species, some general patterns were evident. Two forest dependent species the Black-throated Green Warbler and Hermit Thrush, responded negatively to both harvest types. The 30m uncut buffer was adequate to maintain the Black-throated Green Warbler but not the Hermit Thrush. In contrast, another forest dependent species, the Red-eyed Vireo, was not affected by any riparian forest treatment regime.

- The Winter Wren was the only species that suggested an effect of harvest system. This species occurs in forests that have areas with coarse woody debris or upturned trees for nesting habitat. Because the GPL harvest method involves whole-tree skidding, it likely that these habitat features would be disturbed or removed by this process. In contrast, the CTL harvest system processes the trees where they are felled and no skidding is required. The use of CTL results in less disturbance to the ground and understory vegetation.

- Our power to detect differences in parameters that are generally tested in management responses studies (such as number of individuals, species richness, and individual species) was relatively low. The power to detect differences for the Ovenbird was the highest (0.81) and we detected a significant response to harvest for this species. A possible remedy to the problem of low power with univariate tests, is to conduct multivariate community response statistic.

- We used a newly developed method (PRC) that was very useful at examining effects of treatment on bird communities. This method allowed us to compare bird communities within various treatment groups while holding the values of the control group constant. The graphic output of these tests was used to describe changes that occurred over time in the treatment groups and also allowed us to show which species were most responsible for the differences.

- The PRC method could be a very useful analytical method in management response studies where it is not feasible to have a high number of replicates. Our test was significant for the first PRC and illustrated the response of the bird community to the harvest types and systems that are biologically meaningful and intuitively correct. From this diagram we can predict which species are sensitive to any riparian treatment which include the Ovenbird, Scarlet Tanager, Black-throated Green Warbler, Veery, Yellow-bellied Sapsucker, and Hermit Thrush. As expected, species that responded positively to removal of canopy from the riparian area included several early-successional species like the White-throated Sparrow, Chestnut-sided Warbler, Song Sparrow, and Rose-breasted Grosbeak.

Management Recommendations

- The projected amounts of edge and forest interior that would result if riparian buffers were applied across this landscape provide important insight on the effects that these practices will have on future conditions. We found that applying prescribed riparian buffers around all water bodies would further increase the amount of edge on the landscape, especially with the 28.5m buffer width. Given this result, **we suggest that application of riparian buffer guidelines should not be uniformly applied across the landscape.**

- We need to understand how to protect the function of riparian systems on a landscape level, which likely does not require the protection of every riparian buffer piece. We suggest that emphasis should be placed on prioritizing riparian areas that currently provide habitat for riparian dependent bird species. To accomplish this, we need to quantify structural habitat and landscape features of riparian areas where these species occur. **A management strategy would be to protect important riparian areas with wider buffers, extended rotation, or uneven-aged forest management practices.**

- Although we did not find a large number of riparian-dependent individuals in our study areas, we can examine life history requirements of these species to suggest forest management activities that may benefit riparian-dependent species. Riparian-dependent birds have life history characteristics that are adapted to the use of large trees in association with water. This condition would occur under the natural historic disturbance regime for northern forests (primarily fire and blowdown). Although the fire frequency in this region ranged from 50-3000 years (depending on the forest community type), riparian forests were often protected from fires, occurring in fire shadow areas on the landscape (Frelich and Lorimer 1991). It is postulated that disturbance frequency in riparian areas from fires was on a longer rotation than the mean fire frequency in northern forests. This disturbance scenario would provide areas of the landscape that had older and larger trees that were associated with water bodies.

- **A management goal for riparian areas would be to maintain large diameter and tall trees in these areas. This can be accomplished by maintaining a percentage of riparian habitat in an extended rotation forestry condition or by leaving a large number of long lived tree species as residual trees in harvest areas adjacent to water bodies. In addition, these structural features should be protected from wind which may be accomplished by buffering the target residual trees within a clump of trees. This management strategy may require more planning than a simple application of a uniform, no-harvest buffer strip, but will likely be more successful in providing habitat features that riparian-dependent bird species require.**

- **Results of our study and others suggest that riparian guidelines need to be flexible and that management plans for riparian areas should be done on a landscape level.**

We need to ask ourselves what ecological service is being provided by buffers and then identify riparian areas that have unique riparian communities. It is likely that once these areas are identified, a wider and possibly a no harvest buffer would be required to protect these features. An approach that recommends prescriptive riparian buffers assumes that all riparian areas are identical. Results from this study and others suggest that this assumption is not valid for northern Minnesota riparian forests.

Chapter 1. Effects of riparian buffers on landscape characteristics: Implications for breeding birds

Introduction

Riparian areas have multiple environmental and socioeconomic functions (see Schueler 1995; Malanson 1993). They maintain water quality, protect and provide substrate for fish, provide terrestrial habitat and travel corridors for many wildlife species, offer aesthetic and recreational opportunities, and are a source of forest products. Historically, multiple-use areas such as forests adjacent to streams, rivers, wetlands and lakes have been subject to a variety of management strategies to protect their important functions. However, because riparian areas serve multiple functions, management recommendations are often a compromise that provide some protection for water quality, some habitat components required by fish and terrestrial wildlife, while still allowing for resource extraction and recreational opportunities.

Currently, most management guidelines that recommend protection of riparian area function are based on studies from singular disciplines (e.g, water quality) and have resulted primarily in the prescription of set buffer widths to mitigate impacts of removing riparian vegetation. Buffer widths have been suggested that would mitigate impacts due to sedimentation, nutrients, contaminants, aquatic structural habitat, and terrestrial wildlife habitat (see review by Wegner 1999). Some investigators have used soil characteristics and slope to calculate variable buffer widths required to protect water quality (Xiang 1996). Breeding birds are probably the most commonly studied animal group in terms of their response to forest management in riparian forests and several studies have suggested minimum buffer widths (each side of stream or river) required to maintain pre-impact species composition (Wegner 1999). For example, recommended buffer widths from previous bird studies ranged from 15 m (Thurmond et al. 1995) to 175 m (Wegner 1999). Darveau et al. (1995) recommended a 60 m riparian buffer in boreal forests while Keller et al. (1993) indicated that a 100 m buffer is required in eastern deciduous forests. All of these studies imply that no harvest should occur in these buffers.

More recent investigations have questioned the utility of riparian buffers for both breeding and migrating birds and for general forest health. For example, because several studies have reported a decrease in bird reproduction along edges compared to interior forest areas (Small and Hunter 1988; Fenske-Crawford and Niemi 1997; Donovan et al. 1995; 1997) and in riparian buffer strips (VanderHaegen and DeGraff 1996), wider buffers (150 m) have been suggested to reduce edge related predation. In addition, studies on bird movements suggest that a 100 m buffer is required to aid juvenile bird dispersal (Machtans et al. 1996). One study (Darveau et al. 1995), however, questioned the value of strips less than 15 m. They found that trees left in narrow buffers blew down at a higher rate than trees left in wider riparian buffers. In these studies, the area adjacent to the riparian buffers were clearcut.

Current evidence suggests that buffers in the range of 100-200 m are required to provide "safe" breeding habitat for birds, but this is based on the assumption that buffers would be used by forest birds and that bird use is positively correlated with buffer width. However, neither of these assumptions are valid in all watersheds. For example, Whittaker and Montevecchi (1999) suggested that we wrongly assume that buffers will be used by all species that were present in the area prior to management activities. In addition, Meiklejohn and Hughes (1999) found that riparian buffers usually support only edge species and not the full compliment of forest birds. Finally, wider buffers do not always increase use of these areas by breeding birds (Whitaker and Montevecchi 1999).

In addition to concerns about whether buffers will provide adequate habitat for wildlife species as intended, landscape level effects of preserving intact buffer areas adjacent to streams, rivers, wetlands and lakes and the concomitant effects on animals in these landscapes have not been documented. For example, effects of applying buffers to riparian areas on the amount of edge and forest interior habitat on the landscape have largely been ignored. Our objectives were to; 1) quantify landscape characteristics resulting from imposing two different buffer widths on riparian areas in northern Minnesota, 2) quantify the change in forest composition and landscape characteristics over a five year time period, and 3) discuss the pros and cons of leaving buffers in terms of potential effects this practice could have on breeding bird communities in this region.

Study Areas

Northern Minnesota is a heterogeneous forested landscape interspersed with lakes, wetlands, streams, and rivers. This region has multiple owners (federal, state, county and private) and is subject to forest management activities. For the purposes of this investigation we selected a 100 x 100 km area for a detailed landscape analysis. This area was selected because it is representative of forest type, ownership, and management that occurs in this region.

Methods

We quantified area of riparian habitat within individual cover types in the 100 x 100 km study area using Landsat Thematic Mapper (TM) data. Wolter et al. (1995) have developed a technique that uses multiple TM scenes over different phenological time frames to identify forest cover types to a species level. The spatial resolution of TM data was 28.5 m^2 and dominant tree species and land use type were classified for each of these cells. The accuracy of the classification was greater than 80% (Wolter et al. 1995). We used two dates of TM data (1990 and 1995) and calculated hectares of forest types and riparian habitat for each of the dates. We then calculated the total area of forest harvested and amounts and types of riparian habitat harvested over the five year period.

The identification of water bodies was completed in multiple steps. Riparian buffers were applied to the landscape with 1-pixel and 2-pixels, corresponding to 28.5 m and 57 m buffers respectively, for each water body type. We chose these two buffer widths because they represent the range in width that was recommended for protection of Minnesota's riparian forest areas (Minnesota Forest Resources Council 1999). We first identified all water bodies that were large enough or wide enough to be classified with the satellite data. For lakes and ponds, the smallest area was 0.04 ha and for rivers and streams, those >14 m wide were detectable using TM data. All these water bodies were buffered as one class in ERDAS. The second type of water body buffered was rivers and streams <14 m wide which were identified in the United States Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing system) data base. Perennial and intermittent stream-course arcs (no width) were buffered separately in ARC/INFO using 28.5 m and 57 m radii and were then rasterizd and imported into ERDAS. When all buffers were in ERDAS, perennial stream buffers were overlaid on top of intermittent stream buffers to create a four class buffer layer. This four class layer was then overlaid on top of the satellite water buffers to create a six class water buffer layer: (1) satellite water, 28.5 m; (2) satellite water, 57 m; (3) TIGER intermittent, 28.5 m; (4) TIGER intermittent, 57 m; (5) TIGER perennial, 28.5 m; and (6) TIGER perennial, 57 m. In addition, non-forested wetlands were identified with both National Wetlands Inventory (NWI) data and the satellite classified image. One wetland classification that is under-represented in these data are vernal pools which are difficult to identify with remotely sensed data.

After water bodies were identified and buffered, we calculated the area of each individual cover type within each water body class and buffer width from digital maps created from the satellite data. In this process, overlap in perennial and intermittent stream buffers that we identified with both satellite classified water and TIGER data were identified and these areas were not summed twice. TIGER data were used only when satellite data could not detect water.

The next step was to quantify landscape characteristics in the 100 x 100 km study area for the two buffer widths around all water body types. For this exercise, we were most interested in amount of edge and interior forest that remained after an area was harvested when the buffers were imposed. This was accomplished in multiple steps. First, the areas identified with the 28.5 m and 57 m buffers were recoded and added to their respective classifications as forest. Each classification was then recoded into either forest or non-forest. We considered portions of forest patches as interior forest if they were greater that 114 m (4 pixels) from an edge. We chose this distance because it is commonly used in avian ecology to define interior forest area (Temple 1986; Blake and Karr 1987). Therefore, we buffered our non-forest class by four pixels and anything greater than four pixels away from non-forest was considered interior forest. The total perimeter of the remaining interior forest patches was calculated using ARCVIEW.

Results

The total area of the 100 x 100 km study area was 1,000,697 ha. Of the total area, 585,144 ha was classified as forest in the 1990 coverage (Table 1). The dominant forest cover types were aspen/birch (51% of total) and lowland conifer (24% of total). Analyses of the 1995 coverage indicated that 26,978 ha (4.6%) of the forest area was harvested from 1990 to 1995. Forest types harvested were primarily white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), jack pine (*Pinus banksiana*) and northern hardwoods (Table 1).

Table 1. Area (ha) and percent change of forest cover types and other habitat or land-use types (including roads and developed) in the study area in 1990 and 1995. Change in forest cover was primarily due to forest harvest.

Forest cover type	1990	1995	% change
Jack pine (*Pinus banksiana*)	43,333	40,835	-5.8
Spruce/fir (*Picea glauca/Abies balsamea*)	63,118	59,214	-6.2
Cedar (*Thuja occidentalis*)	10,897	10,713	-1.7
Lowland conifer (*Picea mariana, Larix laricina*)	140,858	138,212	-1.9
Black ash (*Fraxinus nigra*)	17,272	16,728	-3.2
Aspen/birch (*Populus tremuloides/Betula papyrifera*)	297,471	280,210	-5.9
Northern Hardwood (*Acer* spp., *Quercus* spp.)	12,861	12,254	-4.8
Other (water, non-forest, developed)	414,887	415,553	+<1.0
New harvest		26,978	
TOTAL	1,000,697	1,000,697	-4.6 % of forest area

A total of 113,993 ha (19.5%) of forest area was adjacent to and within 28.5 m of non-forested wetlands, intermittent or perennial streams, or lakes (Table 2). A total of 214,298 ha of forest was within 57 m of these water bodies, representing 36.6% of the total forest area. Over 80% of the total amount of riparian forest was adjacent to non-forested wetlands (Table 2). Riparian areas adjacent to perennial streams and lakes represented about 9% of the total riparian area and less than 2% was adjacent to intermittent streams (Table 2).

Based on the 1995 TM coverage, about 7% of forest area adjacent to water bodies was harvested from 1990 to 1995 (Table 2). The change in forest area adjacent to intermittent streams was about 5%, and there was a 2% change in forest area adjacent to perennial rivers and streams during this time period. The smallest amount of change in forest area was found for those areas adjacent to lakes (less than 2%).

Table 2. Amount of forest habitat (ha) within 28.5 m and 57 m of non-forested wetlands, intermittent streams, perennial streams and lakes in 1990 and 1995 within the study area. The percent change from 1990 to 1995 was due primarily to forest harvest.

Water body type	Buffer width (m)	1990	1995	Percent change
Non-forested wetlands	28.5	92,896	86,394	-7.0
	57	172,163	160,284	-6.9
Intermittent streams	28.5	550	523	-5.0
	57	1,160	1,099	-5.3
Perennial streams and rivers	28.5	9,584	9,392	-2.0
	57	20,450	19,980	-2.3
Lakes and ponds	28.5	10,963	10,832	-1.2
	57	20,525	20,094	-2.1
TOTAL	28.5	113,993	107,141	-6.0
TOTAL	57	214,298	201,457	-6.0

Landscape analyses of the study area indicated that the amount of forest edge increased by a factor of >10 (5,560 km to 92,686 km) in the five year period from 1990 to 1995 (Figure 1). In addition, about 6% less interior forest existed in the study area in 1995 than in 1990 (Figure 2). When we surrounded all water bodies with a 28.5 m buffer, the amount of edge on the landscape in 1995 increased ten-fold (Figure 1) and there was a slight increase in amount of interior forest area (Figure 2). When water bodies were buffered with a 57 m forest strip, there was a slight

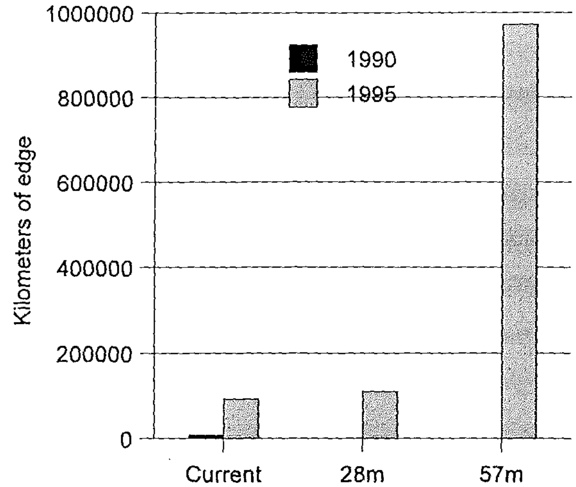

Figure 1. Kilometers of edge in study area in 1990 and 1995 and projected amount of edge with a 28m and 57m buffer.

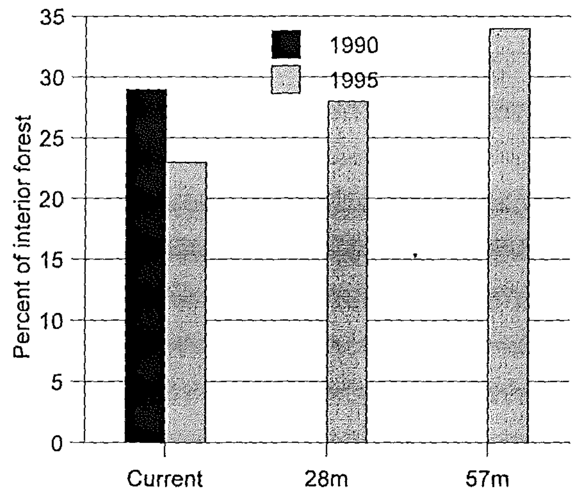

Figure 2. Percent of interior forest in study area under current management (1990 and 1995) and a projected 27m and 57m buffer width.

increase in forest edge compared to the non-buffered riparian area and this buffer width resulted in the largest amount of interior forest.

Discussion

This study illustrates the powerful use of classified, remotely sensed habitat data in a GIS system to: 1) compare current and past habitat and landscape characteristics, 2) quantify changes due to current forest management and land use practices on riparian forests, and 3) predict future land conditions under a variety of management scenarios. This information can be used to modify forest management practices such that concerns identified at the landscape level can be mitigated by site-level practices.

Comparison of the 1990 and 1995 remotely sensed data revealed important information on effects of current forest harvest practices on forest composition and landscape characteristics in this region. Approximately 5% of the area was harvested over the five year period between 1990 and 1995, but habitat types were not harvested in proportion to their availability. In general, upland forest types such as jack pine, spruce/fir and aspen/birch were harvested at a rate greater than the average of 5%. In contrast, lowland forest types like cedar, lowland conifer and black ash were harvested at a rate that was lower than the average. Although the rate of harvest was approximately 1% per year, the amount of edge in the landscape increased greater than ten-fold in this five year period. The amount of interior forest decreased over the same time period by about 5% and we also found that there was a slight increase in developed areas including roads.

The significant increase in amount of edge in this landscape from 1990 to 1995 is likely due to the small size of harvests that are currently prescribed by landowners in this region. From a basic geometry comparison, more edge will be created with several small versus one large harvest area that total the same number of acres. For example, the average size of harvest is about 5 ha (Minnesota Department of Natural Resources personal communication), which results in the creation of a large amount of edge habitat. Larger harvest units would result in less edge, more intact forest interior areas, and fewer roads. In addition, if riparian buffers were not applied uniformly across the landscape, less edge would be created and a smaller number of harvests would have to be accomplished to produce the same amount of wood volume.

Comparison of 1990 and 1995 TM data also revealed the types and amounts of riparian habitat associated with each type of water body in this region and the effect of current management practices on these riparian areas. The change in amount of riparian forest area from 1990 to 1995 was -6.0% which was slightly higher than the percent of total forest that changed. The largest change occurred adjacent to non-forested wetlands probably because there are no forest management practices that protect these areas from harvest. The amount of harvest that occurred within 27.5 m of lakes, ponds, and perennial streams and rivers was about 1.5% which indicates that most of these areas were managed under previous guidelines designed to protect water quality with filter strips which applies primarily to waters that contain trout.

The projected amounts of edge and forest interior that would result if riparian buffers were applied across this landscape provide important insight on the effects that these practices will have on future conditions. We found that applying prescribed riparian buffers around all water bodies would further increase the amount of edge on the landscape, especially with the 28.5m buffer width. Given this result, we suggest that application of riparian buffer guidelines should not be uniformly applied across the landscape. We need to understand how to protect the function of riparian systems on a landscape level, which likely does not require the protection of every riparian buffer piece. For example, most bird species associated with riparian area forests in northern Minnesota are commonly found in other forest habitat types in the region (Hanowski and Niemi 1993a, 1993b, 1994; Blake et al. 1994; Niemi et al. 1995; Hawrot et al. 1998). If we consider the negative impacts of imposing riparian buffers on a landscape level, it is difficult to support the practice of maintaining buffers adjacent to all water bodies for breeding birds. We suggest that emphasis should be placed on prioritizing riparian areas that currently provide habitat for riparian dependent bird species. To accomplish this, we need to quantify structural habitat and landscape features of riparian areas where these species occur. A management strategy would be to protect these important areas that would likely require wider buffers, extended rotation, or uneven-aged forest management practices.

We caution that although our study does not support the need to maintain riparian buffers around all water bodies for breeding bird diversity, buffers are necessary to protect water quality and may be important for birds in other times of the year. For example, riparian areas are used extensively by migrating birds. Stevens et al. (1977) found that over 10 times as many individual birds migrate through riparian areas in comparison to surrounding upland sites in the spring and Hehnke and Stone (1979) found 14 times as many individuals using riparian corridors during fall migration compared with adjacent upland habitat. Bird use of riparian areas during migration is likely due to the high abundance and concentration of both animal and plant-based food supplies (e.g., berry-producing trees and shrubs) in these areas (Weisbrod et al. 1993). These food resources are important to both fall and spring migratory species (Winker et al. 1992). We need to quantify the effect that change in or loss of riparian habitat has on the fitness of individuals or on the overall population. Another function that riparian areas may have is to aid dispersal in juvenile birds. We are now only beginning to understand the biology of bird dispersal (Machtans et al. 1996; Schmiegelow et al. 1997). Recent studies suggest that riparian corridors may be important to survival rates of these young birds and aid in maintaining adult movements as well (Machtans et al. 1996). More work is needed to document the importance of riparian buffers to these activities.

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Common names for species depicted by their abbreviations within figures in Chapters 2 and 3.

AMRE	American Redstart
AMRO	American Robin
BAWW	Black-and-white Warbler
BCCH	Black-capped Chickadee
BHCO	Brown-headed Cowbird
BHVI	Blue-headed Vireo
BLBW	Blackburnian Warbler
BLJA	Blue Jay
BRCR	Brown Creeper
BTBW	Black-throated Blue Warbler
BTNW	Black-throated Green Warbler
CAWA	Canada Warbler
COYE	Common Yellowthroat
CSWA	Chestnut-sided Warbler
DOWO	Downy Woodpecker
EAWP	Eastern Wood-Pewee
GCFL	Great Crested Flycatcher
GCKI	Golden-crowned Kinglet
HAWO	Hairy Woodpecker
HETH	Hermit Thrush
LEFL	Least Flycatcher
MAWA	Magnolia Warbler
MOWA	Mourning Warbler
MYWA	Yellow-rumped Warbler (Myrtle)
NAWA	Nashville Warbler
NOPA	Northern Parula
OVEN	Ovenbird
PUFI	Purple Finch
RBGR	Rose-breasted Grosbeak
RBNU	Red-breasted Nuthatch
RCKI	Ruby-crowned Kinglet
REVI	Red-eyed Vireo
RUGR	Ruffed Grouse
SCTA	Scarlet Tanager
SOSP	Song Sparrow
SWSP	Swamp Sparrow
SWTH	Swainson's Thrush
VEER	Veery
WBNU	White-breasted Nuthatch
WIWR	Winter Wren
WOTH	Wood Thrush
WTSP	White-throated Sparrow
YBFL	Yellow-bellied Flycatcher
YBSA	Yellow-bellied Sapsucker

Chapter 2: Associations of breeding birds to riparian forests in northern Minnesota

Introduction

Riparian habitat has been shown to be important to breeding birds in many areas of North America (Carothers and Johnson 1975; Szaro 1980; Knopf 1985). For example, over 50% of 166 species that breed in riparian areas in the southwestern United States depend completely on this habitat (Johnson et al. 1977). Breeding bird densities are also higher in riparian cottonwood stands in the southwest United States than in all other habitats (Carothers and Johnson 1975: Johnson et al. 1977). In the eastern United States, at least four studies have reported that breeding bird diversity in riparian habitat is higher than diversity in adjacent forest habitat (Dickson 1978; Best et al. 1979; Hair et al. 1979; Stauffer and Best 1980). One study in this region (Murray and Stauffer 1995) however, did not find higher species richness and bird abundance in riparian zones compared with uplands in Virginia.

Regional variation in relative importance and use of riparian areas by breeding birds may be partially explained by amounts and types of disturbance that have occurred in an area. Historically, riparian areas have been influenced by both subtle and dramatic perturbations including water management practices, channelization, grazing, conversion to agriculture, recreational development, and timber harvest (Knopf 1985). The amount of land converted to other land uses in a region may partially explain the relative importance of riparian habitat to breeding birds. Use of riparian areas by forest-associated breeding birds is probably inversely related to the amount of other suitable breeding habitat in a region.

Forests in the northern Great Lakes region have been altered in vegetation species composition and structure since presettlement, but the region remains largely forested. Few studies have been done to document associations of breeding birds to riparian habitat, specifically lotic systems in forests of the Great Lakes region. However, despite this lack of information, agencies have drafted and implemented forest management guidelines in this region without documenting the importance of riparian forests to wildlife. Our objectives were to: 1) identify breeding bird relationships to stream riparian areas along a stream width gradient in northern Minnesota, 2) quantify the relative importance of riparian areas to breeding bird species and communities along this gradient in this region and 3) identify riparian-dependent bird species use of stream riparian forest.

Study Area

Thirty-six study sites in three watersheds in northern Minnesota were studied to examine relationships of breeding birds to streamside riparian areas (Figure 2.1). The streams in these watersheds represent types of lotic systems in this region that would be subject to forest management activities (e.g. merchantable timber in adjacent upland areas). Study sites (12 in each watershed) were used as replicates for an on-going study to examine effects of harvest level and harvest type in the riparian area on breeding birds. Data presented here were collected prior to forest harvest. Each study site was at least 4 ha in size and sites were separated by at least 100 m. Tests for independence (Moran's I) (Sokal and Oden 1978) indicated that bird communities on adjacent sites were as independent from each other as compared with sites greater than 1 km away. In two watersheds, study sites were located adjacent to and on one side of the stream. In one watershed (Pokegama), the study sites crossed the stream.

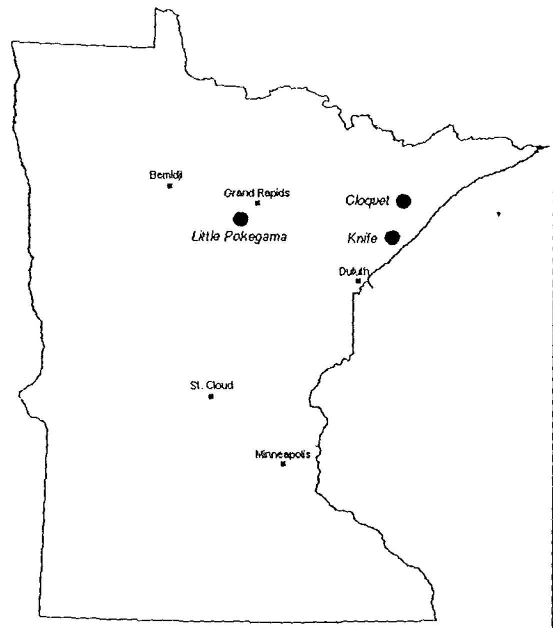


Figure 2.1. Location of study watersheds in northern Minnesota.

The streams studied here fell within three broad ranges of widths generally representing first, second and third order streams of this region (Strahler 1964). All streams were perennial. Streams in the Pokegama watershed were narrow (1-3 m) and the tree canopy extended over the stream. Streams in the Knife watershed were wider (3-5 m) and there was a discernible opening of the canopy above the stream. In contrast, streams in the Cloquet watershed were the widest (5-10 m), there was a definite stream edge and several sites had a shrubby riparian edge of willow (*Salix* spp.) and alder (*Alnus* spp.).

Bird Surveys

Three breeding bird surveys were conducted on each study site in 1997. One survey was done in mid-May to document breeding permanent resident species (e.g., chickadees and woodpeckers), one in mid-June to capture peak singing migrant species on territories, and one in early-July for later breeding species (e.g., goldfinches). Because we were interested in determining locations of birds relative to the stream, we used line-transects to conduct bird surveys (Hanowski et al. 1990). Surveys were completed by three experienced observers who passed a bird identification test, hearing test, and received training to standardize counts (Hanowski and Niemi 1995). All surveys were completed during early morning hours (within 4 hours of sunrise) and under good weather conditions (no rain and winds < 20 kph). Rate of travel along transects was standardized at 1km/hr. Birds were recorded at a distance of 100 m on either side of the transect center line.

Statistical Analyses. We used two types of statistical tests to determine response of birds (univariate tests) and bird communities (multivariate tests) to the riparian forest area. For these tests, all transects were divided into 50 m segments relative to distance from the stream and bird observations were summed for each segment. We used the maximum number of individuals observed on the three surveys for each species in the data analyses. All data were transformed (ln (count + 0.2)) prior to statistical analyses with all statistical methods except the Poisson regression.

Bird community analysis. We used multivariate techniques including detrended correspondence analysis (DCA) and partial redundancy analysis (RDA) to determine whether bird community composition was influenced by distance from the stream edge in each watershed (ter Braak and Šmilauer 1998). Uncommon species that occurred on less than 5% of the blocks were excluded from the analysis. The first step was to calculate the length of bird community gradients with DCA. When gradients are short, monotonic models like RDA are more appropriate than unimodal models such as DCA or CCA. Because gradient lengths were < 4.0 for all axes in all watersheds, we used RDA for subsequent analyses (ter Braak and Šmilauer 1998). The partial RDA was done for each watershed using distance categories as explanatory variables and transects as blocks (covariables). This model uses distance categories to explain variation in the bird species data set, after within-transect variation is partialled out. We tested the significance of the first canonical axis and all canonical axes combined with a Monte Carlo permutation procedure. If there was an overall effect of distance in this test, we completed a blocked multi-response permutation procedure (BMRPP) to make multiple comparisons between distance categories and used Holm's procedure to control the experiment-wise error rate for the multiple comparison tests (Legendre and Legendre 1998).

Univariate statistical analyses. We were also interested in examining the relationship between species richness, total abundance, and abundances of edge, forest, ground-nesting and permanent residents individuals with distance from the stream. Because our data did not meet normality and homogeneity of variance assumptions even after transformations, we used Poisson regression to test for distance effects of the dependent variables in each watershed (SAS, Proc GENMOD). We used Poisson regression because count data usually follow a Poisson distribution, especially when counts are not very small or very large. Because transects in plots within the Knife watershed were not equal in length resulting in an unbalanced design, tests of individual differences were carried out on the least-squared means. If overall tests of distance effect were significant, multiple comparisons were computed between all possible distance categories. Edge, forest and other species were classified into guilds based on several peer reviewed sources that were compiled in Niemi and Hanowski (1992).

Results

Bird community response to stream edge. The RDA on breeding bird community parameters indicated slightly different responses of the bird community to the stream edge forest habitat in each watershed. The percent variance in the bird data set that could be explained by individual transects (n=12) within each watershed varied from 33% in the Pokegama watershed to 19% and 18% in the Cloquet and Knife watersheds respectively (Table 2.1). This indicates that bird

Table 2.1. Summary of redundancy analysis (RDA) on breeding bird community data from three northern Minnesota watersheds in 1997.

Watershed	% variance due to transects in watershed	% variance that may be explained by distance from stream	% variance explained by distance from stream	% distance variance explained by all axes	% distance variance explained by axis 1
Pokegama	33	67	7	10 (P=0.14)	7 **(P=0.04)**
Knife	19	81	11	14 (P=0.19)	4 (P=0.59)
Cloquet	18	82	17	22 **(P=0.002)**	14 **(P=0.002)**

communities varied more among transects in the Pokegama watershed than in the Cloquet or Knife watershed transects. Of the remaining variance in the bird data set, 17% was explained by distance from stream in the Cloquet watershed, 11% of the variance in the Knife watershed, and 7% of the remaining variance in the Pokegama watershed sites was attributed to distance from stream (Table 2.1). This indicates that bird communities in the Cloquet watershed study sites varied more in the distance categories from the stream edge than did bird communities in the Knife and Pokegama watersheds.

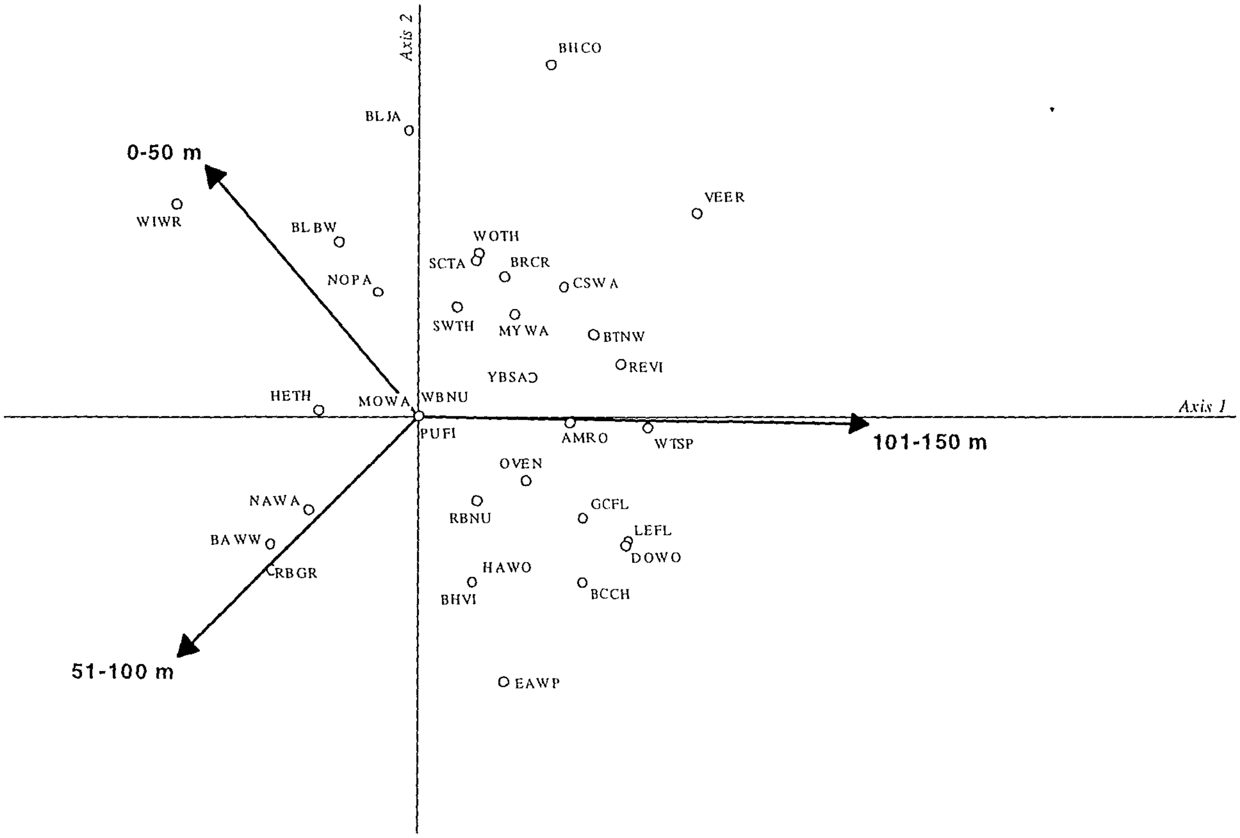
When we examined the variance explained in the RDA that was due to distance from stream we found that 10% of the variance was explained by all axes in the Pokegama watershed (P=0.14), but 7% (P=0.04) of this variance was explained by one axis (Table 2.1). Results of this analysis from the Knife watershed showed that 14% (T=0.19) of the variance due to distance was explained by all axes, but only 4% was explained on the first axis (Table 2.1). A higher proportion of the variance in the bird community data set was explained by distance in the Cloquet watershed (22% all axes; P=0.002 and 14% on axis 1 P=0.002). Because the RDA in the Cloquet watershed was significant, multiple comparison tests were completed. These results indicated that bird communities in the area closest to the stream (0-50m) were significantly different than bird communities at all other distance categories (Table 2.2)

Table 2.2. P-values and corrected Holm's P-values from the blocked multi-response permutation procedure that compared bird communities in six different distance blocks from the stream in the Cloquet watershed. 1=0-50m, 2=51-100m, 3=101-150m, 4=151-200m, 5=201-250m, and 6=251-300m.

Contrast	P-value	Holm's P-value
1 and 2	0.001	0.011
1 and 3	0.002	0.019
1 and 4	0.001	0.011
1 and 5	0.001	0.011
1 and 6	0.001	0.012
2 and 3	0.215	0.773
2 and 4	0.038	0.226
2 and 5	0.015	0.112
2 and 6	0.012	0.108
3 and 4	0.193	0.773
3 and 5	0.248	0.773
3 and 6	0.232	0.773
4 and 5	0.047	0.233
4 and 6	0.006	0.057

When we examined the ordination diagrams illustrating the influence of distance from stream on bird communities in each watershed, a few consistent patterns were evident in individual species positions along distance axes. For example, in the Pokegama watershed, the Winter Wren (*Troglodytes troglodytes*), Blackburnian Warbler (*Dendroica fusca*), Northern Parula (*Parula americana*) and Blue Jay (*Cyanocitta cristata*) were positively associated with the 0-50 m transect blocks (Figure 2.2). Similarly, in

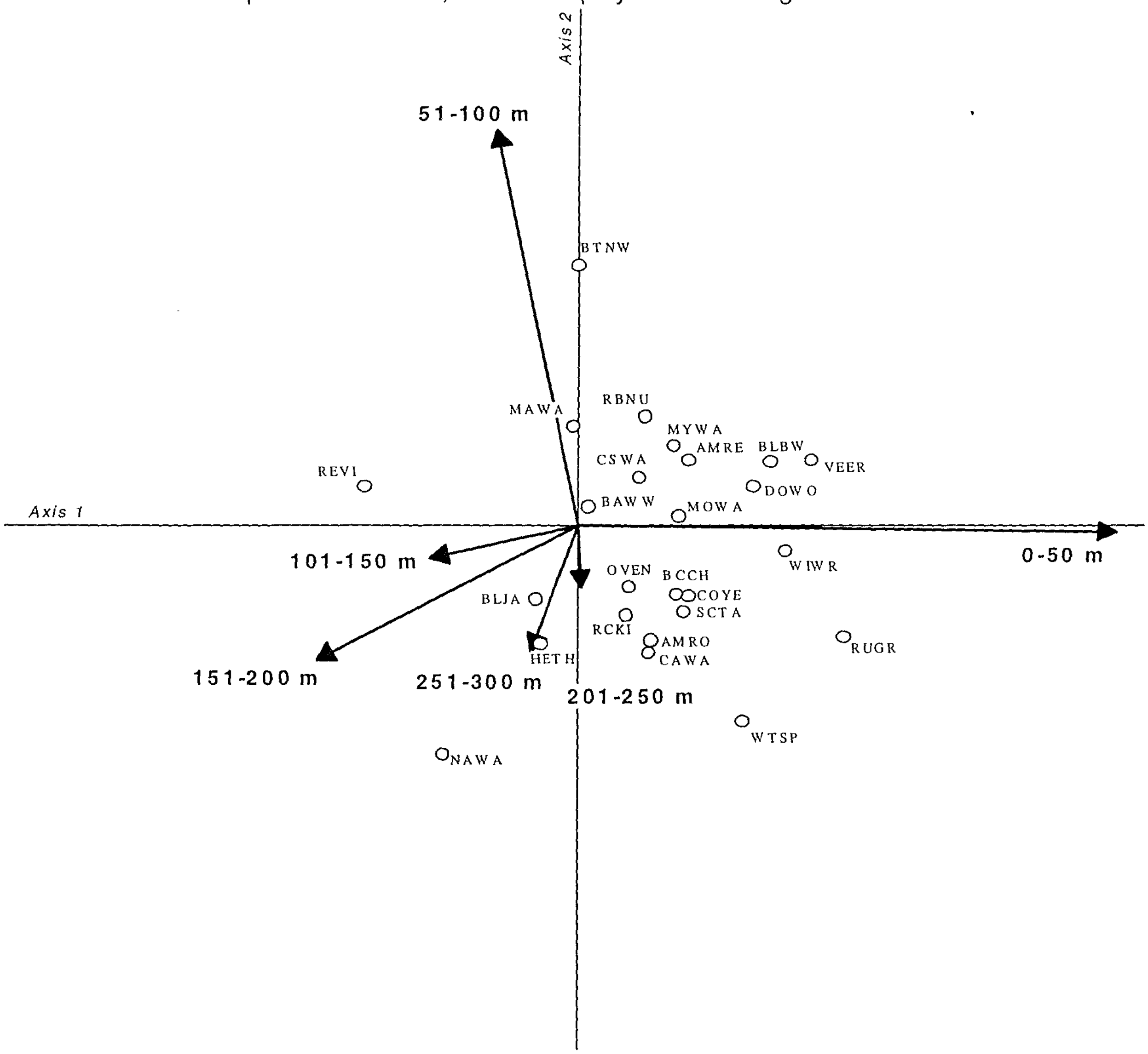
Figure 2.2. Ordination diagram (RDA) portraying the influence of distance from stream on bird community composition at the Pokegama River study area. Distance categories were used as explanatory variables. Of all the species variance, 7% can be attributed to the explanatory variables. Of the explained variance, 100% is portrayed in this diagram.



the Knife River both the Winter Wren and Blackburnian Warblers were associated with the 0-50 m transect block as well as the Ruffed Grouse (*Bonasa umbellus*), White-throated Sparrow (*Zonotrichia albicollis*) , and Veery (*Catharus fuscescens*) (Figure 2.3). In the Cloquet watershed sites, the White-throated Sparrow and Northern Parula had positive associations with the 0-50 m segment along with the Common Yellowthroat (*Geothlypis trichas*) and Swamp Sparrow (*Melospiza georgiana*) (Figure 2.4). In contrast, the Ovenbird (*Seiurus aurocapillus*), Red-eyed Vireo (*Vireo olivaceus*) , and Black-throated Green Warbler (*Dendroica virens*) were all associated with distance blocks greater than 50 m from the stream edge (Figures 2.2, 2.3, 2.4).

Univariate comparisons. We found a significant relationship between species richness and distance from stream in the Cloquet watershed sites but not in the other two watersheds (Figure 2.5). Richness was greater in the first 50 m adjacent to the stream in the Cloquet watershed. Patterns for total numbers of individuals observed relative to stream position were similar to the

Figure 2.3. Ordination diagram (RDA) portraying the influence of distance from stream on bird community composition at the Knife River study area. Distance categories were used as explanatory variables. Of all the species variance, 11% can be attributed to the explanatory variables. Of this explained variance, 53% is displayed in this diagram.



pattern found for species richness. In these tests, significantly more individuals were observed in the block closest to the stream in the Cloquet watershed sites, but fewer individuals were observed in the block closest to the stream in the Pokegama watershed sites (Figure 2.5).

We also found more edge-associated individuals within the first 50 m of the stream in the Cloquet and Knife watershed sites (Figure 2.5). The larger number of total individuals in the area closest to the streams was not totally due to an increase in edge species. We found more forest associated individuals in the area closest to the stream in the Cloquet watershed sites. The Pokegama sites showed a pattern opposite to the other two watersheds; more forest bird individuals were observed at distances greater than 50 m from the stream.

Abundance patterns for ground nesting birds relative to the stream edge indicated a significant positive relationship for sites in the Cloquet and Knife watersheds (Figure 2.5). An opposite, but not significant relationship was observed in the Pokegama watershed. The distribution of permanent resident individuals to the stream edge was different in each watershed (Figure 2.5).

Figure 2.4. Ordination diagram (RDA) portraying the influence of distance from stream on bird community composition at the Cloquet River study area. Distance categories were used as explanatory variables. Of all the species variance, 17% is explained by distance. Of this explained variance, 80% is displayed in this diagram.

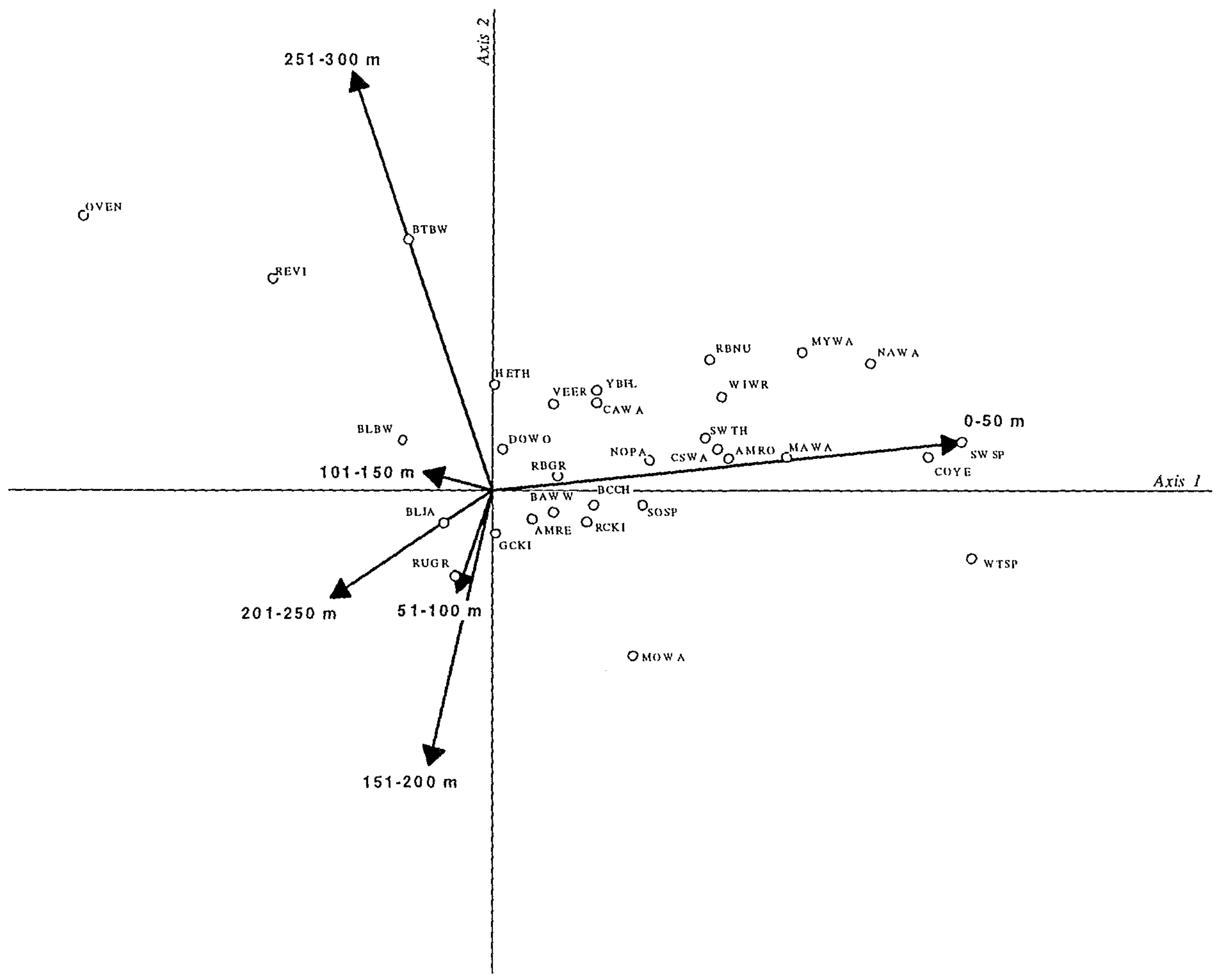
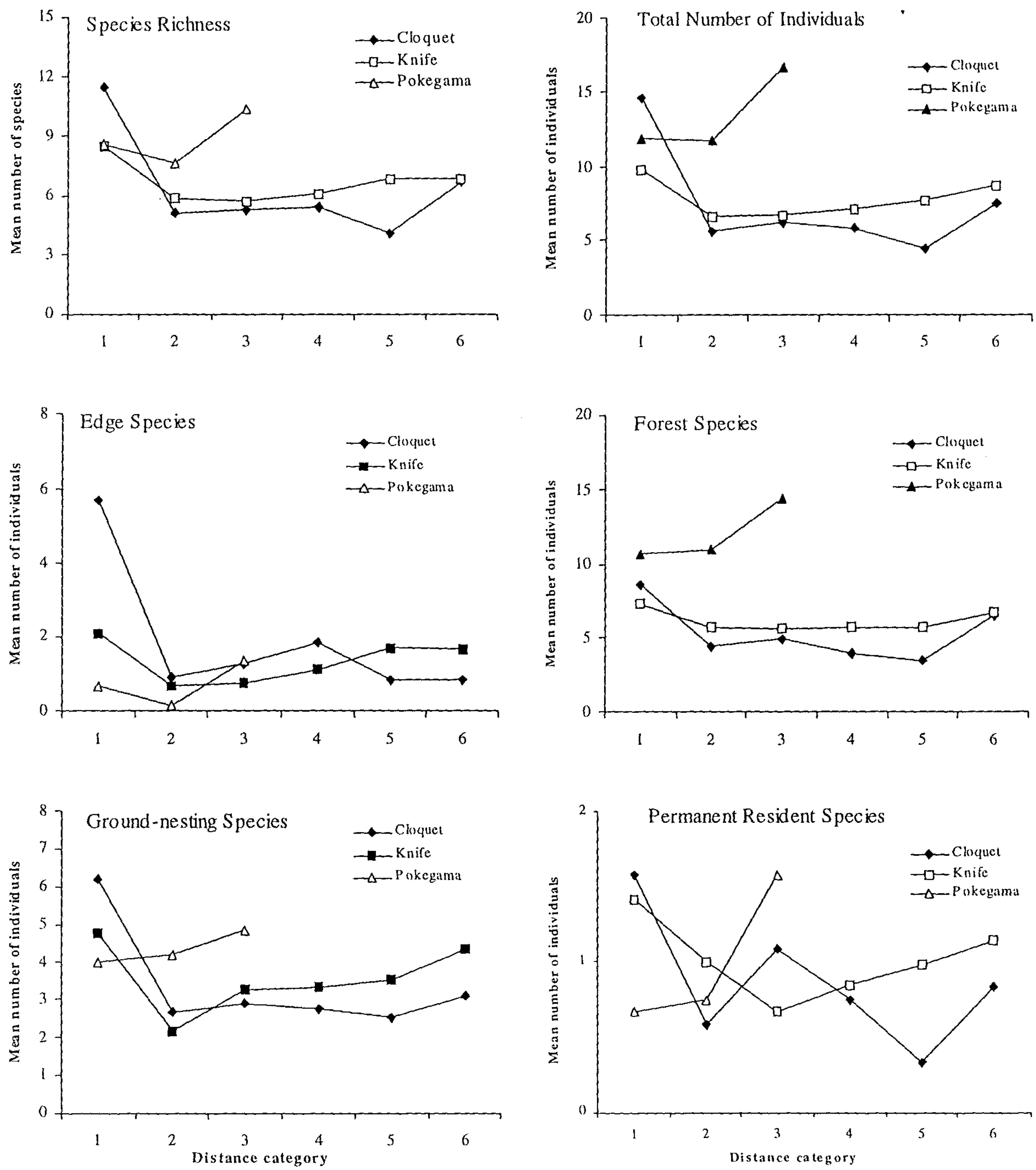


Figure 2.5. Least square means of the number of species or individuals by guild categories according to distance from stream (n = 12 transects per watershed). Distance categories are in 50 m increments (e.g. distance category 1 = 0-50 m from stream). Least squared means are presented because the number of distance categories is not equal at all transects in the Knife River watershed. Darkened symbols for a watershed in a plot indicate a statistically significant effect of distance from stream on richness or the number of individuals (alpha = 0.05).



In these tests, a significant effect was found for the Cloquet watershed, where more permanent residents were found in the area closest to the stream edge (Figure 2.5).

Riparian-dependent species. Only two riparian-dependent bird species were observed in our study sites. One Northern Waterthrush (*Seiurus noveboracensis*) observed in May on the Pokegama site was likely a migrant individual because no individuals were recorded in June or July. The Common Merganser (*Mergus merganser*) observed on the Cloquet site was likely a breeding individual.

Discussion

We found more bird species and total individuals in the area closest to the stream in only one of three watersheds that we studied in northern Minnesota. Birds in forests adjacent to widest streams showed this relationship, but we found a negative relationship between total number of individuals and distance from stream edge in sites located along the narrowest streams (Pokegama watershed). Our result from the Cloquet watershed is consistent with previous results reported by Dickson (1978), Best et al. (1979), Hair et al. (1979), Stauffer and Best (1980), and Parker et al. (1998). In contrast, results from the Knife and Pokegama watershed sites support results from other studies (Murray and Stauffer 1995; Parker et al. 2000). We also found that species richness was not consistently higher in riparian areas across all watersheds. This result is likely due to stream width. For example, streams in the Pokegama watershed were narrow (1 to 3 m) and the canopy extended over the stream. In this watershed, we did not find higher numbers of individuals and species closer to the stream. In addition, no relationship between either number of species or individuals and distance was found in the Knife watershed (streams between 3 and 5 m in width). In contrast, the Langley River in the Cloquet watershed was wide (5 to 10 m) and had a well-developed flood plain with shrub vegetation (primarily alder (*Alnus* spp.) and willow (*Salix* spp.)) in the riparian area. More species and individuals were found closer to the stream in this watershed. These results indicate that not all riparian areas are equal in terms of the habitat they provide for breeding birds. In northern Minnesota, forest areas adjacent to narrow streams do not provide the same habitat conditions as forest areas adjacent to wider streams that have a definable edge. Our study and another study by Meiklejohn and Hughes (1999) suggest that the generalization that riparian habitat has greater value to wildlife than adjacent upland habitat is not relevant to all riparian habitat.

As expected, we found a positive relationship between number of individuals of edge-associated species in study sites in the two watersheds where we could visibly discern an edge, the Cloquet and Knife. Meiklejohn and Hughes (1999) reported similar results for the main stem rivers (10 to 30 m wide) that they studied in New England. In addition, they did not find that edge species were more common along the tributary streams they investigated that were similar in width to streams in the Pokegama watershed (1 to 3 m). The distribution of forest-dependent bird species in our study watersheds indicated results that were counter-intuitive. For example, we found more forest-dependent birds in the areas closest to the stream in the Cloquet watershed that had the most obvious physical edge and a negative response of forest birds in the Pokegama watershed. We would have predicted that numbers of forest dependent species would not have been influenced by the stream in this watershed because it is so narrow. The 50 m area along streams in the Cloquet watershed had more total birds, which included more edge and forest-dependent individuals and also more permanent resident individuals.

Past research has indicated that songbirds that nest near edges have lower reproductive success due to nest predation events (see Paton 1994 and Andren 1995 for reviews). If natural edges like those that exist along wider streams in this region attract mammalian predators we may expect that individual birds that nest on the ground would avoid these areas and that abundance of ground nesting species would be lower in the area closest to the stream edge. However, we found a positive association to the riparian area in watersheds with the widest streams (Knife and Cloquet) that we studied. The distribution of ground nesting birds was evenly distributed across the study site in the Pokegama watershed. Ground nesting birds are not avoiding stream edges, which may indicate that microhabitat conditions present along the edge, including an increase in food resources may be attracting breeding birds to these areas. Based on research conducted by Song and Hannon (1999), these individuals may not be susceptible to higher predation events than those individuals that nest near anthropogenic edges, especially in heterogenous forest systems.

Counts of most individual species in our 50 m blocks were quite low, so no statistical analyses were completed on individual species. However, we can examine species distributions along the multivariate community analysis to identify species that were associated with the riparian forest area. These plots indicated that a few species had positive associations with the riparian area and that some associations were evident in more than one watershed. For example, the Winter Wren and Blackburnian Warbler showed positive association with the forest area within 50 m of the stream in the Pokegama and Knife watersheds. Parker et al. (1998) also found a positive association for the Winter Wren in the streams they studied in New Brunswick. In our study the Northern Parula was also positively associated with the riparian forest area in the both the

Pokegama and Cloquet watersheds. The Winter Wren, Blackburnian, and Northern Parula are forest dependent species which respond to microhabitat conditions which were more common in the riparian area forest (conifer trees or coarse woody debris). In contrast, the species that were positively associated with the alder and willow edge along the widest stream were shrub species such as the White-throated Sparrow, Common Yellowthroat, and Swamp Sparrow.

Although we identified some bird species that had positive associations with the riparian area, none of these species could be classified as riparian-dependent, because all commonly occur in forested habitat throughout northern Minnesota (Niemi and Hanowski 1984, 1992, 1993; Hanowski and Niemi 1993, 1994; Hanowski et al. 1999; Hanowski 1999). Several species are associated with understory or shrub vegetation and their association with riparian areas reflects the presence of shrubs that are typically found in riparian areas with definable edges. Other species that were observed more commonly in the riparian area are conifer-associated species, which were likely responding to the higher densities of conifer vegetation, primarily balsam fir (*Abies balsamea*) that occurs in riparian area forests in this regions. In general, most bird species that were more abundant in the forest area adjacent to streams in this region were responding to habitat features in this area, and not necessarily the presence of the stream.

Needs of Great Lakes forest riparian dependent birds. Twenty-one riparian-dependent bird species occur in Great Lakes forests, including six species of herons and egrets, seven waterfowl species, two raptor species, and six passerines (Niemi and Hanowski 1992). Three of these species, Bald Eagle (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), and Louisiana Waterthrush (*Seiurus motacilla*) are species of special concern or have a threatened status either in the state or nationally (Coffin and Pfannmuller 1988). We observed only two riparian-dependent bird species in our study areas (Northern Waterthrush and Common Merganser). Several riparian-dependent species are uncommon rare in the study region (Common Goldeneye (*Bucephala clangula*), Bufflehead (*Bucephala albeola*)) or have distributions outside the general study region. The Great Egret (*Casmerodius albus*), Black-crowned Night Heron (*Nycticorax nycticorax*), Yellow-crowned Night Heron (*Nycticorax violaceus*), Prothonotary Warbler (*Protonotaria citrea*), and Louisiana Waterthrush have distributions to the south of our study area and the Rusty Blackbird (*Euphagus carolinus*) occurs furthur north. Therefore, we did not expect these species to occur in the study area.

Absence of more common riparian-dependent species from our study areas may be explained by examining their life history requirements. These species have common structural habitat characteristics requirements which provides some guidance on how to manage riparian forests for them. Herons (Great Blue (*Ardea herodias*), Black-crowned Night, and Yellow-crowned Night) require large trees as a nesting substrate in close proximity to water that is suitable for foraging activities (Ehrlich et al. 1988; Hoffman and Prince 1975). All of the riparian dependent duck species, except the Black Duck (*Anas rubripes*) (Cadman et al 1987) are cavity nesters, including the Wood Duck (Scott et al. 1977), Common Goldeneye (Ehrlich et al. 1988), Bufflehead (Roberts 1932), Hooded Merganser (*Lophodytes cucullatus*) (Morse and Wight 1969) and Common Merganser (Scott et al. 1977). Due to their large body sizes, the cavities must also be large which requires a large diameter tree that is close to the water's edge. For example, a Common Goldeneye requires a tree at least 50 cm DBH with a cavity (DeGraaf et al. 1991). The Bufflehead, a smaller sized bird, prefers to use old Northern Flicker (*Colaptes auratus*) cavities as nest sites (Roberts 1932).

The two raptor riparian dependent species, the Bald Eagle and Osprey, also require large trees to support their nest (Dunstan et al. 1975; Poole 1989). Information from the Chippewa National Forest in northern Minnesota indicatse that Bald Eagles vary in their choice of nest tree in relationship to distance to water. Of 541 nests in this area, 30% were located on shorelines, 42% were within 350 m of water, and 64% were located within 900 m of water. Osprey nests and Great Blue Heron colonies were often located at greater distances from water (J. Mathisen personal data; Mathisen 1983). Nest sites over water are preferred by Ospreys due to the protection they provide from predators (Poole 1989). Other large perch trees located near the nest are also required in these species' territories.

Specific habitat requirements for riparian dependent passerine species that occur within the study region are similar for Northern Waterthrush and Eastern Phoebe (*Sayornis phoebe*). Although the Eastern Phoebe is associated with buildings and bridges near water (Harrison 1975), it is likely that the species used upturned root masses as a nest substrate before these structures were available (personal observation). The Northern Waterthrush also places its nest among roots of an uprooted tree (Ehrlich et al. 1988). The Rusty Blackbird does not occur commonly in northern Minnesota, being more abundant in the boreal region of Canada where it is associated with all types of water bodies and nests in dense conifers (Brewer et al. 1991).

There are several factors that may explain the lack of riparian-dependent bird species in our study areas. First, many of the larger-bodied species likely require wider streams, rivers or lakes for foraging activities. Second, the forest adjacent to streams that we studied were all second-growth stands that were less than 70 years in age. Current forests lack tall, super-canopy trees, large snags, and older trees with heartrot suitable for cavity excavation in the area adjacent to the stream that are more common in older forests. In general, habitat characteristics of forests adjacent to streams (other than a higher density of under-story shrubs and conifer species) was not different from the adjacent upland forest. This hypothesis is supported by the observation that bird species associated with upland deciduous forests were evenly distributed across the study areas. Given these conditions, we would not expect to find unique bird species or riparian-dependent bird species in these types of riparian forests.

Management considerations for riparian-dependent bird species. Although we did not find a large number of riparian-dependent individuals in our study areas, we can examine life history requirements of these species to suggest forest management activities that may benefit riparian-dependent species. Riparian-dependent birds have life history characteristics that are adapted to the use of large trees in association with water. This condition would occur under the natural historic disturbance regime for northern forests (primarily fire and blowdown). Although the fire frequency in this region ranged from 50-3000 years (depending on the forest community type), riparian forests were often protected from fires, occurring in fire shadow areas on the landscape (Frelich and Lorimer 1991). It is postulated that disturbance frequency in riparian areas from fires was on a longer rotation than the mean fire frequency in northern forests. This disturbance scenario would provide areas of the landscape that had older and larger trees that were associated with water bodies. A management goal for riparian areas would be to maintain large diameter and tall trees in these areas. This can be accomplished by maintaining a percentage of riparian habitat in an extended rotation forestry condition or by leaving a large number of long lived tree species as residual trees in harvest areas adjacent to water bodies. In addition, these structural features should be protected from wind which may be accomplished by buffering the target residual trees within a clump of trees. This management strategy may require more planning than a simple application of a uniform, no-harvest buffer strip, but will likely be more successful in providing habitat features that riparian-dependent bird species require.

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Chapter 3. Response of breeding birds to harvest level and harvest system in riparian forests in northern Minnesota, USA

Introduction

The role that riparian areas have in protecting water quality and in-stream habitat for aquatic organisms, as well as providing wildlife habitat have been documented in several regions of North America (see Wegner 1999 for review). Riparian areas have been purported to have multiple benefits to wildlife, including providing habitat and serving as movement corridors that connect adjacent habitat patches. Based on previous studies, protection or conservation of forest riparian areas for wildlife habitat during timber harvest has become a common management consideration in current forest practices. Several states, including Minnesota, Maine, Montana, and Vermont have drafted either voluntary or mandatory forest management guidelines designed to protect or enhance riparian forest areas for wildlife. Most riparian guidelines recommend set buffer widths and/or amount of residual basal area that would protect or conserve riparian habitats (Knopf et al. 1985). However, in many situations riparian area protection is often suggested without documenting the benefits of riparian area management to wildlife or water quality in specific regions (Wigley and Melchoirs 1993).

Breeding bird use of, and response to, harvest in riparian areas has been fairly well studied. Most studies on breeding bird response to post-harvest riparian buffers have suggested minimum widths (each side of stream or river) that would be required to maintain pre-impact species composition. The widths of buffers suggested from previous studies have varied considerably across regions of North America. For example, Darveau et al. (1995) recommended a 60 m riparian buffer in boreal forests while Keller et al. (1993) suggested that a 100 m buffer is required in eastern deciduous forests. Lambert and Hannon (2000) found that a 100 m to 200 m buffer was required to maintain Ovenbird (*Seiurus auracapillus*) populations in riparian buffers in Alberta. Some investigators found that narrow buffers act as habitat sinks due to predation and have suggested that wider buffers (150 m) are required to reduce edge-related predation (VanderHaegen and DeGraff 1996). In a study on juvenile bird dispersal, a 100 m buffer was recommended (Machtans et al. 1996).

Some investigators have questioned the long-term value of leaving narrow riparian buffer strips to wildlife populations. For example, Darveau et al. 1995 questioned the value of strips less than 15 m due to their susceptibility to windthrow. In addition, Hanowski et al. (2000) demonstrated that riparian buffers applied uniformly across the landscape would significantly increase the amount of edge habitat. The increase in edge habitat could have negative effects on birds breeding in riparian buffers due to an increase in predation rates especially for ground nesting birds. Additionally, recent studies suggest that harvest events on a watershed scale are more important than buffer width at explaining lake water quality response to harvest in the watershed (Prepas et al. in press). As Parker et al. (1998) indicate, there are many miles of narrow forest ribbons designed to protect health of aquatic systems which are left along streams and lakes under current buffer guidelines. However, we do not know whether these restricted forest corridors provide suitable long-term habitat for terrestrial wildlife.

On a regional level we still lack pertinent information to develop forest management guidelines that protect ecological features of riparian forests. For example, very few replicated studies have been completed that adequately address the response of breeding bird communities to forest harvest in riparian area forests (except see Parker et al. 2000 and Lambert and Hannon 2000). Moreover, we are unaware of any study that examined the response of breeding birds to riparian forest harvest with two different harvest systems. The objective of our study was to describe riparian breeding bird response to harvest level and harvest system in the riparian area. The harvest systems used here were the traditional harvest method using whole-tree grapple skidding (GPL) and the new cut-to-length (CTL) harvest equipment. Our working hypothesis was that removal of basal area to an average of 25-35 ft^2 and type of harvest system used to remove trees would not affect breeding bird communities in riparian forests. In addition, if we found an affect of forest harvest, we expected that the difference would be larger with the traditional harvest system (GPL) because this practice results in a greater amount of disturbance to the understory and forest floor vegetation than the CTL harvest system.

Study Area

The study was conducted within one watershed in northern Minnesota (Figure 3.1). This site was chosen because it had a forest cover at rotation age, the stream morphology was similar along all stream reaches, and the landowner was willing to harvest stands with the designated treatment. The individual study plots (12 total) were located along three separate reaches (Figure 3.1) within a 2 km^2 area, with all streams depositing in Pokegema Lake. All streams were designated trout streams and varied from 1 to 3 m in width. The dominant tree canopy species prior to harvest were sugar maple (*Acer saccharum*) and quaking aspen (*Populus tremuloides*). Study sites for the experiment were selected in the winter-spring of 1997 and before-harvest data were collected in the spring-summer of 1997. All experimental plots (nine total) were harvested in late-summer of 1997.

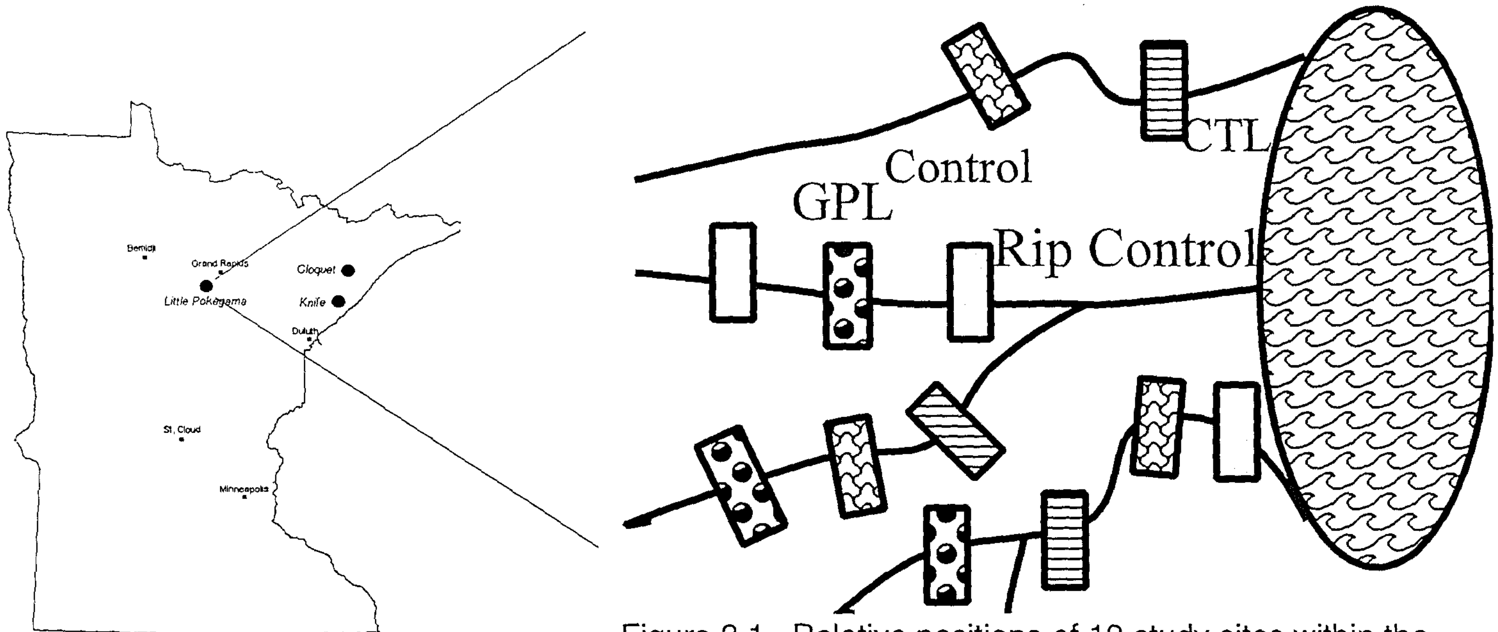


Figure 3.1. Relative positions of 12 study sites within the Pokegama watershed in northern Minnesota and their harvest treatments.

The experimental design consisted of a randomized block design. The treatment combinations consisted of one level of over-story manipulation combined with two types of harvesting operations. Over-story treatments within riparian area were designed to test best management practices (BMP) for water quality in Minnesota. This included leaving an average of 25 ft^2/ac basal area within 100 feet of either side of the stream. These guidelines supercede the current guidelines recommended for forest management in Minnesota

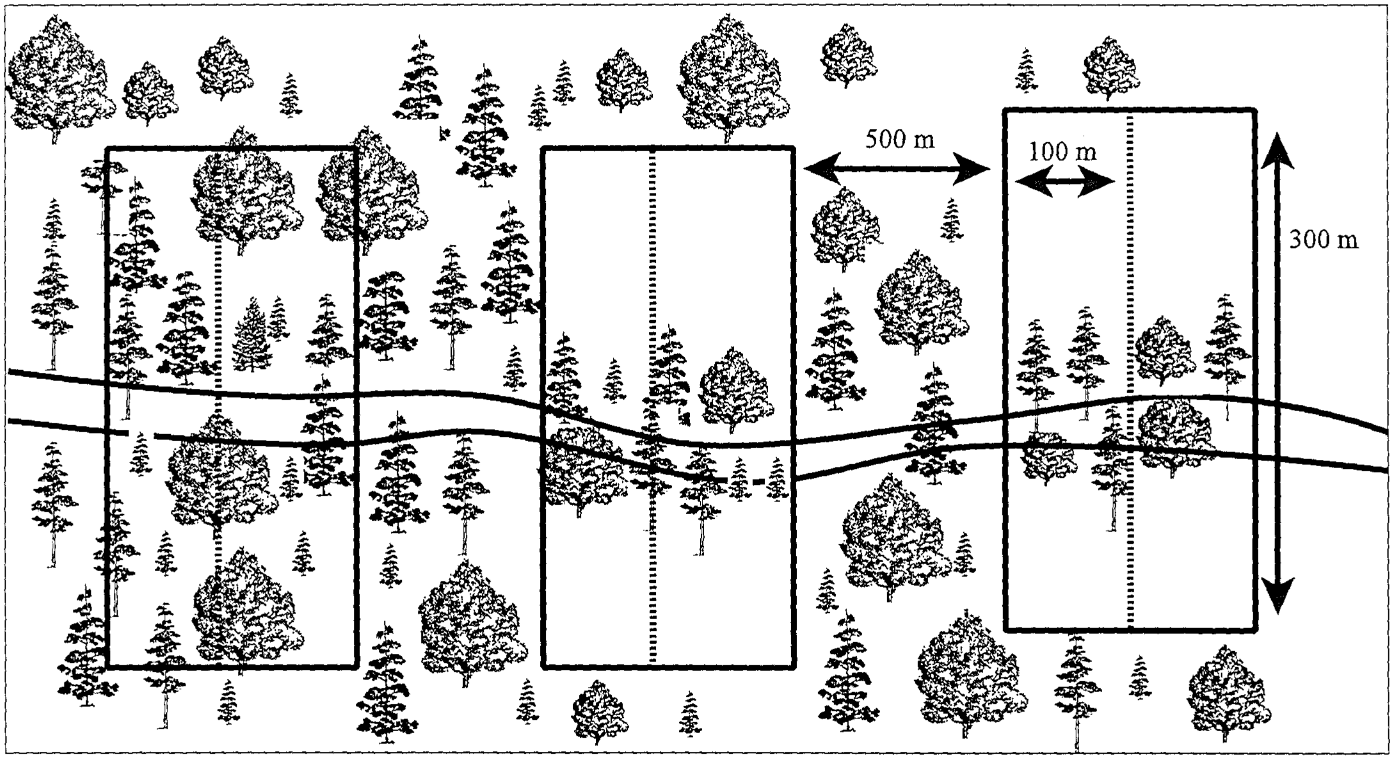


Figure 3.2. Schematic of study area showing study plots in a total control (left), riparian control (middle), and riparian harvest (right). A total of twelve study plots were used in this study and all were located in one watershed in northern Minnesota (Figure 3.1).

(MN Forest Resources Council 1999). A block of uncut riparian control sites was retained in the experimental design as well as a total control (no harvest in the study plot). Treatments were assigned to sites randomly with the restriction that a riparian harvest plot was not immediately upstream of a control site. This was done to accommodate the water quality and aquatic components of the study (Perry et al. 1998).

Timber sales in the study area included the adjacent upland stands to make them commercially operational and also representative of normal operating conditions. Study sites crossed the stream (Figure 3.2), were 4 ha in size, and at least 100 m apart to insure that data collected on each site was independent. Subsequent tests (Moran's I) for independence (Sokal and Oden 1978) indicated that this assumption was met for the bird community data.

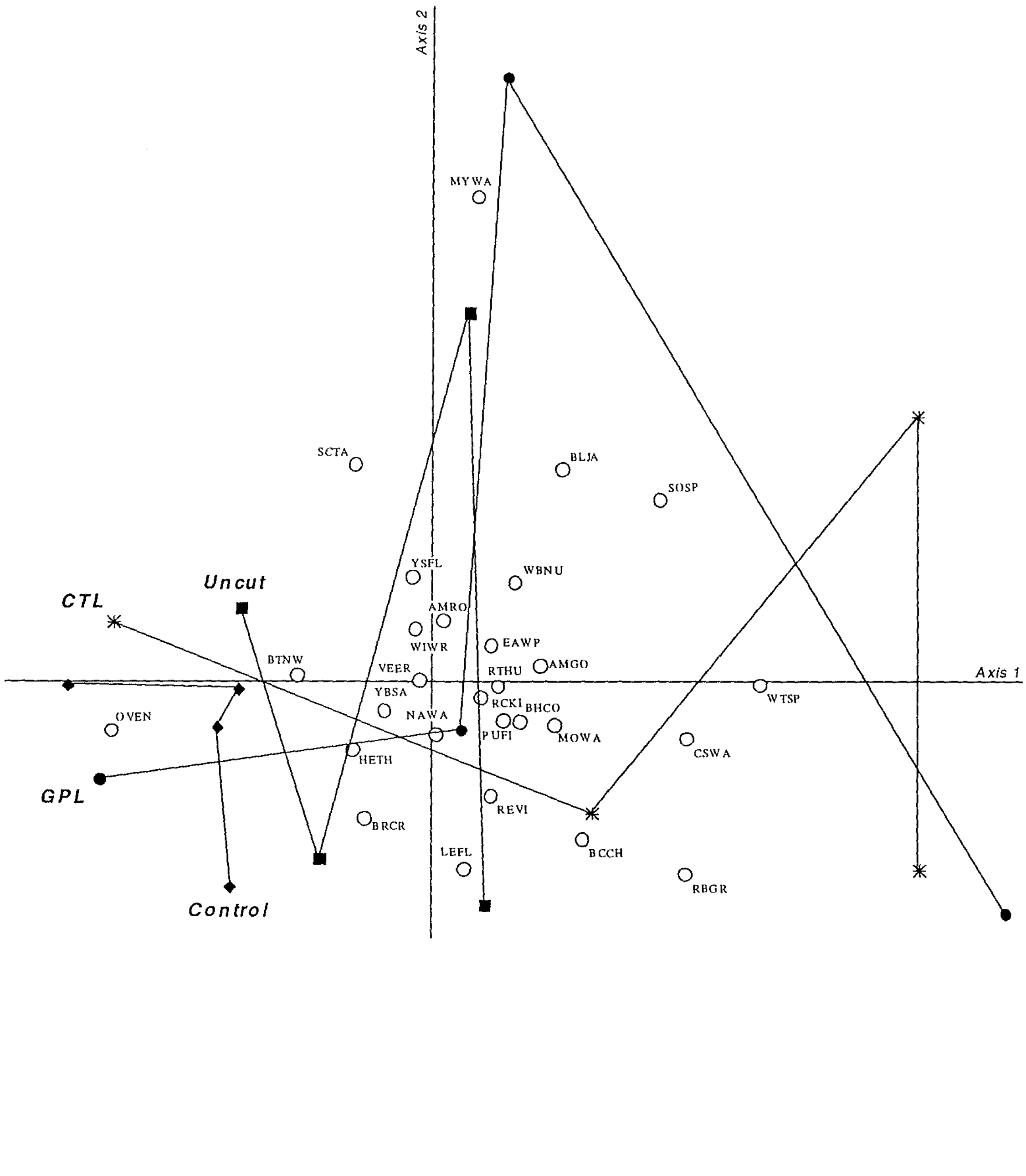
Methods

Bird surveys. Three breeding bird surveys were conducted on each site in each year (1997 through 2000). Before-harvest data were collected on all sites in 1997 and post-harvest data were collected 1998, 1999, and 2000. One survey was done in mid-May to document migratory, early breeding and permanent resident species (e.g., chickadees and woodpeckers), one in mid-June to capture peak singing of long-distance migrants, and one in early-July for the later breeding species (e.g., goldfinches). Because we were interested in documenting locations of birds relative to the stream, we used line-transects to conduct bird surveys (Hanowski et al. 1990) (Figure 3.3). Surveys were completed by four experienced observers who passed a bird identification test, hearing test, and received training to standardize counts. (Hanowski and Niemi 1995). All surveys were completed during early morning hours (within 4 hours of sunrise) and with good weather conditions (no rain and winds < 20 kph).

Statistical analyses. We used the maximum number of individuals observed for each species on either the May, June, or July survey in all statistical analyses. Because we were primarily interested in the bird community response to harvest in the designated buffer, we used only those birds observed within the designated riparian zone (30 m) on both sides of the stream in all analyses.

We focused our statistical analyses on the bird community response to harvest and type of harvest system in the riparian area. Uncommon species were not used in these analyses and were defined as being present on less than 5% of the study sites in any year. This process eliminated 24 of the 52 species observed during the four year study period. All bird counts were transformed before analyses (lncount+0.2). We first computed a detrended correspondence analysis on the bird community data to determine the lengths of the gradients. In general, if gradient lengths are less than 2.0, linear methods such as principal components analysis or RDA are suggested. On the other hand, if gradients are greater than 3 or 4, unimodal methods such as

Figure 3.3. Ordination diagram (redundancy analysis, (RDA) indicating effects of forest harvest technique on riparian bird communities. The sampling period covered one year prior to treatment and three years post-treatment. Lines represent the course of the treatments through time; the label for each treatment is nearest the pre-treatment year. The interactions of time and treatment were used as explanatory variables. Of all variance, 43% can be attributed to the explanatory variables. Of this explained variance, 45% is displayed in this program.



canonical correspondence analysis or detrended correspondence analysis are more appropriate. We found that our gradients were between 3 and 4 indicating no clear choice between the two methods. We used redundancy analysis (RDA) and a new method called principal response curve (PRC) (Van den Brink and Ter Braak 1999). This method (PRC) is based on RDA that is adjusted for changes in community composition over time on the treatment areas while maintaining control areas values constant. The principal components are plotted over time for each treatment group and provide an easily interpreted graph of the bird community response to harvest treatment. This method also allows a quantitative interpretation of how individual species in the community contribute to the observed changes in community composition. We followed methods outlined by ter Braak and Smilauer (1998) to produce the PRC.

We ran an RDA which uses a set of explanatory variables to explain variation in the bird community data. Because we were interested in the effect of treatments through time, we used a set of 4 time and 4 treatments (coded as dummy variables) as explanatory variables. The 16 dummy variables ensure that the transects with the same treatment (replicates) receive identical sample scores each year. This results in each treatment group receiving one score that is eventually plotted along each corresponding axis. A partial RDA (pRDA) is also required to construct PRC. We ran a pRDA which uses explanatory variables to explain variation in the species data set after first accounting for the variation attributable to a third data set (covariable data). In this situation, covariables were denoted by dummy variables indicating sampling year. The 4 explanatory variables that represent the upland control sites were deleted from this analysis to ensure that treatment effects are expressed as deviations from the control. The pRDA results were used to generate the first PRC. In addition, we generated the second PRC by using the sample scores from the first pRDA as covariables in a second pRDA.
Due to the small numbers of individuals observed in the buffer area, we were limited in the number of statistical tests that we could complete on individual species. We used a repeated measures analysis of variance to test for differences in total bird abundance, total number of species, and numbers of the Black-throated Green Warbler (*Dendroica virens*), Hermit Thrush (*Catharus guttatus)*, Mourning Warbler (*Oporornis philadelphia*), Ovenbird (*Seiurus aurocapillus*), Red-eyed Vireo (*Vireo olivaceus*), and Winter Wren (*Troglodytes troglodytes*) among four treatment categories In all tests, the subjects were the individual transects, the within-subjects factor was time (year), and the between-subjects factor was treatment.

We calculated posterior power for the repeated measures tests with NCSS Statistical Software (NCSS 2000). In this analysis if the covariance matrix did not meet the assumption of shpericity, a correction to the degrees of freedom was made with the Box-Epsilon adjustment (NCSS 2000). The power reported for these tests is the power of rejecting the null hypothesis when the alternative hypothesis is true. A high power value in this analysis would indicate that the probability of concluding that there is a difference among treatment groups when the difference actually exists is high.

Results

Bird community composition. We found a significant response of the bird community to forest harvest in the riparian area based on the RDA (Figure 3.3). The explanatory variables (year and treatment) accounted for 43% of the variation in the bird community data. This was significant on the first canonical axis (p=0.002) as well as all canonical axes combined (p=0.002). If we examine the locations of treatment groups in the ordination diagram over time we can see a few patterns. First, the pre-harvest bird communities on sites within all the treatment groups were very similar to each other (Figure 3.3). Second, the upland control plot bird communities remained relatively stable over the four year period. In addition, the uncut riparian buffer plot bird communities changed relative to the control plots with the largest deviations coming in the second and third years after harvest (Figure 3.3). As expected, bird communities were most affected by overstory removal with both harvest methods (Figure 3.3). The bird community responded in a similar direction on both CTL and GPL sites the first and third years after harvest. The direction and extent of change in the second year after harvest were in opposite directions, however after the third year following harvest, bird communities were markedly similar in the CTL and GPL sites (Figure 3.3).

The first PRC explained 32% (Table 3.1) of the variation in the treatment regime and was significant ($P < 0.002$) (Table 3.1). The response of the bird community along the first PRC showed that the bird community became more different from the control plots as time since harvest increased (Figure 3.4). As expected, the riparian control plots where no harvest was completed in the riparian area were most similar to the control plots in each year after harvest. In contrast, bird communities in groups of plots harvested with GPL and CTL were most different from the control plots. Early-successional species like the Song Sparrow (*Melospiza melodia*), White-throated Sparrow (*Zonotrichia albicollis*), Mourning Warbler and Chestnut-sided Warbler (*Dendroica pensylvanica*) were species that were associated with the treatment plots (Figure 3.4) along the first principal response curve. Forest species such as the Scarlet Tanager (*Piranga olivacea*) and Black-throated Green Warbler were on the opposite end of the bird gradient, being more associated with the control plots along the first PRC (Figure 3.4).

Table 3.1. Percentages of the total variation that can be attributed to time and treatment regime from partial redundancy analysis. The treatment component includes the interaction between time and treatment. The remaining percent of variation is residual. The table also shows the percent variation in the treatment regime explained by the first and second principal response curves.

	Percent variance	P-value
Time	13	
Treatment	26	
First PRC	32	0.002
Second PRC	22	0.112

The second PRC explained 22% of the variation and had a p-value of 0.112 (Table 3.1). The second PRC showed that bird communities were most different in the treated areas versus the control plots after the second year after harvest (Figure 3.5). Along this axis, the riparian controls were separated from the control plots with the Black-capped Chickadee (*Poecile atricapillus)* and Mourning Warbler the two species that had the highest associations with the riparian control sites (Figure 3.5). There was less separation of the CLT and GPL sites from the control sites along this axis especially in the first and second years after harvest (Figure 3.5). However, the bird communities on the CTL and GPL plots diverged from the control plots during the third year after harvest when more early-successional bird species (Song Sparrow and American Goldfinch (*Carduelis tristis*)) became more abundant in the treated sites (Figure 3.5).

Bird populations and species richness. Numbers of species and individuals on transects within treatment groups were similar in the before-treatment year (1997) (Figures 3.6 and 3.7). After treatment, species richness and total numbers of birds decreased in the control transects and increased in all treatment transects (Figures 3.6 and 3.7). Results from the RMANOVA did not indicate any significant differences among treatments in either total numbers of individuals or species. However, the power for both of these tests was relatively low (Table 3.2)

Figure 3.4. First principal response curve (PRC) diagram with species weights for birds in the study sites, indicating the effects of harvest technique. The vertical axis represents 32% of the variation in the treatment regime (*p*=-0.002).

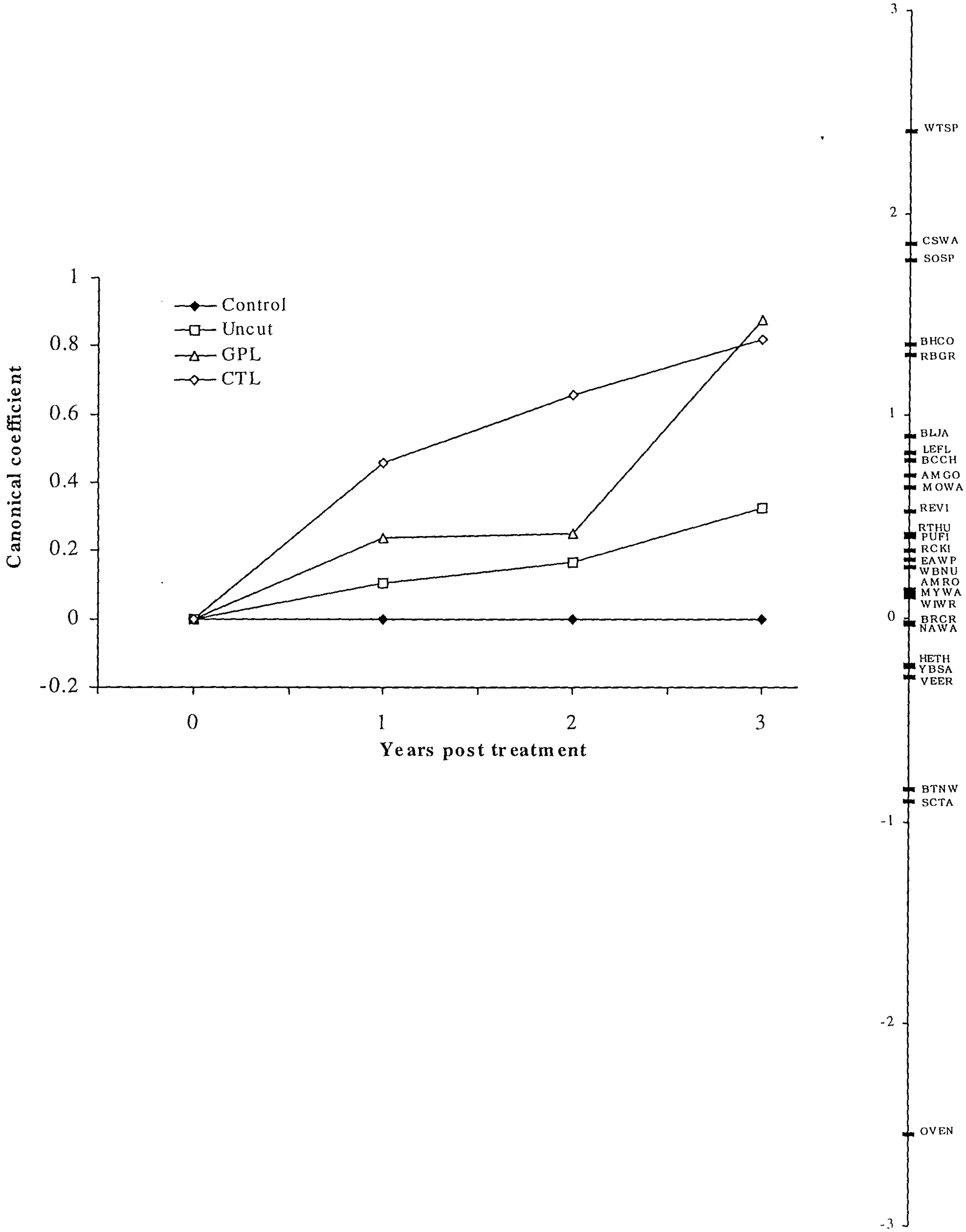


Table 3.2. Posterior power from the repeated measures analysis of variance for the time by treatment interaction. The Box-Epsilon adjustment for degrees of freedom when the sphericity assumption was violated is indicated.

Parameter	Power	Adjusted
Species richness	0.46	Yes
Total number individuals	0.29	Yes
Black-throated Green Warbler	0.46	No
Hermit Thrush	0.64	Yes
Mourning Warbler	0.25	Yes
Ovenbird	0.81	No
Red-eyed Vireo	0.10	No
Winter Wren	0.34	No

Individual species response to treatment. Of the six individual species tested for response of riparian harvest treatment over time, only the Ovenbird showed a significant ($P < 0.03$) time by treatment interaction in the RMANOVA (Figure 3.8). Numbers of Ovenbirds generally increased over the four year time period in both the control and riparian control plots. Numbers decreased in both the CTL and GPL plots through 2000 when no individuals were observed (Figure 3.8). The response of two other forest dependent species, the Black-throated Green Warbler and Hermit Thrush showed similar responses to the treatment as the Ovenbird, however no significant effects were found in the RMANOVA (Figure 3.8). For example, both species became less abundant and then absent from both the CTL and GPL sites after the second year after harvest. Of these three forest dependent species, the Hermit Thrush declined on the uncut riparian plots as well as the CTL and GPL plots (Figure 3.8). Another forest dependent species, the Red-eyed Vireo was the least sensitive to harvest in the riparian area (Figure 3.8). Numbers of individuals observed over the four year study either remained the same or increased on the study plots.

Figure 3.5. Second principal response curve (PRC) diagram with species weights for birds in the study sites, indicating the effects of harvest technique. The vertical axis represents 25% of the variation in the treatment regime ($p = 0.112$).

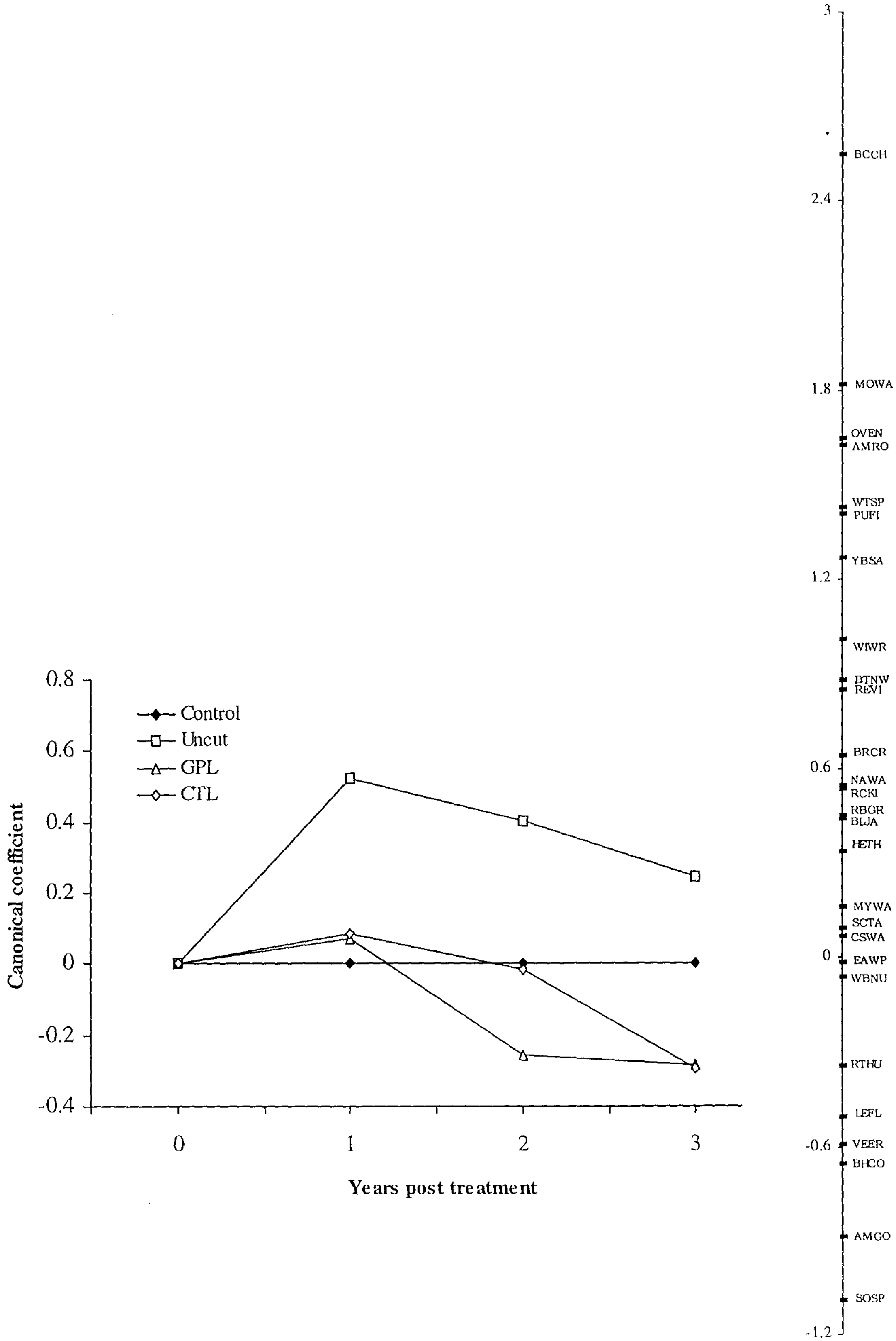


Figure 3.6. Mean species richness per transect within a 30 m buffer.

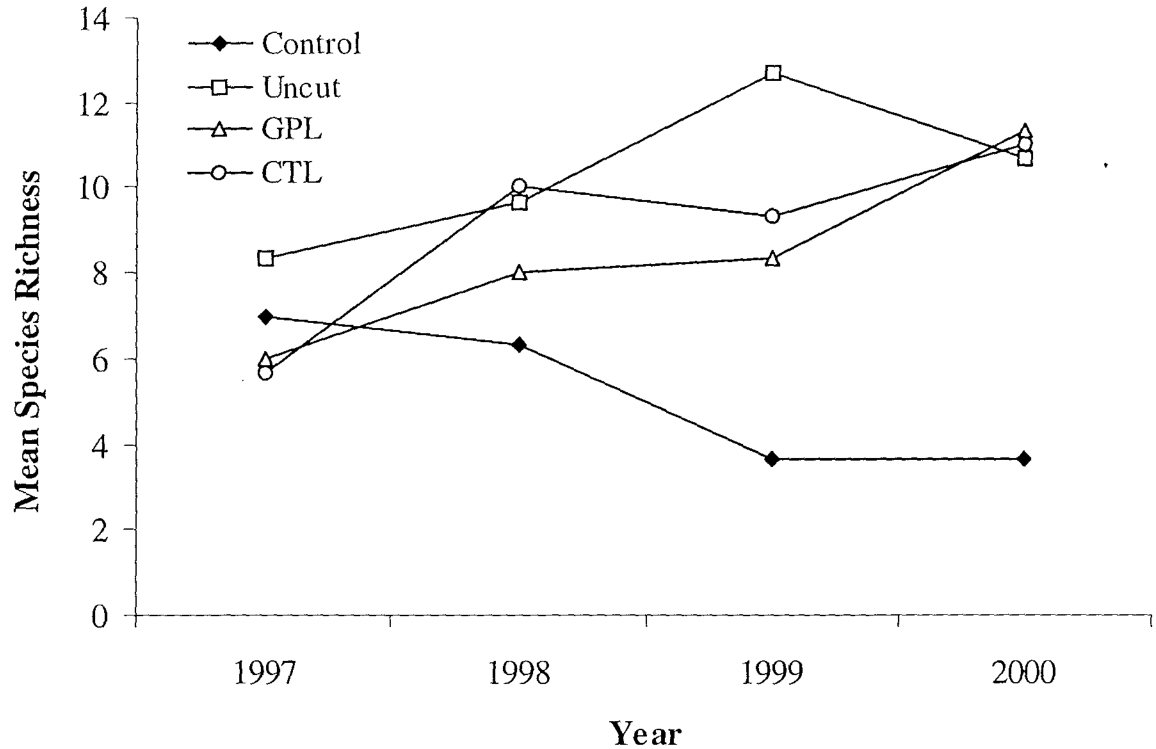


Figure 3.7. Mean number of individuals in four treatment groups within a 30 m buffer.

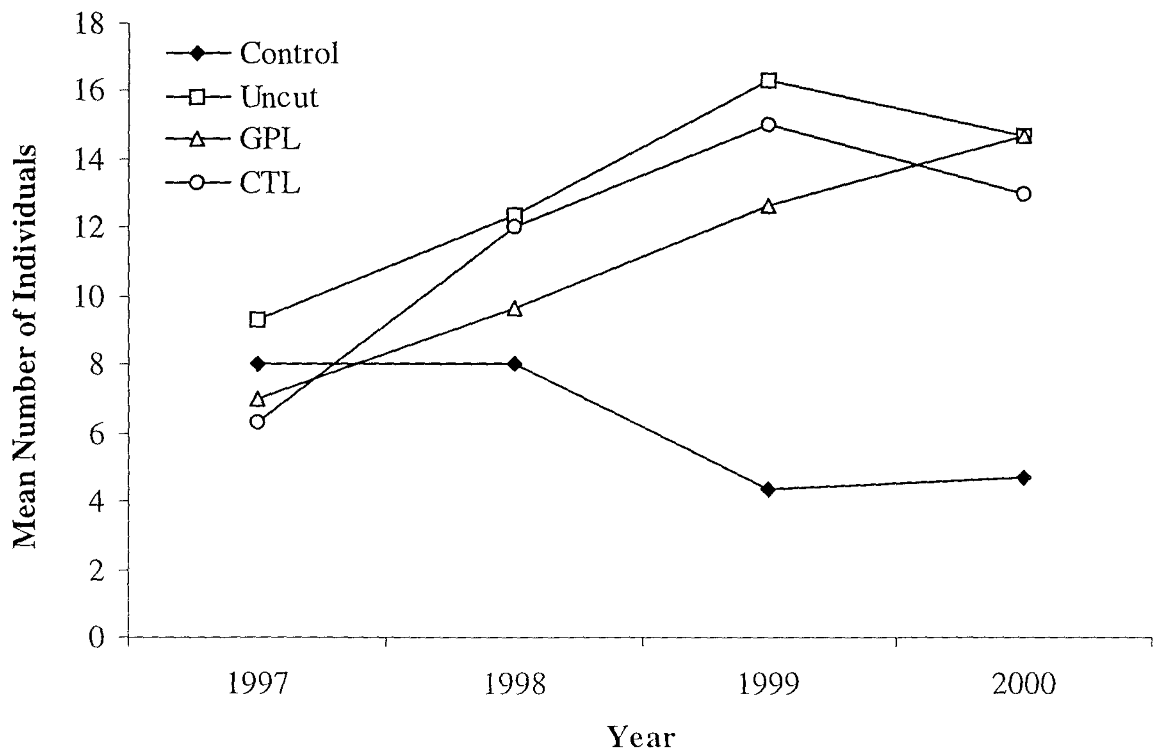
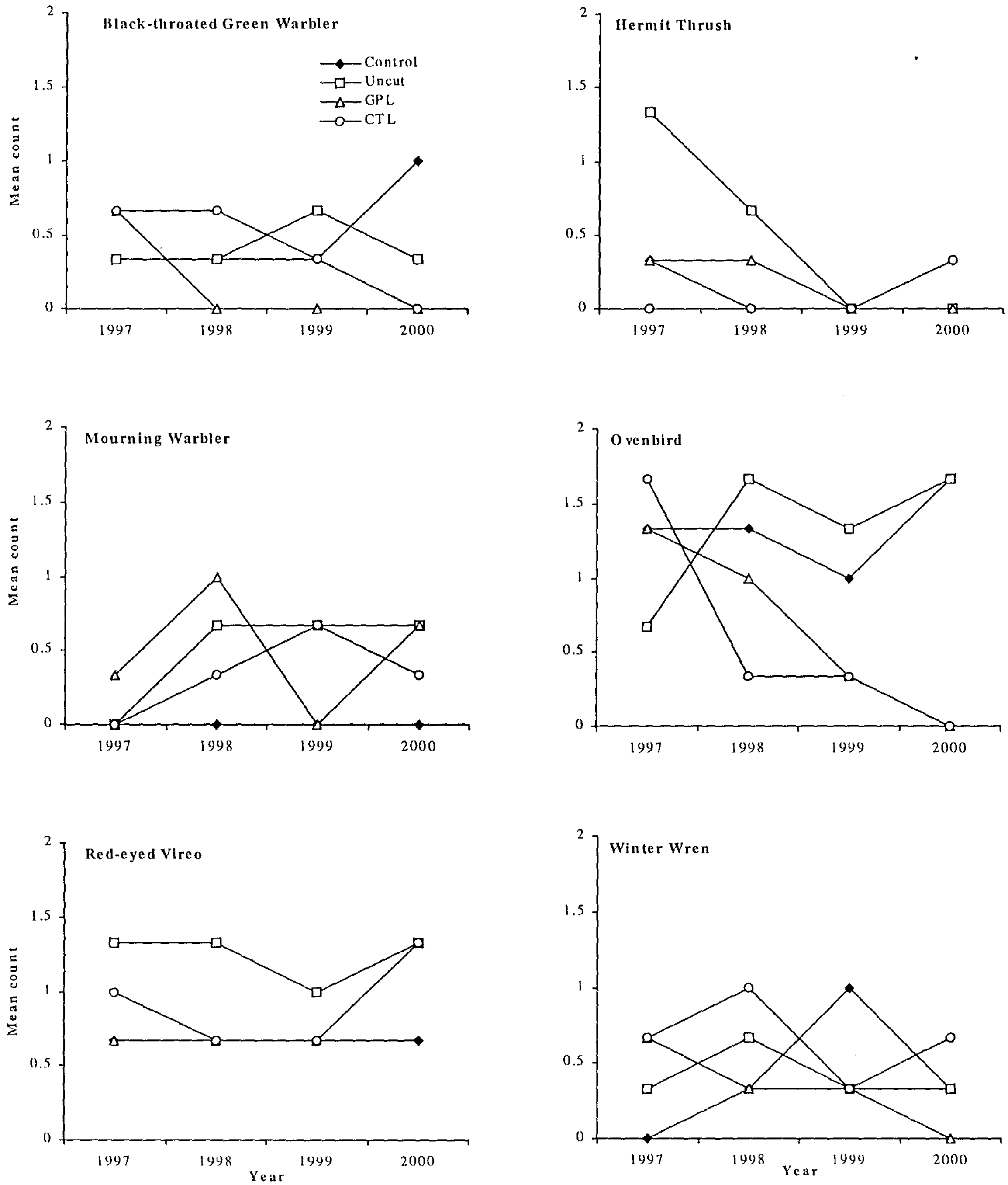


Figure 3.8. Mean count of individuals observed on three replicate transects per treatment. All species were tested with RMANOVA and only the Ovenbird showed a significant treatment by time interaction.



Discussion

Bird community response to harvest and harvest system. We found that bird community composition changed in response to harvest and harvest system in forests adjacent to small (1-3 m in width) streams in northern Minnesota. As expected, bird communities in the CTL and GPL treatment groups changed more relative to the control sites than sites where the riparian forest was left uncut. Similar to what Darveau et al. (1995) found, significant changes in species composition on the treatment sites did not occur in the first year after harvest. However, the composition of bird communities, even three years after harvest continued to diverge, especially on the harvested sites (both CTL and GPL).

The breeding bird composition of the harvested riparian sites included more early-successional species than both the control and uncut plots as time since harvest increased. This result was not unexpected due to the significant amount of basal area removed from the treatment riparian forest plots and the small amount of residual basal area left on the site (about $30ft^2$) (Palik et al. 2000). Although the trajectory patterns of the bird communities in the PRC were not identical on the CTL and GPL sites, overall, the type of harvest system used did not appear to have a significant impact on breeding bird community composition.

Total number of individual birds and numbers of species increased on all treatment plots relative to the control areas in all years after treatment. Unlike results presented by Darveau et al. (1995), numbers of birds and species on our treated sites continued to increase two years after treatment and then slightly decreased in the third year after harvest. This result is likely due to two contributing factors. First, although we did not mark individuals, it is likely that forest dependent individuals occupying these treated sites before harvest returned to the sites the first year after harvest. In addition, individuals that were displaced by the clearcut harvest of mature forest in the surrounding upland forest, likely occupied remaining forest patches left in these riparian strips. We found this result in studies of birds occupying forests adjacent to right-of-ways primarily the first year after the right-of-way is established (Hanowski et al. 1994).
This "species-packing" effect was likely evident in our study sites the first year after harvest. After this time, the increase in numbers of individuals and species in the harvested riparian and uncut plots was likely due to an increase in both early-successional individual and species in the CTL and GPL sites and edge species in the uncut riparian sites.

Individual species response to harvest and harvest type. The Ovenbird was the only species that showed a significant response to harvest in the riparian area and this response was not observed in the uncut riparian plots. Because this species is forest dependent and also suggested to be a forest interior dependent species (Lambert and Hannon 2000), this is a response that would be expected given that little residual forest cover was left in the CTL and GPL study sites. Our observation that Ovenbirds continued to occupy the uncut riparian buffer is contrary to what has been reported for this species in Alberta. For example, Lambert and Hannon (2000) reported that Ovenbirds were absent from 20 m buffer strips and that a 100 m strip was required to sustain Ovenbird populations. In our study, although we observed Ovenbirds in the uncut riparian buffers we did not assess the breeding status of individuals. For example these individuals may be occupying the area but may not be mated. In addition, due to the narrowness of the riparian corridor, these ground nesting birds may be more susceptible to nest predation (see Paton 1994 and Andren 1995) and therefore not successfully reproducing.

The power of our statistical tests to detect treatment effects for five other species that had large enough numbers to conduct tests was quite low (0.10 to 0.64). It is not surprising that no significant treatment by time interactions were detected for these species. In contrast, the power to detect differences for the Ovenbird was 0.81. However, while we did not find significant differences for these species, some general patterns were evident. For example, two other forest dependent species the Black-throated Green Warbler and Hermit Thrush, responded negatively to both harvest types. The 30m uncut buffer was adequate to maintain the Black-throated Green Warbler but not the Hermit Thrush. In contrast, another forest dependent species, the Red-eyed Vireo, was not affected by any riparian forest treatment regime.

The Winter Wren was the only species that suggested an effect of harvest system. This species occurs in forests that have areas with coarse woody debris or upturned trees for nesting habitat (Roberts 1932). Because the GPL harvest method involves whole-tree skidding, it likely that these habitat features would be disturbed or removed by this process. In contrast, the CTL harvest system processes the trees where they are felled and no skidding is required. The use of CTL results in less disturbance to the ground and understory vegetation.

Study design and implementation. Field studies to test hypotheses regarding biotic response to harvest or harvest systems in riparian areas are difficult to complete. It is not surprising that few replicated studies have been done. This study, with three replicates per treatment, has a similar number of replicates as some other studies. For example, two replicates were used in New

Brunswick, five replicates in Quebec, and four or five replicates in Alberta. The most significant problem with low replication is that statistical tests will usually have low power. Therefore, even with replicated studies we risk not finding a significant effect when an effect has occurred. This is not a trivial issue, because results are being used to develop standards and guidelines for forest management practices and interpreting we risk producing results that are not robust enough to make such rules. Unfortunately, there is no simple way to remedy this problem beoause of limited funds and suitable sites to conduct studies.

Our power to detect differences in parameters that are generally tested in management responses studies (such as number of individuals, species richness, and individual species) was relatively low. The power to detect differences for the Ovenbird was the highest (0.81) and we detected a significant response to harvest for this species. A possible remedy to the problem of low power with univariate tests, is to conduct multivariate community response statistics. We used a newly developed method (PRC) that was very useful at examining effects of treatment on bird communities. This method allowed us to compare bird communities within various treatment groups while holding the values of the control group constant. The graphic output of these tests was very useful to describe changes that occurred over time in the treatment groups and also allowed us to show which species were most responsible for the differences. For example, our univariate test for the Ovenbird indicated a significant negative response of canopy removal in the riparian area with both GPL and CTL harvest systems. The Ovenbird is located at the very bottom of the species weightings in the diagram of the PRC indicating the most positive association with the control and uncut buffer sites (Figure 3.4) .

The PRC method could be a very useful analytical method in management response studies where it is not feasible to have a high number of replicates. Our test was significant for the first PRC and illustrated the response of the bird community to the harvest types and systems that are biologically meaningful and intuitively correct. From this diagram we can predict which species are sensitive to any riparian treatment which include the Ovenbird, Scarlet Tanager, Black-throated Green Warbler, Veery, Yellow-bellied Sapsucker (*Sphyrapicus varius*), and Hermit Thrush (bottom of Figure 3.4). As expected, species that responded positively to removal of canopy from the riparian area included several early-successional species like the White-throated Sparrow, Chestnut-sided Warbler, Song Sparrow, and Rose-breasted Grosbeak (*Pheucticus ludovicianus*) . Individual species in the middle of Figure 3.4 are those that are less likely to tolerate canopy removal, but that could occupy a narrow uncut riparian buffer.

Contribution of riparian buffers to forest bird populations. We found that bird species composition in forests adjacent to the small streams in our study area was not different than that found in adjacent upland forests (see Chapter 2). Therefore, riparian buffers applied in this watershed are not protecting a unique bird community. In addition, we found no riparian dependent species in this area before the harvest was completed. We question the value to wildlife, specifically birds, of these riparian buffers in this watershed. The long-term benefit of these narrow strips is also questionable due to the amount of blowdown that occurs in a short period of time in these areas (see Darveau et al. 1995). Another reason to leave riparian buffers on the landscape is to provide corridors for animal movement. However, this theory has received limited testing (Machtans et al. 1996). Another negative factor of applying uniform width buffers across the landscape is the significant amount of edge that is created with this practice (see Chapter 1). Given that these buffers are not providing habitat that contribute uniquely to bird populations in this region, trees left remaining are very susceptible to blowdown, and the amount of edge that is created may decrease bird productivity, we do not think that uniform application of buffers in this landscape is necessary or desired.

Results of our study and others suggest that riparian guidelines need to be flexible and that management plans for riparian areas should be done on a landscape level. We need to ask ourselves what ecological service is being provided by buffers and then identify riparian areas that have unique riparian communities. It is likely that once these areas are identified, a wider and possibly a no harvest buffer would be required to protect these features. An approach that recommends prescriptive riparian buffers assumes that all riparian areas are identical. Results from this study and others suggest that this assumption is not valid for northern Minnesota riparian forests.

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Chapter 4. Bird counts for all study areas and years of the project.

Appendix 4.1. Number of individuals observed in the Gooseberry watershed study site in May, June, and July 1997-2000. This large plot was located north of Two Harbors, MN and was harvested in the summer of 1998. No statistical analyses were completed.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Broad-winged Hawk				1			1					
Ruffed Grouse	1			1			2			2		
Solitary Sandpiper									2	3		
Common Snipe							3		1	2	1	1
American Woodcock									1			
Ruby-throated Hummingbird									2			
Yellow-bellied Sapsucker	5	5	4	8	2		6	5		2		
Downy Woodpecker	6	1	8	10	2	2	1	2	3	3	1	
Hairy Woodpecker	4	2	1	1			2	1	3			3
Northern Flicker							4	3		6	2	
Pileated Woodpecker			1		1							
Eastern Wood-Pewee			2		1				3		3	1
Yellow-bellied Flycatcher		1										
Alder Flycatcher		2							1			
Least Flycatcher		21	7		7	11	21	24	4	6	19	2
Eastern Phoebe									2	1		
Great Crested Flycatcher					1		1				1	
Eastern Kingbird		1										
Red-eyed Vireo		21	24		21	16		30	27		13	9
Blue Jay	1	1		1	2		1	1	5	2	3	
American Crow	1											
Black-capped Chickadee	5	2	3	8	5	10	6		3	1	3	1
Red-breasted Nuthatch	8	3					1		1			
White-breasted Nuthatch			3									
Brown Creeper			1	2	1	3			1			
House Wren								1			1	
Winter Wren	5	4		6	6	7	8	4	4			

Appendix 4.1. Continued.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Ruby-crowned Kinglet										2		
Eastern Bluebird										3	3	
Veery		6	14		13	18	8	6			6	2
Swainson's Thrush				1		1						
Hermit Thrush	1	1	5	4	4	3	1	2	7	2	4	3
Wood Thrush					1	1						
American Robin	12	1	1	11		2	14	19	11	22	12	7
Cedar Waxwing		1	1									
Nashville Warbler	1	6	3		4	4	5	2		8	2	1
Northern Parula								1		1		
Chestnut-sided Warbler		5	4		6	10	11	9		1	22	3
Magnolia Warbler		1					1	1				
Black-throated Blue Warbler		2			1	4						
Yellow-rumped Warbler		1		15	1		3			1		
Black-throated Green Warbler		18	12		15	10	7	4	3	1	2	
Blackburnian Warbler			1									
Palm Warbler										7		
Black-and-white Warbler		5	2		2		2	3				
American Redstart					3		1	2				
Ovenbird	1	30	21		26	17	41	22	1	10	7	1
Northern Waterthrush		1					2			6		
Mourning Warbler		7	1		4	3		20	1		12	6
Common Yellowthroat		2	1		1	2			3		1	1
Canada Warbler		5	4		5	2		7			3	1
Chipping Sparrow									2	1		
Song Sparrow		2	2	1	2	1	5	3	13	16	18	21
Lincoln's Sparrow										1		
Swamp Sparrow	1		2	4	1					1		
White-throated Sparrow	12		2	10	2	3	21	16	33	26	28	25
Rose-breasted Grosbeak					1		1	1		2	1	
Indigo Bunting					1				1		1	

Appendix 4.1. Continued.

Species	1997 May	1997 June	1997 July	1998 May	1998 June	1998 July	1999 May	1999 June	1999 July	2000 May	2000 June	2000 July
Red-winged Blackbird							1					
Common Grackle											3	
Brown-headed Cowbird				2			7	9	1	5	4	
Purple Finch	1			3				2		2	3	
Pine Siskin	3						1					
American Goldfinch							1	4	2	5	4	
Evening Grosbeak	2											
Unidentified passerine	3		2	4			5	2	2	4	2	3
Unidentified sparrow										1		
Unidentified woodpecker				2	1	3	1	2				1
Total Number of Individuals	73	158	132	95	143	133	196	208	143	156	185	92
Total Number of Species	18	29	26	18	30	21	32	28	28	31	29	17

Appendix 4.2. Number of individuals observed on all Pokegama watershed transects in May, June, and July 1997-2000.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Mallard				2								
Sharp-shinned Hawk										1		
Red-Shouldered Hawk										1		
Broad-winged Hawk	1			2								
Red-tailed Hawk										1		
Ruffed Grouse		1									3	
American Woodcock									2			
Chimney Swift					1							
Ruby-throated Hummingbird					2				5	5	8	5
Yellow-bellied Sapsucker	18	5	6	19	6	5	5	4	3	4	7	2
Downy Woodpecker	4			3	1		1		1		1	1
Hairy Woodpecker	2		1	4			2		1			1
Northern Flicker	1				1		1		1			
Pileated Woodpecker				1								
Olive-sided Flycatcher										2		
Eastern Wood-Pewee		4	5		1	5		1	9	3	5	7
Alder Flycatcher								3			1	
Least Flycatcher		26	33		15	11	9	6	4	14	8	8
Eastern Phoebe						1	3		1	1		
Great Crested Flycatcher		6	2		2	1		4		4		
Eastern Kingbird										1		
Yellow-throated Vireo		1			1					2		
Blue-headed Vireo	2						2					
Red-eyed Vireo	1	44	49		20	29		18	25	8	24	11
Blue Jay	2		2	11	2	2	12	3	3	1	2	2
American Crow				3			1					
Common Raven											1	
Black-capped Chickadee	6	1	6	17	3	8	3	1	14	5	9	6
Red-breasted Nuthatch	7	3		5								
White-breasted Nuthatch		1	3			3	4		10		4	7

Appendix 4.2. Continued.

Species	1997 May	1997 June	1997 July	1998 May	1998 June	1998 July	1999 May	1999 June	1999 July	2000 May	2000 June	2000 July
Brown Creeper	12	6	2	6	3		1	1	1	1		1
House Wren							4		2	4	1	
Winter Wren	10	4	3	13	6	5	7	3	3	2	4	2
Golden-crowned Kinglet		1										
Ruby-crowned Kinglet	1			1			1			3		
Eastern Bluebird											1	
Veery		8	8		4	1	2	3		1	4	1
Swainson's Thrush	4											
Hermit Thrush	1	6	17	4	3	7	1	3	2	2	3	5
Wood Thrush		2					2		1			1
American Robin	5			11	2	9	4	1	2		5	1
Gray Catbird										1	1	2
Cedar Waxwing											6	4
Golden-winged Warbler								6	1	16	16	3
Nashville Warbler		4	2				2			12		
Northern Parula		2	2			2			1	1	1	
Chestnut-sided Warbler		2	2		1	1	1	28	8	53	54	10
Magnolia Warbler	1						1					
Cape May Warbler										1		
Black-throated Blue Warbler		1										
Yellow-rumped Warbler	9	2	1	1			56			1		
Black-throated Green Warbler	2	24	16		4	14	5	3	10	5	3	5
Blackburnian Warbler		6								1		
Blackpoll Warbler							1					
Black-and-white Warbler		2	1		1				1	1		
American Redstart							3			7		
Ovenbird	52	67	62		30	12	26	25	1	24	20	4
Northern Waterthrush	1											
Mourning Warbler		1	2		12	13	2	21	9	24	40	13
Common Yellowthroat		1				2		6	7	4	17	11
Wilson's Warbler										1		

Appendix 4.2. Continued.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Scarlet Tanager		5	10		3	4	1	2	8	4	3	3
Chipping Sparrow		1										
Clay-colored Sparrow							1					
Song Sparrow				4	3	5	30	21	38	20	22	21
Lincoln's Sparrow										1		
Swamp Sparrow							1	1				
White-throated Sparrow	3			11	7	4	35	9	9	19	11	7
Dark-eyed Junco				1								
Rose-breasted Grosbeak	1	2	1		2		6	1	1	14	10	2
Indigo Bunting								2		1	6	2
Common Grackle				2								
Brown-headed Cowbird	10			24	6		12	8		7	6	
Baltimore Oriole												1
Purple Finch	3			11			2	1		2		2
Pine Siskin												2
American Goldfinch						1	3		22	13	15	21
Evening Grosbeak			1	18							6	
Unidentified duck	1											
Unidentified passerine	7	4	2	5		2	17		14	4	20	16
Unidentified sparrow							2					
Unidentified thrush				1								
Unidentified warbler		1	1									
Unidentified woodpecker							1	1		2	1	
Total Number of Individuals	167	244	240	180	142	147	273	186	220	305	349	190
Total Number of Species	25	30	24	23	27	23	37	27	32	45	35	33

Appendix 4.3. Number of individuals observed on all Cloquet River watershed transects in May, June, and July 1997-2000. Not all sites have been harvested and no statistical tests were completed.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Common Merganser			1									
Broad-winged Hawk						1						
Red-tailed Hawk											1	
Ruffed Grouse	4			3			2	1				
Killdeer										2		
Solitary Sandpiper									1			
Common Snipe								1			1	
Yellow-bellied Sapsucker	1	1		1	1	1	1	1	1			
Downy Woodpecker	3		1	3			2		2	3	2	
Hairy Woodpecker			1	1		1			1	2		1
Northern Flicker	3			1						2	2	1
Pileated Woodpecker	1											
Yellow-bellied Flycatcher		7	3		3	3		4			2	2
Alder Flycatcher		2	2		4	1		2	2		3	
Least Flycatcher		3		2	1		5	8	1	1		
Great Crested Flycatcher						1						
Yellow-throated Vireo					1							
Blue-headed Vireo	1			1			7	2	1	4	1	
Red-eyed Vireo		17	19		17	16		22	13		21	14
Gray Jay										1	4	
Blue Jay	4			4			5	8	3	6	5	5
Black-capped Chickadee	5	2	4	9	6	6	18	2	7	6	9	5
Boreal Chickadee				1							1	
Red-breasted Nuthatch	15	7	5	6	3	2	20	2	7	5	2	12
White-breasted Nuthatch				1		3						
Brown Creeper	1		1	6		4						1
House Wren										2	2	
Winter Wren	8	3	6	8	6	7	9	4	8	2	1	2
Sedge Wren						1						
Golden-crowned Kinglet	3	5	1	13	2	1	6	2	4	4	5	3

Appendix 4.3. Continued.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Ruby-crowned Kinglet	4			4			2			2	1	
Veery	1	8	7		9	9		6	3	3	4	
Swainson's Thrush		5	9		7	11	3	1	1	3	4	7
Hermit Thrush	2	4	9	1	2	3	2	4	3		2	
Wood Thrush								1				
American Robin	9	5	5	8	4	2	8	5	6	7	10	15
Gray Catbird						1						
Cedar Waxwing			1		3				1			3
Tennessee Warbler						2		1		3	2	
Nashville Warbler	1	21	24	2	17	18	14	15	3	20	14	4
Northern Parula		5	6		2	4	1	4	1	5	1	
Chestnut-sided Warbler	1	20	12		6	4	5	11	6	11	16	2
Magnolia Warbler		7	11		17	8	5	12	5	8	4	4
Black-throated Blue Warbler												1
Yellow-rumped Warbler	18	4	9	24	5	6	23	4	6	10	6	3
Black-throated Green Warbler		5	4	1	7	8	6	11	7	12	5	
Blackburnian Warbler		4	6		8	1	1	2	1	1	3	
Pine Warbler		1										
Palm Warbler	1	2		3		1	1					
Bay-breasted Warbler			1									
Black-and-white Warbler	6	9	2	3	3		2	4		2	1	
American Redstart		5	2		2			4	4		4	3
Ovenbird	21	27	31	1	18	21	25	27	10	28	21	6
Northern Waterthrush				2			2	2				
Mourning Warbler		9	5		4	2		3	4		6	2
Common Yellowthroat		7	8		5	3		4	3		2	3
Canada Warbler		10	6		1	2		18	3	1	20	3
Scarlet Tanager			1					1				
Chipping Sparrow		1	1			1	4			2	1	
Song Sparrow	1	2	2	3	2		2	2	2	3	3	4
Lincoln's Sparrow												2

Appendix 4.3. Continued.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Swamp Sparrow	9	3	10	9	5	1	4		2	2	1	1
White-throated Sparrow	27	19	22	23	11	12	21	11	25	9	14	18
Dark-eyed Junco		1					1					
Rose-breasted Grosbeak	1	2	2		1	1	1	2		3	3	
Purple Finch	2			9			4	1		4	2	1
White-winged Crossbill	6					4						1
Pine Siskin	2	1					6					4
American Goldfinch				1			2					3
Evening Grosbeak				1			3					
Unidentified passerine	4	1	3	11	2	5	4	6	3	10	5	9
Unidentified sparrow									1			
Unidentified thrush											1	
Unidentified warbler			2			1						
Unidentified woodpecker				2		1	1					
Total Number of Individuals	165	235	245	168	185	180	228	221	151	189	218	145
Total Number of Species	29	35	36	31	32	37	35	38	33	34	41	31

Appendix 4.4. Number of individuals observed on all Knife River watershed transects in May, June, and July 1997-2000. Not all sites were harvested and no statistical tests completed.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Mallard				1								
Broad-winged Hawk				1			1				1	
Ruffed Grouse	7			4					3	2		
Ruby-throated Hummingbird									1			1
Yellow-bellied Sapsucker	3		1	5	1	2	4		1	3	1	2
Downy Woodpecker	3		1	6		1	1	1		1	1	1
Hairy Woodpecker					2	1	3			2		
Northern Flicker				1	2	1						
Pileated Woodpecker									1			
Eastern Wood-Pewee					1				1			
Yellow-bellied Flycatcher						1						
Alder Flycatcher								1	1		3	
Least Flycatcher			1	1	3	1	1	1	1			2
Eastern Phoebe							1					
Great Crested Flycatcher		2					1					
Eastern Kingbird						1					1	1
Yellow-throated Vireo		1										
Blue-headed Vireo	1				2		1		1	1		
Red-eyed Vireo		18	16		19	23	1	13	12		19	19
Blue Jay	4	3	1	5	2	3	11	5	2	5	3	3
American Crow					1							
Black-capped Chickadee	14	3	4	10	6	28	14	6	20	9	6	8
Red-breasted Nuthatch	12	3	4				7	2	3	1	2	3
White-breasted Nuthatch			2	1								
Brown Creeper		1	1	4	2		1	2			1	
Winter Wren	2	7	4	8	3	8	5	4	3	2	1	2
Golden-crowned Kinglet	1	1	1	4					1		1	1
Ruby-crowned Kinglet	7											
Veery		20	31		15	30	5	9	4	1	14	8
Swainson's Thrush							1					

Appendix 4.4. Continued.

Species	1997			1998			1999			2000		
	May	June	July	May	June	July	May	June	July	May	June	July
Hermit Thrush	5	1	3	4	2	3		1		5	2	1
Wood Thrush	1	1	1	1	5	2	5	1	3	6	3	2
American Robin	8	3	1	17	8	8	4	3	2	4	6	1
Cedar Waxwing									3		1	7
Golden-winged Warbler											1	
Nashville Warbler		17	12	12	8	6	12	5	2	12	7	8
Northern Parula								1				
Chestnut-sided Warbler		15	10		15	9	20	22	14	15	27	25
Magnolia Warbler		6	10		8	5	7	4	7	6	4	1
Cape May Warbler					1							
Yellow-rumped Warbler	4	1		3	2		3	1		2	1	1
Black-throated Green Warbler	5	18	20	4	15	18	16	15	16	12	13	9
Blackburnian Warbler		9	6		5	3				1	1	1
Bay-breasted Warbler							1					
Black-and-white Warbler	6	7	3	3	7	3	3	1		2	1	2
American Redstart		4	5		1	2	3		2		1	6
Ovenbird	8	46	48	14	41	32	43	29	16	31	25	22
Northern Waterthrush				1								
Mourning Warbler		6	8		14	6	3	18	1		7	16
Common Yellowthroat		1	3		6	3		6	4	1	2	
Canada Warbler		9	7		8	4		9	1		4	8
Scarlet Tanager		4										1
Chipping Sparrow		1	1	1	3							
Song Sparrow	1	1	1	1	3	1	8	6	8	3	5	8
Lincoln's Sparrow								2	2			
Swamp Sparrow	2			5	1		2	1	1	1		
White-throated Sparrow	14	3	5	13	6	8	15	7	11	13	8	19
White-crowned Sparrow										1		
Dark-eyed Junco				1								
Rose-breasted Grosbeak		1			2	1		2		2	1	1
Red-winged Blackbird					1							

Appendix 4.4. Continued.

	1997			1998			1999			2000		
Species	May	June	July	May	June	July	May	June	July	May	June	July
Brown-headed Cowbird	2			4			3		2	2	14	
Purple Finch	2			2			2	1		2	3	
White-winged Crossbill												2
American Goldfinch				1		1			2	1	1	2
Evening Grosbeak	1			6					1			
Unidentified passerine	6	2	4	3	1	3	4	6	8	7	6	5
Unidentified thrush												1
Unidentified warbler			1				1					
Unidentified woodpecker				5		3	2	1			2	
Total Number of Individuals	119	215	216	152	222	221	215	186	161	156	200	200
Total Number of Species	23	30	29	31	35	30	33	30	34	30	36	33

Appendix 4.5. Number of individuals observed in the Knife River large plot in May, June, and July 1997-1999.

	1997			1998			1999		
Species	May	June	July	May	June	July	May	June	July
Ruffed Grouse	4	1		2	1		2	1	
Belted Kingfisher	1								
Yellow-bellied Sapsucker						1			
Downy Woodpecker	1		1						
Hairy Woodpecker								1	
Northern Flicker		1							
Pileated Woodpecker									1
Yellow-bellied Flycatcher		2			3				
Least Flycatcher							4		1
Great Crested Flycatcher		1			1				
Blue-headed Vireo							1	2	
Red-eyed Vireo		3	6		7	5	5	4	5
Gray Jay						1			
Blue Jay	2			1			5	4	1
American Crow				2	2				
Black-capped Chickadee	8	8	10	16	4	10	9	4	6
Red-breasted Nuthatch	15	5	3		1	5	10	5	1
Brown Creeper	2		1	5					
Winter Wren		2	2	5	3	5			
Golden-crowned Kinglet		1		4		3	1		1
Veery		17	13		10	18	9	11	11
Swainson's Thrush							2		
Hermit Thrush	2		1						1
Wood Thrush			1						
American Robin	4	7	6	8	4	3	4		2
Cedar Waxwing						1			
Tennessee Warbler							2		
Nashville Warbler		12	15		8	13	15	20	9
Northern Parula						1			
Chestnut-sided Warbler		4	3		2	2	5	2	

Appendix 4.5. Continued.

	1997			1998			1999		
Species	May	June	July	May	June	July	May	June	July
Magnolia Warbler		3			6	1	4	2	
Cape May Warbler		1							
Yellow-rumped Warbler			2		2	1	3		
Black-throated Green Warbler		4	8		10	9	10	10	5
Blackburnian Warbler		3	5		2	2		1	1
Palm Warbler					2				
Black-and-white Warbler	1	1						3	
American Redstart		2			2		2	1	
Ovenbird		16	7		14	12	22	22	13
Northern Waterthrush	1								
Mourning Warbler		5	9		7	4	1	4	6
Common Yellowthroat		5	4		4	3	1	2	1
Canada Warbler		3	2		3	3		5	
Scarlet Tanager							1	1	
Chipping Sparrow								1	
Song Sparrow		1		1			1		
White-throated Sparrow	18	10	10	7	6	13	10	10	10
Dark-eyed Junco	1								
Rose-breasted Grosbeak					1		5		
Purple Finch	2			7				1	
Pine Siskin	1	1						1	
American Goldfinch							2		1
Evening Grosbeak	3		3	2		1			
Unidentified passerine		1	4	1		9	3	3	2
Unidentified sparrow			1						
Unidentified warbler		1			1			1	
Unidentified woodpecker				1				3	
Total Number of Individuals	66	121	117	62	106	126	139	125	78
Total Number of Species	16	26	21	12	24	23	26	24	18