2005 Project Abstract
For the Period Ending June 30, 2008

PROJECT TITLE:	Evaluating Riparian Timber Harvesting Guidelines: Phase II
PROJECT MANAGER:	Charles R. Blinn
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FUNDING SOURCE:	Environment and Natural Resources Trust Fund

LEGAL CITATION: ML 2005, First Special Session, Chp. 1, Art. 2, Sec. 11, Subd. 9(d)
Evaluating Riparian Timber Harvesting Guidelines: Phase 2

APPROPRIATION AMOUNT: $333,000

<u>Overall Project Outcome and Results</u>

This project continues research begun with a 2001 appropriation from the Trust Fund and is being further continued by a 2007 appropriation.

Minnesotans care about how timber harvesting practices may impact the terrestrial, aquatic, and wildlife components of forested riparian areas. Research addressing the long-term effectiveness of riparian guidelines to mitigate harvesting impacts is critical to effectively resolve riparian management conflicts and sustain Minnesota's forest resources. This project evaluated post-harvest impacts of Minnesota's riparian guidelines on eight northern Minnesota sites harvested in 2004 and 2005.

Terrestrial findings include: 1) partially-harvested riparian management zones (RMZs) have substantial aspen suckering, although at or just below the low range of full stocking; 2) partially-harvested RMZs, particularly at medium residual basal areas, have significant hardwood regeneration; 3) medium basal area retention maintains leaf litter input to streams at control levels; 4) RMZs with medium basal area retention promote development of aspen-mixed wood stands, while retaining adequate stream litter inputs; and 5) residual tree blowdown was low.

Site-level stream effects include: 1) harvesting resulted in reduced canopy cover but increased woody cover; 2) fine sediments increased downstream of the intermediate harvest treatment; 3) harvest effects were observed for macroinvertebrate abundance and species richness, and the proportion of tolerant fish and fish Index of Biotic Integrity (IBI) scores in some treatments; and 4) water quality parameters exhibited seasonal and year-to-year variation with few harvest effects. Although significant harvest effects were found, the changes were relatively small and suggest that application of the RMZ guidelines minimizes negative impacts.

Bird community effects include: 1) no change in species richness or diversity, 2) decrease in total abundance in harvested treatments, and 3) dramatic community compositional change from domination by mature forest species to domination by early successional bird species. These results suggest that if the management goal is to maintain pre-harvest bird species composition in RMZs with a concurrent upland harvest, it is best to leave RMZs at their unharvested basal areas.

Because these results only assessed dynamics three years post-harvest, there is a need to continue monitoring the sites to more fully assess effects over time.

Project Results Use and Dissemination

Project results were disseminated to scientists, natural resource managers, private landowners, legislators, and others through fifteen presentations, two posters, and two field tours. Three additional manuscripts are in preparation. Three graduate student produced theses or dissertations from their project work. Other graduate students continue to collect, analyze, and summarize data which will result in additional theses, dissertations, and manuscripts. As this research study was designed to be a long-term assessment with little dissemination during the initial project phases, researchers will continue to monitor, analyze, and report post-harvest effects in the future as funding permits. With that additional information, we will be able to assess how birds and terrestrial and aquatic ecosystems respond to timber harvesting within RMZs over the long-term. Results will then be used to inform on-the-ground decision making as well as suggest changes to the guidelines to more effectively manage forested riparian areas.

LCCMR 2005 Work Program Final Report

Date of Report: June 30, 2008

LCCMR 2005 Work Program Final Report

Date of Next Status Report: June 2008
Date of Work Program Approval: June 14, 2005
Project Completion Date: June 30, 2008

I. PROJECT TITLE: Evaluating Riparian Timber Harvesting Guidelines: Phase II

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Location: Beltrami, Carlton, Cook, Lake, and St. Louis Counties.

Total Biennial LCMR Project Budget:	**LCCMR Appropriation:**	**$333,000.00**
	Minus Amount Spent:	**$332,048.14**
	Equal Balance:	**$ 951.86**

Legal Citation: ML 2005, First Special Session, Chp. 1, Art. 2, Sec. 11, Subd. 9(d)
Evaluating Riparian Timber Harvesting Guidelines: Phase 2

Appropriation Language: $167,000 the first year and $166,000 the second year are from the trust fund to the University of Minnesota for a second biennium to assess the timber harvesting riparian management guidelines for postharvest impacts on terrestrial, aquatic, and wildlife habitat. This appropriation is available until June 30, 2008, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

II. and III. FINAL PROJECT SUMMARY

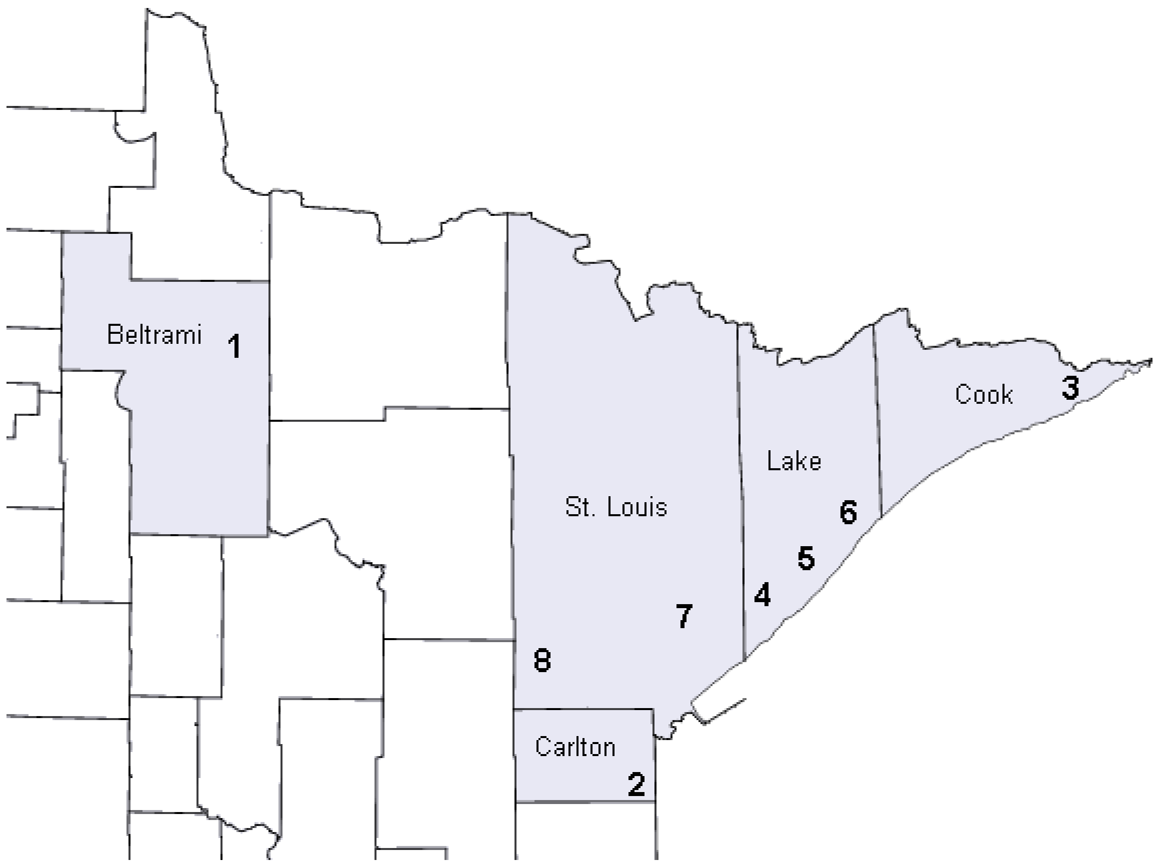
Minnesotan's care about how timber harvesting practices may impact the terrestrial, aquatic, and wildlife components of forested riparian areas. Research addressing the long-term effectiveness of riparian guidelines to mitigate harvesting impacts is critical to effectively resolve riparian management conflicts and sustain Minnesota's forest resources. This project evaluated post-harvest impacts of Minnesota's riparian guidelines on eight northern Minnesota sites harvested in 2004 and 2005.

Terrestrial findings include: 1) partially-harvested riparian management zones (RMZs) have substantial aspen suckering, although at or just below the low range of full stocking; 2) partially-harvested RMZs, particularly at medium residual basal areas, have significant hardwood regeneration; 3) medium basal area retention maintains leaf litter input to streams at control levels; 4) RMZs with medium basal area retention promote development of aspen-mixed wood stands, while retaining adequate stream litter inputs; and 5) residual tree blowdown was low.

Site-level stream effects include: 1) harvesting resulted in reduced canopy cover but increased woody cover; 2) fine sediments increased downstream of the intermediate harvest treatment; 3) harvest effects were observed for macroinvertebrate abundance and species richness, and the proportion of tolerant fish and fish Index of Biotic Integrity (IBI) scores in some treatments; and 4) water quality parameters exhibited seasonal and year-to-year variation with few harvest effects. Although significant harvest effects were found, the changes were relatively small and suggest that application of the RMZ guidelines minimizes negative impacts.

Bird community effects include: 1) no change in species richness or diversity, 2) decrease in total abundance in harvested treatments, and 3) dramatic community compositional change from domination by mature forest species to domination by early successional bird species. These results suggest that if the management goal is to maintain pre-harvest bird species composition in RMZs with a concurrent upland harvest, it is best to leave RMZs at their unharvested basal areas.

Because these results only assessed dynamics three years post-harvest, there is a need to continue monitoring the sites to more fully assess effects over time.



Site 1: Shotley Brook, Blackduck DNR
Site 2: No Name, Nemadji State Forest, Cloquet DNR
Site 3: Reservation tributary, Two Harbors DNR, Grand Marais Office
Site 4: West Split Rock River, Two Harbors DNR
Site 5: East Beaver River, Two Harbors DNR
Site 6: East Baptism River, Lake Co Land Dept, Finland Office
Site 7: Cloquet River tributary, St. Louis Co Land Dept, Pike Lake Office
Site 8: St. Louis River tributary, St. Louis Co Land Dept, Pike Lake Office

IV. OUTLINE OF PROJECT RESULTS*:*

Result 1: Evaluate terrestrial impacts

Description: We will evaluate the effects of our management treatments on regenerating riparian tree species and understory associates. Wildlife habitat will be assessed by measuring conifers, snags, blowdown, long-lived trees, and mast-producing trees and shrubs. We will evaluate these response variables in 2005 and 2006.

Summary Budget Information for Result 1:	**LCMR Budget**	**$185,327**
	Balance	**$ 951.86**

Completion Date: June 2008

Final Report Summary:

Introduction

Thomas et al. (1979) suggest that riparian areas represent systems with maximum potential conflict among multiple users. This reflects the diverse values associated with riparian areas, including timber production, recreation, protection of water quality and aquatic habitat, and provision of habitat for a diverse flora and fauna. Response to these real and potential conflicts between uses and values often takes the form of guidelines designed to protect or conserve riparian resources (Knopf 1985).

In Minnesota, voluntary site-level forest management guidelines and best management practices (BMPs) for water quality were developed in the late 1980s (Anonymous 1989), revised in 1995 (Anonymous 1995), and further revised in 1999 (Minnesota Forest Resources Council 1999). As noted within the current guidebook, the guidelines are designed to help forest landowners, resource managers, and loggers meet two goals: 1) to conduct forest management activities such as timber harvesting while addressing the continued long-term sustainability of riparian areas, and 2) to promote or enhance the functions and values of water resources and riparian areas (Minnesota Forest Resources Council 1999).

The geographic importance of riparian areas in Minnesota is widely recognized (Palik et al. 2004), yet little information is available about regeneration dynamics of tree species in response to different management approaches within riparian areas. Moreover, we have limited information on the fate of residual trees in riparian management areas. Finally, measures of functional changes in riparian areas after harvest are limited for the region. To address these needs, riparian areas at eight locations in northern Minnesota's have been harvested and are being monitored for regeneration and plant community responses, blowdown of residual trees, and changes in the flux of coarse particulate organic matter into the streams from the adjacent forest, as one measure of riparian functionality. Results may lead to changes in the guidelines so that they will more effectively sustain forested riparian areas and associated resources.

Objectives
The primary objective of this study result was to continue to evaluate site-level effects of applying various riparian management treatments on tree regeneration and riparian plant communities, RMZ blowdown, and particulate organic matter input to study streams. Specifically, we examined how different levels of overstory retention in a riparian management zones (RMZ) affects these variables, three years after harvest.

Study Location and Design
Eight forested riparian areas were located in north central and north eastern Minnesota (Figure 1, Table 1). Each site was divided into two 3.2 ha stands that were separated by a 61 m unmanaged buffer strip. Each stand was further subdivided into two zones: a 183 x 183 m upland, and a 46 x 183 m riparian management zone (RMZ). The upstream stand was considered a local control (i.e., the upstream RMZ was not harvested). The downstream stand was harvested either to a target "low" residual basal area (RBA) of 10.7 m^2 ha^{-1} or to a "medium" RBA of 18.2 m^2 ha^{-1}. All upland stands, including those above RMZ areas in control stands, were clearcut. The protocol for harvesting followed the Minnesota Forest Resource Council's riparian guidelines for timber harvesting (Minnesota Forest Resources Council 1999). With the exception of the Reservation Tributary site that was harvested during the winter of 2004-2005, timber harvesting commenced in mid-December of 2003, and was completed by March of 2004.

Methods
Vegetation Assessment and Blowdown Monitoring
Permanently monumented plots were established along transects running perpendicular to the stream. Each of these monumented plots was 4.6 m wide by 7.6 m long (Figure 2). A total of 50 plots were established in each treatment site and the following variables were quantified in each plot using a nested design (Figure 2).

- **Trees** (dia.> 10 cm at 1.37 m (DBH)) and saplings (2.5 cm > DBH < 10 cm) were sampled in 4.6 m by 7.6 m rectangular plots, with the long axis parallel to the stream. Species, diameter, and total height were recorded for all species greater than 2.5 cm.
- **Shrubs** of a size class less than 2.5 cm DBH and height greater than 0.76 m were sampled at two 0.6 by 4.6 m nested plots within the larger tree plot. Each shrub was classified into 0.2 cm size classes based upon diameter at 13 cm from the ground. Species, diameter, and a subset of total height were measured for each species tallied.
- **Regeneration plots** were used to quantify tree regeneration. Six 0.61 by 0.61 m plots were established within the nested shrub plots and are labeled 1A through 2C in Figure 2. In each plot we tallied of the number of stems of individual woody species present.
- **Blowdown** was sampled in 2006 within tree plots, recording species and diameter of tree.

Leaf Litter Input to Streams
Coarse particulate organic matter (mostly leaves) input to steams was measured using a series of litter traps placed adjacent to the stream bank in each study site. Litter was collected periodically and dried and weighed.

White Cedar and Balsam Fir Regeneration
An associated study, not funded by the LCCMR, addressed regeneration dynamics of northern white cedar and balsam fir within the uncut RMZs and the medium residual basal area treatment. The goals of this study were 1) to gain a better understanding of species' dynamics following partial harvest and 2) to identify preferential niches for planting cedar that give it a competitive edge over balsam fir and 3) to develop planting recommendations for recruitment of cedar into forest stands. Northern white cedar and balsam fir seedlings were planted inside and outside of deer exclosures on mound, pit, and slash microsites. Growth and survival were followed over time.

Results

Vegetation Responses

Table 2 summarizes results for vegetation responses by comparing pre-harvest values to 1 year and 3 year values for all treatments. We discuss these various results below.

Overstory Structure
Harvesting treatments were successful in creating significantly different overstory residual basal areas in the RMZ. These differences were still strong at three years post-harvest (Table 2). The majority of standing basal area in the harvested RMZs was aspen and paper birch. Residual conifers and mast-producing trees were very limited in abundance and consisted mainly of balsam fir and spruce.

Tree harvesting intensity, and hence the distribution of residual basal area, was not uniform throughout the entire RMZ. Basal area decreased with distance from stream ($p = 0.003$) in a nonlinear pattern (Figure 3), but the shape of the decline depended on the treatment (significant treatment by distance interaction, $p = 0.02$). The basal area of trees left standing in harvested sites was greatest near the stream edge, and continued to decrease towards the upland, reaching the lowest level in the plots closest to the clearcut edge. As a consequence, light availability increased with distance from stream ($p = 0.007$, data not shown). Compared to average light levels in the control treatments, average light levels in RMZ harvest treatments were 151% and 189% higher in the medium RMZ and low RMZ treatments, respectively.

Tree Regeneration
Total regeneration density (all stems < 2.5 cm diameter), while not significantly different among treatments after three years (Table 2), was lower in the uncut RMZ compared to harvest treatments. Regeneration density did not differ appreciably among the medium basal area treatment, the low basal areas treatment, or the upland clearcut (Table 2). Aspen and birch regeneration (stems ha^{-1}) increased from the uncut RMZ to the medium and low basal area treatments, to the clearcuts. Densities were significantly higher in

clearcuts compared to the uncut RMZ ($p = 0.001$) and harvest treatments ($p = 0.02$), but not among harvest treatments (Table 2, Figure 4).

Regeneration densities of hardwoods other than aspen and birch were not significantly changed through time and did not differ significantly among treatments after three years (Table 2, Figure 5). However, total densities of hardwood species added substantially to total regeneration amounts and exceeded aspen and birch in the medium basal area treatment. Composition of hardwoods varied among the eight study sites but usually included sugar maple, red maple, and black ash.

Conifer regeneration decreased substantially from pre-treatment to three years after treatment. However, there were no significant differences among treatments in conifer regeneration densities among treatments three years after harvest (Table 2).

Shrub and Herbaceous Response

Potential deterrents to successful tree regeneration include various shrub species and herbaceous plants. Both groups increased substantially by three years after treatment in all but the uncut RMZ treatment (Table 2). By the third year after treatment, shrub densities (exclusive of hazel) were highest in the upland clearcuts, followed by the low basal area treatment and the medium basal area treatment, and were lowest in the uncut RMZ treatment (Figure 6).

Three years after treatment, hazel stem densities had increased substantially only in the upland clearcuts, relative to pre-harvest levels (Figure 7). Increases in the two partially harvested RMZ treatments were modest (Figure 7).

Biomass of herbaceous vegetation increased substantially over pre-harvest levels in the two partially harvested RMZ treatments and in the upland clearcut (Figure 8). The two partial-harvest RMZ treatments had similar magnitudes of increases, the upland clearcut was substantially higher than the RMZ treatments, while herbaceous biomass in the uncut RMZ was generally stable over time.

Northern White Cedar and Balsam Fir Regeneration

Survival of both cedar and fir (inside deer exclosures) differed depending on microsite. Survival was highest on mounds and slash. Only fir survival differed with overstory treatment. Overall, survival of cedar was much higher than for fir (Figure 9).

Cedar height and diameter differed among overstory treatments, with greater growth in harvest RMZs (Figures 10-11). Growth did not differ among microsites within treatments. Balsam fir height did not differ among treatments or microsite (Figure 10), but diameters were greater in the partially harvested RMZs (Figure 11).

<u>RMZ Blowdown</u>

Blowdown of residual trees three years after harvest was low in all treatments. After three years, on average only 9 trees/ha had blowdown in the medium and low basal area treatments and about 3 trees/ha in the uncut RMZ (Figure 12).

Litter Flux to Streams

Riparian areas contribute energy and nutrient to the aquatic systems with the addition of litter from trees and other plants surrounding the stream. Figure 13 illustrates the amount of coarse particulate organic matter (mostly tree leaves) deposition as a function of treatment.

By the third year after harvest, the low RMZ basal area treatment had less litter entering the streams than either the medium basal area treatment or the uncut control. The latter treatments did not differ in litter input.

Significance of Results

Vegetation Responses

Residual Overstory

A key observation of this study is that it is difficult to meet residual basal area targets uniformly across an RMZ. Rather, there is a trend towards leaving more basal area (i.e., above the residual target) nearer the stream and less than the target farther from the stream, while on average the entire RMZ may be at the target level.

This pattern results from generally wetter soil conditions nearer the stream, limiting operability at certain times of the year, as well as more difficult access nearer the stream due to topography. A tendency to retain higher than target residual basal areas nearer the stream is likely of ecological benefit as trees nearer the stream have a greater functional connection to the water then do trees farther from the stream (Palik et al. 1999). Lower than target residual basal area farther from the streams, but still within the RMZ, is a primary reason that aspen regeneration was approaching adequate numbers with the partially harvested treatments.

Tree Regeneration

Third year results demonstrate that both the medium and low partial harvest treatments in the RMZ result in lower aspen (and birch) regeneration density than typically occurs in a clearcut. However, density of aspen suckers in still within the range of full stocking on low BA treatment. It is a bit below the lower end of this range in the medium basal area treatment and potentially declining.

Hardwood regeneration density (red maple, sugar maple, black ash) was variable among the treatments. It was highest in medium basal area treatment and moderate in the low basal area treatment.

In combination, these results indicate that the partial harvest treatments used in this study have the potential to regenerate aspen-mixed wood stands, as opposed to purely aspen dominated stands. Aspen can regenerate successfully in either treatment. However, the lower residual basal area treatment favors aspen to a greater degree, whereas the medium residual basal area treatment favors other hardwood species to a greater degree.

Shrub and Herb Responses
Woody shrub densities, including hazel, and herbaceous biomass responded in a similar pattern as aspen regeneration. Responses increased with increasing amount of overstory removal, from the uncut RMZ, to the low and then medium basal area treatments, to the upland clearcut. Since these responses paralleled aspen regeneration responses, an increase in understory competitor abundance in the partial harvest treatments cannot be implicated as a cause of reduced aspen suckering in these treatments.

Planted Northern White Cedar and Balsam Fir Regeneration
Results from this study show that mound and slash microsites within partially harvested RMZ are the best places to plant northern white cedar and balsam fir to maximize survival. Mortality in pits can be high for both species due to seasonal flooding.

Harvest areas in general emerge overall as the best places to plant both cedar and balsam fir to maximize growth. Cedar is more sensitive to microsite characteristics, while fir shows its generalist tendencies.

<u>RMZ Blowdown</u>
When trees left at the edge of RMZ adjacent to clearcuts are exposed to wind, they are more susceptible to blowdown (Ruel et al. 2001). Residual trees left after a thinning carry the same risk. Therefore, blowdown can have serious managerial and ecological implications, especially in the sensitive RMZ. Excessive blowdown can lead to a reduction in RMZ ecological function.

In this study, blowdown of residual trees has not been substantial after three years. Such events tend to be episodic, so the potential still exists that substantial numbers of trees in the RMZs could blow down over time. Continued losses of residual overstory trees would likely increase the growth of aspen that has already suckered in the treatment.

<u>Leaf Litter Input to Streams</u>
Our results show that leaf litter input to the study streams was substantially reduced in the low basal area treatment, compared to the uncut control RMZ, and that the change has lasted at least four years. This result, coupled with the fact that residual basal area in this treatment was concentrated within the first 15 m (50 ft) from the stream, suggests that the functional extent of the riparian area (as a source of stream litter) extends beyond this distance, up to 30 to 45 m (100 to 150 ft) and that harvesting within the RMZ impacts this function.

Temporal Dimension
The results presented above only report the short-term (three years) dynamics following harvest in the RMZs. To fully understand the long-term consequences (i.e., minimum of nine years post-harvest as suggested in prior studies), further study will be necessary.

Unanticipated and Unresolved Problems
The procedures used to meet the objectives of this Result were adequate and sufficient. One aspect of the overall study that could have been changed, given sufficient land areas

and cooperators, is use of a complete block design where all three harvesting treatments were included at each of the study locations. There are no unresolved problems relative to this Result at present. All work has been completed as planned.

Unspent Funds
A total of $951.86 was not spent within this Result. Unspent funds resulted when an error was made in encumbered monies which were returned to the Result at a date that was too late to spend them due to accounting system changes at the University of Minnesota.

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Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands - The Great Basin of southeastern Oregon. Riparian Zones. USDA, For. Serv. Gen. Tech. Rep. PNW-80.

Table 1. Site location information.

Stream name	Legal description	Section, township, range	County	Landowner
Shotley Brook	Lots 1 & 2 of 19, SENE of 24	19,24 153 30W,31W	Beltrami	DNR
Nemadji State Forest	NWNW NENW	36 46 16W	Carlton	DNR
Reservation Tributary	NESW	25 63 04E	Cook	DNR
West Split Rock River	NENE NWNE SENE	7 55 09W	Lake	DNR
East Branch of Beaver River	SWNW SENW NWSW NESW	16 56 08W	Lake	DNR Two Harbors
East Baptism River	SW ¼	25 58 07W	Lake	Lake County Land Department
Cloquet River tributary	SWNE SENE NESE NWSE	11 54 13W	St. Louis	St. Louis County Land Department
St. Louis River Tributary	SWNW SENW NWSW NESW	23 51 20W	St. Louis	St. Louis County Land Department

Table 2. Stand structural variables (ls mean +- se) by sampling period for all treatments. Significant differences among treatments are indicated by differing lower case letters within each time period.

	Pre- Harvest				1 Yr Post- harvest				3 Yrs Post- harvest			
Structural Variable	**Control RMZ's**	**Medium RBA RMZ's**	**Low RBA RMZ's**	**Clearcut Uplands**	**Control RMZ's**	**Medium RBA RMZ's**	**Low RBA RMZ's**	**Clearcut Uplands**	**Control RMZ's**	**Medium RBA RMZ's**	**Low RBA RMZ's**	**Clearcut Uplands**
Tree/Sapling Basal Area (m^2/ha)	26.94 (1.92) **a**	30.09 (2.7) **a**	26.46 (2.7) **a**	26.37 (1.91) **a**	27.42 (1.92) **a**	18.17 (2.7) **b**	10.74 (2.7) **c**	2.51 (1.91) **d**	27.20 (1.92) **a**	18.23 (2.7) **b**	10.61 (2.7) **c**	2.48 (1.91) **d**
Herbaceous Biomass (kg/ha)	403.19 (124.0) **a**	332.99 (175.4) **a**	397.28 (175.4) **a**	481.48 (124.0) **a**	401.03 (124.0) **a**	399.56 (175.4) **a**	470.17 (175.4) **a**	492.42 (124.0) **a**	529.68 (124.0) **a**	1009.29 (175.4) **b**	912.71 (175.4) **ab**	1442.38 (124.0) **c**
Woody Regen (thousand stems/ha)	190.8 (31.8) **a**	137.0 (44.9) **a**	248.7 (44.9) **a**	207.3 (31.8) **a**	157.8 (31.8) **a**	196.0 (44.9) **a**	187.0 (44.9) **a**	229.0 (31.8) **a**	146.2 (31.8) **a**	189.5 (44.9) **a**	190.1 (44.9) **a**	193.0 (31.8) **a**
Non-commercial Shrub Regen (thousand stems/ha)	37.1 (11) **a**	24.9 (15.5) **a**	40.5 (15.5) **a**	50.7 (11) **a**	47.3 (11) **a**	45.6 (15.5) **a**	55.6 (15.5) **a**	74.2 (11) **a**	39.2 (11) **a**	42.7 (15.5) **a**	60.8 (15.5) **a**	75.9 (11) **a**
Aspen/Birch Regen (thousand stems/ha)	12.9 (11) **a**	15.3 (15.3) **a**	15.9 (15.3) **a**	21.2 (11) **a**	20.3 (11) **a**	42.6 (15.3) **a**	45.5 (15.3) **a**	92.5 (11) **b**	22.4 (11) **a**	32.1 (15.3) **a**	44.3 (15.3) **a**	78.4 (11) **b**
Hardwoods Regen (thousand stems/ha)	26.8 (8.1) **a**	37.9 (11.5) **a**	16.6 (11.5) **a**	31.7 (8.1) **a**	24.4 (8.1) **a**	35.9 (11.5) **a**	17.9 (11.5) **a**	33.8 (8.1) **a**	28.8 (8.1) **a**	42.3 (11.5) **a**	19.7 (11.5) **a**	34.1 (8.1) **a**
Conifer Regen (thousand stems/ha)	69.9 (24.4) **a**	49.5 (34.5) **a**	99.0 (34.5) **ab**	149.2 (24.4) **b**	26.9 (24.4) **a**	17.5 (34.5) **a**	18.0 (34.5) **a**	18.0 (24.4) **a**	23.6 (24.4) **a**	19.7 (34.5) **a**	17.2 (34.5) **a**	16.6 (24.4) **a**
Hazel Regen (thousand stems/ha)	27.7 (16.7) **a**	28.4 (23.6) **a**	38.9 (23.6) **a**	44.8 (16.7) **a**	28.6 (16.7) **a**	39.1 (23.6) **a**	35.8 (23.6) **a**	64.3 (16.7) **a**	31.0 (16.7) **a**	44.0 (23.6) **ab**	53.9 (23.6) **bc**	111.4 (16.7) **c**

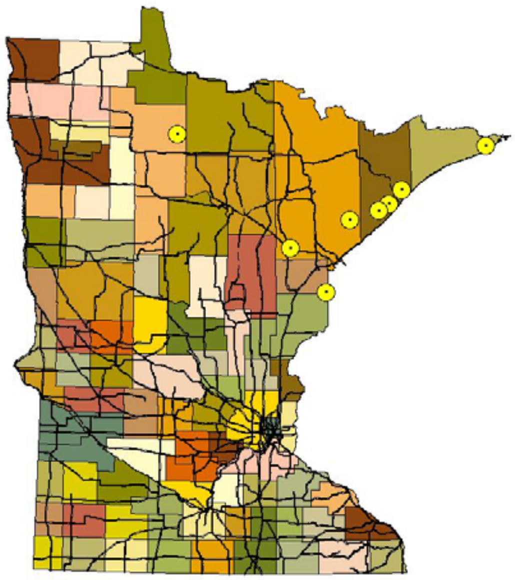

Figure 1. Study site locations.

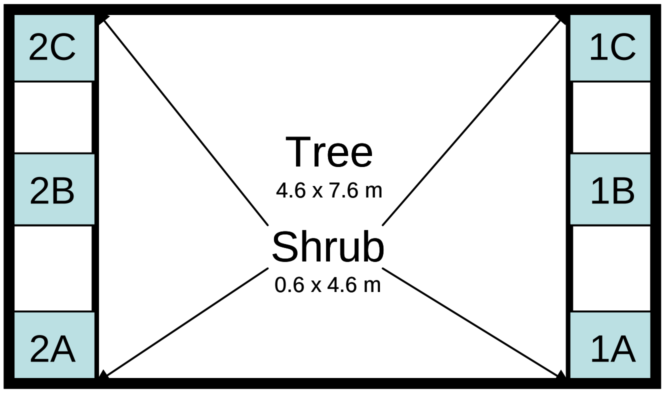

Figure 2. Nested plot design.

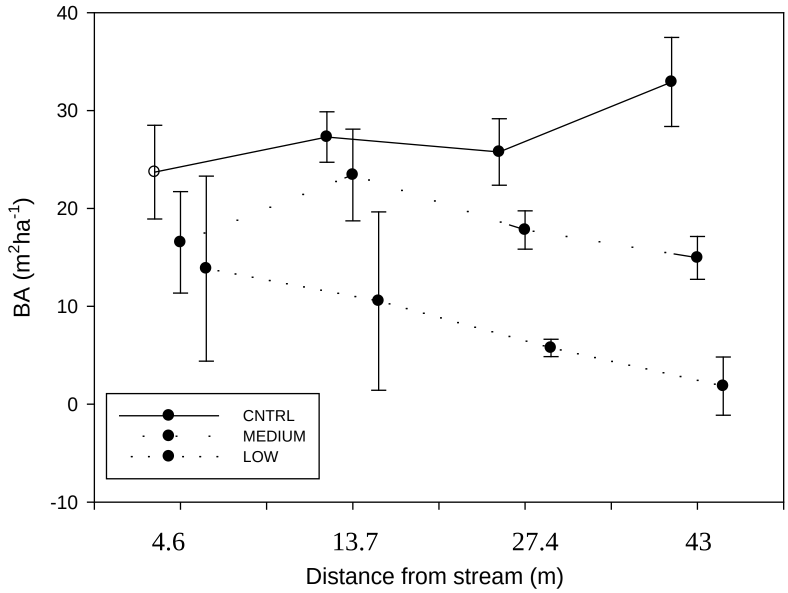

Figure 3. Average basal area versus distance from the stream.

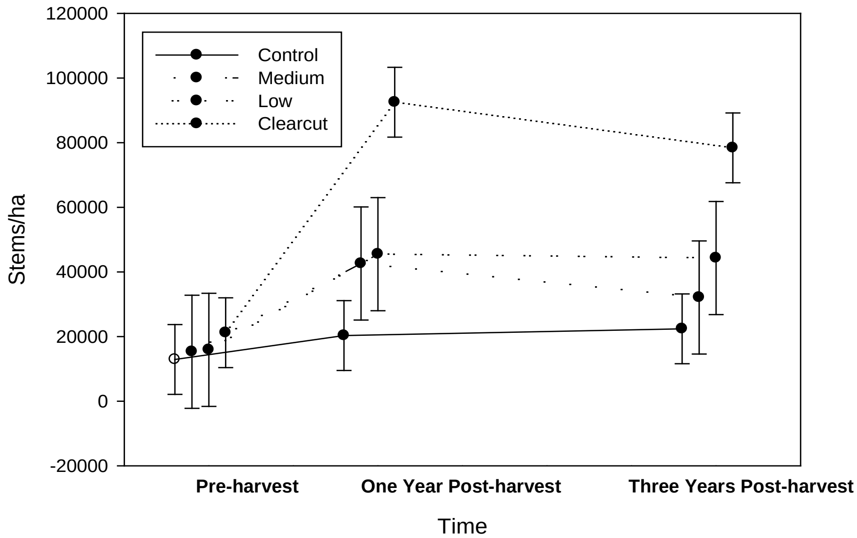

Figure 4. Aspen and birch regeneration across treatments over time.

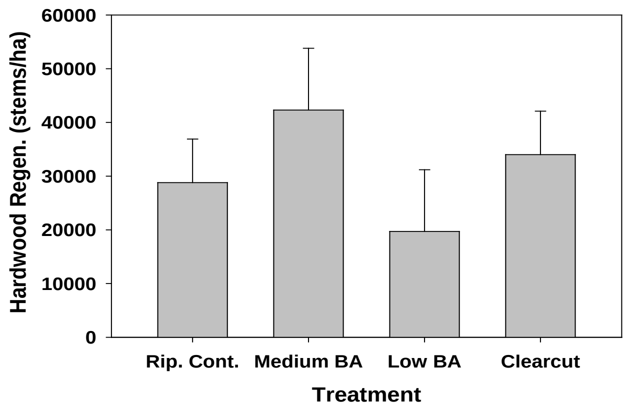

Figure 5. Hardwood species regeneration densities three years after harvest.

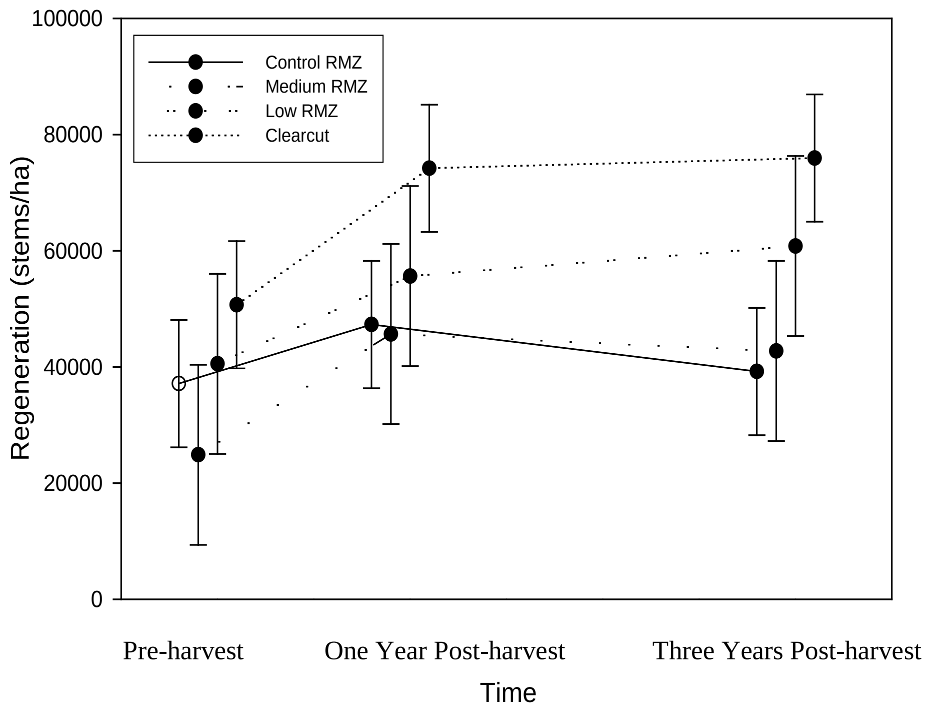

Figure 6. Changes in noncommercial shrub densities across treatments and over time.

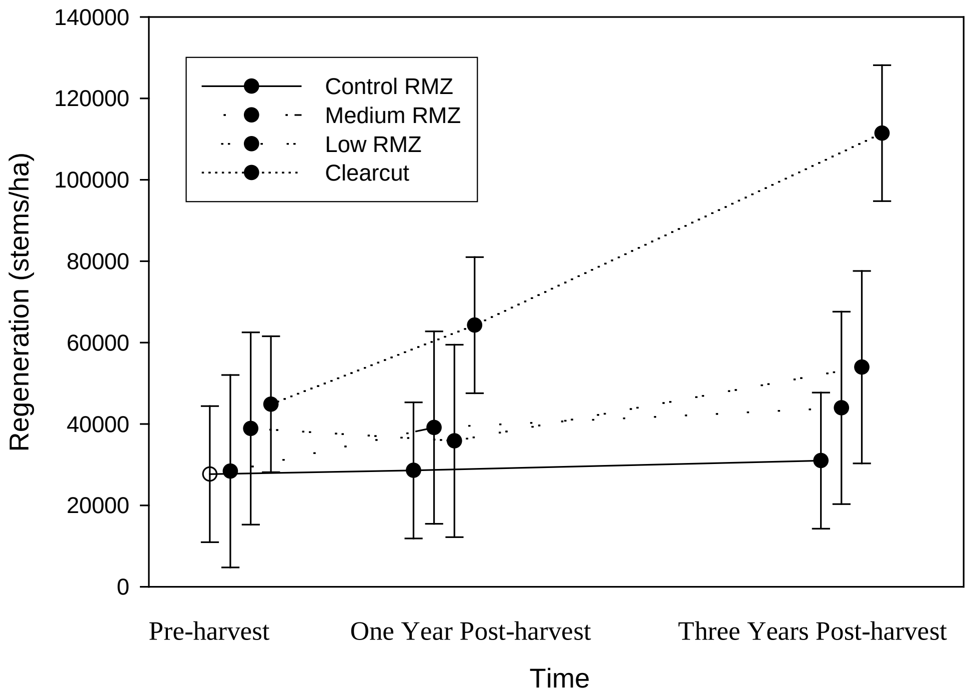

Figure 7. Changes in hazel densities across treatments and over time.

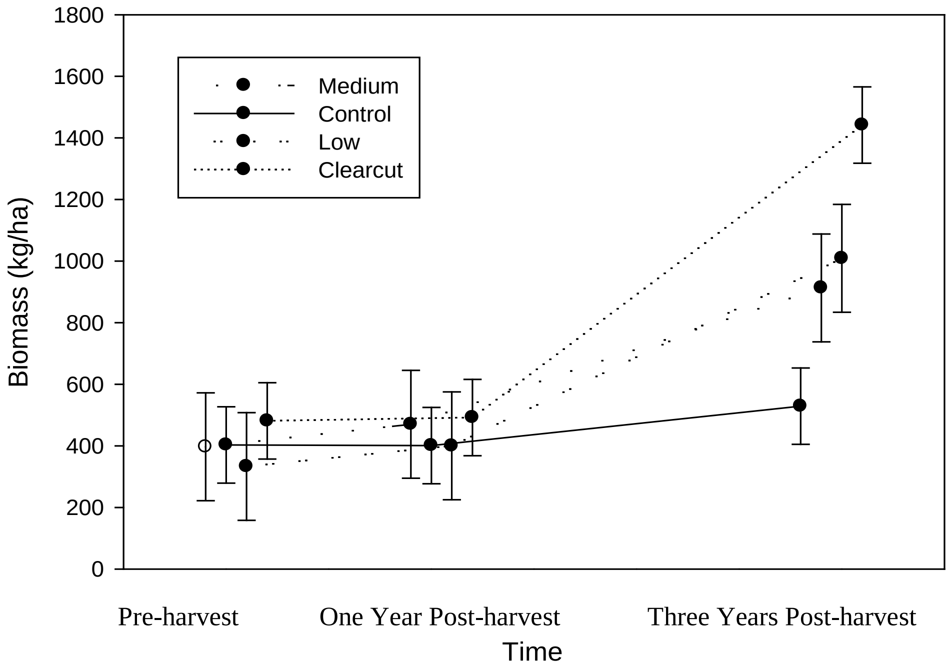

Figure 8. Changes in herbaceous biomass across treatments and over time.

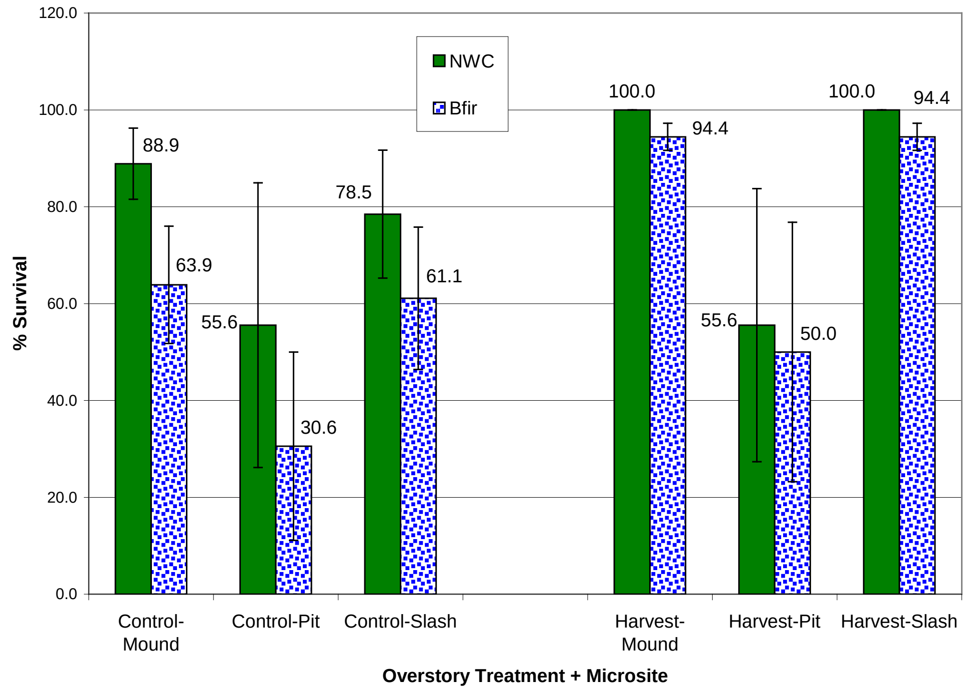

Figure 9. Northern white cedar (NWC) and balsam fir (B fir) survival in riparian areas.

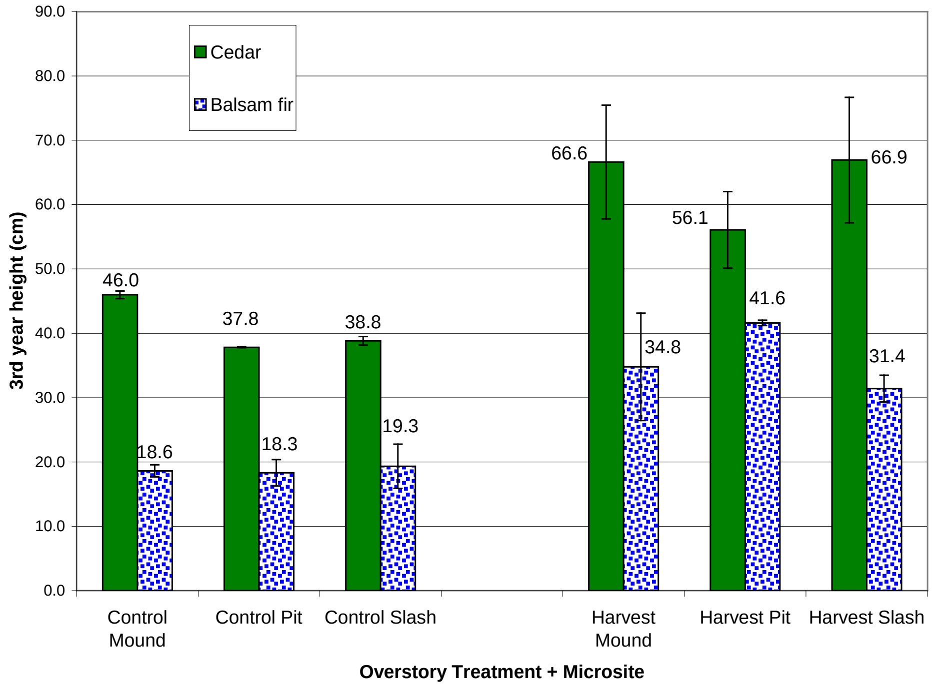

Figure 10. Northern white cedar and balsam fir seedling height response to overstory treatment and microsite condition.

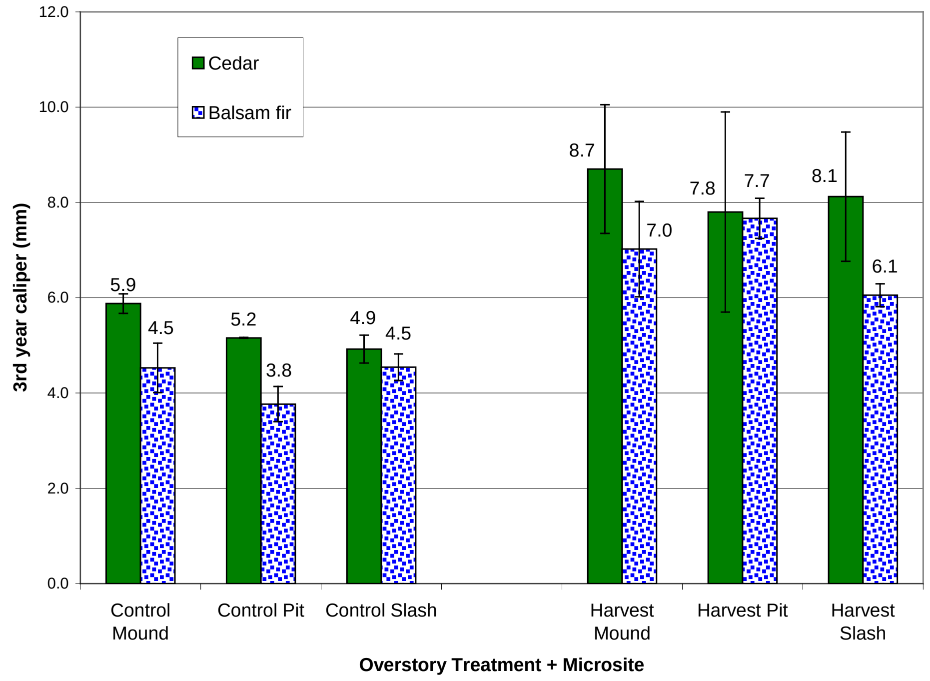

Figure 11. Northern white cedar and balsam fir seedling diameter response to overstory treatment and microsite condition.

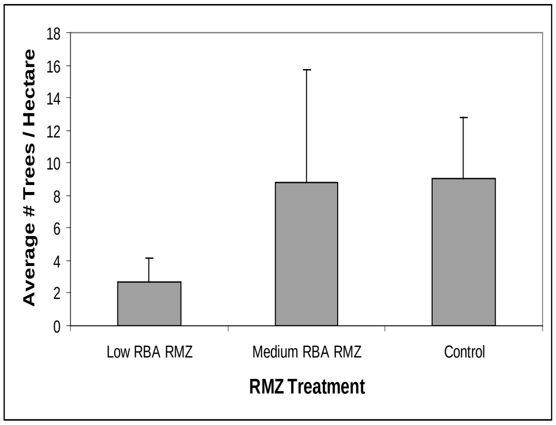

Figure 12. Blowdown of residual trees three years after harvest.

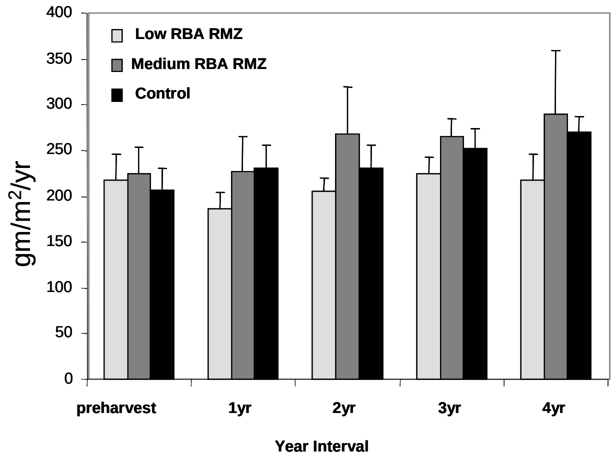

Figure 13. Coarse particulate organic matter input to streams.

Result 2: Evaluate aquatic habitat impacts

Description: We will evaluate the effects of our treatments on fish and invertebrate habitat (temperature, sediment composition and embeddedness, depth, width, cover, bank stability, canopy coverage, woody debris, etc.), benthic macroinvertebrates and stream fish communities. We will evaluate these response variables in 2005 and 2006.

Summary Budget Information for Result 2:	**LCMR Budget**	**$97,673**
	Balance	**$ 0**

Completion Date: June 2008

Final Report Summary:

Introduction

Riparian forest harvesting can affect canopy cover reducing shading that may lead to increased stream temperatures (Rishel et al. 1982, Bowlby and Roff 1986) and a reduction of leaf litter inputs (Webster et al. 1983, Palik et al. 2000). Riparian tree removal may also result in sediment and nutrient inputs to water bodies (Taylor et al. 1999) that affect water quality, fish communities and macroinvertebrate assemblages. While some effects related to riparian harvesting (e.g., change in flow, increases in water temperature, reduction in leaf inputs) are usually short term and decline as trees grow, other effects (e.g., sediment inputs due to roads, reduced inputs of large woody debris) can persist. Harvest effects can occur at the site-level (within, or immediately downstream of a harvested area) or at the basin level. Some studies have found varied effects of forest harvesting on aquatic communities. De Groot et al. (2007) found no effects of forest harvesting on cutthroat trout or instream habitat even with riparian harvest. Hemstad et al. (2008) found few significant site-level responses of instream habitat or fish variables to harvest treatments but significant basin-scale changes related to increased fine sediment. In this study, we investigated site-level effects of harvesting using RMZ forest management guidelines on stream habitat, water quality, fish and macroinvertebrates, in eight streams.

Methods

On the eight streams we established no harvest control, riparian control (upland harvest) and treatment plots. At each plot, we sampled reaches upstream, within and downstream reaches that were 100m in length. We assessed harvest effects with within-upstream and downstream-upstream comparisons of measured habitat, water quality, and fish and macroinvertebrate attributes. Response variables were calculated for each plot by subtracting the upstream value from the related within or downstream value. The within- and downstream-reaches of each treatment plot represented the potentially impacted reaches. We measured six water quality, fourteen aquatic habitat, eight macroinvertebrate and six fish variables in 100-m reaches at each reach. Data were collected during one year of pre-harvest (2003) and three years of post-harvest (2004-2006). Data were analyzed using repeated measures ANOVA.

Results

Assessing effects of riparian forest harvesting

Harvest effects on habitat variables

Significant harvest effects were detected for some habitat variables. Percent canopy cover was significantly reduced in the within reaches of low and intermediate treatments, but was similar between riparian and non-harvested controls (Figure 1). Percent woody cover increased in the within reaches of both low and intermediate RBA treatments and was significantly higher in the riparian treatments than the riparian control and non-harvested control reaches one-year post-harvest (Figure 2). However, differences in woody cover were less distinct two and three years post-harvest. Percent fine sediments increased in the below harvest reaches of the intermediate RBA treatment sites and was significantly higher than in the riparian control and non-harvested control reaches in all three years after harvest (Figure 3). However, no harvest effect was observed for percent fine sediments in the treatment reaches of the low RBA treatment sites (Figure 4). No other habitat response variables differed between treatment, riparian control and non-harvested control plots.

Harvest effect s on water temperature

The average 7-day maximum summer water temperatures ranged from 21.9 °C to 27.7 °C across all sites (Table 1). Air temperature obtained from surrounding stations during the pre-harvest year (2003) and third year post-harvest (2006) were relatively warmer (range 24.3 – 27.7 °C) than the first and second years (2004 and 2005) post-harvest (range 21.9 – 25.4 °C) (Table 2). Stream discharge was negatively correlated with water temperatures; low discharge was correlated with high air and water temperatures. Discharge was significantly higher in 2004 and 2005 at most sites compared to 2003 and 2006. Site 8 (St. Louis River Tributary) was dewatered during summer 2006.

Harvest effects on water quality parameters

There was little indication of a harvest effect on the mean seasonal concentrations of the six water chemistry variables examined, except for nitrate. A significant harvest effect was observed for nitrate concentrations in both treatments (Figure 5). Nitrate concentrations increased after harvest. Relatively higher nitrate concentrations in fall were observed during wet years in both treatments, and nitrate concentrations in spring were higher in the second and third year after harvest in both treatments. However, trends in water quality parameters were observed at all streams, and were similar between non-harvested control, riparian control and harvest reaches of both treatments. There were significant trends across years among all water chemistry variables in both treatments, and we detected correlations between water quality data, precipitation (as reflected by stream discharge), and season.

There were significant year-to-year differences for alkalinity, orthophosphate, nitrate, dissolved oxygen (DO), conductivity, and pH measured in spring and fall in the intermediate RBA treatments; and orthophosphate, nitrate, DO, conductivity, and pH in spring and fall in the low RBA treatments. There were also significant year-to-year differences for alkalinity measured in fall in the low RBA treatments.

Higher alkalinity concentrations were generally observed in fall season and in drier years. Relatively higher orthophosphate values were observed during the spring season and in wet years. Relatively higher DO and conductivity were observed during the fall season in both treatments during drier years. Also, relatively higher pH values were observed during the spring season whereas lower pH values were observed in fall of drier years.

<u>Harvest effects on fish communities</u>
Significant harvest effects were observed for the proportion of tolerant fish (Figure 6) and IBI scores (Figure 7) in the within-harvest reaches. There was an increase in the proportion of tolerant fish species, potentially indicating an effect on water quality or habitat quality, in the within- and below-treatment reaches. There was no significant harvest effect on the number of fish species or fish IBI scores for the low and intermediate RBA treatments separately. However, when data from both low and intermediate RBA treatments and riparian and non-harvested riparian controls were pooled, there was a significant harvest effect on fish IBI scores in the within harvested reaches. Fish IBI scores declined the year after harvest but appeared to recover by 2006 (Figure 7). As well, there was a significant harvest effect on the pooled IBI scores in the below treatment reaches. Lower pooled IBI scores were noted in the below treatment reaches compared to the riparian control and non-harvested control reaches. No other significant harvest effects were found.

Characterizing variability between reaches
Ordination of fish community data by Nonmetric Multidimensional Scaling (NMS) did not indicate distinct trends in community structure that could be attributed to riparian harvest. NMS analysis indicated that 89.4% of the cumulative variance in fish distribution and composition was explained. Several habitat variables (QHEI, percent canopy cover, percent woody cover, percent fine sediment, embeddedness and percent boulder pockets) were significantly associated with fish communities. Fish species commonly found in coldwater streams (brook trout, slimy sculpin, longnose dace, blacknose dace, creek chub, and white sucker) were negatively correlated with fine sediments, water temperature and embeddedness. Fish IBI scores were negatively correlated with average 7-day maximum summer temperature and fine sediments across all sites and years. Species richness and percent abundance of tolerant species, which are metrics of the IBI score, were negatively correlated with IBI scores, whereas percentage of tolerant species was positively correlated with water temperature. Relative abundances of brook trout and slimy sculpin, both coldwater species that are sensitive to increases in water temperature and adverse habitat modification, were negatively correlated with water temperature and percent fine sediment, but positively correlated with percent canopy cover.

Harvest effects on macroinvertebrates

Total abundance

Significant harvest effect s were observed on the total insect abundance in the within harvest reaches of the intermediate RBA treatment. Total insect abundance was significantly higher at the within harvest reaches of the intermediate RBA treatment sites than at both the riparian control and non-harvested control reaches one year post-harvest (Figure 8). By second year post-harvest, total insect abundance was higher in the harvest reaches than in riparian control reaches, but was not different from the non-harvested control reaches. The trend in total abundance indicated an increase in insect abundance after harvest in the treatment reaches at the low RBA treatment sites compared to both the riparian control and non-harvested control reaches, but this increase was not significantly greater than the increase observed in total insect abundance in the riparian control and non-harvested control reaches. The apparent increase in invertebrate abundance may have been due to more algae as a result of more sunlight due to reduced canopy cover.

Richness

Macroinvertebrate community richness measured by Margalef's richness index (Margalef's richness index was calculated using the formula $(S\text{-}1)/\ln(n)$ where S is the number of taxa, and n is the number of individuals in the sample) was significantly higher in the below harvest reaches of the intermediate RBA sites three years post-harvest (Figure 9), and richness was similar during the first and second year post-harvest. The significantly higher richness at the below harvest reaches of the intermediate RBA treatment sites in the third year post-harvest appeared to be a response to harvesting. Richness at the intermediate RBA sites fluctuated more than the low RBA sites where richness was relatively stable over the 3 years post-harvest. Richness generally decreased immediately after harvest, but increased at most sites with post-harvest levels being slightly higher three years after harvest than pre-harvest levels. Richness was higher in the harvest reaches than both the riparian control and non-harvested control reaches. Higher values of Margalef's richness at several sites coincided with an increase in total abundance.

Macroinvertebrate assemblage characteristics

Relative abundance of functional feeding groups among streams was examined to determine which taxa were responsible for the observed trends in community structure. Assemblage composition varied considerably between streams and between years (Table 3). There was a significant harvest effect on the proportion of collector-filterers, indicating more fine organic matter was available, in the below harvest reaches of the low RBA treatment sites. A marginally significant harvest effect on the proportion of collector-gatherers, also suggested more fine organic matter was available in the within harvest reaches of the intermediate RBA treatment sites. In 2005, the proportion of collector-gatherers in the within harvest reaches of the intermediate RBA treatment sites was significantly higher than in the riparian control reaches. Additionally, there was a marginally significant harvest effect on the proportion of scrapers, indicating more algal growth due to reduced canopy cover, in the within harvest reaches, and below harvest reaches of the low RBA treatment sites. In 2005, the proportion of scrapers in the two reaches was higher compared to both the riparian control and non-harvested control reaches.

Mean %EPT (Ephemeroptera, Plecoptera, and Trichoptera) abundance and number of taxa varied widely between streams, and higher %EPT abundance and number of EPT taxa were recorded in larger streams. EPT organisms generally indicate good water quality. EPT organisms were generally rare in smaller streams (Nemadji State Forest, Cloquet River Tributary, and St. Louis River Tributary); the exception was Baetidae (Ephemeroptera) that was occasionally abundant in the Nemadji State Forest site. There was a significant harvest effect on %EPT in the within harvest reaches of the intermediate RBA treatment sites. In 2004 and 2006, %EPT was significantly lower in the within harvest reaches than the riparian control reaches of the intermediate RBA sites, although it was similar to the non-harvested control reaches (Figure 10). Additionally, there was a marginally significant harvest effect on %EPT in the below harvest reaches of the intermediate RBA treatment. In 2004 and 2006, %EPT was significantly lower in the below harvest reaches than the riparian control and non-harvested control reaches of the intermediate RBA treatment sites (Figure 11). In addition, %EPT was lower in non-harvested control reaches than in riparian control reaches in 2006.

Community structure
Ordination of macroinvertebrate community data by NMS did not indicate distinct trends in community structure that could be attributed to riparian harvest. However, the ordination demonstrated differences in community structure between sites. There were some differences in clusters between smaller and larger streams, although there was little difference in ordination clustering between harvest, riparian control and non-harvested control reaches before and after harvest in both low and intermediate treatments. Overall, the ordination indicated that patterns in community structure were more similar in streams of comparable size and no shifts associated with harvesting treatment were apparent.

Discussion and Conclusions
Several instream habitat, water chemistry, fish and macroinvertebrate variables showed significant site-level responses to harvesting treatments. These results indicate that riparian timber harvesting may have both direct and indirect effects on stream habitat and biotic communities. Riparian harvesting led to a significant canopy cover reduction and increase in woody cover. However, the initial reduction in canopy cover was not enough to significantly raise stream temperatures, but may have indirectly led to an increase in invertebrate abundance following harvest. Therefore leaving a residual basal area of at least $8.1m^2$/ha on one side of the stream for cuts less than 200m long, may protect similar streams from increases in water temperature that can affect fish and macroinvertebrate communities.

Several recent studies have also shown that riparian forest harvesting employing best management practices to reduce soil and bank disturbance can be conducted with minimal impacts on stream habitat or biota. Hemstad et al. (2008) found few instream habitat or fish variables showing significant site-level responses to riparian harvest. De Groot et al. (2007) found no effects of forest harvesting on cutthroat trout or instream habitat even with riparian harvest. They attributed the lack of impacts to careful harvesting practices. Kreutzweiser et al. (2004, 2005) found few effects of riparian harvesting on organic matter inputs and accumulation and on benthic macroinvertebrates when $\leq$42% of the riparian basal area was harvested, but effects at higher harvest levels were noted.

Results from our study indicate that riparian harvesting on one side of the stream that leaves residual basal areas $\geq 8.1 m^2/ha$ along stream reaches $\leq$ 200m in length results in relatively few negative harvesting impacts, implying adequate protection for stream habitat in these low gradient streams. We found a few negative impacts. Canopy cover was reduced, proportion of fine sediment and tolerant fish species increased while the proportion of EPT and fish IBI decreased. These results indicate that caution should be exercised when harvesting in riparian areas. Greater caution should be exercised because our study had low replication of harvesting treatment for our analyses due to incomplete replication of all treatments. We recommend a strong precautionary principle be applied when interpreting these results because weather conditions varied greatly between years (very dry and very wet). Also, our results only reflect the short-term (three years) dynamics following harvest in the RMZs. That being said, Minnesota's RMZ guidelines (MFRC 1999) that were used in carrying out our experimental harvesting may moderate the impact of riparian harvesting on instream resources over the short-term when applied to forested RMZs in northern Minnesota. To fully understand the long-term consequences (i.e., minimum of nine years post-harvest as suggested in prior studies), further study will be necessary.

Further research work should be done using more replicates with similar characteristics and complete treatments. Also further research work should be done to determine the effect of reach length.

Unanticipated and Unresolved Problems

The procedures used to meet the objectives of this Result were adequate and sufficient. There are no unresolved problems relative to this Result at present. All work has been completed as planned.

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Table 1. Mean 7-day maximum summer temperature (± 1SE) for low and intermediate residual basal area (RBA) treatments pre-harvest (2003) and post-harvest (2004-2006).

Temperature °C (SE)	2003	2004	2005	2006
Low RBA treatment				
Below treatment	25.42(0.35)	23.69(1.18)	24.68(0.53)	25.84(0.08)
Within treatment	25.77(0.54)	24.66(1.02)	25.24(0.33)	26.10(0.81)
Riparian control	25.93(0.50)	24.16(0.49)	24.74(0.38)	26.05(0.83)
Control	26.90(0.42)	25.38(0.99)	25.04(0.77)	26.54(0.39)
Intermediate RBA treatment				
Below treatment	24.3(1.89)	21.87(1.29)	23.37(1.19)	24.77(1.42)
Within treatment	25.02(1.01)	24.49(0.33)	23.10(1.22)	25.42(0.70)
Riparian control	25.52(1.03)	22.71(0.49)	23.61(0.47)	24.67(0.69)
Control	27.72(0.65)	24.4(0.73)	24.73(0.20)	25.82(0.99)

Table 2. Annual summer maximum air temperature (°C) near study streams in northern Minnesota.

	Year					
Site Name	2001	2002	2003	2004	2005	2006
Shotley Brook	27.0	28.4	27.2	24.7	26.8	29.1
Nemadji State Forest	28.2	29.1	28.9	26.1	29.5	31.9
Reservation River Tributary	22.9	24.6	24.5	22.3	24.4	27.1
West Split Rock River	26.3	27.0	25.9	24.7	26.3	28.7
East Branch Beaver River	24.8	28.2	25.8	24.1	25.1	28.6
East Baptism River	24.7	26.6	25.1	22.7	24.8	28.5
Cloquet River Tributary	25.8	26.9	25.9	24.1	25.7	28.1
St. Louis River Tributary	26.1	26.8	26.4	24.2	25.7	28.6

Table 3. *R*-statistics and significance levels for pairwise tests in the multivariate analysis of similarity (ANOSIM) as a measure of dissimilarity among macroinvertebrate communities at the treatment (T), riparian control (R) and control (C) reaches of the intermediate and low residual basal area (RBA) sites. Higher *R*-values indicate greater dissimilarity. The harvest occurred after 2003 but prior to 2004 sampling.

		Low RBA sites		Intermediate RBA sites	
Year	Pairwise test	Significance	*R*-statistic	Significance	*R*-statistic
2003	T vs R	p = 0.420	0.006	p = 0.734	0.057
	T vs C	p = 0.731	0.055	p = 0.398	0.001
	R vs C	p = 0.526	0.022	p = 0.639	0.031
2004	T vs R	p = 0.240	0.188	p = 0.248	0.133
	T vs C	p = 0.619	0.039	p = 0.827	0.074
	R vs C	p = 0.978	0.083	p = 0.891	0.044
2005	T vs R	p = 0.319	0.176	p = 0.323	0.119
	T vs C	p = 0.487	0.022	p = 0.483	0.024
	R vs C	p = 0.500	0.021	p = 0.391	0.004
2006	T vs R	p = 0.616	0.054	p = 0.488	0.028
	T vs C	p = 0.458	0.007	p = 0.411	0.030
	R vs C	p = 0.771	0.072	p = 0.364	0.031

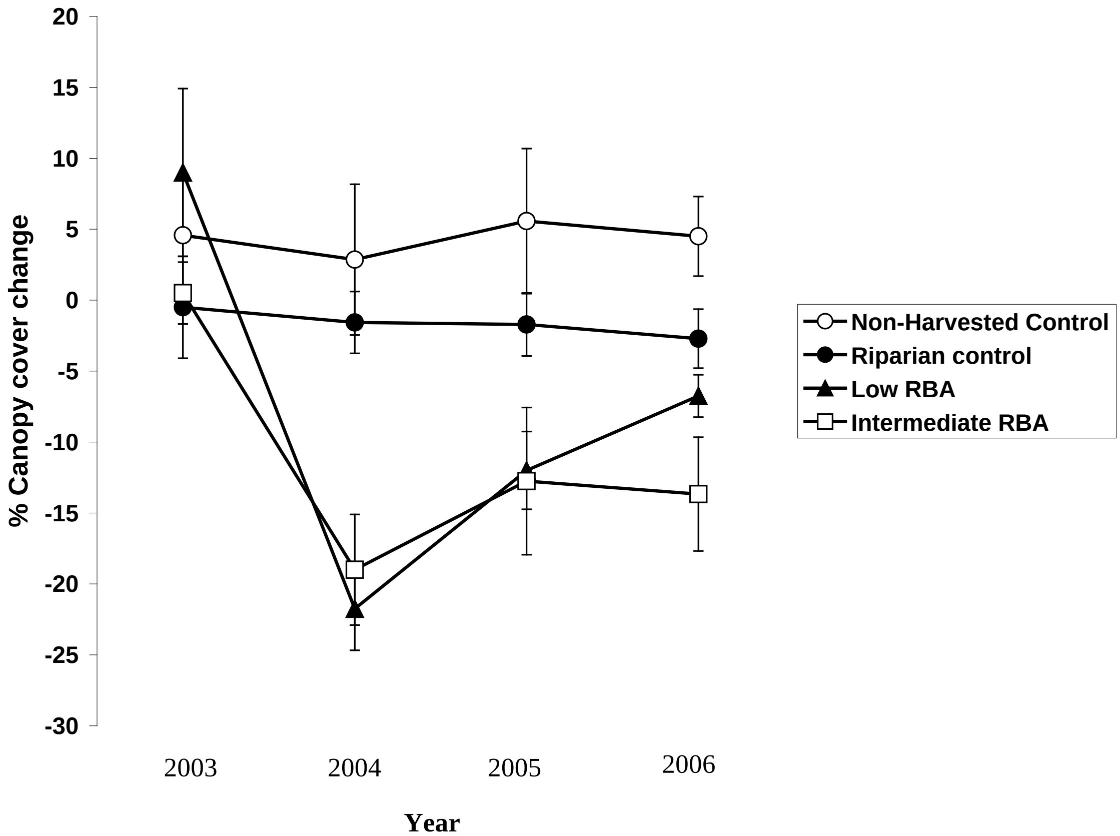

Figure 1. Mean change in percentage canopy cover at within reaches of the low and intermediate residual basal area (RBA) treatments by year. The change in canopy cover was calculated by subtracting upstream values from within-plot values. Nonharvested control and riparian control had eight replicates whereas low and intermediate RBA had four replicates each. Error bars are one standard error.

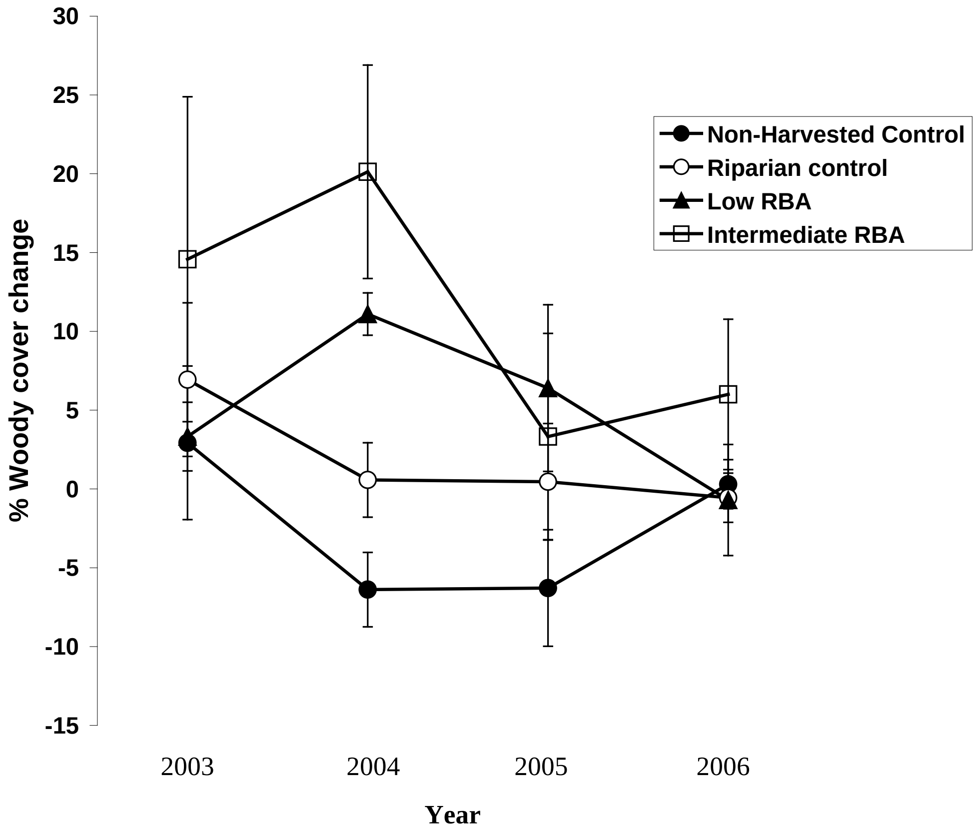

Figure 2. Mean change in percentage woody cover at within reaches of the low and intermediate residual basal area (RBA) treatments by year. The change in woody cover was calculated by subtracting upstream values from within-plot values. Non-harvested control and riparian control had eight replicates whereas the low and intermediate RBA had four replicates each. Error bars are one standard error.

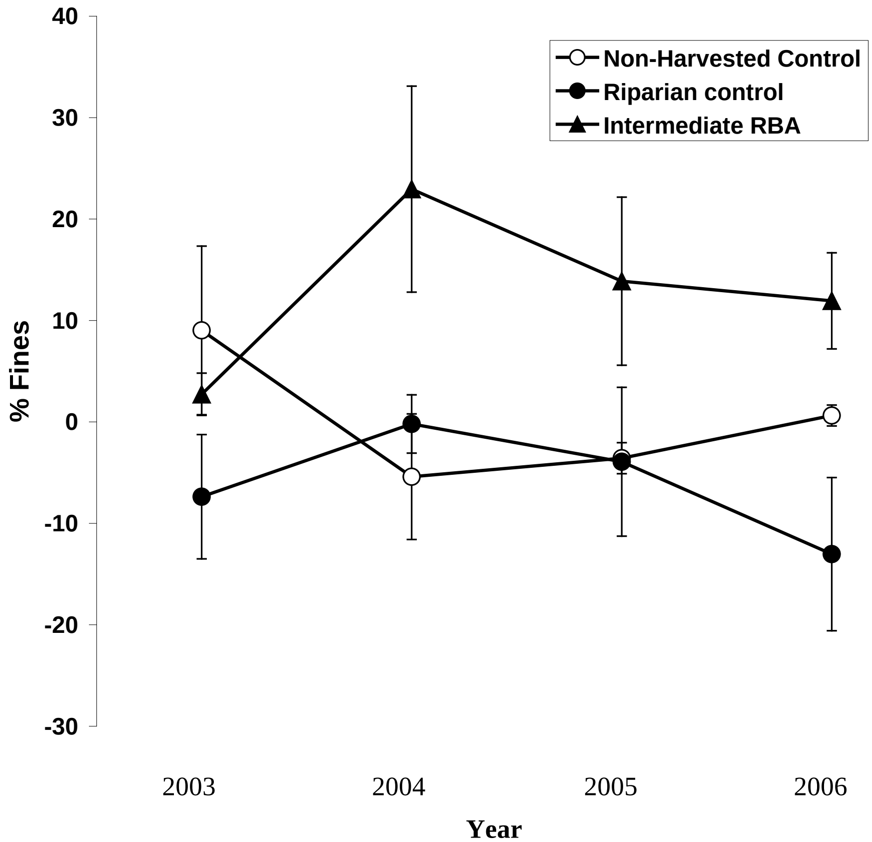

Figure 3. Mean change in percentage fine sediment at below reaches of the intermediate residual basal area (RBA) treatment across years. The change in fine sediment was calculated by subtracting upstream values from below-plot values. Error bars are one standard error.

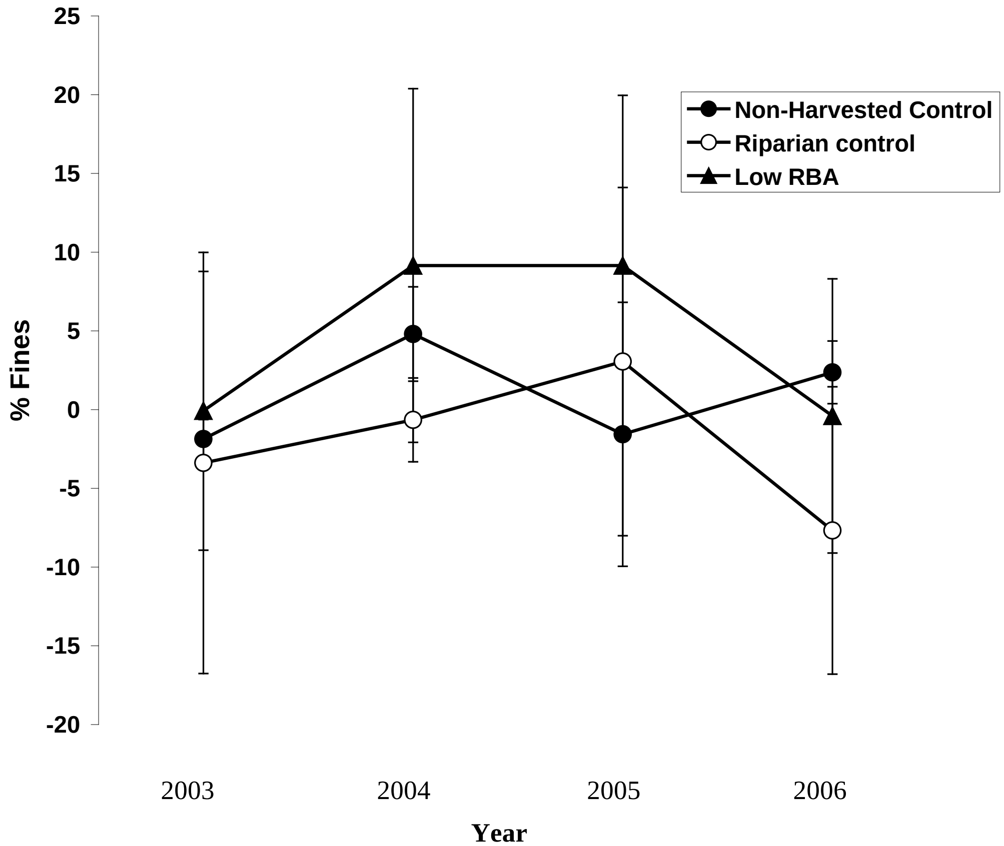

Figure 4. Mean change in percentage fine sediment at below reaches of the low residual basal area (RBA) treatment across years. The change in fine sediment was calculated by subtracting upstream values from below-plot values. Error bars are one standard error.

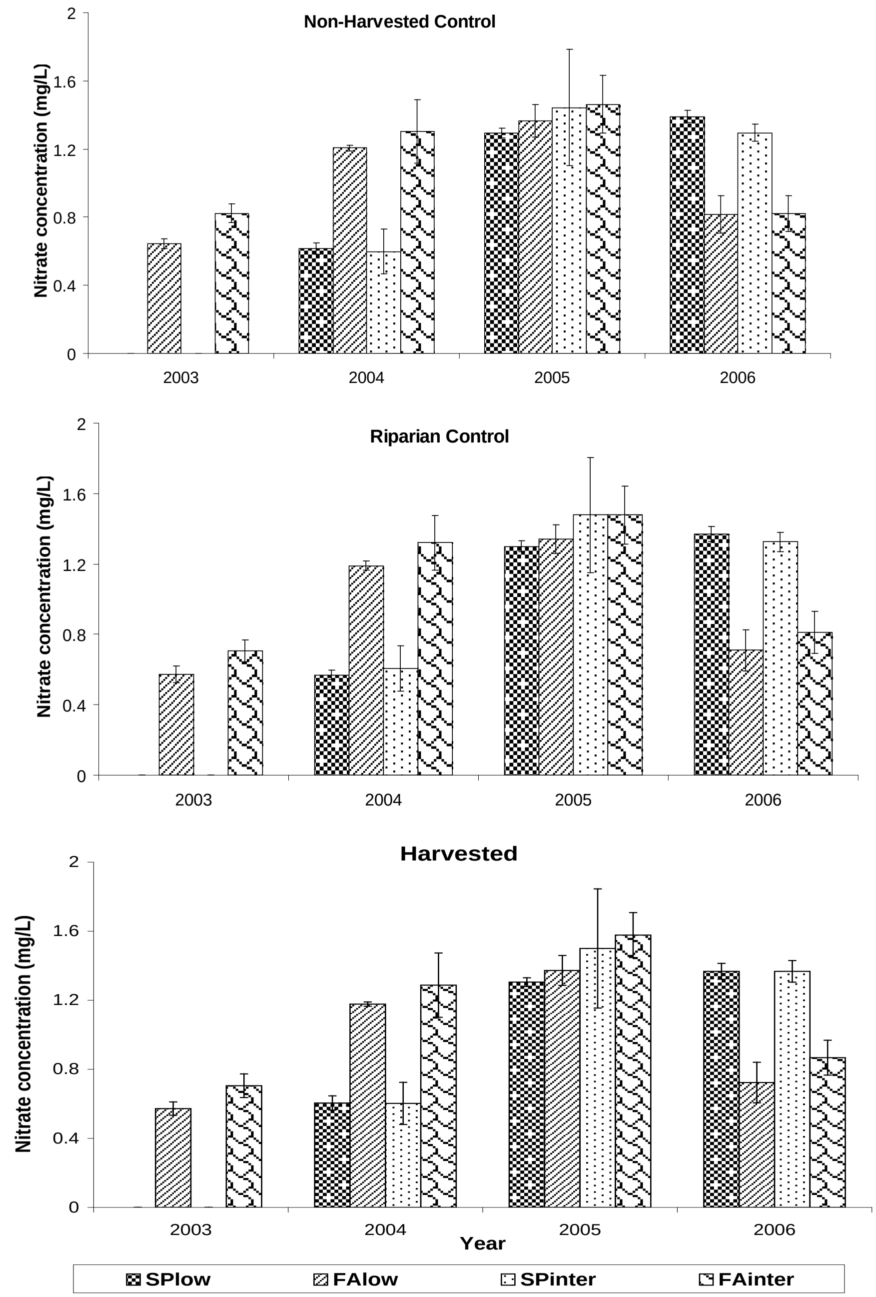

Figure 5. Mean (± 1 SE) seasonal concentration of nitrate (mg/L) in the nonharvested control, riparian control, and harvested reaches of the low and intermediate residual basal area treatment streams. The harvest occurred in the winter of 2003. SPlow = spring low; FAlow = fall low; SPinter = spring intermediate; and FAinter = fall intermediate.

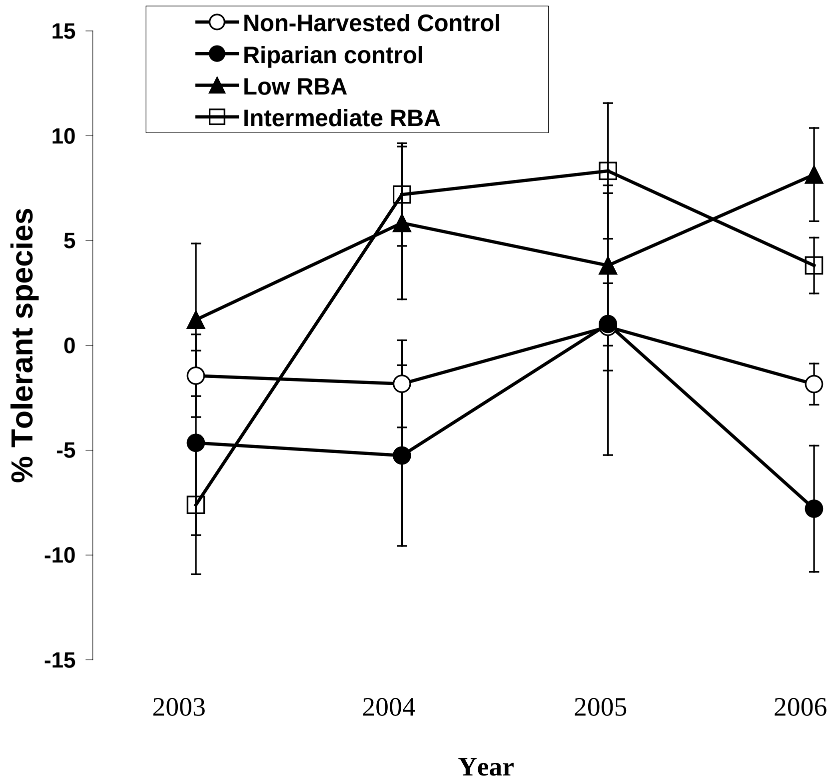

Figure 6. Mean change in proportion of tolerant fish species at within reaches of the low and intermediate residual basal area (RBA) treatments by year. The change in proportion of tolerant species was calculated by subtracting upstream values from within- and below-plot values respectively. Error bars are one standard error.

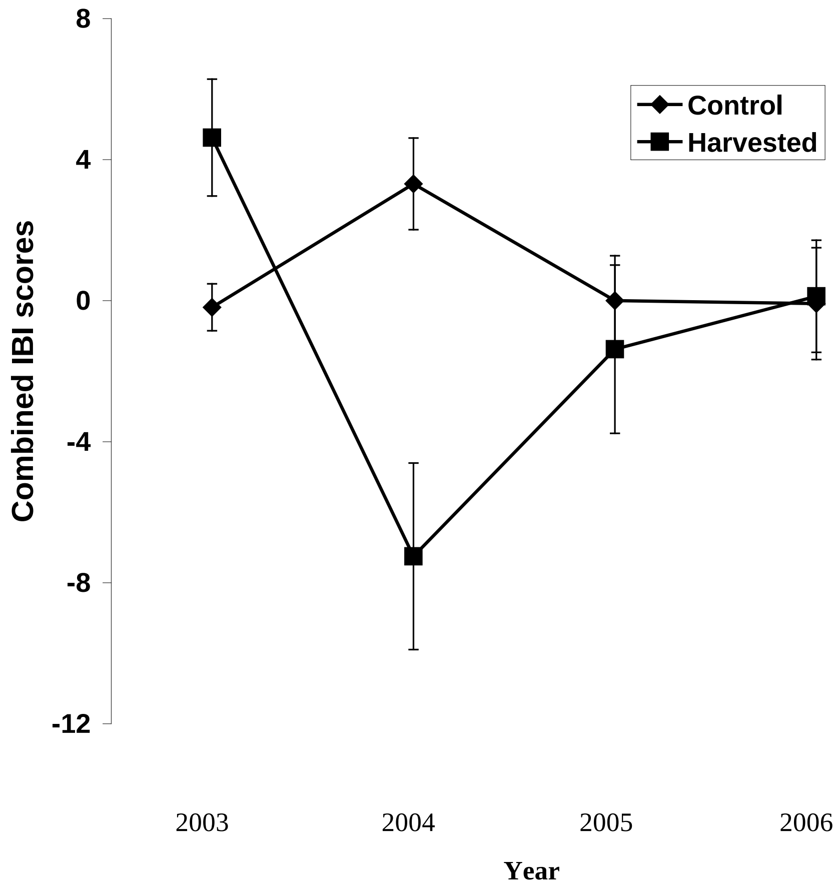

Figure 7. Mean change in combined Index of Biotic Integrity (IBI) scores at within reaches of the low and intermediate residual basal area treatments by year. The change in combined IBI scores was calculated by subtracting upstream values from within- and below-plot values respectively. Control plots had sixteen replicates, whereas harvested plots had eight replicates. Error bars are one standard error.

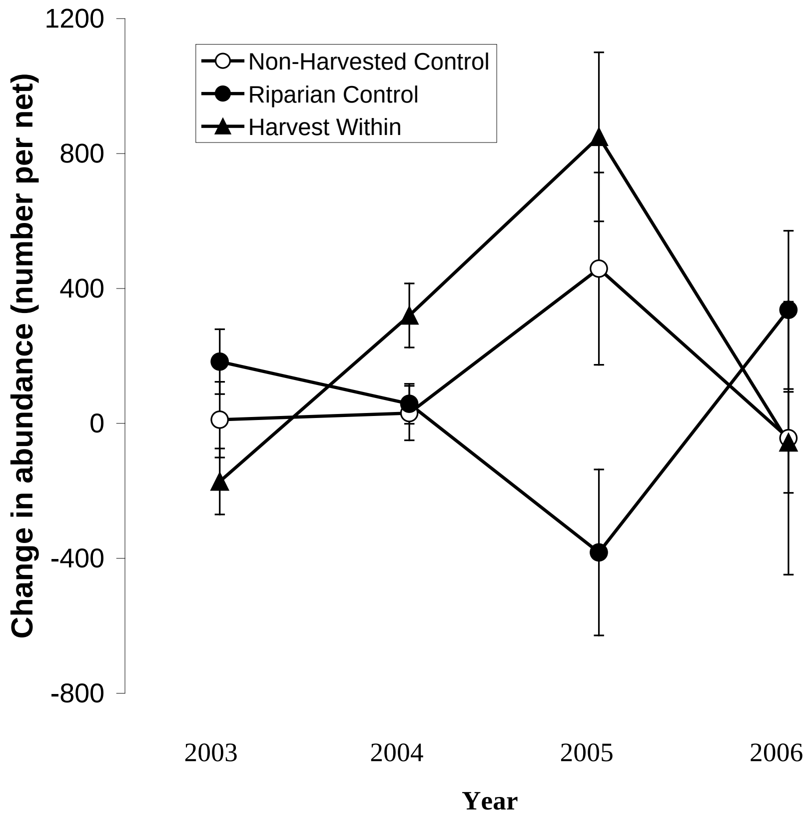

Figure 8. Mean (± 1 SE) change in insect abundance in the within-harvest reaches of streams with the intermediate residual basal area treatment.

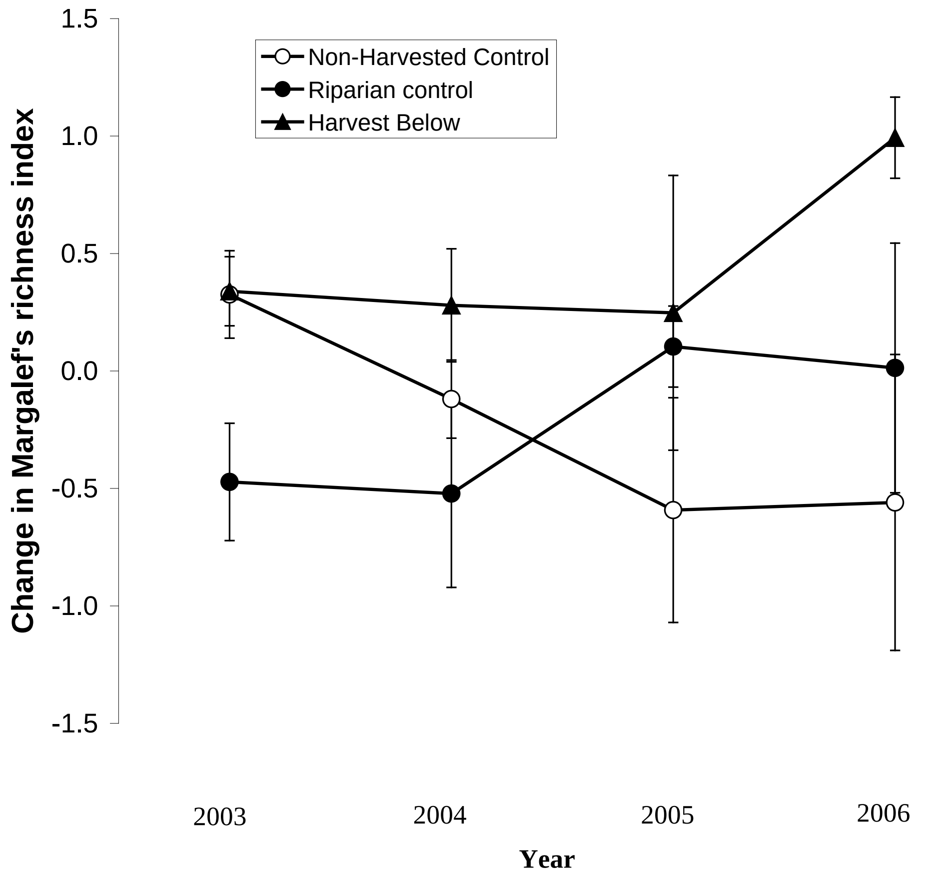

Figure 9. Mean (± 1 SE) change in Margalef's richness index in the below harvest reach of streams with the intermediate residual basal area treatment.

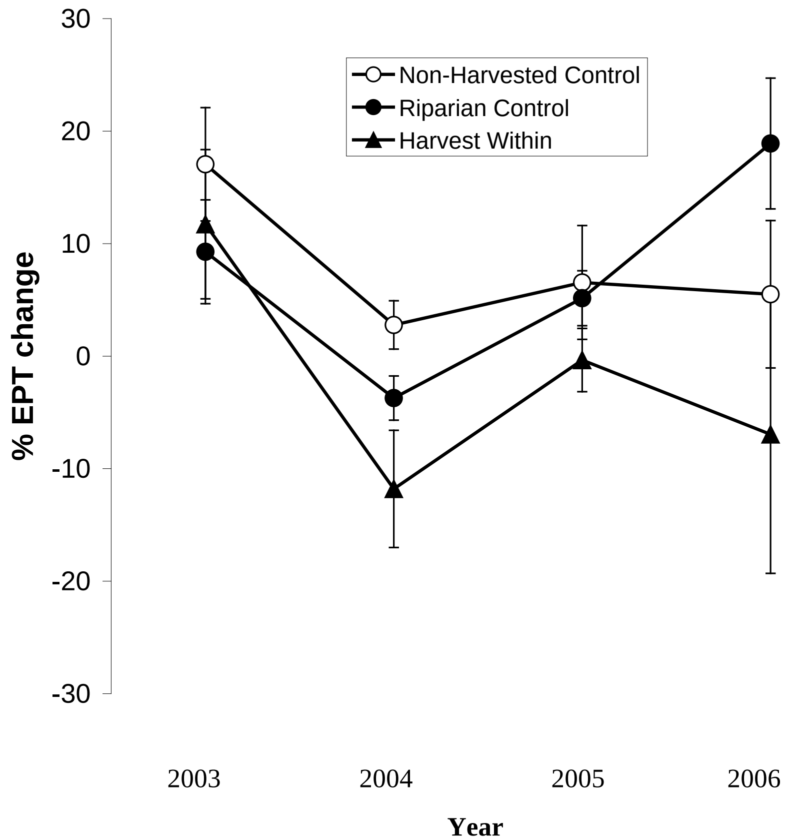

Figure 10. Mean (± 1 SE) change in %EPT (Ephemeroptera, Plecoptera, and Trichoptera) in the within-harvest reaches of streams with the intermediate residual basal area treatment.

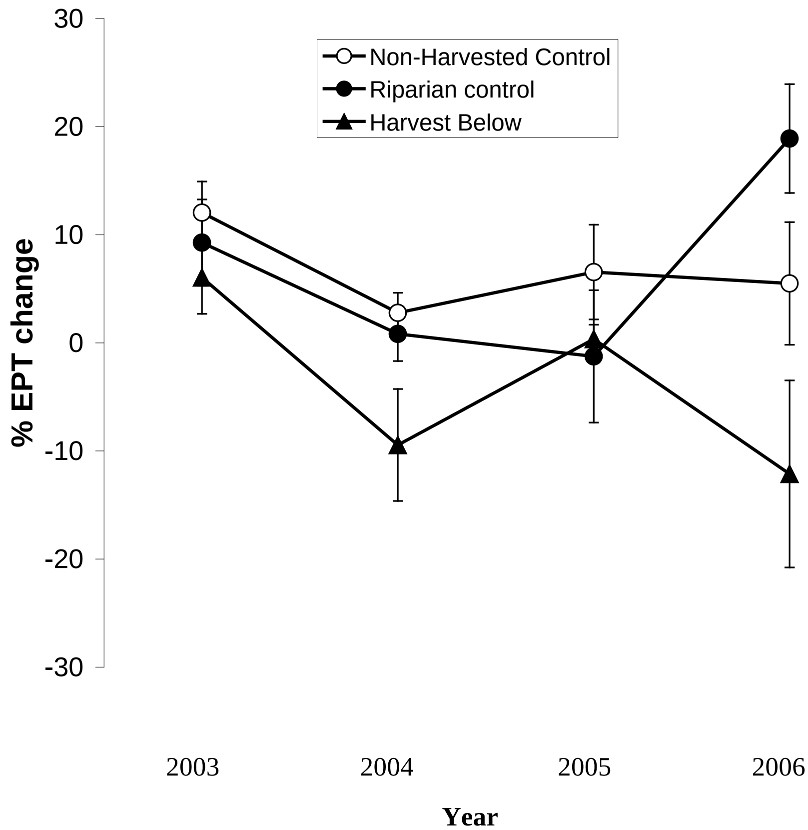

Figure 11. Mean (± 1 SE) change in %EPT (Ephemeroptera, Plecoptera, and Trichoptera) in the below harvest reaches of streams with the intermediate residual basal area treatment.

Result 3: Evaluate wildlife impacts

Description: We will evaluate the effects of our treatments on breeding birds in northern Minnesota. Breeding bird response to habitat elements such as conifers, snags, long-lived tree species and mast-producing trees and shrubs will also be evaluated. We will evaluate these response variables in 2005 and 2006.

Summary Budget Information for Result 3:	**LCMR Budget**	**$50,000**
	Balance	**$ 0**

Completion Date: June 2008

Final Report Summary:

Introduction

Thirty-seven percent of commercial forests in northern Minnesota are within 30 meters of a body of water, including rivers and streams (Hanowski et al. 2001). The objective of this study was to examine the population response of forest birds to riparian harvest in Northern Minnesota and to assess the effectiveness of Minnesota's riparian guidelines. More specifically, this study was developed to examine bird community response to various levels of residual tree basal area left in harvested riparian management zones.

Methods

Before- and after-harvest data on breeding birds were collected using standardized methods in seven riparian study areas in northern Minnesota during 2003 (pre-harvest) and 2004-2006 (post-harvest). One transect was established on both the treatment and control riparian management zone plots running parallel to the stream, and centered midway between the stream and the adjacent upland clearcut edge. Bird surveys were conducted at each site once during each of the three breeding season months (May-June-July) within 4 hours of sunrise during favorable weather conditions (no rain, and winds <20 kph). Breeding birds were sampled using standard point counts along transects within the RMZs (Hanowski et al. 1990). Only those birds detected within the RMZ were recorded and analyzed. Surveys were completed by experienced observers who passed both a bird identification test and hearing test, and received training to standardize counts (Hanowski and Niemi 1995).

To understand the effects of riparian harvest on the bird community, individual bird species as well as bird habitat associations were utilized and compared among study sites and years since harvest. Treatment RMZs were placed into one of two categories based on the percent removal of tree basal area from pre-harvest measurements: INT sites had < 40% removal of tree basal area and LOW sites had > 40% removal of tree basal area. Bird species and habitat association are listed in Appendix 1. We examined bird abundance, bird diversity and species richness using a before-after control-impact (BACI) approach. We modeled the dependent variable using a reduced maximum likelihood (REML) approach in Proc MIXED using SAS (version 9.1) statistical software. Proc MIXED was used because it permits explicit modeling of temporal autocorrelation in time series using a one-step autoregressive model (AR(1)); Year was the repeated-measures factor and Site(TRT) was the subject. The model contained treatment level (TRT; control, INT = < 40% removal of Tree basal area, LOW = > 40% removal of tree basal area) that was nested within Site, Year (YEAR; 2003 = before, 2004 = 1 year after; 2005= 2 years after; and 2006 = 3 years after), and a treatment level and year interaction (TRT*YEAR). Site was treated as a random variable. If significant differences were found for treatment and year, group-wise differences in least square means were assessed a posteriori. The interaction term was critical for testing the hypothesis that forest harvesting levels caused a persistent change in our dependent variables. We did not adjust significance levels using sequential Bonferroni corrections because of the numerous issues identified with the correction on ecological data (Moran, 2003). Thus, statistical significance was assessed at $p \leq 0.05$.

Results

Bird community composition

A total of 65 species were identified in this study (Appendix 1), with 56 identified in the control sites and 56 in the treatment sites. All species occurred in the control and treatment sites except American Woodcock (*Scolopax minor*), Baltimore Oriole (*Icterus galbula*), Barred Owl (*Strix varia*), Common Merganser (*Mergus merganser*), Mallard (*Anas platyrhynchos*), Northern Waterthrush (*Seiurus noveboracensis*), Pine Warbler (*Dendroica pinus*), and Pileated Woodpecker (*Dryocopus pileatus*) that occurred only in control sites. Belted Kingfisher (*Ceryle alcyon*), Chipping Sparrow (*Spizella passerine*), Common Grackle (*Quiscalus quiscula*), Evening Grosbeak (*Coccothraustes vespertinus*), Golden-winged Warbler (*Vermivora chrysoptera*), Orange-crowned Warbler (*Vermivora celata*), Sharp-shinned Hawk (*Accipiter striatus*), Yellow-throated Vireo (*Vireo flavifrons*) occurred only in the treatment sites.

Bird community composition following forest timber harvest

Before harvest, study sites were dominated by mature forest associated species (Ovenbird, Red-eyed Vireo, Least Flycatcher, Veery, Black-throated Green Warbler) (Table 1). The Ovenbird accounted for 16% of the total bird abundance during the pre-harvest year. After harvest, Ovenbirds ranked second highest in abundance (12% of abundance) on control sites behind Red-eyed Vireos (13%). In contrast, Ovenbirds accounted for only 1% of the total abundance on INT sites and 3% of total abundance on LOW sites after harvest. Red-eyed Vireos also decreased in abundance on treatments sites and accounted for only 7% and 4% of the total abundance on INT and LOW sites respectively. The most abundant species found in the treatment sites was the White-throated Sparrow (*Zonotrichia albicollis*), which accounted for 13% and 21% of the total abundance on INT and LOW sites, respectively. In contrast, the White-throated Sparrow was the third most abundant species in control sites (8% of total) and accounted for <1% of the total bird abundance on the sites pre-harvest. Further examination of control and treatment sites by harvest year showed distinct shifts in bird species rank abundance and proportion through time (Figures 2-4). At control RMZ sites, the proportion of mature forest species such as the Ovenbird and Red-eyed Vireo remained high throughout the study period. However at INT and LOW sites, Ovenbird rank abundance fell well below 10% of the population immediately following harvest and remained low throughout the study. Early successional species such as the White-throated Sparrow, Chestnut-sided Warbler, and Mourning Warbler made up the majority of the population in all years post-harvest on LOW sites (> 40% tree basal area removal). At INT sites (< 40% tree basal area removal), White-throated Sparrows slowly moved up in rank abundance in succeeding years post-harvest. Although this early successional species showed high abundance in INT sites post-harvest, mature forest species such as the Red-eyed Vireo, Least Flycatcher, and Black-capped Chickadee maintained high proportions post-harvest.

Species richness and diversity

Mean bird species richness ranged from 10.0 to 11.2 species in the control RMZs, from 7.7 to 11.3 in the in the < 40% reduction in basal area treatment RMZs (INT sites), and from 10.25 to 11.75 in the > 40% reduction in basal area treatment RMZs (LOW sites). Mean species richness did not significantly differ among treatment sites ($F_{2,38} = 0.39$, $p = 0.6830$) or among years ($F_{3,38} = 0.96$, $p = 0.4207$). Following similar trends with species richness, the control and LOW sites had greater peak diversity than the INT sites, but mean diversity did not significantly differ among these treatments ($F_{2,38} = 0.39$, $p = 0.6830$) or among years ($F_{3,38} = 1.09$, $p = 0.3652$).

Bird abundance

Mean log transformed bird abundance significantly varied among treatments ($F_{2,37} = 4.23$, $p = 0.0222$) and years ($F_{2,37} = 5.22$, $p = 0.0042$) but not significantly treatment and year interaction ($F_{6,37} = 2.23$, $p = 0.0621$). During the pre-harvest year, log-transformed bird abundances were statistically similar among all treatments and control sites. At one year post-harvest, there were no significant differences between control and INT sites (T value 1.93, df = 37, $p = 0.062$). However, there were significant mean log-transformed bird abundance differences between the control and LOW sites ((T value 2.96, df = 37, $p = 0.005$), Table 2). At two years post-harvest bird abundance at the control sites was not significantly different from the LOW sites or the INT sites (T value 1.92, df = 37, $p = 0.063$, T value 1.14, df = 37, $p = 0.2628$ respectively). Three years post-harvest the INT sites were significantly different (T value 2.91, df = 37, $p = 0.0061$) from the control treatment but the LOW sites were not (T value 0.43, df = 37, $p = 0.6678$). There were no significant differences among INT and LOW sites until 2006 when bird abundances were significantly less in the INT sites than the LOW sites.

Discussion and Conclusions

This study coincides with several other regional studies to investigate effects of Minnesota's forest harvesting guidelines in riparian management zones on bird communities (Hanowski et al. 2002, 2003, 2005, 2007). The specific design of this study differed from past studies in that it assessed the role of varying residual basal area in the RMZ at mitigating impacts on the bird communities. Despite the differences in objectives of this study with prior studies, the overall results of this study are consistent with the previous studies.

Although bird species richness and diversity did not differ in RMZs between sites or over time, the total abundance of birds present did change temporally in the RMZs. In relation to the control treatments, the harvested treatments had lower abundance three years post-harvest but the two harvest treatments did not differ from each other. A likely explanation for the change in abundance but not change in diversity or richness is likely the replacement of the mature forest species by the early successional bird species. This change in bird community type was reflected in all sites and all treatments, including control treatments, following harvest. After harvest, two early successional species, White-throated Sparrows and Chestnut-sided Warblers increased in abundance and quickly became the dominant species on all RMZs post-harvest, including the controls. The greatest change in abundance of these two species was observed in the treatments with the greatest decrease in basal area on the most heavily harvested RMZs. This bird community turnover is similar to other regional studies where early successional species inhabited unharvested areas adjacent to harvested areas (Hanowski et al. 2005, 2007). As previous studies have described, this turnover in the bird community would be expected with the forest community change following harvest and it is likely that the greater proportion of early successional will likely continue to occur in the harvested RMZs for many years to come.

Alternatively, mature forest species, such as the Ovenbird and Red-eyed Vireo, declined with harvest in the RMZs, yet continued to be abundant in the control RMZs after harvest. This result is also consistent with other regional studies (Hanowski et al. 2005) that observed similar responses of the mature forest species reaction to harvesting. The response of Ovenbirds, a high priority “watch list” species of northern Minnesota forests (Rich et al. 2004, Lind et al. 2006), indicates that retaining an unharvested riparian buffer may be critical in maintaining abundance of “priority species” populations following timber harvesting in northern Minnesota.

All RMZ study sites exhibited a similar bird species composition prior to harvest, a composition that reflected the large tree basal area indicative of a mature forest. After harvest, the bird species composition changed considerably in treatment RMZs, regardless of the degree of harvest applied. However, riparian control treatments experienced only a slight change in bird species composition one-year post-harvest and remained similar through time. A similar study by Hanowski et al. (2007) indicated that the bird composition in a harvested RMZ may take up to nine years post-harvest to return to post-harvest bird community composition. Our results suggest that the dominant bird species in the RMZ bird community composition change slightly in the unharvested treatments over the three years following timber harvest. There was an indication that there was an infiltration of early successional species such as the White-throated Sparrow and Chestnut-sided Warbler, slightly changing the bird community. The infiltration by early successional species in the unharvested treatments suggest that upland timber harvesting influenced composition in the unharvested RMZs, but the riparian control RMZ treatments maintained the mature forest bird species composition.

Overall, these results suggest that if the management goal is to maintain pre-harvest bird species composition in RMZs with a concurrent upland harvest, it is best to leave RMZs at their unharvested basal areas. However, doing so may result in increased blowdown of residual trees along the edge between the upland and RMZ. Where RMZ harvesting will occur, management approaches which retain as much of the mature forest as possible will have the greatest chance of mitigating substantial shifts in the bird community. Additionally, these results suggest that implementation of riparian guidelines need to be flexible and site-specific, population status and life history of bird species of conservation priority (e.g., Ovenbird) should be fully considered in riparian forest timber management, and management plans for riparian areas should be done on a landscape level to mitigate impact on bird communities. The results from this study only reflected the short-term (three years) dynamics following harvest in the RMZs. To fully understand the long-term consequences (i.e., minimum of nine years post-harvest as suggested in prior studies), further study will be necessary.

Unanticipated and Unresolved Problems

The procedures used to meet the objectives of this Result were adequate and sufficient. There are no unresolved problems relative to this Result at present. All work has been completed as planned.

Budget Shifts

While all Result funds were expended, additional monies were needed to finish analyzing data. To cover that additional expenditure, funds were not spent from other budget categories for the following reasons: 1) no additional field supplies were required, 2) travel involved fewer days and less mileage than estimated, and 3) a University vehicle was available eliminating the need to rent/lease a vehicle. A summary of the changes is presented below.

Budget item	Approved budget ($)	Revised budget ($)
Personnel	36,516	40,908.07
Lab/field supplies	500	458.43
Travel expenses in MN	8,984	7,558.16
Short-term rent/lease (vehicle and ATV)	2,924.66	0
Total of listed items	48,924.66	48,924.66

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Wegner, S. 1999. A review of the scientific literature on riparian buffer width, extent and vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia, Athens, GA.

Table 1. Proportion (prop) of individual bird species pre-harvest and at post-harvest control and treatment (INT and LOW) sites. Bird species codes: AMRE = American Redstart, BCCH = Black-capped Chickadee, BTNW = Black-throated Green Warbler, CSWA = Chestnut-sided Warbler, LEFL = Least Flycatcher, MOWA = Mourning Warbler, OVEN = Ovenbird, REVI = Red-eyed Vireo, VEER = Veery, WTSP = White-throated Sparrow, YBSA = Yellow-bellied Sapsucker.

Pre-harvest		Control		INT sites		LOW sites	
Species	Proportion	Species	Proportion	Species	Proportion	Species	Proportion
OVEN	0.16	REVI	0.13	WTSP	0.13	WTSP	0.21
REVI	0.13	OVEN	0.12	BCCH	0.11	CSWA	0.07
LEFL	0.11	WTSP	0.08	LEFL	0.07	LEFL	0.07
VEER	0.06	LEFL	0.06	REVI	0.07	YBSA	0.05
BTNW	0.05	CSWA	0.05	AMRE	0.07	MOWA	0.05

Table 2. Generalized least-squares (GLS) means (ln[n+1]) and effect sizes from pairwise comparisons of BACI hypotheses for bird abundances.

Treatment	2003	2004	2005	2006
Control (CN)	2.61(0.22)	2.57(0.22)	2.39(0.22)	2.51(0.22)
Treatment 1 (INT)	2.54(0.30)	1.99(0.30)	1.75(0.34)	1.63(0.30)
Treatment 2 (LOW)	2.65(0.27)	1.77 (0.27)	2.09(0.27)	2.40 (0.27)
Effect size (CN –INT)	0.07(0.30)	0.58 (0.30)*	0.65(0.34)*	0.88(0.30)**
Effect size (CN –LOW)	-0.03(0.27)	0.80(0.27)**	0.31(0.27)	0.12(0.27)
Effect size (INT – LOW)	-0.10(0.36)	0.22(0.36)	-0.34 (0.39)	-0.76 (0.36)**

* Indicates statistically significant effects at $p < 0.10$ and ** indicates $p < 0.05$.

Figure 1a-d. Bird species rank abundance reaction at Control RMZ sites pre-harvest (a), post-harvest year one (b), year two (c), and year three (d). Bird species codes appear in Appendix 1.

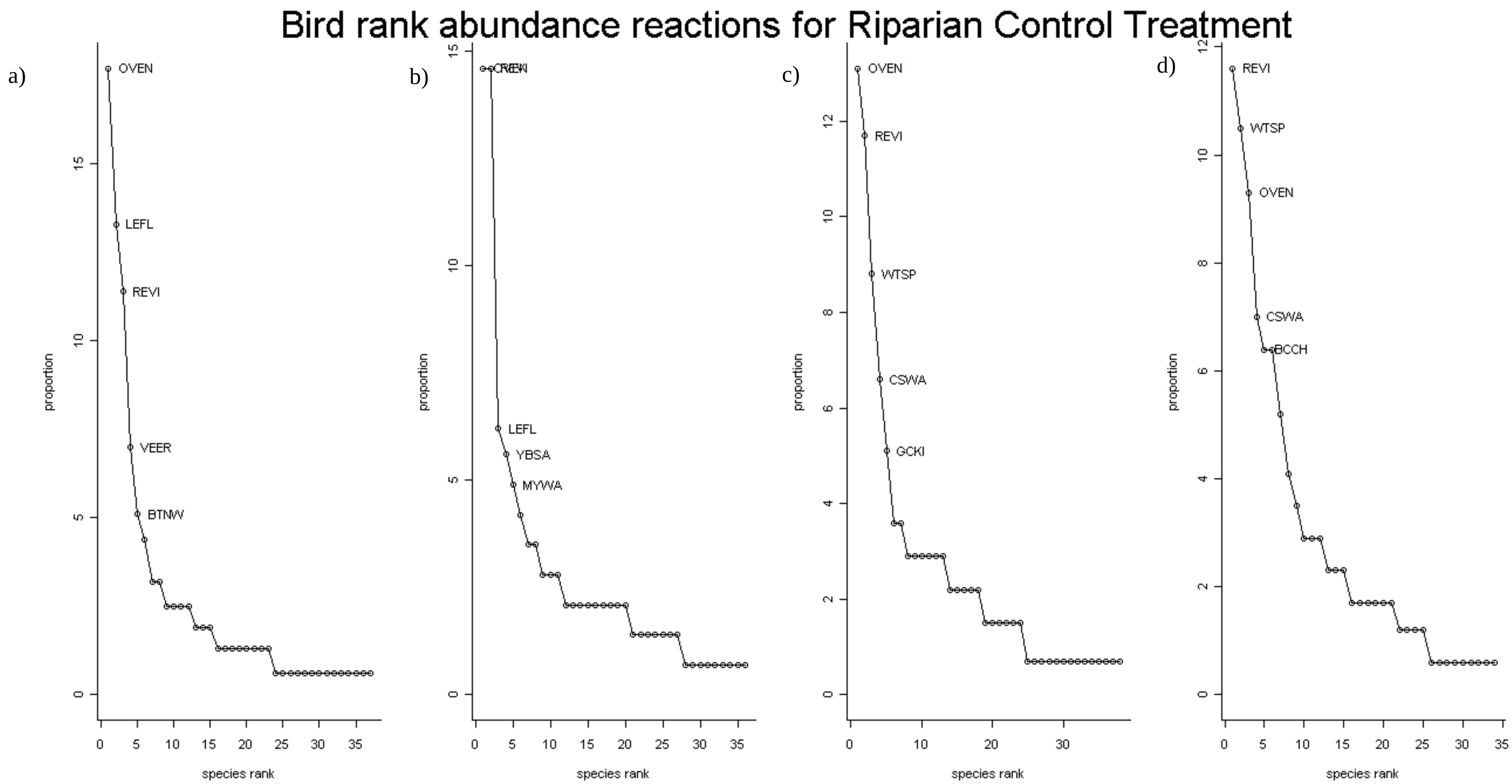


Figure 2a-d. Bird species rank abundance reaction at INT (<40% removal of tree basal area) RMZ sites pre-harvest (a), post-harvest year one (b), year two (c), and year three (d). Bird species codes appear in Appendix 1.

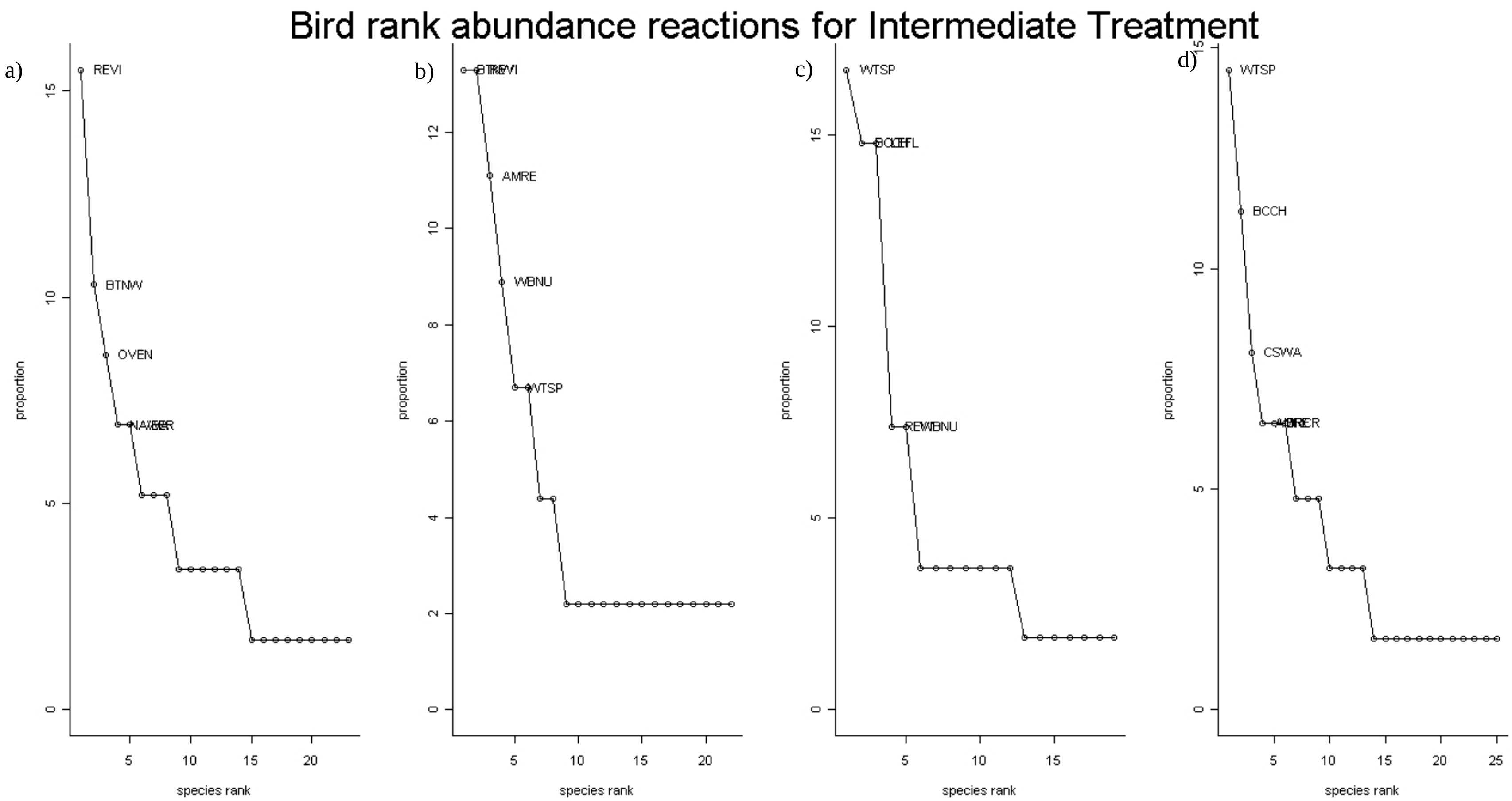
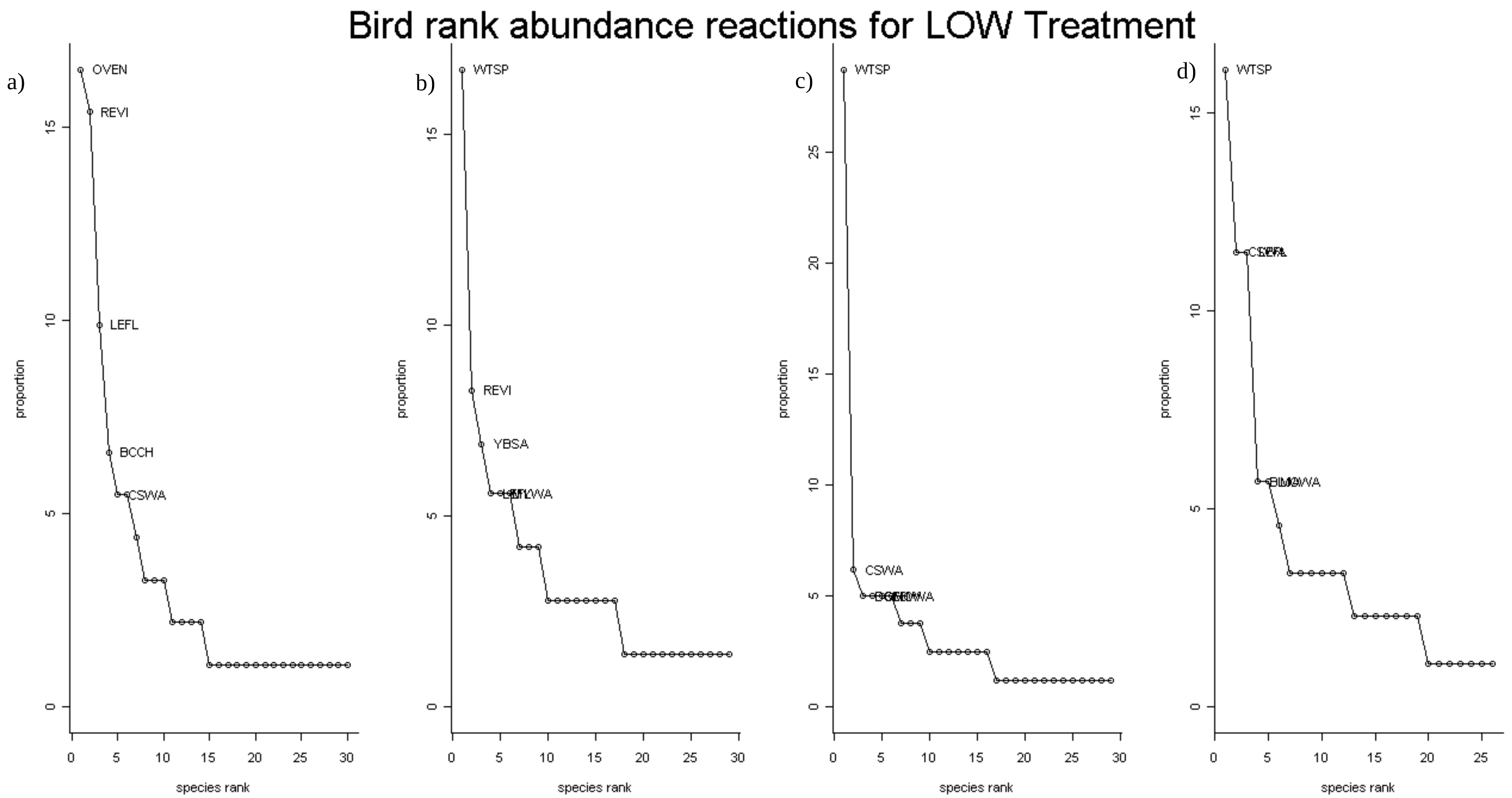


Figure 3a-d. Bird species rank abundance reaction at INT (<40% removal of tree basal area) RMZ sites pre-harvest (a), post-harvest year one (b), year two (c), and year three (d). Bird species codes appear in Appendix 1.



Appendix 1a. English and taxonomic bird species names and guild associations for species recorded at study sites. Guild associations are taken from Lind et al. (2006). Habitat Guild: ES = Early Successional, FLME = Fields and Meadows, MAT = Mature, URBN = Urban.

English Name	Taxonomic Name	Code	Habitat
Alder Flycatcher	*Empidonax alnorum*	ALFL	ES
American Crow	*Corvus brachyrhynchos*	AMCR	MAT
American Goldfinch	*Carduelis tristis*	AMGO	FLME
American Redstart	*Setophaga ruticilla*	AMRE	ES
American Robin	*Turdus migratorius*	AMRO	FLME
American Woodcock	*Scolopax minor*	AMWO	MAT
Baltimore Oriole	*Icteris galbula*	BAOR	MAT
Black-and-white Warbler	*Mniotilta varia*	BAWW	MAT
Black-capped Chickadee	*Poecile atricapillus*	BCCH	MAT
Barred Owl	*Strix varia*	BDOW	MAT
Belted Kingfisher	*Ceryle alcyon*	BEKI	MAT
Brown-headed Cowbird	*Molothrus ater*	BHCO	MAT
Blue-headed Vireo	*Vireo solitarius*	BHVI	MAT
Blackburnian Warbler	*Dendroica fusca*	BLBW	MAT
Blue Jay	*Cyanocitta cristata*	BLJA	MAT
Brown Creeper	*Certhia americana*	BRCR	MAT
Black-throated Green Warbler	*Dendroica virens*	BTNW	MAT
Broad-winged Hawk	*Buteo platypterus*	BWHA	FL_MDS
Canada Warbler	*Wilsonia canadensis*	CAWA	MAT
Cedar Waxwing	*Bombycilla cedrorum*	CEDW	PLST
Chipping Sparrow	*Spizella passerina*	CHSP	ES
Common Grackle	*Quiscalus quiscula*	COGR	MAT
Common Merganser	*Mergus merganser*	COME	MAT
Common Yellowthroat	*Geothlypis trichas*	COYE	MAT
Chestnut-sided Warbler	*Dendroica pensylvanica*	CSWA	SBSW
Downy Woodpecker	*Picoides pubescens*	DOWO	MAT
Eastern Phoebe	*Sayornis phoebe*	EAPH	URBN
Eastern Wood-pewee	*Contopus virens*	EAWP	MAT
Evening Grosbeak	*Coccothraustes vespertinis*	EVGR	MAT
Great Crested Flycatcher	*Myiarchus crinitus*	GCFL	MAT
Golden-crowned Kinglet	*Regulus satrapa*	GCKI	ES
Golden-winged Warbler	*Vermivora crysoptera*	GWWA	MAT
Hairy Woodpecker	*Picoides villosus*	HAWO	MAT
Hermit Thrush	*Catharus guttatus*	HETH	MAT
Indigo Bunting	*Passerina cyanea*	INBU	FLME

Appendix 1b. English and taxonomic bird species names and guild associations for species recorded at study sites. Guild associations are taken from Lind et al. (2006). Habitat Guild: ES = Early Successional, FLME = Fields and Meadows, MAT = Mature, URBN = Urban.

English Name	**Taxonomic Name**	**Code**	**Habitat**
Least Flycatcher	*Empidonax minimus*	LEFL	MAT
Mallard	*Anas platyrhynchos*	MALL	MAT
Magnolia Warbler	*Dendroica magnolia*	MAWA	MAT
Mourning Warbler	*Oporornis philadelphi*	MOWA	ES
Nashville Warbler	*Vermivora ruficapilla*	NAWA	MAT
Northern Parula	*Parula americana*	NOPA	MAT
Northern Waterthrush	*Seiurus noveboracensis*	NOWA	MAT
Orange-crowned Warbler	*Vermivora celata*	OCWA	MAT
Ovenbird	*Seiurus aurocapilla*	OVEN	MAT
Pine Warbler	*Dendroica pinus*	PIWA	MAT
Pileated Woodpecker	*Dryocopus pileatus*	PIWO	MAT
Purple Finch	*Carpodacus purpureus*	PUFI	MAT
Rose-breasted Grosbeak	*Pheuctuicus ludovicia*	RBGR	MAT
Red-breasted Nuthatch	*Sitta canadensis*	RBNU	MAT
Ruby-crowned Kinglet	*Regulus calendula*	RCKI	MAT
Red-eyed Vireo	*Vireo olivaceus*	REVI	MAT
Ruby-throated Hummingbird	*Archilochus colubris*	RTHU	MAT
Scarlet Tanager	*Piranga olivacea*	SCTA	MAT
Song Sparrow	*Melospiza melodia*	SOSP	FLME
Sharp-shinned Hawk	*Accipiter striatus*	SSHA	MAT
Swainson's Thrush	*Catharus ustulatus*	SWTH	MAT
Veery	*Catharus fuscescens*	VEER	MAT
White-breasted Nuthatch	*Sitta carolinensis*	WBNU	MAT
Winter Wren	*Troglodytes troglodytes*	WIWR	ES
Palm Warbler	*Dendroica palmarum*	WPWA	MAT
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	MAT
Yellow-bellied Flycatcher	*Emipdonax flaviventris*	YBFL	MAT
Yellow-bellied Sapsucker	*Sphyrapicus varius*	YBSA	MAT
Yellow-rumped Warbler	*Dendroica coronata*	YRWA	MAT
Yellow-throated Vireo	*Vireo flavifrons*	YTVI	MAT

V. TOTAL LCMR PROJECT BUDGET:

All Results: Personnel: $310,883
All Results: Equipment: $0
All Results: Development: $0
All Results: Acquisition: $0
All Results: Other: $22,117 Photocopying ($260), miscellaneous lab/field supplies (including flagging, paint, binoculars, tree tags, notebooks, ethanol, sampling bottles, sampling nets, chemicals for water quality assessment, replacement temperature loggers, and batteries – $3,261), courier and mailing services for equipment repair and maintenance ($32), travel expenses in Minnesota ($16,438), repair and maintenance of sampling meters ($563), short-term rent lease of vehicle and ATV ($1,563).

TOTAL LCMR PROJECT BUDGET: $333,000

Explanation of Capital Expenditures Greater Than $3,500: N/A

VI. OTHER FUNDS & PARTNERS:

A. Project Partners: Project team members from the University of Minnesota and US Geological Survey (USGS) who contributed time and effort to the project are JoAnn Hanowski and Jerry Niemi (received $50,000 from the request); Ray Newman and Bruce Vondracek (USGS) (received $97,673 from the request); and Charlie Blinn (received $75,132 from the request). Brian Palik and Randy Kolka (received $110,195 from the request through a subcontract with University of Minnesota) from the USDA Forest Service contributed $75,000 worth of time and effort to the project and $70,000 to partially fund a graduate research assistant. The Minnesota Department of Natural Resources, St. Louis County Land Department, and Lake County Land Department, cooperated by providing their lands for study treatments.

B. Other Funds being Spent during the Project Period: The USDA Forest Service provided $75,000 of in-kind support and $70,000 cash during the project.

C. Required Match (if applicable):

D. Past Spending: The LCMR provided $200,000 during the 2001 biennium to locate and establish treatment sites in eight watersheds, collect baseline data, implement harvest treatments, and collect 1-year post-harvest data. The USDA Forest Service provided $50,000 to partially fund two graduate research assistants. The University of Minnesota provided $5,000 to help support travel and other expenses. The Water Resources Center (USGS) provided $47,500 from May 2003-May 2005. Project partners used approximately $75,000 of in-kind monies to cover data collection and analysis from July 1, 2004 - June 30, 2005.

The Minnesota DNR provided $37,500 during 2004-2005.

E. Time: It is anticipated that the entire project will be completed in 2013. It is anticipated that Phase 2 will continue through 2011 with increasing focus on longer-term data collection, analysis, reporting, and dissemination of study results. Additional funds would be requested from LCMR in future biennia. Throughout the entire project, additional monies to support this research will be solicited from other sources. Results will provide information that is critical to ongoing revisions of the MFRC's riparian guidelines beginning in 2005 and continuing beyond.

VII. DISSEMINATION: A list of presentations and publications resulting from this funding is presented below.

Presentations

Atuke, D. M., R. M. Newman, and B. Vondracek. 2007. Evaluating the response of instream habitat, water quality and macroinvertebrate assemblages to riparian forest harvest in northern Minnesota. 55th North American Benthological Society Annual Meeting, Columbia, SC.

Atuke, D. M., R. M. Newman, B. Vondracek, and N. J. Schlesser. 2005. Effects of riparian forest harvest on instream habitat, water quality and macroinvertebrate communities in northern Minnesota. American Fisheries Society, Minnesota Chapter Annual Meeting, Grand Rapids, MN.

Atuke, D. M., N. J. Schlesser, B. Vondracek, and R. M. Newman. 2005. Variability in response of instream habitat, and fish and macroinvertebrate assemblages, to riparian forest harvest in northern Minnesota. 53rd North American Benthological Society, Annual Meeting. New Orleans, LA (Poster). [*Eos Transactions AGU, 86*(18), Joint Assembly Supplement, Abstract NB33M-01.]

Atuke, D. M., B. Vondracek, and R. M. Newman. 2005. Evaluating the effects of riparian forest harvest on macroinvertebrate communities and water quality in northern Minnesota. Minnesota Water 2005 and Annual Water Resources Joint Conference, Brooklyn Center, MN (Poster).

Atuke, D. M., B. Vondracek, and R. M. Newman. 2007. Evaluating effects of riparian forest harvest on instream habitat and fish assemblages in northern Minnesota. American Fisheries Society, Minnesota Chapter Annual Meeting, St. Cloud, MN.

Blinn, C. R., S. Eggert, D. Kastendick, N. Danz, and B. Vondracek. 2007. Evaluating riparian timber harvesting guidelines. 2007 Northeastern Forest Soils Conference, Silver Bay, MN.

Blinn, C. R., J. Lind, B. Vondracek, and E. Zenner. 2005. Overview of riparian effectiveness monitoring study. Legislative Commission on Minnesota Resources, Silver Bay, MN.

Haworth, B. 2007. Safe-sites for cedar – a riparian harvest study. Department of Forest Resources Seminar, St. Paul, MN.

Lind, J. 2006. Overview of the effects of forest management on bird use within the riparian management zone. Minnesota Natural Resources Conference. Brainerd, MN.

Martin, M. 2007. Understory plant and tree regeneration responses to different harvesting approaches in riparian areas nine years after treatment. 2007 North American Forest Ecology Workshop, Vancouver, British Columbia.

Martin, M. 2007. Understory plant responses to different harvesting approaches in riparian areas in Northern Hardwood forests. Society of American Forester's Annual Meeting, Portland, OR.

Olszewski, S. L. 2007. Structural and compositional changes in vegetation of forested riparian areas following a gradient of timber harvesting regimes. North American Forest Ecology Workshop, Vancouver, B.C.

Palik, B. 2007. Revisiting riparian areas in the Lake States: Long-term responses to different management scenarios. NCASI Northern Regional Meeting, Green Bay, WI.

Peterson, A. 2008. Effects of forest management on bird use within riparian buffers. 6th Forest and Wildlife Research Review. University of Minnesota Duluth, MN.

Steil, J. 2006. Riparian forest management. Woodlands as a Resource Conference. Minnesota Forestry Association, Collegeville, MN.

Steil, J., C. R. Blinn, and R. Kolka. 2006. Windthrow dynamics in northern Minnesota riparian management zones: Summary of forester perspectives. Sustainable Natural Resources Management: Defining our Legacy, Brainerd, MN.

Vondracek, B., D. M. Atuke, N. J. Schlesser, and R. M. Newman. 2006. Effects of riparian forest harvest on aquatic systems in northern Minnesota. 1st Minnesota Natural Resources Conference, Brainerd, MN.

Publications

Atuke, D. M. 2007. Effectiveness or riparian forestry best management practices to protect stream habitat and biota: lessons from temperate and tropical systems. Ph.D. Dissertation, University of Minnesota, St. Paul, Minnesota. 273 p.

Schlesser, N. J. 2007. Effects of riparian forest harvest on instream habitat and fish assemblages in northern Minnesota. M.S. Thesis, University of Minnesota, St. Paul, Minnesota. 81 p.

Steil J. 2007. Effects of timber harvesting on windthrow activity and coarse woody debris attributes in mixed conifer-deciduous riparian forests in northern Minnesota. MS Thesis, Department of Forest Resources, University of Minnesota. 219 p.

Publications in preparation

Atuke, D. M., N. J. Schlesser, B. Vondracek, and R. M. Newman. Evaluating the effect of riparian forest harvest on instream habitat and fish assemblages in northern Minnesota. Canadian Journal of Fisheries and Aquatic Sciences (In preparation).

Atuke, D. M., R. M. Newman, and B. Vondracek. Stream macroinvertebrate community responses to riparian forest harvest in low gradient northern Minnesota streams. Journal of the North American Benthological Society (In preparation).

Olszewski, S. L. Structural and compositional changes in the terrestrial vegetation of forested riparian areas as a result of a gradient of timber harvesting regimes. University of Minnesota. M.S. Thesis. (In preparation)

Steil, J. C., C. R. Blinn, and R. K. Kolka. Perceptions of windthrow dynamics in northern Minnesota streamside riparian management zones. Northern Journal of Applied Forestry (Submitted)

VIII. REPORTING REQUIREMENTS: Periodic workprogram progress reports were submitted in January 2006, July 2006, January 2007, July 2007, and January 2008. A final workprogram report and associated products was submitted on August 15, 2008.

IX. RESEARCH PROJECTS: N/A

Attachment A: Budget Detail for 2005 Projects

Proposal Title: *Evaluating Riparian Timber Harvesting Guidelines: Phase II (H-04)*

Project Manager Name: *Charles R. Blinn*

LCMR Requested Dollars: $*333,000*	**Result 1**			**Result 2**			**Result3**					
	Proposed Budget			**Proposed Budget**			**Proposed Budget**			**Proposed Budget**		
2005 LCMR Proposal Budget	**Result 1 Budget:**	**Amount Spent** *(6/08)*	**Balance** *(6/08)*	**Result 2 Budget:**	**Amount Spent** *(6/08)*	**Balance** *(6/08)*	**Result 3 Budget:**	**Amount Spent** *(3/08)*	**Balance** *(3/08)*	**Project Total**		
	Evaluate terrestrial impacts			*Evaluate aquatic habitat impacts*			*Evaulate wildlife impacts*					
BUDGET ITEM										**TOTAL FOR BUDGET ITEM**	**TOTAL AMOUNT SPENT**	**BALANCE TOTAL**
PERSONNEL: Staff Expenses, wages, salaries and fringe – *Personnel employed through University of Minnesota to collect, process, and report data*	$73,918.31	$72,966.45	$951.86	$85,861.24	$85,861.24	$0.00	$40,908.07	$40,908.07	$0.00	$200,688	$199,735.76	$951.86
Contracts												
Professional/technical *(University of Minnesota subcontract with US Forest Service to collect, process, and report data) (7901)*	110,195	110,195.00	0.00	0	0	0	0	0	0	$110,195	$110,195.00	$0.00
Printing	0	0	0	260.00	260.00	0.00	0	0	0	$260	$260.00	$0.00
Other Supplies *(list specific categories)*												
Lab/field supplies (7320)	725.65	725.65	0	2,077.11	2,077.11	0.00	458.43	458.43	0.00	$3,261	$3,261.19	$0.00
Courier and mailing services (7340)*	0	0	0	31.98	31.98	0.00	0	0	0	$32	$31.98	$0.00
Travel expenses in Minnesota (7600)	0	0	0	8,880.07	8,880.07	0.00	7,558.16	7,558.16	0.00	$16,438	$16,438.23	$0.00
Other *(Describe the activity and cost) be specific*												
Repair and maintenance (meters) (8020)	0	0	0	562.60	562.60	0.00	0	0	0	$563	$562.60	$0.00
Rent/lease (vehicle) (8030)	0	0	0	0	0	0	0.00	0	0.00	$0	$0.00	$0.00
Short-term rent/lease (vehicle and ATV) (8130)**	488.04	488.04	0	0	0	0	1,075.34	1,075.34	0.00	$1,563	$1,563.38	$0.00
COLUMN TOTAL	$185,327	$184,375.14	$951.86	$97,673.00	$97,673.00	$0.00	$50,000	$50,000.00	$0.00	$333,000	$332,048.14	$951.86

*Mailing for equipment repair/calibration.