2007 Project Abstract
For the Period Ending June 30, 2007

PROJECT TITLE: Evaluating Riparian Timber Harvesting Guidelines: Phase 3
PROJECT MANAGER: Charles R. Blinn
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: ML 2007, Chap. 30, Sec. 2, Subd. 5(f).

APPROPRIATION AMOUNT: $400,000

Overall Project Outcome and Results

This project continues research begun with M.L. 2001 and M.L. 2005 appropriations from the Environment and Natural Resources Trust Fund.

Research addressing the long-term effectiveness of riparian guidelines to mitigate harvesting impacts is critical to resolve management conflicts and sustain Minnesota's forest resources. This project:

1. Evaluated the long-term effectiveness of Minnesota's riparian timber harvesting guidelines within Pokegama Creek (single-basin study) and on eight separate basins located across northern Minnesota (multiple-basin study);
2. Began to combine and synthesize data from the various study components through a "meta-analysis";
3. Provided outreach information.

Terrestrial findings that can help guide future management of Minnesota's forests and streams include:

- Partially-harvested riparian management zone (RMZ) treatments resulted in fully-stocked stands, however, species composition differed among treatments;
- Northern white cedar and balsam fir seedlings survive and grow well in non-wet microsites with medium residual basal area; cedar seedlings require protection from deer browsing;
- Different treatments had minimal impact on the amount of organic matter input to streams;
- Residual tree blowdown was low, but future potential is still high.

Effects of riparian harvest on fish and fish habitat were assessed at the basin scale. Sediment levels remained above 1997 pre-harvest conditions until fall 2007. Riparian harvest may have contributed to increased stream temperatures, but fish abundances were negatively associated with differences in mean summer air temperature.

Aquatic findings that can help guide future management of Minnesota's forests and streams include:

- No differences in water chemistry between harvested and unharvested riparian reaches;

- Trends toward higher in-stream light levels and elevated periphyton standing crops within harvested riparian areas compared to control reaches;
- Trends toward a greater proportion of scraper invertebrates and fewer shredder invertebrates in harvested riparian reaches.

At the single-basin tributary sites, the majority of bird species present were associated with mature forest habitat pre-harvest. After harvest, early successional habitat associated species maintained dominance in all sites. The pre-harvest bird community was neither maintained nor able to reestablish on unharvested riparian buffers 9-11 years after harvest.

We observed interannual variation in diversity and species richness within the macroinvertebrate and fish communities, but few effects related to harvest treatments. Few changes in diversity and richness were observed in the bird community but changes were observed by the replacement of mature forest species by early successional avian species, related closely to the vegetation type.

There is a need to continue monitoring the sites to more fully assess effects over time.

Project Results Use and Dissemination

A workshop entitled "At the Water's Edge: Current State of Riparian Forest Management Research in Minnesota" was presented in Grand Rapids on May 20, 21, and 22, 2008. The purpose of the workshop was to interpret research results from the single- and multiple-basin riparian effectiveness monitoring studies as well as the Minnesota Forest Resource Council's Riparian Science Technical Committee findings for natural resource managers and loggers. The program included both indoor and outdoor components. There were 102 participants over the course of the three days.

A website was developed to provide information about the project, including a project overview, more detailed descriptions of our research, information about project personnel, a listing of project cooperators, project publications, and information presented during our workshop. The url for that website is http://rmzharvest.cfans.umn.edu/. A second website was created to allow project researchers to access data (http://rmzharvest.cfans.umn.edu/login).

Beyond the workshops and website, project results were disseminated to scientists, natural resource managers, private landowners, researchers, and others through nine presentations, one refereed manuscript, and one field tour. Three additional manuscripts are in preparation. One graduate student produced a thesis from their project work. Other graduate students continue to collect, analyze, and summarize data which will result in additional theses. Annual summaries of project results were provided to the Minnesota Forest Resources Council for inclusion in their Annual Report.

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.

Trust Fund 2007 Work Program Final Report

Date of Report: August 17, 2009

Trust Fund 2007 Work Program Final Report

Date of Report: June 30, 2009
Date of Work Program Approval: March 23, 2007
Project Completion Date: June 30, 2009

I. PROJECT TITLE: Evaluating Riparian Timber Harvesting Guidelines: Phase 3

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

Total Trust Fund Project Budget:	**Trust Fund Appropriation:**	**$400,000.00**
	Minus Amount Spent:	**$393,494.96**
	Equal Balance:	**$ 6,505.04**

Legal Citation: ML 2007, Chap. 30, Sec. 2, Subd. 5(f).

Appropriation Language: $400,000 is from the trust fund to the University of Minnesota to assess the timber harvesting riparian management guidelines for postharvest impacts on terrestrial, aquatic, and wildlife habitats.

II. and III. FINAL PROJECT SUMMARY

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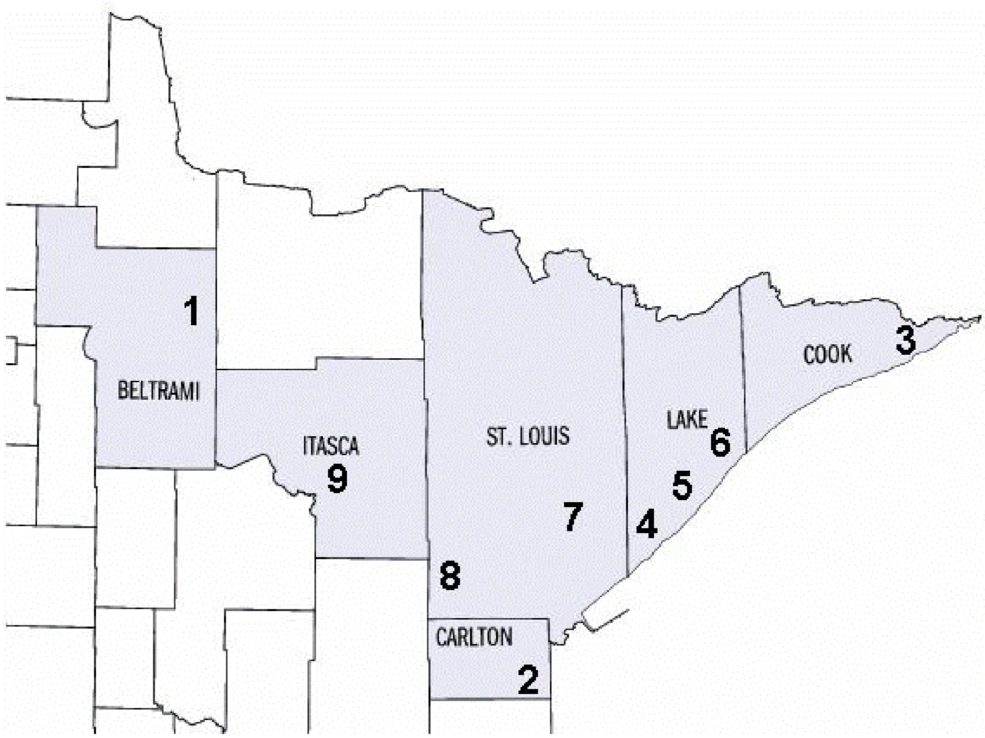

<u>Multiple-basin sites (1-8):</u>

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 trib, St. Louis Co Land Dept, Pike Lake Office

Site 8: St. Louis River trib, St. Louis Co Land Dept, Pike Lake Office

<u>Single-basin site (9):</u>

Site 9: Pokegama Creek, UPM (Blandin Paper Company)

Figure 1. Study site locations.

IV. OUTLINE OF PROJECT RESULTS:

Result 1: Evaluate terrestrial impacts

Description: We evaluated the effects of our management treatments on riparian tree regeneration responses and blowdown of residual trees. We evaluated regeneration in summer 2008 and blowdown in fall 2007 (single- and multiple-basin sites) and 2008 (multiple-basin sites only).

Summary Budget Information for Result 1:	**Trust Fund Budget:**	**$138,296.00**
	Amount Spent:	**$134,971.93**
	Balance:	**$ 3,324.07**

Deliverable	Completion date	Budget	Status
1. Measure recent blowdown of riparian trees on 24 study sites	11/1/07	$23,050	Completed
2. Summarize and analyze data from deliverable 1	2/1/08	$23,049	Completed
3. Measure regenerating trees on 12 study sites	9/1/08	$23,049	Completed
4. Measure recent blowdown of riparian trees on 12 study sites	11/1/08	$23,050	Completed
5. Summarize and analyze data from deliverables 3 and 4	3/1/09	$23,049	Completed
6. Prepare and submit final report	6/30/09	$23,049	Completed

Completion Date: June 2009

Final Report Summary:

Introduction

Thomas et al. (1979) suggested that riparian areas represent ecosystems with maximum potential for 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 terrestrial 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 forested 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 have been harvested and monitored for various measures of riparian functionality including 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. Results may lead to changes in the management guidelines so that they will more effectively sustain forested riparian areas and associated resources.

Objectives

The primary objective was to continue to evaluate the effects of our management treatments on riparian tree regeneration responses, riparian plant communities, and blowdown of residual trees. We evaluated five year post-harvest riparian plant community and tree regeneration responses in 2008 and residual tree blowdown in 2007 (single- and multiple basin sites) and 2008 (multiple-basin sites only). Specifically, we examined how different levels of overstory tree retention in RMZs affect these variables, five years after harvest.

Study location and design

Multiple-basin study

Eight forested riparian areas were located in northern Minnesota. 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 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" RBA of 5.7 m^2 ha^{-1} or to a "medium" RBA of 11.5 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.

Single-basin study

Twelve 4.6 ha plots located along 3 first to third order streams (Pokegama Creek, Little Pokegama Creek, unnamed stream) draining into Pokegama Lake (south of Grand Rapids) were selected within a 2 km^2 area. Three replicates of 4 treatments were used: true control plots (no harvest in riparian zone or upland), riparian control (uplands clearcut/riparian zone uncut), whole-tree harvest (uplands and riparian zone cut using the feller-buncher grapple skidder system), and cut-to-length (uplands and riparian zone cut using cut-to-length system). Harvesting took place in late summer-fall 1997.

Methods

Vegetation assessment
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 1.1). A total of 50 plots were established in each treatment site and the following variables were quantified in each plot using a nested design.

Trees (diameter ≥ 10 cm at 1.37 m [diameter at breast height or 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. Tall woody regeneration less than 2.5 cm DBH but ≥ 0.76 m tall was sampled in two 0.6 by 4.6 m nested plots within the larger tree plot. Each woody stem was classified into 0.2 cm size classes based upon diameter at 15 cm from the ground. Species, diameter, and a subset of total heights were measured for each species tallied. Small woody regeneration (tree and shrub stems < 0.76 m tall) was measured in six 0.61 by 0.61 m plots nested within the tall regeneration plots (labeled 1A through 2C in Figure 1.1). In each of these plots, we tallied the number of stems of individual woody species.

Although not officially part of the work plan, herbaceous vegetation was also sampled so that we could track changes in ground layer plant communities and their potential interactions with tree regeneration. Herbaceous cover was tallied by major life form (herb/forb, fern, sedge/grass, bryophyte, and coarse woody debris) within the small regeneration plots with coverage visually quantified into the following classes: **1**=trace-1%, **2**=1-5%, **3**=6-15%, **4**=16-30%, **5**=31-60%, **6**=61-100%.

Assessment of northern white cedar and balsam fir seedling survival and growth
In a related study, three-year old northern white cedar (*Thuja occidentalis* L.) and balsam fir (*Abies balsamea* (L.) Mill.) were established at three multiple-basin study sites (Red Lake, Nemadji State Forest and East Branch Beaver River) in 2004. Plantings utilized microsites (mound, pit and slash) as identified in the existing literature. We erected deer exclosure fencing, with duplicate plantings inside and outside, in order to compare establishment of both browsed and unbrowsed seedlings. In the summer of 2006, environmental field measurements were performed at each replicate plot in order to characterize the vegetation and soil features. In October 2008, final field measurements were performed on planted individuals for mortality, vitality, height, basal diameter, and browse.

Blowdown of residual trees
Blowdown of RMZ residual trees was sampled in October-November 2007 and 2008. Sampling included 100% assessment of all blown down trees in each riparian stand. Data collected for each blowdown tree included basal area around that tree, tree diameter, height, landform position, distance from the stream, and type of damage to the individual. Trees were also permanently marked with numbered tags and recorded spatially with a GPS. The latter will allow us to track the fate of blowdown trees and continue to track new blowdown over time.

Leaf litter input to streams
Coarse particulate organic matter (CPOM) 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 from 2007 to 2009, dried, weighed, and reported on an annual basis.

Results

Vegetation responses

Overstory structure
Harvesting treatments were successful in creating significantly different overstory residual basal area among all RMZ and upland treatments immediately after harvest. These differences were still strong ($p < 0.0001$) five years after harvest, although slight changes in basal area and increased variability led to fewer significant differences among all treatment combinations at year 5 (Table 1.1). 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 tended to decrease with distance from stream. As a consequence, light availability increased with distance from stream ($p = 0.007$, data from 2005 report). 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 five years (Table 1.1), was 28 to 41 % greater in the two riparian harvest treatments compared to the uncut RMZ. Regeneration density also increased with increasing harvest intensity from the uncut RMZ to the upland clearcut (Table 1.1). Aspen and birch regeneration (stems ha^{-1}) increased from the uncut RMZ to the medium and low basal area treatments, to the clearcuts. Aspen and birch densities were significantly higher in the upland clearcuts compared to the uncut RMZ ($p = 0.013$), but not different among riparian harvest treatments (Table 1, Figure 1.2). Densities of aspen and birch have consistently been decreasing annually since the first year after harvest and are presently less than half of their original densities in all harvest treatments (Figure 1.2).

Recruitment of aspen and birch into larger sizes classes over time is evident. In the first year after harvest, the density of stems less than 0.75 m in height were significantly greater ($p = 0.016$) in the clearcut compared to the riparian control. By the third year after harvest this difference ($p < 0.001$) existed only in the tall regeneration layer (>0.75m and <2.5cm dbh). Five years after treatment, aspen and birch densities in the tall regeneration layer were again significantly greater in the clearcuts and low RBA treatments, compared to riparian controls ($p < 0.0001$). Moreover, significantly greater sapling (10 cm < dbh > 2.5cm) densities were observed in the clearcuts, when compared to the medium RBA and riparian controls ($p = 0.007$).

Regeneration densities of hardwoods other than aspen and birch have remained similar among treatments over time ($p = 0.51$ at year 5, Table 1.1). However, total densities of hardwood species added substantially to total regeneration amounts and exceeded aspen and birch in all treatments. Composition of hardwoods varied among the eight study sites, but commonly included sugar maple, red maple, and black ash. The medium basal area treatment had the highest hardwood densities five years after harvest (Table 1.1).

Conifer regeneration has decreased substantially from pre-treatment to five years after treatment. There were no significant differences among treatments in conifer regeneration densities at any sampling period ($p = 0.69$, Table 1.1). However, conifer regeneration densities were consistently greatest in the control RMZ and lowest in the clearcut uplands, but had greater variability in the medium and low RBA riparian zones.

Five years after harvest, all multiple-basin riparian treatments have sufficient commercial tree densities to be considered adequately stocked stands. However, composition of regeneration differed among treatments. Shrub species, notably hazel, and aspen densities increased with decreasing residual basal area from the riparian controls, through the medium and low residual basal areas treatments, to the upland clearcut. Notably, densities in the medium basal area RMZ treatment were not substantially different than the uncut RMZ for several species groups, suggesting that this treatment mitigated changes in the regeneration environment to some degree.

Shrub and herbaceous response

Potential deterrents to successful tree regeneration include various shrub species, which increased substantially by five years after treatment in all but the uncut RMZ treatment (Table 1.1). By the fifth 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 (Table 1.1). Non-commercial shrub species and aspen regeneration densities both decreased with increasing overstory residual basal area retention.

Hazel densities specifically illustrated the trend of increasing densities with decreasing residual tree density (Table 1.1). Five years after treatment, hazel stem densities had increased substantially in both the low RBA treatment and the upland clearcuts, relative to pre-harvest levels (Table 1.1). Hazel densities in medium RBA treatment also were nearly doubled their pre-harvest levels, but were 2.5 times lower than densities observed in the low RBA and clearcut treatments.

Herbaceous vegetation also illustrated responses to riparian treatments. Five years after RMZ treatments, both bryophyte and fern cover was highest in the control and medium RBA RMZs (Figure 1.3). Moreover, forb cover was greatest in the harvested treatments and lowest in the riparian control, while sedge and grass cover was greatest in the clearcut treatment (Figure 1.3).

Northern white cedar and balsam fir seedling survival and growth

Inside deer exclosures, survival of both species was highest on mounds and slash microsites. Both species suffered significant losses in pit microsites, with survival roughly 50% and lower. Cedar had no survival differences between RMZ overstory treatments, while fir survival was significantly lower in controls than in medium harvests (Figure 1.4). Outside of exclosures, survival patterns were the same but lower for both species. Survival was highest on mounds and slash microsites; pit microsites again had the lowest survival. Cedar showed no survival difference between RMZ overstory treatments, while fir exhibited significantly lower survival in controls than in medium harvests (Figure 1.5). Overall, survival of cedar was much higher than for fir.

Cedar height and basal diameter inside exclosures differed between overstory treatments, with greater growth in medium harvest RMZs over controls. Growth did not differ between microsites within treatments. Balsam fir height and basal diameter also differed between overstory treatments, responding with greater growth to medium harvest treatments, and did not differ significantly between microsites (Figures 1.6-1.7). Outside of exclosures, the incidence of repeated herbivory on cedar reduced all growth so that there were no significant effects of overstory treatments or microsites. Balsam fir height and basal diameter outside of exclosures showed significantly greater growth in harvest RMZs than in controls, though not between microsites (Figures 1.8-1.9).

Blowdown of riparian residual trees

Multiple-basin study sites
Blowdown of residual trees in the multiple-basin riparian areas occurred in all treatments. Expressed as either percentage of original basal area (Figure 1.10) and density (Figure 1.11), blowdown was highest in both the harvested treatments, compared to the control. Five years after treatment, the medium RBA treatment had the greatest percentage of basal area and density blown down, followed by the low RBA treatment and riparian control (Figures 1.10 and 1.11). However, the differences among treatments were generally small. Blowdown did differ dramatically among species independent of RMZ treatment. Trembling aspen lost the greatest percentage of basal area in the RMZs over the five year period since treatment origin, followed by balsam fir and red maple (Figure 1.12).

Single-basin study sites
Blowdown of residual riparian trees were remeasured in the fall of 2007 and spring of 2008, 10 years after treatment. The riparian controls (uplands harvested) and the two RMZ harvest treatments lost 30-35% of residual basal area to blowdown over 10 years, significantly more than the control treatment (uplands not harvested) ($P=0.03$, Figure 1.13). Similarly, the riparian control and the riparian harvest treatments had the highest percent residual tree density lost to blowdown (Figure 1.14). In general, these results suggest the potential for substantial loss of the original RMZ to blowdown, with the amount of loss continuing to increase over time through at least 10 years.

Riparian area treatment effects on stream organic matter inputs
In 2008, lateral coarse particulate organic matter (CPOM: leaf litter, twigs, seeds, etc.) input from the riparian forest to the stream was highest in the medium RBA RMZ treatment, followed by the control and the low RBA treatment (Figure 1.15). Overhead input of CPOM was more variable within treatments, with no treatment related trend evident (Figure 1.16).

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
Fifth 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 is 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, but highest in medium 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.

Conifer regeneration was not favored by any of the RMZ treatments. Conifer densities declined dramatically in all treatments over time, including the riparian control. The latter result suggests a mechanism other than direct harvest related impacts to account for conifer decline, e.g., increased deer browsing with enhanced edge environment.

Shrub and herbaceous responses
Woody shrub densities, including hazel, and some herbaceous life forms responded in a similar pattern as aspen regeneration. Shrub 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. Bryophyte and fern life forms positively responded with an increase in residual overstory, while sedge, grass, and forbs all responded positively to an increase in overstory removal, indicating direct treatment influence on establishment and growth.

Northern white cedar and balsam fir seedling survival and growth
Results from this related study show that mound and slash microsites within medium RBA treatment 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. Three year old cedar seedlings appear to transplant with a higher rate of survival success than balsam fir. Outside of exclosures where seedlings are subject to deer browse, survival after three years declines significantly for cedar which is browsed preferentially. Mortality will continue, and we expect to see cedar survival percentages decline in relation to fir in coming seasons.

Harvest areas in general emerge as the best places to plant cedar and balsam fir to maximize growth. At this stage of development (3 years *in situ*), cedar shows higher mean height growth than fir, while basal diameters are more similar. This demonstrates resource allocation differences between species. Protection from herbivory is important for continued cedar growth and recruitment; balsam fir is not routinely browsed and so will fare better over the long run if unprotected.

Blowdown of residual trees in riparian management zones
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 after RMZ creation is a potential concern. Excessive blowdown can lead to a reduction in RMZ ecological function.

Multiple-basin study sites
In the multiple-basin study, blowdown of residual trees has been moderate after five years, averaging about 10% of basal area and density in the harvested RMZ treatments and 6% in the riparian control. The later rate is within the range of background mortality rates for similar forests, while the rates for the two harvested treatments are above background expectations. 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 and other early seral species that have already established the riparian treatments.

Results indicate that trembling aspen is at high risk of blowdown in RMZs as 32% of residual aspen basal area had blown down by 5 years. Balsam fir was moderately susceptible, with 19% of its basal area blowing down after five years. White spruce, black ash, paper birch, basswood, and sugar maple appear to be at much lower risk of blowdown.

Single-basin study sites
At the single-basin study site, a high percentage of blowdown, measured as both basal area and tree density, has occurred since harvest 10 years ago. The riparian control and the harvested RMZ treatments were all about equally high. The implication of this is that RMZ, at least in this study, are at risk of damage from blowdown, and that loss of these trees can reduce the functionality of the RMZ. The need for wider RMZs (100 foot in this study) is suggested by these results.

Coarse particulate organic matter input to streams

In 2008, our results show that coarse particulate organic matter input to the multiple-basin study streams was only slightly different between the low and medium basal area treatments and the uncut control RMZ. There, results suggest no strong longer-term effect of treatment of the amount of coarse particulate organic matter entering streams with similar treatments or geomorphic settings of the riparian area.

Temporal dimension

The results presented above report mid-term (five years) responses following riparian harvest treatments. To fully understand the longer-term consequences (i.e., 8-10 year post-harvest), follow-up 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 area and cooperators, is use of a complete block design, where all three harvesting treatments were included at each of the study locations. There were no unresolved problems relative to this Result. All work was completed as planned.

Literature cited

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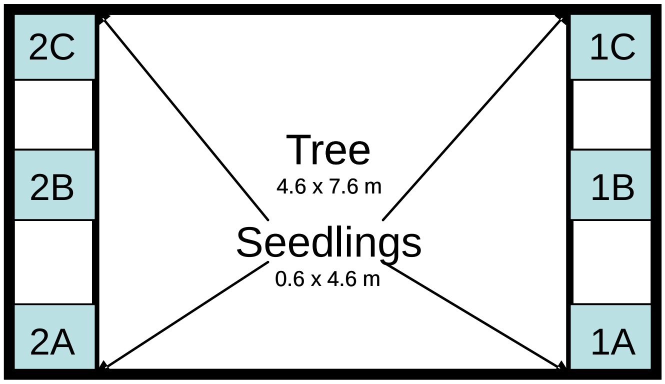

Figure 1.1. Depiction of vegetation sampling nested plot design.

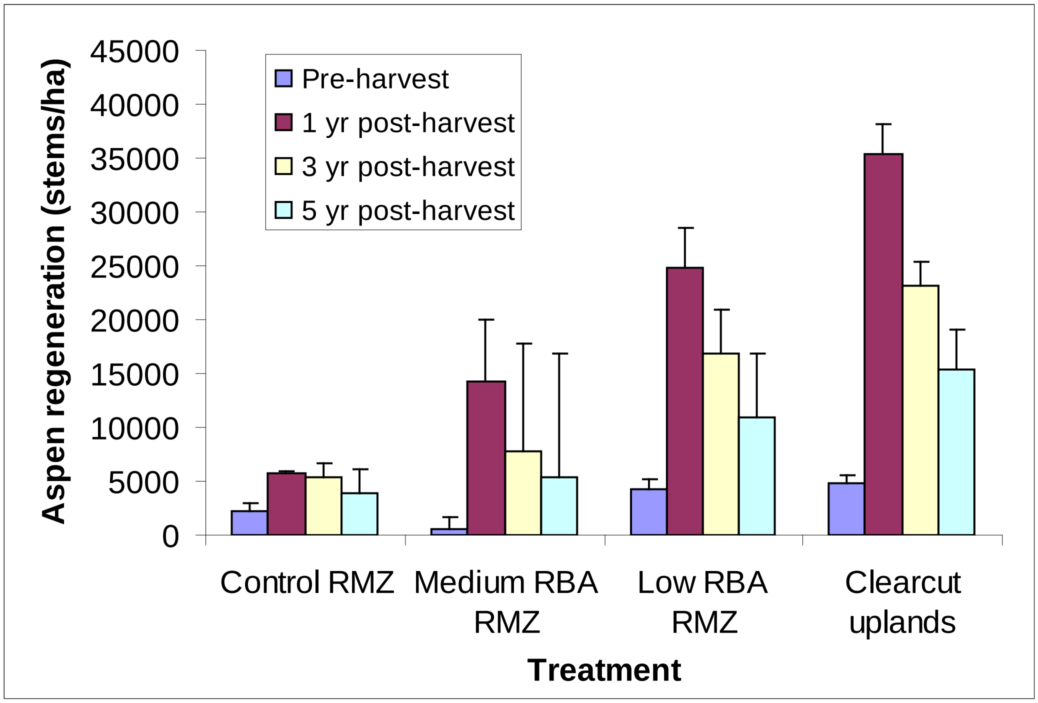

Figure 1.2. Trembling aspen regeneration densities (stems/hectare) among treatments over time.

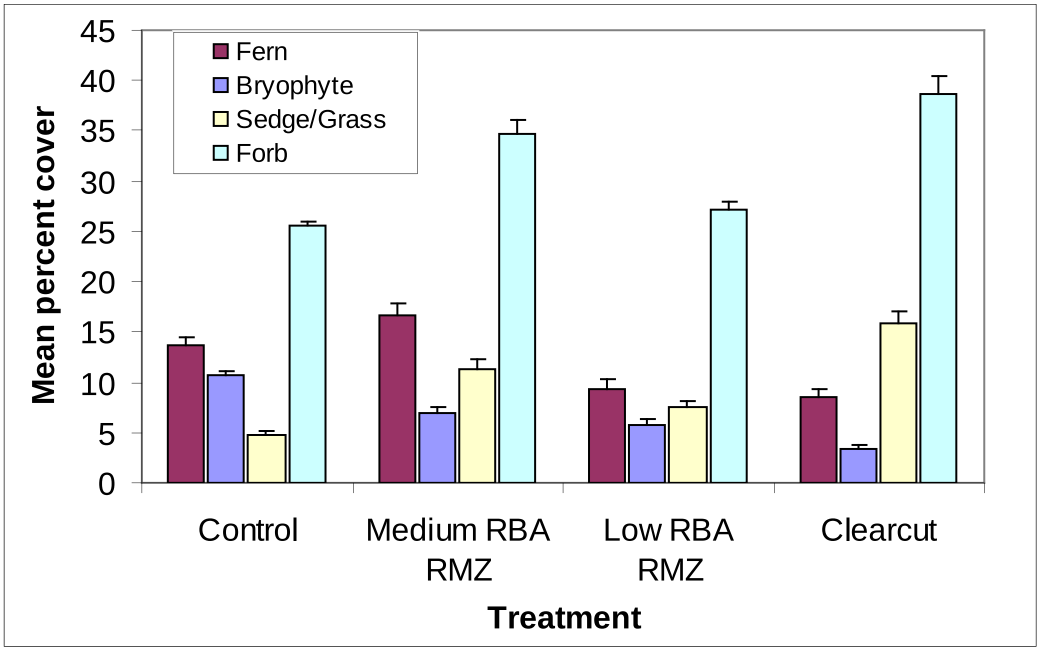

Figure 1.3. Mean percent cover (± standard error) of ferns, bryophytes, sedge/grasses, and forbs five years after the RMZ treatments occurred.

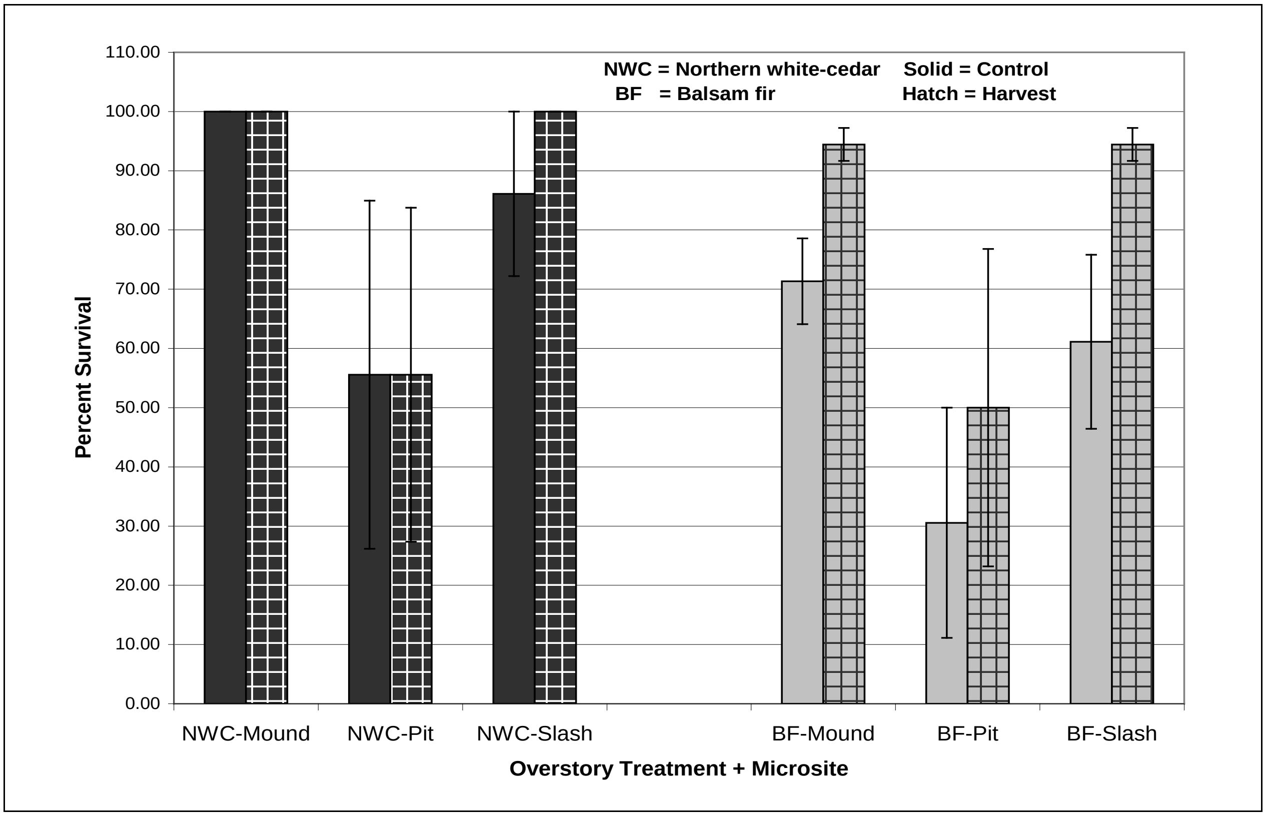

Figure 1.4. Inside exclosure survival of northern white-cedar (NWC) and balsam fir (BF) seedlings in overstory treatments (control vs. harvest) and microsite at the Red Lake, Nemadji State Forest and East Branch Beaver River multiple-basin study sites.

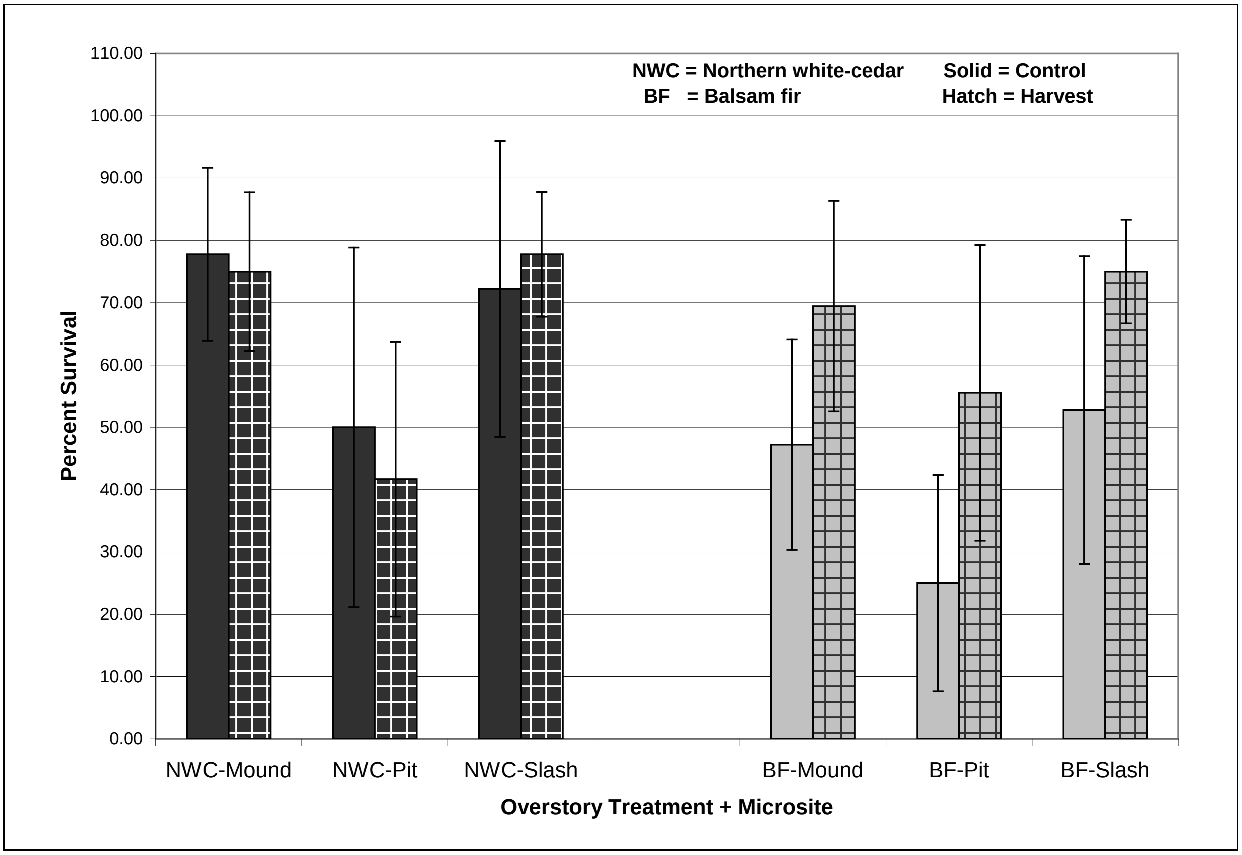

Figure 1.5. Outside exclosure survival of northern white-cedar (NWC) and balsam fir (BF) seedlings in overstory treatment (control vs. harvest) and microsite at the Red Lake, Nemadji State Forest and East Branch Beaver River multiple-basin study sites.

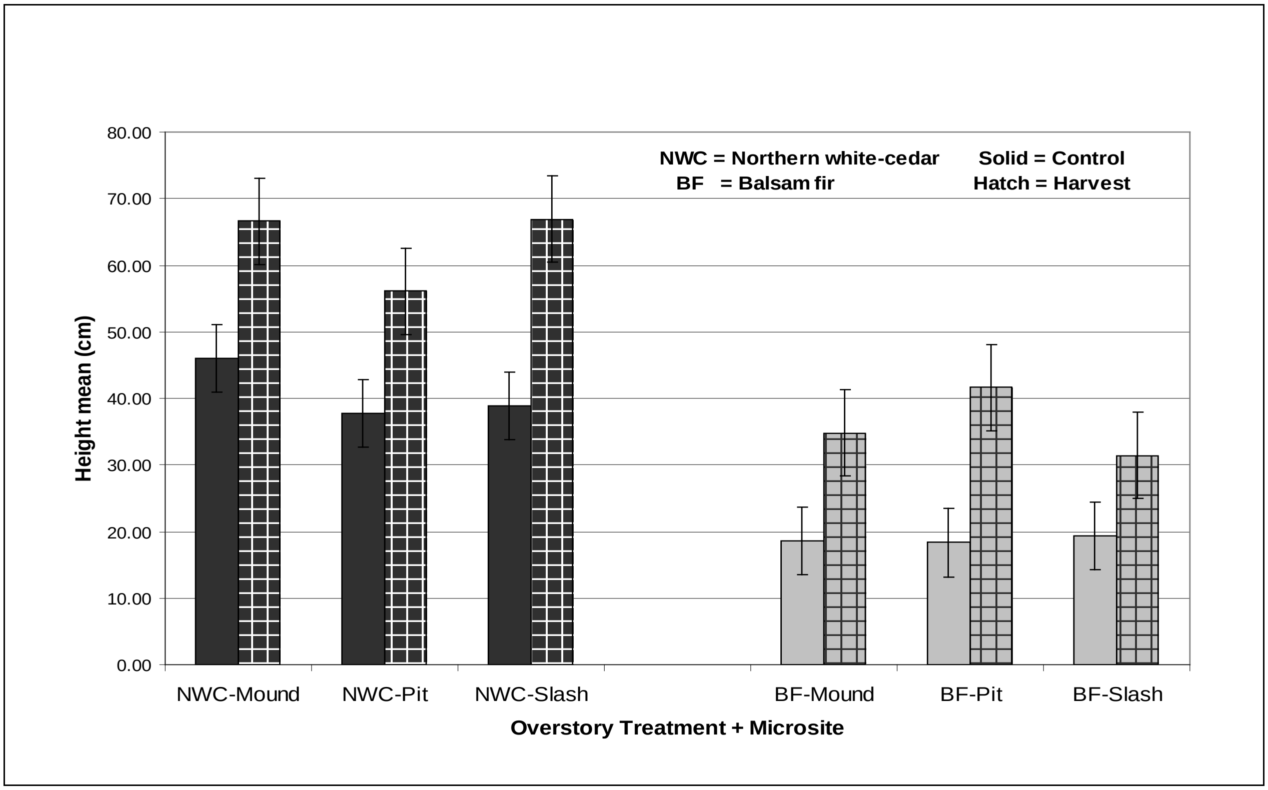

Figure 1.6. Inside exclosures: northern white-cedar and balsam fir seedling height response to overstory treatment (control vs. harvest) and microsite at the Red Lake, Nemadji State Forest and East Branch Beaver River multiple-basin study sites.

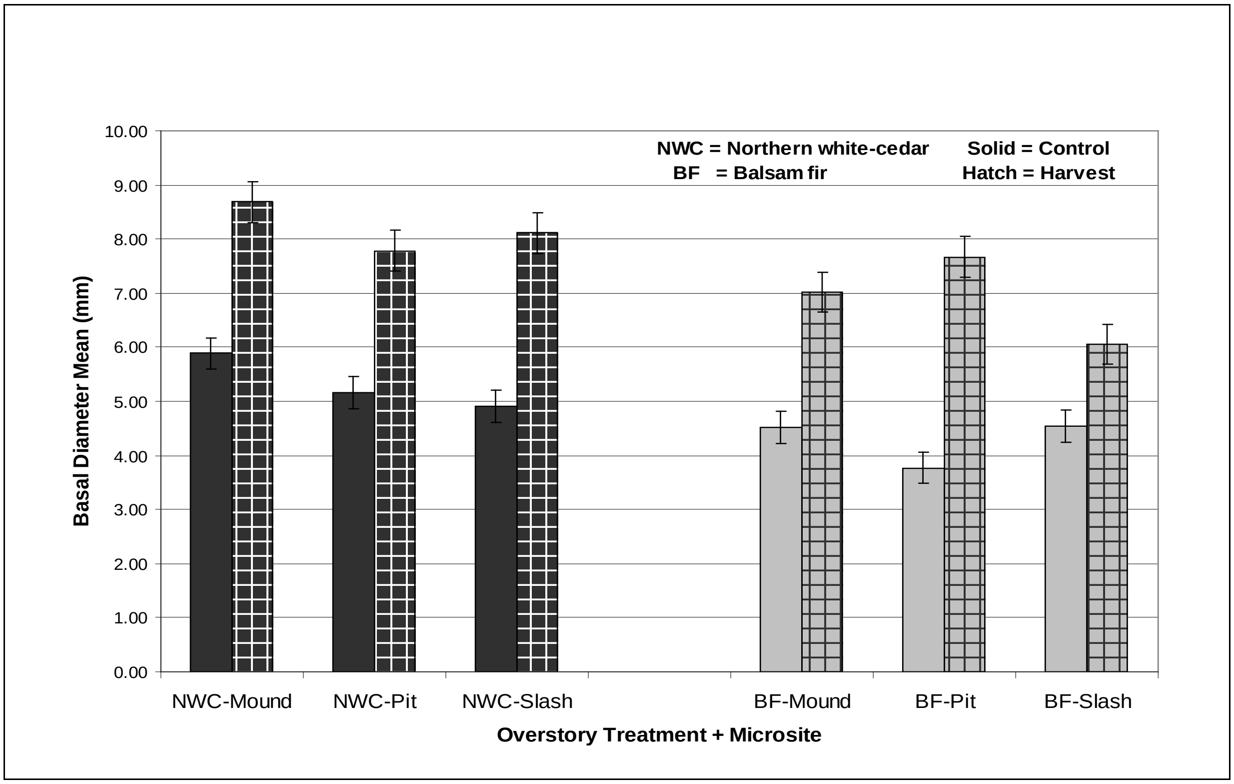

Figure 1.7. Inside exclosures: northern white-cedar and balsam fir seedling basal diameter response to overstory treatment (control vs. harvest) and microsite at the Red Lake, Nemadji State Forest and East Branch Beaver River multiple-basin study sites.

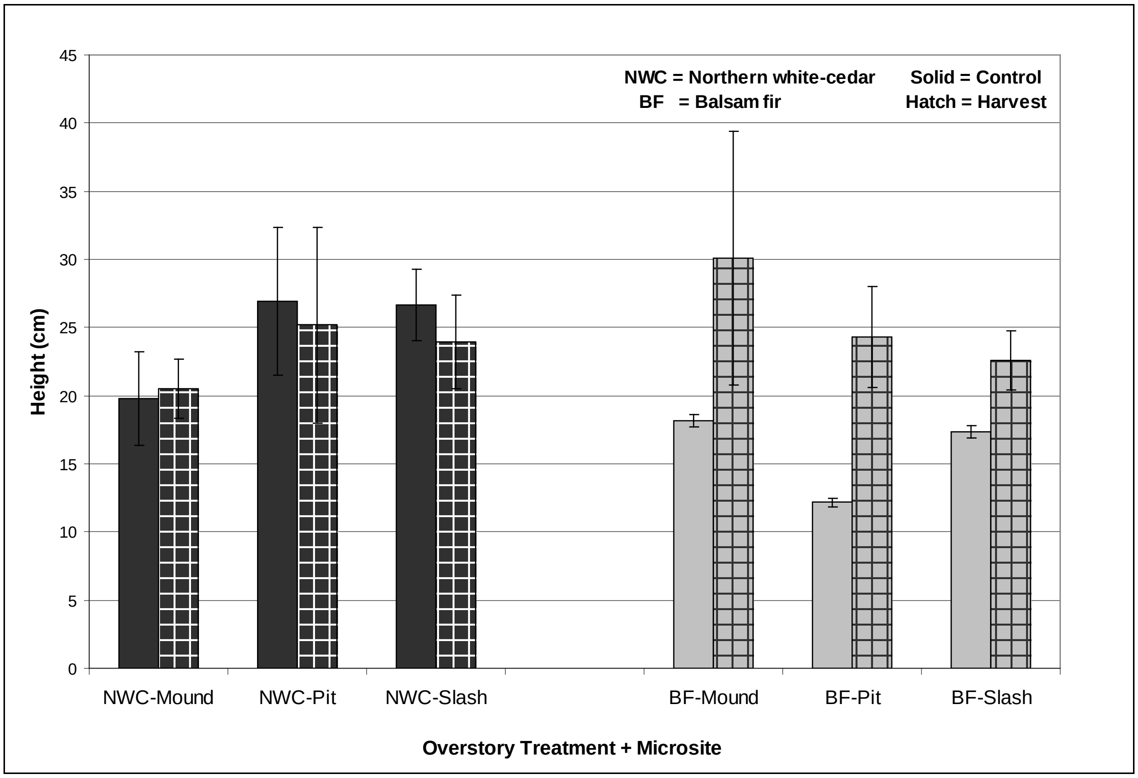

Figure 1.8. Outside exclosures: northern white-cedar and balsam fir seedling height response to overstory treatment (control vs. harvest) and microsite at the Red Lake, Nemadji State Forest and East Branch Beaver River multiple-basin study sites.

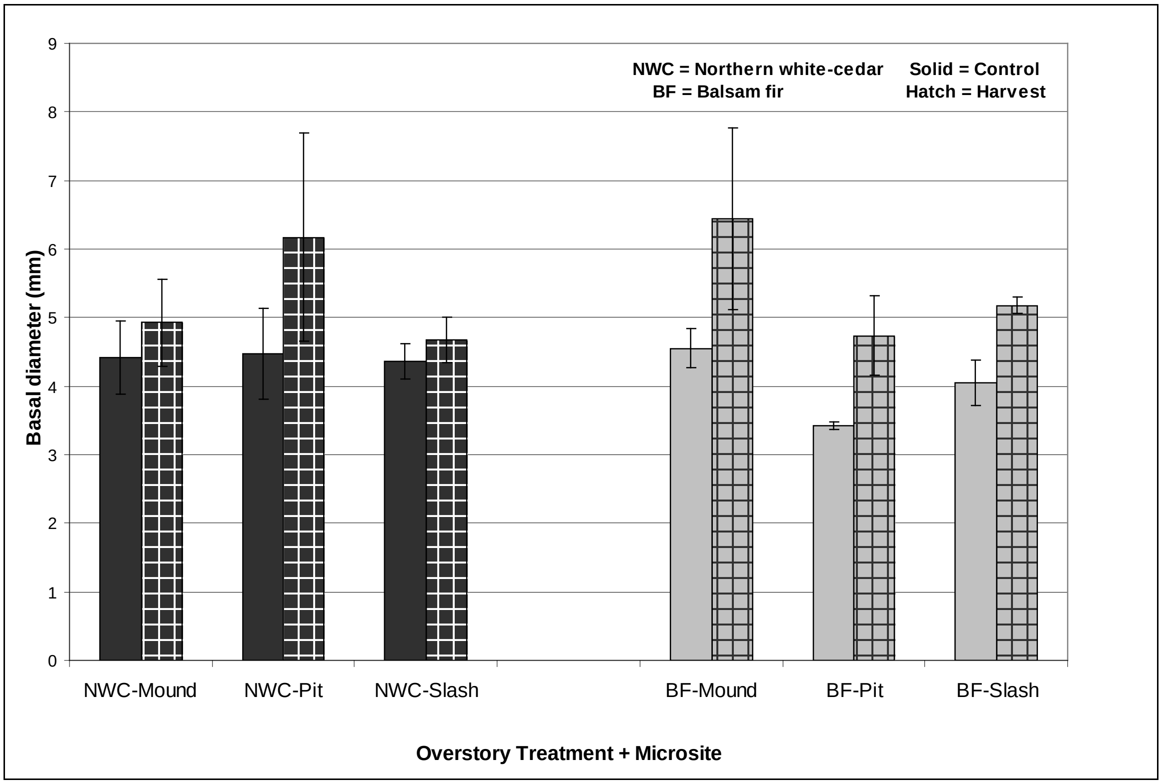

Figure 1.9. Outside exclosures: northern white-cedar and balsam fir seedling basal diameter response to overstory treatment (control vs. harvest) and microsite at the Red Lake, Nemadji State Forest and East Branch Beaver River multiple-basin study sites.

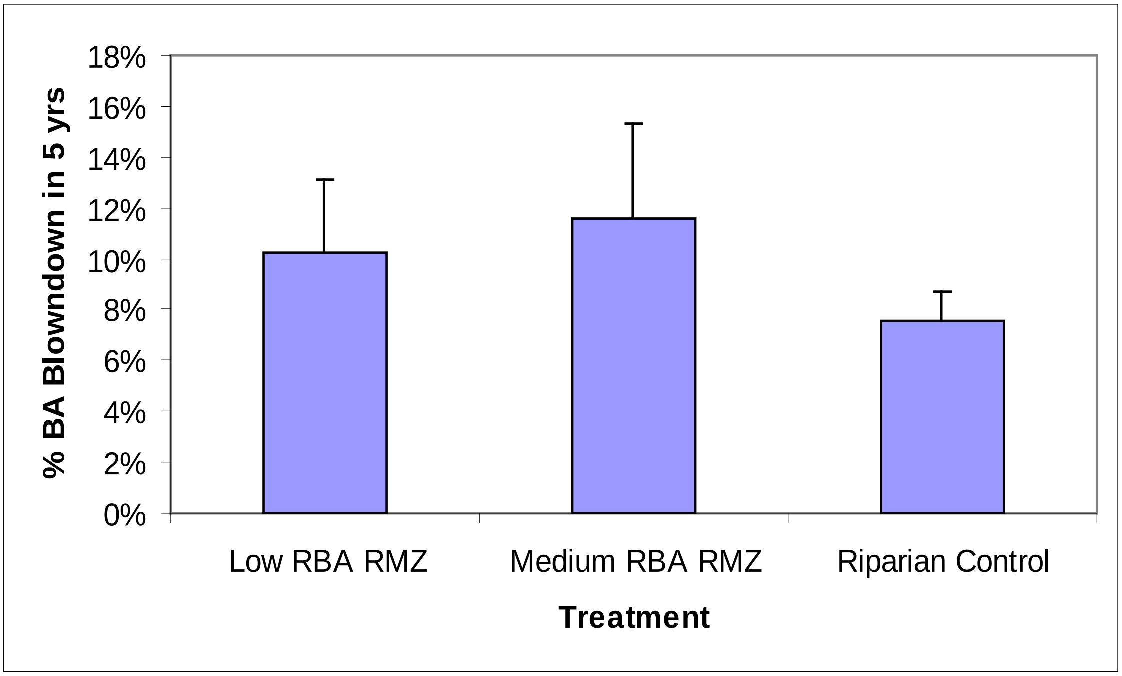

Figure 1.10. Percent (± standard error) residual tree basal area lost to blowdown five years after the RMZ treatments occurred.

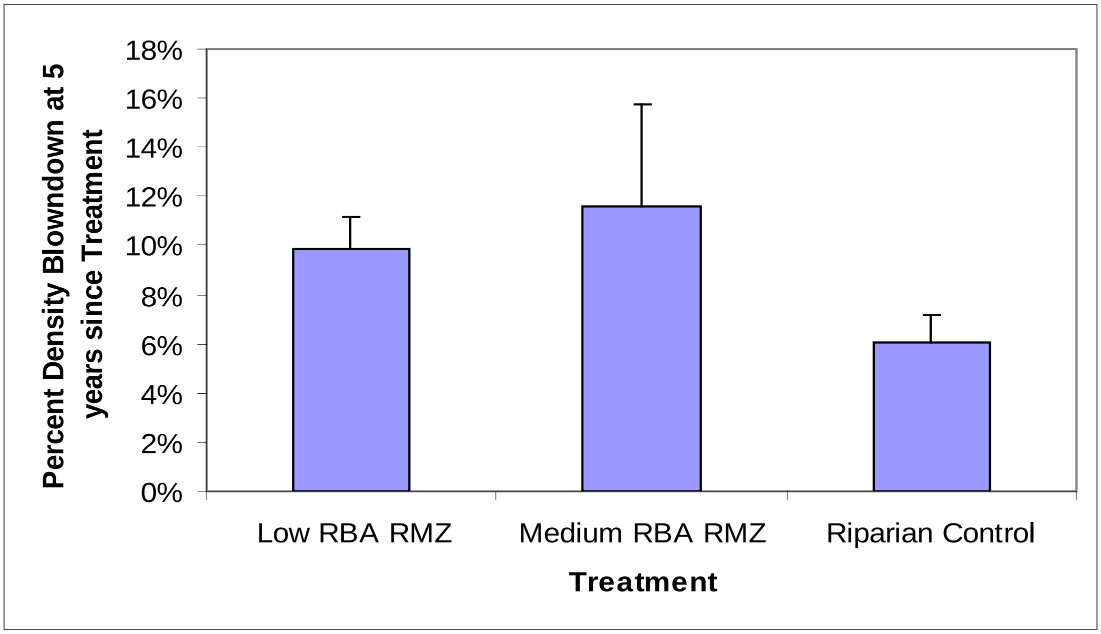

Figure 1.11. Percent (± standard error) residual tree density blown down five years after the RMZ treatments occurred.

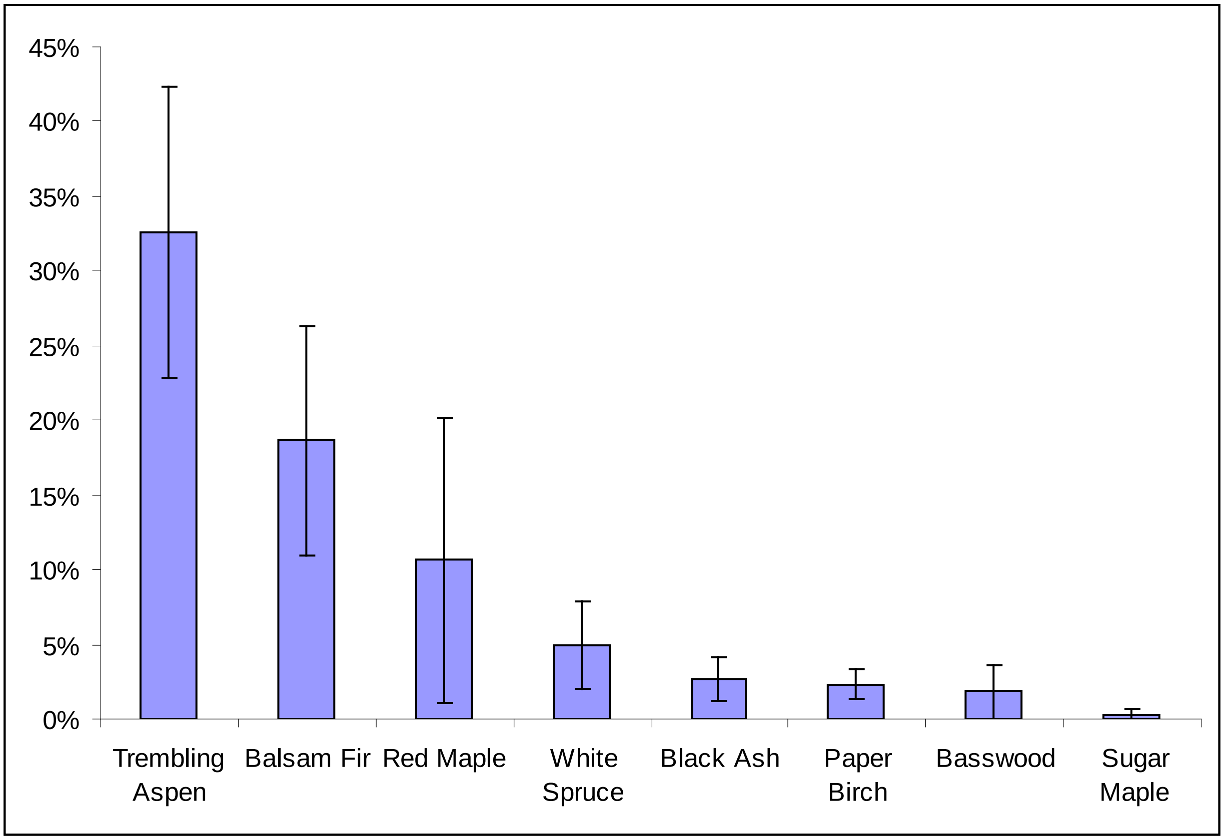

Figure 1.12. Percent basal area blown down (± standard error) by individual species (percent of that species post-harvest basal area) in riparian management zones five years after the harvesting occured.

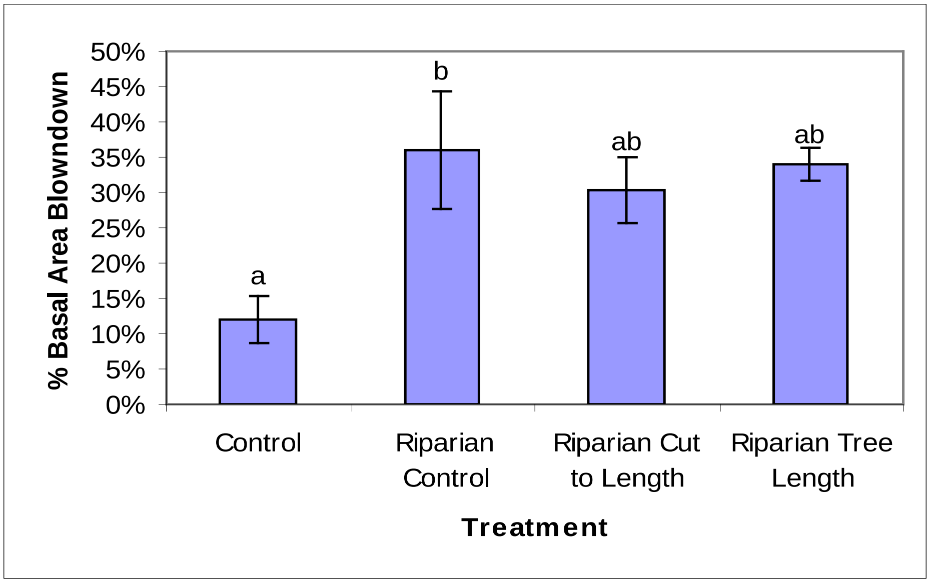

Figure 1.13. Average (± standard error) percentage of residual tree basal area lost to blowdown among riparian treatments ten years after treatments originated at the single-basin study site. Columns with differing letters are significantly different at (• =0.05).

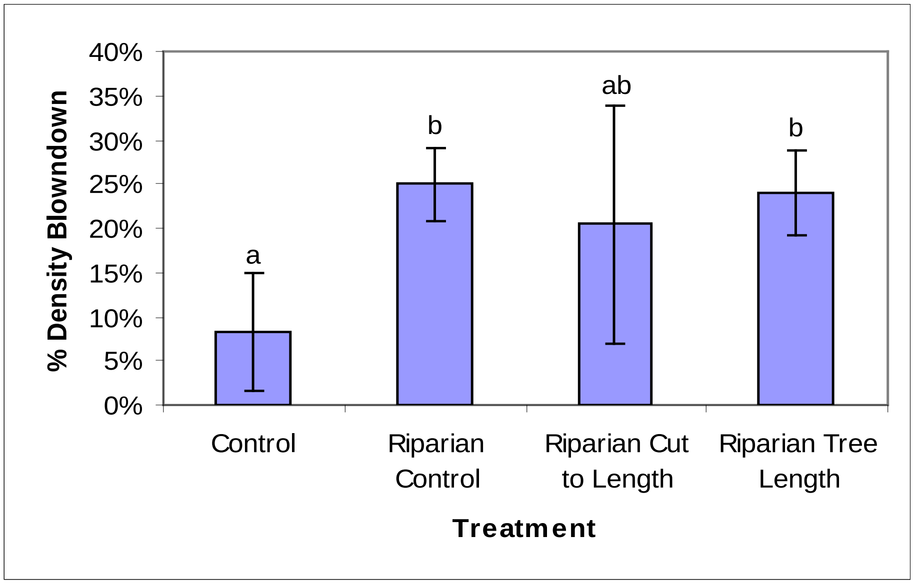

Figure 1.14. Average (± standard error) percent residual tree density lost to blowdown among riparian treatments at the single-basin study site ten years after the treatments occurred. Columns with differing letters are significantly different at (• =0.05).

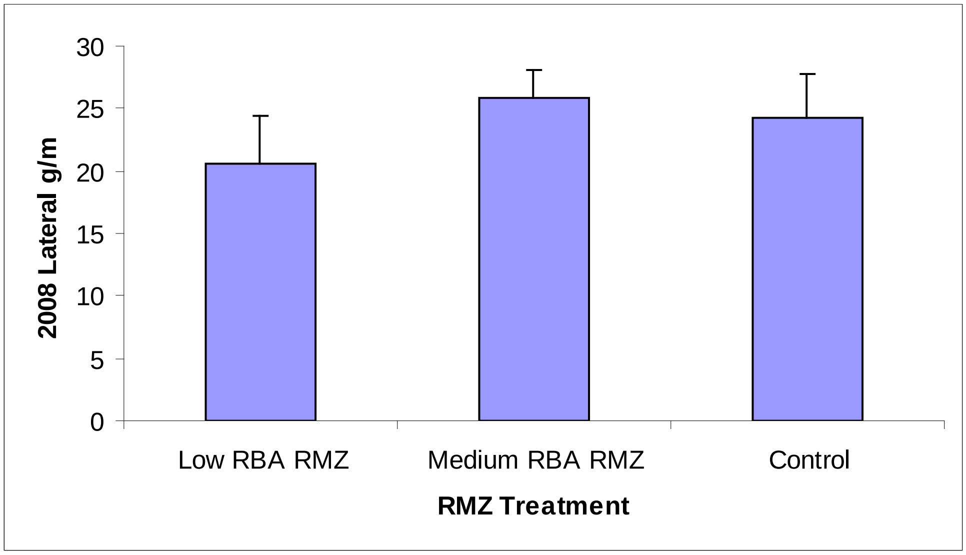

Figure 1.15. Mean (± standard error) lateral coarse particulate organic matter (g/m) collected in lateral traps among all RMZ treatments in 2008.

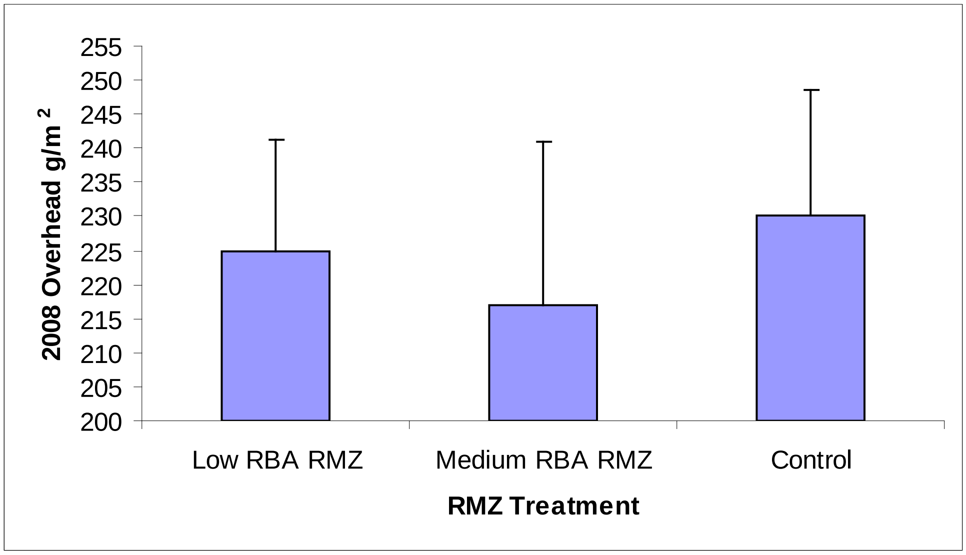

Figure 1.16. Mean (± standard error) overhead coarse particulate organic matter (g/m^2) collected in overhead traps among all RMZ treatments in 2008.

Result 2: Evaluate aquatic habitat impacts

Description: We evaluated the effects of our treatments on stream ecosystem functioning using measures of invertebrate biomass, in-stream leaf and wood decomposition rates, and food web analyses. We evaluated these response variables, along with in-stream habitat in 2007. We also reevaluated in-stream habitat and fish communities in the single-basin system in 2007. These results are divided below into two components: a) effects on fish habitats and communities and b) effects on macroinvertebrates and organic matter dynamics.

Summary Budget Information for Result 2:	**Trust Fund Budget:**	**$175,195.78**
	Amount Spent:	**$170,045.54**
	Balance:	**$ 5,150.24**

Result 2a: Evaluate long-term effects on fish habitats and communities

Description: We evaluated the effects of past harvest treatments in the single-basin system on fish habitat (temperature, sediment composition and embeddedness, depth, width, cover, bank stability, canopy coverage, woody debris, etc.) and stream fish communities (fish abundance, index of biotic integrity). We also assessed stream geomorphic measurements, including bank stability, sediment composition, and residual pool depth. We evaluated these response variables in summer of 2007 and compared them with measurements made in 1997-2000 and 2006 in the single-basin system.

Summary Budget Information for Result 2a:	**Trust Fund Budget:**	**$ 40,964.78**
	Amount Spent:	**$ 40,964.78**
	Balance:	**$ 0.00**

Deliverable	Completion date	Budget	Status
1. Collect fish habitat, fish abundance, stream geomorphic measurements, and submit update report	1/31/08	**$27,156**	Completed
2. Summarize and analyze data from deliverable 1	6/30/08	**$13,808.78**	Completed
3. Prepare and submit final report	6/30/09		Completed

Completion Date: June 2009

Final Report Summary:

Introduction

Timber harvesting has the potential to impact stream ecosystems. It has been related to decreased inputs of leaf litter and wood, and community shifts in invertebrates and other biota (Salo and Cundy 1987, Chamberlin et al. 1991, Palik et al. 2000). Timber harvesting can also affect stream hydrology. In a study in British Colombia, peak snowmelt discharge remained above pre-harvest levels for the five-year duration of the study (Macdonald et al. 2003). Verry (2004) noted that channel-forming flows double or triple after 60% of a catchment is converted from forest to non-forest conditions in the upper Midwest; however, little work has been done on the effect of elevated flows on sediment inputs. An altered stream hydrograph can lead to increased bank erosion (Brooks et al. 1997), and may take decades to recover after timber harvesting (Moore and Wondzell 2005). Excess sediment from timber harvesting can manifest as increases in total suspended sediment (Gomi et al. 2005), streambed aggradation (Keim and Schoenholtz 1999), or the proportion of surficial fine substrates (Davies and Nelson 1994, Thompson et al. 2009). For example, suspended sediment during stormflow events increased significantly in a Fiji catchment after salvage logging and slash burning; much of the sediment was mobilized from new logging roads and landing areas (Waterloo et al. 2007). Similarly, thinning only 11% of the standing timber volume with horse skidding produced a significant increase in suspended sediment to a stream in Turkey (Serengil et al. 2007a). Hydrographs also indicated significantly more stormflow in both study areas (Waterloo et al. 2007, Serengil et al. 2007b).

Impacts from riparian timber harvesting can be more direct. Machine traffic in riparian areas can damage stream banks and lead to large inputs of fine sediment (Keim and Schoenholtz 1999). Riparian timber harvesting can also decrease stream shading and cause warmer stream temperatures in summer (Brown 1970, Beschta et al. 1987, DeGroot et al. 2007). Warmer temperatures can lead to changes in growth rates for fish and invertebrates (Weatherley and Ormerod 1990) and alter the competitive balance between species (Baltz et al. 1982, Reeves 1985).

Although the potential for timber harvesting to impact streams is clear, it remains difficult to predict the exact effects of a particular harvest treatment in a specific location. Previous work documented short-term effects of timber harvesting on sediment in the single-basin system, and suggested that basin-scale effects were more important than local-scale effects or harvesting technique (Hemstad et al. 2008). Thus, the purpose of our analyses was to examine changes over a ten-year period at the basin scale.

Methods

Data collection in 2006-2007 followed the same methods as previous sampling in 1997 – 2000 (Hemstad et al. 2008); additional variables were also measured as described below. Unless noted otherwise, data were collected from three 50-m reaches at each plot: 50-m immediately upstream from the plot, 50-m at the downstream end of the plot, and 50-m immediately downstream from the plot. Data were not included from Plot 9 because the stream contained no fish during 2006 or 2007 sampling and contained little water.

Geomorphology and fish habitat

A variety of data were collected at the study plots for examination of basin-scale year effects (i.e., overall differences between years when considering all plots). Six variables were measured to characterize stream bank and channel conditions: proportion of unstable banks, canopy cover, surficial fine substrates, embeddedness, streambed depth of refusal, and residual pool depth. Visual estimates of the proportion of bank area that was unstable (not covered by vegetation, roots, or rocks) were made in the three 50-m reaches at each plot. The value for each 50-m reach was the mean of three 17-m sections. Canopy cover was also determined at the center of each 17-m section using a spherical concave forest densiometer in all four directions. Unstable banks and canopy cover were assessed in July 1997-2000 and 2006-2007.

Surficial substrates were examined in the three reaches at each of the 11 study plots. Each 50-m reach at each plot was divided into five 10-m subreaches, to avoid sampling substrates exclusively at the upstream or downstream end of a 50-m reach. Seven circular quadrats (28 cm in diameter) were placed in random locations in each 10-m subreach to visually estimate the percentage of sand, silt, or clay (i.e., fine substrates) on the streambed surface (for a total of 1,155 quadrats per year). Embeddedness was estimated in each quadrat as the degree to which larger substrates were buried in fine substrates (e.g., a quadrat with cobbles half-buried in sand was 50% embedded, whereas a quadrat with only fine substrates visible was 100% embedded). Surficial substrates were examined in July 1997-2000 and 2006-2007.

Sediment storage in the channel was evaluated using depth of refusal and residual pool depth. At each of the 11 study plots, the ten riffles with the largest substrates and the ten deepest pools were sampled. Depth of refusal was determined at each riffle and pool by probing with a tapered aluminum rod to determine the thickness of the fine sediment layer (i.e., sand or silt) in the stream channel. The depth of refusal for each plot was the mean of the ten riffles and ten pools. Depth of refusal was measured in summer 1997, 1998, 2006, and 2007. Residual pool depth (i.e., pool depths minus riffle depths) was determined for each plot in summer 1997, 2006, and 2007 with a laser level.

In fall 2007, rain events that totaled 112 mm above the August/September mean for the study period caused high flows throughout the study area (Minnesota State Climatology Office). Depth of refusal data were collected at all plots in November 2007 to investigate whether sediment had been flushed from the streams by these high flows.

Basin-scale year effects were evaluated at all study plots, regardless of harvest treatment, using repeated measures ANOVAs that included new data from 2006-2007. Two factors were included in each analysis: a factor for year and a blocking factor for the four streams. The blocking factor was necessary to address a lack of independence between sampling units on the same stream. Variables were transformed as needed to reduce heteroscadasticity and improve normality. A repeated measures ANOVA was examined separately for canopy coverage, unstable banks, embeddedness, and surficial fine substrates. In addition, repeated measures ANOVAs were used to evaluate year effects on depth of refusal and residual pool depth, using a year factor but no blocking factor (due to greater separation between sampling units and lower replication). When ANOVAs were significant ($P < 0.05$), Tukey's HSD was used to compare differences in mean values for the response variable between years. The statistical software R was used for all analyses.

Large wood was assessed in July 1997-2000 and 2006-2007 as an indicator of fish habitat. Large wood was assessed at five evenly-spaced transects in each 50-m reach. The total length was recorded for each piece of large wood that intersected a transect and that met the following criteria: the piece had to include a portion within the bankfull channel that was at least 0.05 m in diameter for at least 1 m of length. Large wood measurements were summarized as total length density (m/m^2), which is the length of pieces per unit area of stream bed.

Fish and temperature

Fish were sampled during August in 1997 (pre-harvest), 1998-2000, and 2006-2007. All sampling was conducted with a Wisconsin AbP-3 backpack electrofisher. A coldwater fish index of biotic integrity (IBI) value was calculated for each 50-m reach (Mundahl and Simon 1999). The IBI increases with the proportion of species that are ranked as intolerant, top carnivores, and coldwater obligates (e.g., brook trout [*Salvelinus fontinalis*]) and decreases with the proportion of tolerant species (e.g., central mudminnow [*Umbra limi*, Kirtland] or creek chub [*Semotilus atromaculatus*, Mitchill]). The southern stream contained > 99% brook trout, thus brook trout analyses only used data from that stream; analyses for other individual species only used data from the three northern streams, and the IBI analyses used data from all four streams.

Basin-scale trends in fish variables were examined using the mean from all plots in the single-basin system each year. Univariate regressions were used to investigate temporal trends for the basin means for fish index of biotic integrity and abundances, and to investigate relationships between fish and habitat variables (i.e., large wood and fine substrates) at the basin scale. Univariate regressions were also used to examine the relationships between fish variables and two climate variables. The first climate variable was summer air temperature, using the mean air temperature from June through August of each year at the nearest monitoring station 10 km to the north (Minnesota State Climatology Office). The second climate variable was total spring precipitation, the cumulative precipitation from April 1 through July 12 (prior to field sampling) of each year. The proportion that each fish species contributed to total fish abundance was also examined with a rank abundance curve for each year sampled.

Plot-level effects on stream temperature were examined in 2006 and 2007 during August (the warmest month). An Onset® Pro v2 temperature recorder was placed 0-50 m upstream and another was placed 0-50 m downstream of each plot. Each recorder was cabled to a brick in the deepest pool available and was set to measure water temperature every 15 minutes. The response variable examined for water temperature was the mean temperature in August for the downstream recorder minus the mean temperature in August for the upstream recorder (i.e., plot-level warming). Of the 24 recorders set each year, two became exposed to air due to low water levels, one was buried by bedload, and one was vandalized; the corresponding plots were omitted from the plot-level analysis. A two-factor ANOVA was used to evaluate plot-level warming. The first factor for the ANOVA was year (2006 versus 2007) and the second factor was treatment (unharvested control, riparian buffer, or thinned riparian). No transformations were necessary; Tukey's HSD was used to compare mean values.

Results

Geomorphology and fish habitat

Canopy cover, unstable banks, embeddedness, and surficial fine substrates were significantly different across years during the study period (Table 2a.1). Although canopy cover at the basin scale was not directly affected by harvest itself (i.e., 1997 and 1998 were not significantly different), canopy cover declined as a result of windthrow (an indirect effect of harvesting) by

2000 and had recovered to pre-harvest levels by 2006 (Figure 2a.1A). The proportion of unstable banks increased between 1997 and 2000, but had recovered by 2007 (Figure 2a.1B). Embeddedness increased from 1997 to 1998 and remained above pre-harvest levels through 2007 (Figure 2a.1C). Surficial fine substrates also increased from 1997 to 1998, but partially recovered in 1999 after a heavy summer storm (Figure 2a.1D). The proportion of surficial fine substrates again increased significantly relative to pre-harvest levels in 2000 and 2006, but recovered in 2007.

Sediment storage was also significantly different across years during the study period. Residual pool depths were shallower than pre-harvest conditions in both 2006 and 2007 (Figure 2a.2A). Depth of refusal was not significantly different between 1997 and 1998 but increased significantly between 1998 and 2006, and remained significantly greater than pre-harvest levels in summer of 2007 (Figure 2a.2B). However, following heavy rains in fall 2007 large amounts of freshly deposited sand were noted on the floodplains and depth of refusal in November was no longer significantly different from pre-harvest levels (Figure 2a.2B).

Fish and temperature

The IBI scores and fish abundances generally indicated trends over the study period (Table 2a.2). IBI scores decreased significantly over time (Table 2a.2), as did mean abundance for brook trout and northern redbelly dace (*Phoxinus eos*, Cope) (Table 2a.2). Mean abundance of brook stickleback (*Culaea inconstans*, Kirtland) also decreased over time, whereas creek chub increased, although neither trend was significant (r = -0.70 and 0.79, P = 0.12 and 0.06). Central mudminnow and finesecale dace (*Phoxinus neogaeus*, Cope) indicated no trend. Other species (i.e., emerald shiner [*Notropis atherinoides*, Rafinesque], fathead minnow [*Pimephales promelas*, Rafinesque], Iowa darter [*Etheostoma exile*, Girard], and northern pike [*Esox lucius*, Linnaeus]) were uncommon (Table 2a.2) and were not included in species-level analyses. In terms of relative abundances, brook trout were the most abundant species from 1997 through 1999 but declined to fourth and third most abundant by 2006 and 2007. Central mudminnow were fourth or fifth most abundant from 1997 through 2000 and became the most abundant species in 2006 and 2007 (Figure 2a.3).

Some changes occurred with instream habitat and local weather. Fine substrates increased after 1997, large wood decreased, and total spring precipitation increased through 1999 and subsequently decreased (Table 2a.3). On average, summer air temperatures increased over the study period by 0.062 °C/year at the nearest weather station (Figure 2a.4), which is comparable to the regional trend of 0.06 °C/year (Austin and Colman 2008).

Fish index of biotic integrity and abundances were not significantly related to habitat variables or spring precipitation at the basin scale (Table 2a.4). However, some fish variables were significantly related (P • 0.05) to estimated summer air temperatures. IBI scores and abundances for brook trout, northern redbelly dace, and brook stickleback (Figure 2a.5) as well as finescale dace (r^2 = 0.49, not shown) were negatively related to warmer summer air temperatures. Abundances of creek chub or central mudminnow were not significantly related to any variables.

There were significant plot-level treatment effects on stream warming (i.e., downstream-upstream differences in water temperature, Figure 2a.6). The ANOVA for plot-level warming indicated that the year factor was not significant (P = 0.65), but the treatment factor was significant (P = 0.02). Tukey's HSD comparison indicated that warming was significantly greater (P = 0.01) in thinned riparian plots compared to riparian buffer plots. However, warming at the unharvested control plots was not significantly different from the riparian buffer plots or the thinned riparian plots (P > 0.17).

Discussion

Geomorphology and fish habitat

Our study demonstrated that headwater streams in moraine landscapes may require ten years to recover after a large input of fine sediment, depending on the rate of stream bank revegetation and the frequency of large storm events. Embeddedness, depth of refusal, and residual pool depth values remained significantly changed ten years after the input of sediment between 1997 and 1998. The year effects we documented may be related to changes in bank scour, windthrow, storm events, and damage from timber harvesting equipment.

Bank scour throughout the study area may have contributed fine sediment through at least 2000, as evidenced by higher proportions of unstable banks. Banks were fully revegetated by 2007, by which time bank scour was presumably reduced. Excess sediment (i.e., embeddedness, depth of refusal, and residual pool depth) remained in the streams through summer 2007. Storm events in fall 2007 led to high streamflows that flushed enough sediment onto the floodplain to return depth of refusal values to 1997 conditions.

Local weather patterns can influence windthrow, sediment storage, and sediment transport (Brooks et al. 1997). Storm events occurred during 1998 and 1999 (Minnesota State Climatology Office), followed by a period through 2001 with no storm events when sediment likely stayed in the channel. Heavy rainfall events occurred again in 2001-2005, many caused by summer storms with high winds that may have caused windthrow and inputs of associated sediment (Grizzel and Wolff 1998). Another period followed from 2006 through mid-2007 when sediment likely remained in the channel, until the storms of fall 2007 led to sediment deposition onto the floodplains. The analysis of decade-long studies should be interpreted in the context of such weather cycles.

Windthrow along the channel banks (Hemstad et al. 2008) may also have led to increases in unstable banks and channel sediment (Grizzel and Wolff 1998). Rootwads exposed by windthrow influenced channel morphology by adding associated sediment, partially blocking the channel, and inducing bank cutting around the rootwad. Studies of windthrow in riparian buffers in the upper Midwest are rare (Heinselman 1955, Heinselman 1957, Elling and Verry 1978) but suggest that windthrow rates are greatest near the edge of buffers (*sensu* Martin and Grotefendt [2007]); thus wider buffers may protect streamside trees from windthrow.

High discharge may also have contributed to the increases in unstable banks and channel sediment. The streams in the single-basin system may have experienced increases in bankfull discharge due to increases in water yield from harvested areas (Verry 2004, Brooks et al. 1997, Macdonald et al. 2003, Detenbeck et al. 2005, Moore and Wondzell 2005, Waterloo et al. 2007). Although the harvested percentages of the four basins were only 2 to 11%, Serengil et al. (2007b) found hydrologic effects after 11% of a basin was harvested. Lower thresholds may simply be precluded by the accuracy of hydrologic measurements (Verry 1986). Hemstad et al. (2008) found few plot-level effects of timber harvesting in the single-basin system from 1997-2000, but suggested that basin-scale changes may have masked impacts at the plot level. Hemstad and Newman (2006) also found few plot-level effects in the Knife River basin in northeast Minnesota, but observed basin-scale increases in unstable banks and surficial fine substrates 0-2 years after timber harvesting. It is noteworthy that the greatest changes in surficial fine substrates and embeddedness during the study period occurred immediately after timber harvesting, indicating a possible response to altered hydrology or soil disturbance from harvesting equipment.

Small tributary channels, if impacted by harvesting equipment, can also contribute to sediment loading in mainstem channels. Study plot 3 contained a small, yet steep (7.2%) intermittent tributary 1.2 m wide and 15 cm deep that was crossed repeatedly with harvesting equipment (*sensu* unrestricted harvest treatment of Keim and Schoenholtz [1999]). Machine traffic broke down the banks and razed the intermittent channel. In subsequent years the channel was reformed by bankfull discharges, delivering large amounts of fine sand into the mainstem of Pokegama Creek North. The pool in Pokegama Creek North just below the confluence of the tributary was nearly filled with sediment (89% loss of cross sectional area) and mean depth was reduced by 82% (E. Verry, unpubl. data). Use of a temporary bridge at a designated crossing site on the intermittent tributary would likely have preserved channel dimensions and prevented sediment delivery to the mainstem channel. Minnesota's voluntary guidelines for timber harvesting now recommend such crossings for intermittent channels as well as perennial channels (MFRC 2005).

Fish and temperature

We found that IBI scores and the abundances of brook trout, northern redbelly dace, and brook stickleback were significantly related to mean summer air temperatures at the basin scale, but not to fine substrates, large wood, or total spring precipitation. Below we discuss overall changes in the fish community, followed by discussion of changes in abundance for common species.

Although the four headwater streams in this study were all within a single basin, the spatial scale matched well with the life cycles of the fish species (Fausch et al. 2002). Brook trout were apparently isolated in one of the streams, and the other small-bodied species likely spent their entire life cycles within the stream system. IBI scores showed a significant negative trend over the study period, and abundances of more sensitive species (i.e., brook trout, northern redbelly dace [Stasiak 1972], and brook stickleback [Winn 1960]) also appeared to decline. Meanwhile, the abundance of tolerant creek chubs increased.

Overall fish numbers were markedly lower in 2006 and 2007; there are several possible explanations for the decline. First, diminished leaf litter inputs after timber harvesting (Palik et al. 2000) may have led to bottom-up trophic effects, as could decreased retention of leaf litter due to less large wood in the channels. Second, another study in the single-basin documented a decrease in macroinvertebrate diversity from 1997 through 2000, driven largely by increasing proportions of Chironomids (Chizinski et al. *Submitted*). Chironomids may be less available as prey for the fish species in the single-basin system, which could potentially lead to increased mortality over time through chronic undernourishment. Third, total spring precipitation in 2006 and 2007 was the lowest of the study period, thus low water levels (Lake 2003) are another possible explanation for reduced fish numbers.

The fish community in the single-basin system appears to have responded to different environmental conditions over the study period. Prior research in the single-basin system showed a negative relationship between IBI scores and fine substrates from 1997-2000 (Hemstad et al. 2008). However, our analyses showed no relationship between IBI scores and fine substrates at the basin scale. Our analyses indicate a strong connection between summer air temperatures and the fish community; warmer temperatures may favor some species (e.g., creek chub) at the expense of others (e.g., brook trout).

Brook trout: The abundance of brook trout declined consistently during the study period. Based on previous research with salmonids (Alexander and Hansen 1986, Waters 1995, Finstad et al. 2007), a chronic response to elevated levels of fine sediment was feasible. While low levels of large wood provide little habitat for macroinvertebrates (Johnson et al. 2003), we found no basin-scale relation between brook trout abundance and large wood. Our study design could not rule out bottom-up trophic effects or reduced availability of macroinvertebrate prey as explanations for the chronic reduction in brook trout abundance, although the study basin was free from confounding effects of agriculture (Durance and Ormerod 2009). Overall, the most compelling explanation for the brook trout decline is that warming temperatures over the study period caused mortality (or emigration to the nearest coldwater stream 5 km south). Although the highest seven-day mean water temperatures we observed (17.9° C in 2006 and 17.4° C in 2007) did not reach the critical thermal maximum of 22.3° C for brook trout (Eaton et al. 1995), sublethal thermal effects on fish can be subtle (Boughton et al. 2007). Invertebrate production may have been limited by high levels of fine sediment (Waters 1995, Matthaei et al. 2006) or warming temperatures (Durance and Ormerod 2007), and thus precluded fish from consuming sufficient quantities of invertebrates during warmer temperatures (Ries and Perry 1995).

Northern redbelly dace: Abundance of northern redbelly dace decreased significantly over time. At the basin scale, northern redbelly dace abundance had a negative relation to warmer air temperatures in summer. Stasiak (1972) noted that northern redbelly dace prefer streams with a constant flow of cool groundwater; warmer summer temperatures in our study may have caused direct mortality or emigration.

Brook stickleback: Abundance of brook sticklebacks decreased over time, although not significantly. As for northern redbelly dace, brook stickleback abundance at the basin scale was negatively related to warmer air temperatures in summer. Brook sticklebacks require cool water (Winn 1960), but they are also sensitive to environmental degradation (Lyons 2006). Although increased fine sediment after timber harvesting (Hemstad et al. 2008) could have reduced invertebrate prey numbers (Waters 1995, Matthaei et al. 2006), there was no significant relationship between fine substrates and brook stickleback abundance.

Creek chub: The creek chub was the only species that increased significantly over time. Contrary to previous studies, creek chub abundance was not significantly related to large wood (Quist and Guy 2001) or spring precipitation (Franssen et al. 2006) at the basin scale. The increasing temporal trend for creek chubs is not surprising, as previous studies have also documented increases in creek chub numbers after timber harvesting (Jones et al. 1999, Sutherland et al.

2002). Creek chub abundance may have increased due to less predation on their eggs and fry from other species (i.e., northern redbelly dace and brook stickleback), or less competition for invertebrate prey. Creek chubs may also have gained a competitive advantage from warmer water temperatures, as has been documented with other pairs of species (Baltz et al. 1982, Reeves 1985). Finally, creek chubs build a clean gravel nest by exporting mouthfuls of sand and importing gravel (Ross 1977), which may have made their reproductive success more resistant to increased levels of fine sediment.

Central mudminnow: The abundance of central mudminnows was fairly stable for the duration of the study, and was not related to temperature or habitat variables at the basin scale. Central mudminnows are eurythermal (Klinger et al. 1982), generalist feeders (Paszkowski 1984) and can use fine sediment as habitat by burrowing into the substrate (Peckham and Dineen 1957). Central mudminnows appear to have become the most abundant species in 2006 and 2007 by default, as most species had declined in abundance and creek chubs, though increasing, remained relatively uncommon.

Warming due to timber harvesting: Stream warming was significantly greater in thinned riparian plots relative to riparian buffer plots, possibly due to patches of open canopy (Hemstad et al. 2008). Although stream warming associated with narrowed buffers has been documented in the past (Beschta et al. 1987), the current study is unusual in that we have documented warming ten years post-harvest. Removal of riparian vegetation may exacerbate the effects of warmer air temperatures by reducing shade. However, the sample size was limited for testing plot-scale warming, and it is not clear why warming at unharvested control plots was not significantly different from other treatments.

Conclusions

Previous research has shown that headwater streams can be negatively impacted by fine sediment following riparian logging and concomitant changes in land use in the catchment (Kreutzweiser and Capell 2001, Gomi et al. 2005, Hemstad et al. 2008). Although our study did not discern between changes due to timber harvesting, road crossings, or natural causes, we evaluated recovery after a large input of fine sediment. Our study demonstrated that moraine, headwater streams can require an enabling event (e.g., high stormflows) to recover from large inputs of fine sediment. Although study plots were relatively small (4.9 ha) and retained some riparian trees, we observed basin-scale year effects for fine sediment in the stream channels that are consistent with timber harvesting effects documented elsewhere (Gomi et al. 2005).

This study also demonstrated relationships between temperature and abundance of sensitive fish species. Ongoing climate change (Rosenzweig et al. 2008) can be more important to fish communities than direct anthropogenic effects (Daufresne and Boet 2007), highlighting a pressing need to protect cool water temperatures (Eaton and Scheller 1996, Pilgrim et al. 1998, Stefan et al. 2001, Chu et al. 2008). The effects of warmer temperatures on fish may be exacerbated in streams where degraded habitat prevents prey production from keeping pace with increased metabolic demands (Ries and Perry 1995). Forest management can preserve cool water temperatures by maintaining or restoring wide forested buffers with sufficient overstory to fully shade the stream (Beschta et al. 1987). Based on previous literature (Salo and Cundy 1987, Chamberlin et al. 1991), a conservative approach would be to maintain pre-harvest levels of leaf litter inputs, hydrologic fluctuations, large wood inputs, and fine sediment loading.

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.

Result expenditures

Funds in the amount of $866.78 were shifted from Result 4 to get the Result 2a budget to a zero balance.

Unanticipated and unresolved problems

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

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Table 2a.1. Basin-scale year effects for canopy cover, unstable banks, embeddedness, and surficial fine substrates from 1997 (pre-harvest) to 2007 (ten years post-harvest) using repeated measures ANOVAs. The significance of the year factor is shown for each response; blocking factors are not shown.

	Df	Sum Sq	F value	p
Canopy cover	5	450.98	13.0034	<0.001
Residual error	152	1054.33		
Unstable banks	5	5111.7	14.3824	<0.001
Residual error	152	10804.5		
Embeddedness	5	11958.2	30.8455	<0.001
Residual error	152	11785.5		
Surficial fines	5	5325	13.5825	<0.001
Residual error	152	11919		

Table 2a.2. Yearly average IBI score and mean number of fish by species per 50-m reach, based on calculated abundance estimates. Standard errors of the mean are in *italics*. The Pearson correlation coefficient (r) and p-value (p) are for the regression with year. *species counts were too small to compute a meaningful statistic.

	1997	1998	1999	2000	2006	2007	r	p
IBI score	57.78	55.56	62.92	59.86	39.44	39.31	-0.91	0.01
	5.84	*5.54*	*5.19*	*5.71*	*5.16*	*6.24*		
Brook trout	13.34	12.77	10.16	8.84	1.03	1.83	-0.99	0.00
	5.29	*4.16*	*3.57*	*2.31*	*0.55*	*0.79*		
Northern redbelly dace	4.8	3.85	2.41	5.23	0.89	0.36	-0.86	0.03
	2.15	*2.21*	*0.84*	*2.32*	*0.37*	*0.19*		
Brook stickleback	10.69	11.35	1.92	8.78	2.19	3.19	-0.70	0.12
	4.93	*2.86*	*0.6*	*2.87*	*0.81*	*1.88*		
Creek chub	0.06	0.71	0.14	1.02	0.86	1.83	0.79	0.06
	0.06	*0.33*	*0.09*	*0.39*	*0.29*	*0.94*		
Central mudminnow	4.74	7.57	1.75	3.74	5.39	3.42	-0.14	0.79
	1.26	*1.44*	*0.55*	*0.87*	*1.35*	*1.22*		
Finescale dace	0.16	5.57	2.09	19.11	1.83	1.22	-0.19	0.72
	0.16	*2.01*	*0.79*	*8.38*	*0.78*	*0.44*		
Fathead minnow	0	11.34	1.01	0.53	0	0	*	*
	0	*4.04*	*0.45*	*0.51*	*0*	*0*		
Iowa darter	0	0	0.03	0	0	0	*	*
	0	*0*	*0.03*	*0*	*0*	*0*		
Northern pike	0	0	0	0	0	0.03	*	*
	0	*0*	*0*	*0*	*0*	*0.03*		
Emerald shiner	0	0	0.03	0	0	0	*	*
	0	*0*	*0.03*	*0*	*0*	*0*		

Table 2a.3. Yearly average values for all reaches for the proportion of fine substrates, large wood, estimated summer water temperature, and total spring precipitation. Standard errors are in *italics*.

	1997	1998	1999	2000	2006	2007
Fine substrates (%)	53.6 *3.4*	69.2 *1.9*	60.9 *2.9*	62.6 *2.6*	67.2 *4.1*	60.8 *3.1*
Large wood (m/m^2)	0.03 *0.006*	0.021 *0.003*	0.016 *0.003*	0.017 *0.004*	0.017 *0.003*	0.015 *0.002*
Estimated summer water temperature (°C)	15.31	15.33	15.57	15.03	15.95	15.70
Total spring precipitation (mm)	274	388	404	260	247	231

Table 2a.4. Coefficients of determination (r^2) for IBI scores and fish abundances in relation to the proportion of fine substrates, large wood, summer air temperature, or total spring precipitation at the basin scale. P-values are in *italics*.

	Fine substrates (%)	Large wood (m/m^2)	Summer air temperature (°C)	Total spring precipitation (mm)
Index of Biotic Integrity	0.08 *0.59*	0.10 *0.54*	0.56 *0.05*	0.41 *0.17*
Brook trout	0.07 *0.61*	0.41 *0.17*	0.53 *0.05*	0.40 *0.18*
Northern redbelly dace	0.07 *0.62*	0.34 *0.23*	0.85 *0.01*	0.05 *0.67*
Brook stickleback	0.01 *0.86*	0.48 *0.13*	0.62 *0.03*	0.02 *0.81*
Creek chub	0.10 *0.55*	0.37 *0.20*	0.05 *0.35*	0.32 *0.23*
Central mudminnow	0.28 *0.28*	0.14 *0.46*	0.01 *0.45*	0.01 *0.92*
Finescale dace	0.05 *0.67*	0.07 *0.61*	0.49 *0.07*	0.01 *0.85*

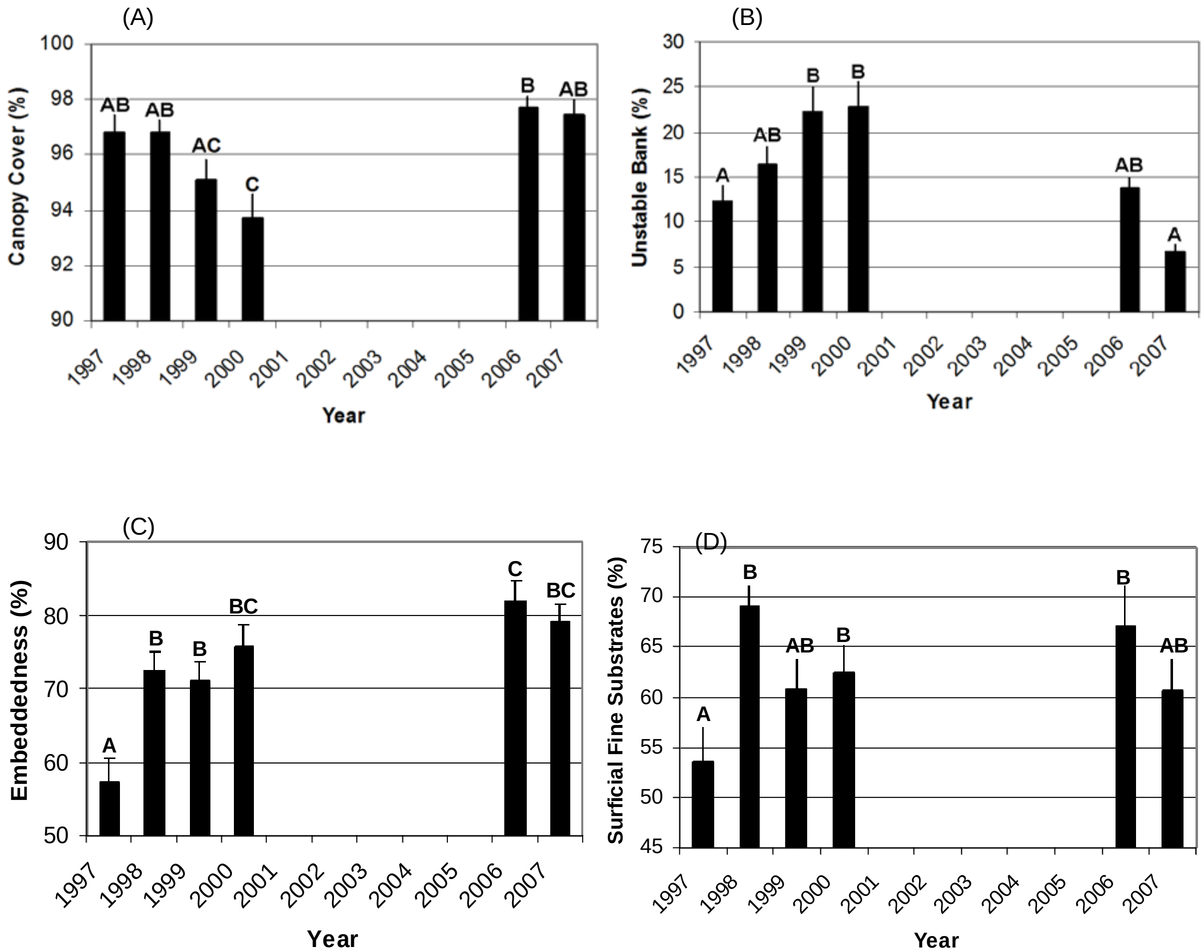

Figure 2a.1. (A) Canopy cover remained high in 1998 the year after harvest, declined in 1999 and 2000 from windthrow, and recovered by 2006. (B) Unstable banks increased in the 3 years after harvest but recovered by 2006. (C) Embeddedness increased after harvest and remained high, as did (D) the proportion of surficial fine substrates. For all graphs, error bars are 1 standard error; columns with a letter in common are not significantly different ($P < 0.05$, Tukey's HSD).

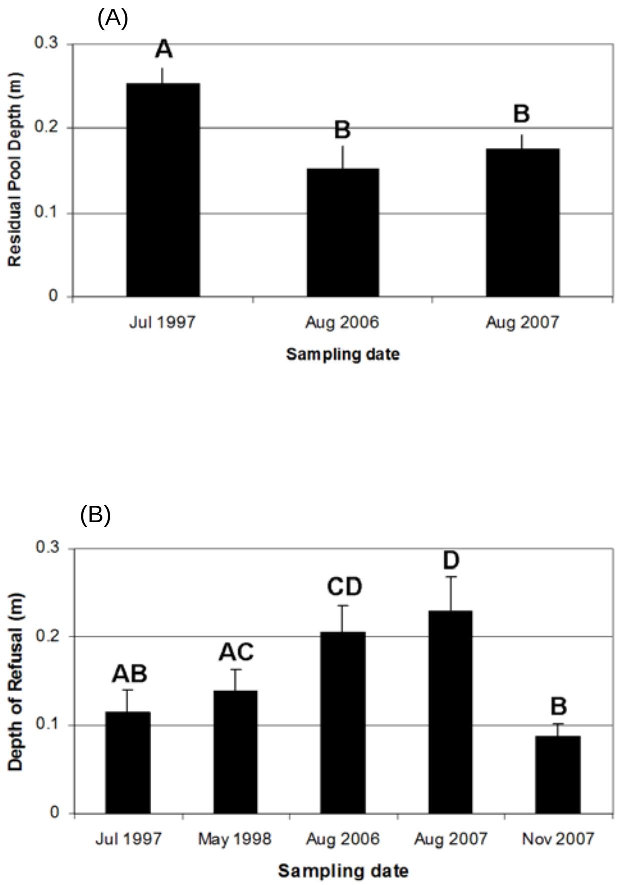

Figure 2a.2. (A) Residual pool depth reflected filling with sand after the pre-harvest 1997 measurement, (B) depth of refusal increased through all sample periods until after a large storm in November 2007. For all graphs, error bars are 1 standard error; columns with a letter in common are not significantly different ($P > 0.05$, Tukey's HSD).

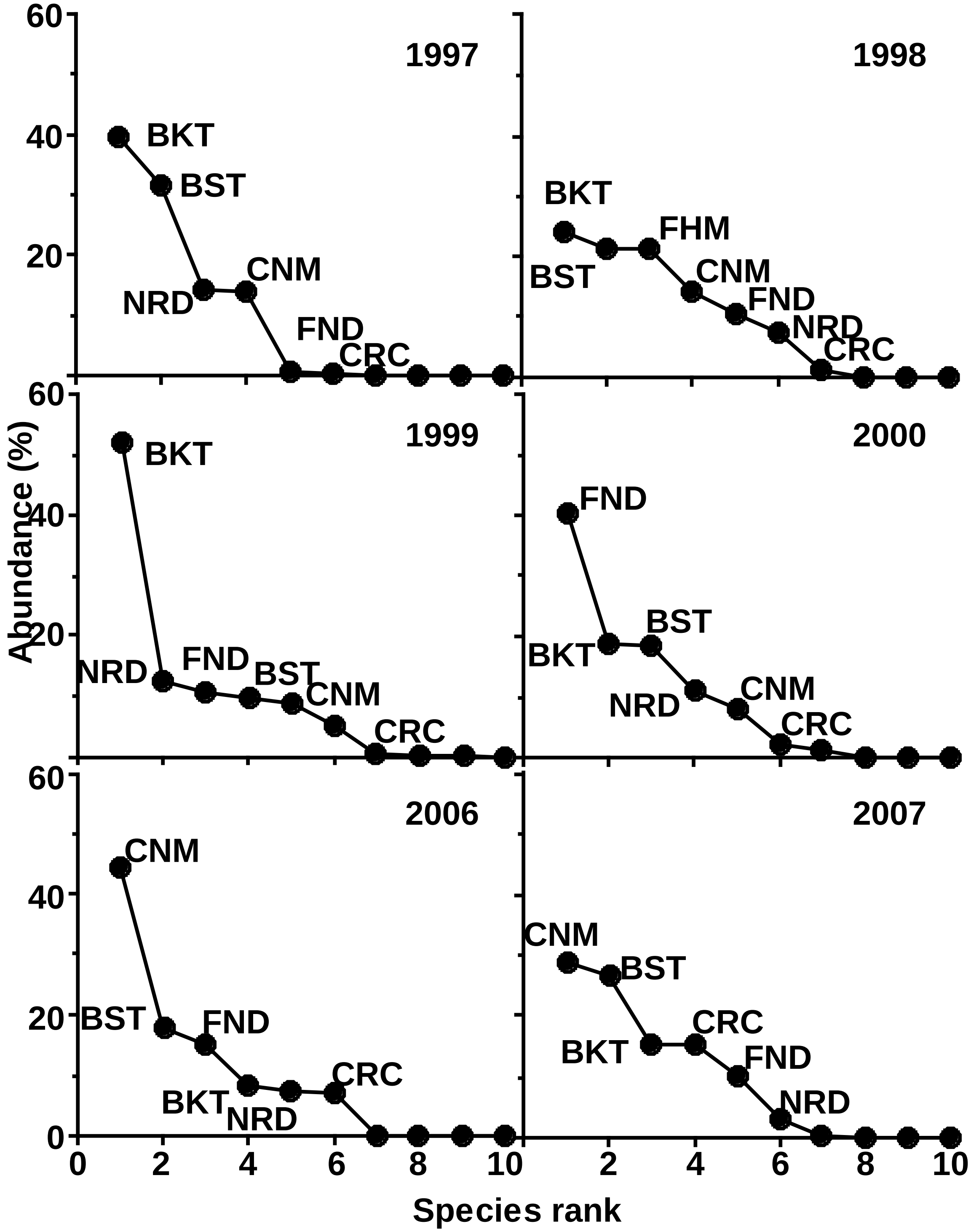

Figure 2a.3. Rank abundance curves for fish species across all plots. BKT = brook trout, BST = brook stickleback, NRD = northern redbelly dace, CNM = central mudminnow, FND = finescale dace, CRC = creek chub, FHM = fathead minnow.

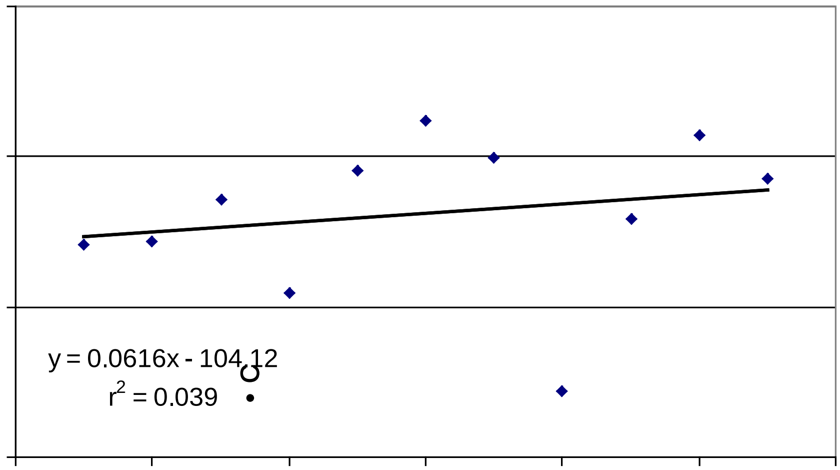

Figure 2a.4. Mean summer air temperatures for June through August 1997 through 2007.

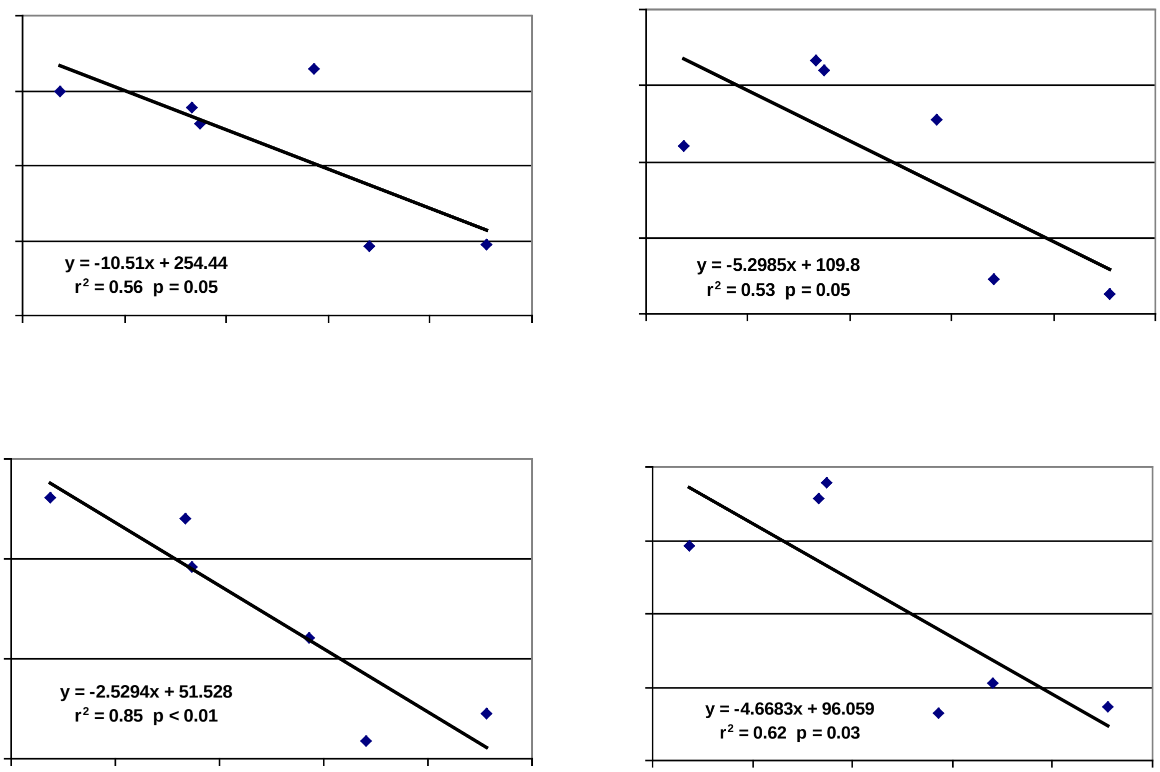

Figure 2a.5. The relationship between mean summer air temperature from June through August and the IBI scores and abundance (annual mean for all 50-m reaches in the basin) of brook trout, northern redbelly dace, and brook stickleback.

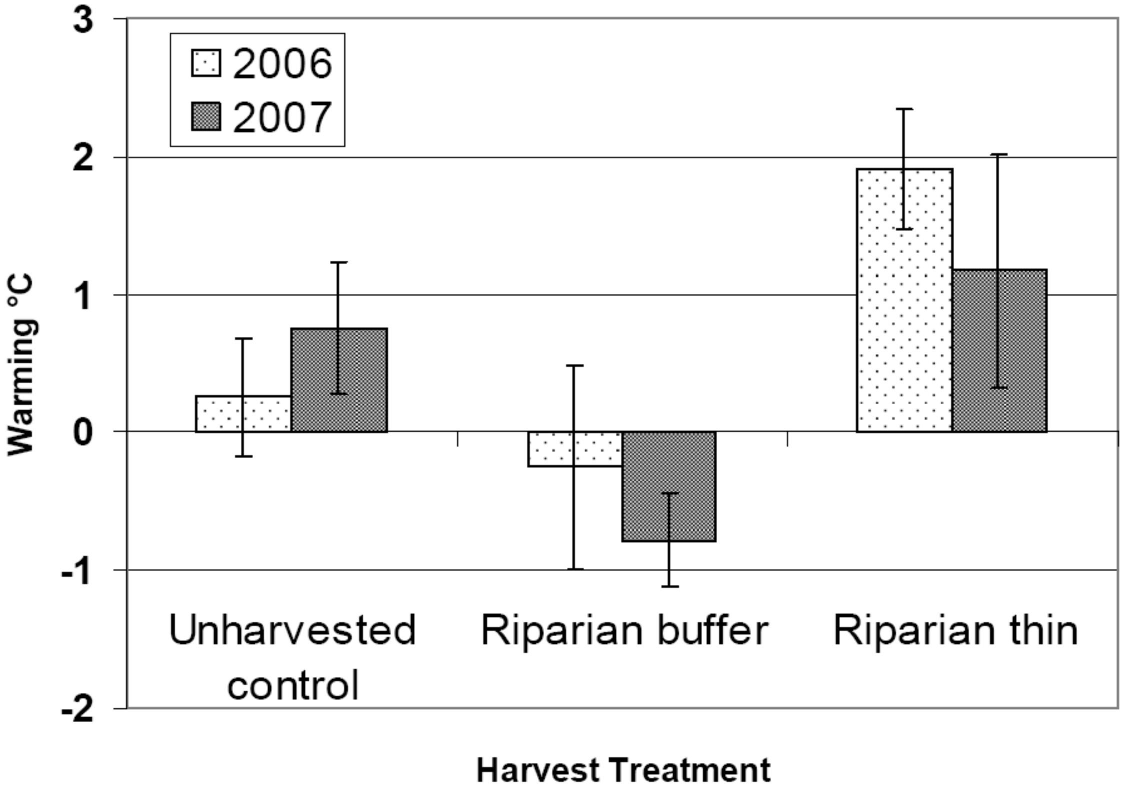

Figure 2a.6. Mean August temperature just downstream of each plot minus the mean August temperature just upstream of each plot (i.e., stream warming) by harvest treatment and year. Error bars are the standard error of the mean.

Result 2b: Evaluate macroinvertebrates and organic matter dynamics

Description: We evaluated the effects of our management treatments on stream ecosystem functioning using measures of invertebrate biomass, in-stream leaf and wood decomposition rates, and food web analyses. We evaluated these response variables during summer, autumn, and winter 2007 and spring 2008.

Summary Budget Information for Result 2b:		
	Trust Fund Budget:	**$ 134,231.00**
	Amount Spent:	**$ 131,952.67**
	Balance:	**$ 2,278.33**

Deliverable	Completion date	Budget	Status
1. Collect summer and autumn samples, initiate litter decomposition study, and submit update report	1/31/08	$52,468	Completed
2. Collect spring samples, complete litter decomposition study, and submit update report	6/30/08	$52,467	Completed
3. Process summer and autumn samples and submit update report 3	1/31/09	$14,648	Completed
4. Process spring and litter decomposition samples and prepare and submit final report	6/30/09	$14,648	Completed

Completion Date: June 2009

Final Report Summary:

Introduction

The Minnesota Forest Resources Council (MFRC) was charged under the Sustainable Forest Resources Act with coordinating the development of voluntary site-level timber harvesting and forest management guidelines. Finalized in 1998, these guidelines recommend practices to address riparian, wildlife habitat, soil, water quality, wetlands, visual quality, and historic and cultural resources. Guideline users include timber harvesters, owners of private forest land, and the state, county land departments, US Forest Service, and major forest products companies.

Riparian timber harvesting guideline research was conducted in two regions in northern Minnesota. Multiple-basin study sites were previously harvested and monitored after one, two and three year post-harvest. Another set of twelve sites located in the single-basin watershed were harvested in 1997 and monitored after one and six year post-harvest. This study documents stream ecosystem responses after five years (4 years for Reservation Tributary) post-harvest at the multiple-basin sites and 10 and 11 years post-harvest at the single-basin watershed and will be used to evaluate how effective the guidelines are at protecting forested riparian areas at a site-level.

Objectives

Our primary objective was to assess long-term effects of riparian management techniques on stream ecosystem function at both the LCMR sites and single-basin sites. Based on results from previous studies from the scientific literature we hypothesized that any long-term effects of riparian timber harvesting at the experimental levels within this study would result in increased: nutrient concentrations, water temperatures, fine sediment, wood inputs, in-stream light (reduced canopy cover), periphyton, number of invertebrates that feed on periphyton (scrapers), and leaf and wood breakdown rates (Tank and Webster 1998, Swank et al. 2001, Eggert and Wallace 2003, Moore et al. 2005, Thompson et al. 2009). We also expected that riparian timber harvesting might result in decreased leaf inputs to streams and a decline in number of invertebrates that feed on leaf material (shredders) (Wallace et al. 1999, Stone and Wallace 1998, Nislow and Lowe 2006). A growing body of scientific literature indicates that measurements of ecological processes and ecosystem function can be sensitive indicators of disturbances to stream function (Bunn et al. 1999, Gessner and Chauvet 2002, Young et al. 2003). Initial research conducted at these sites suggested that litter inputs to streams were significantly less in harvested riparian buffers, with unknown consequences for the stream food webs (Palik in Perry et al. 1998). Our research examined these linkages between stream functions (food resources and detrital processing) and riparian harvest practices. Specific objectives included: 1) quantifying fish and invertebrate habitat, available food resources for stream food webs, and macroinvertebrate response in stream reaches subjected to various riparian management treatments, and 2) evaluating breakdown rates of leaf litter and wood in streams under the different riparian treatments.

Study Sites

Multiple-basin sites

Eight study sites were established in northern Minnesota (Beltrami, Carlton, Cook, Lake, and St. Louis counties) in 2003 to monitor the biological and ecological effects of riparian forest management. Site 1: Shotley Brook, Site 2: Nemadji River Trib., Site 3: Reservation River Tributary, Site 4: West Split Rock River, Site 5: East Branch of Beaver River, Site 6: East Branch of Baptism River, Site 7: Cloquet River tributary, Site 8: St. Louis River tributary.

Treatments were designed to comply with Minnesota's current site-level guidelines (Minnesota Forest Resources Council 2005). Within the eight study sites, riparian management treatments were applied to compare no riparian management with the two different RBA levels. The two treatments of residual basal area were chosen to test "low" and "medium" levels of the current recommended values for riparian management within a fixed width RMZ of 45.7 m. The target "low" and "medium" residual basal area values were 5.7 m^2/ha and 11.5 m^2/ha respectively, however due to logger and topography issues those target RBAs were not always consistent within a site and across all sites (Kastendick 2005). Each of the eight sites was split into two blocks. The upstream block was treated using a passive management approach where no harvesting was allowed within the RMZ, and the downstream block RMZ was randomly assigned one of the two residual basal areas. After assigning treatments to the study sites, they were paired based upon similarities in species composition, soil and aquatic characteristics. This pairing allows comparisons to be made between the low and medium residual basal area treatments and their respective management controls. We also sampled a non-harvested control reach (upland and riparian zone not harvested). Samples could not be collected at the control reach at Site 7 due to a beaver dam downstream of the reach.

Harvest operations began in December 2003 and were completed in seven of the eight sites in March 2004 and the eighth site in March 2005. All harvest operations used conventional harvesting equipment (i.e., feller-buncher and grapple skidder on all sites except the West Split Rock River site where trees were chainsaw felled and cable skidded).

Single-basin sites

Riparian management techniques were also studied within the single-basin watershed in north central Minnesota. Twelve 4.6 ha plots located along 3 first to third order streams (Pokegama Creek, Little Pokegama Creek, unnamed stream) draining into Pokegama Lake (Itasca County, 47' 05" N latitude 93' 35" W longitude) were selected within a 2 km^2 area. Streams reaches through the plots were 1-3 m wide, 137-198 m in length, and contain a mixture of sand and cobble substrate. Dominant tree species on the plots included sugar maple (*Acer saccharum*), paper birch (*Betula papyrifera*), basswood (*Tilia americana*), and quaking aspen (*Populus tremuloides*). Three replicates of 4 treatments were used: True Control plots (no harvest in riparian zone or upland), Riparian Control (uplands clearcut/riparian zone uncut), Whole-tree harvest (uplands and riparian zone cut using the feller-buncher grapple skidder system), and cut-to-length (uplands and riparian zone cut using cut-to-length system). In plots where cutting took place within the 30m riparian zone, 6-10 m^2/ha basal area was left in place (Perry et al. 1998, Kastendick 2005). Harvesting took place in late summer-fall 1997.

Methods

Water quality and habitat measurements

In situ measurements of dissolved oxygen (YSI DO 200 meter), pH, and conductivity (EXTECH ExStickII) were made during June and July 2008 at the multiple-basin sites and during August 2006, June 2007, and July 2007 at the single-basin plots. Water samples for turbidity (LaMotte 2020e Turbidimeter) and alkalinity were collected, returned to the laboratory and processed according to APHA (1995) methods. Anions and cations were analyzed using ICP-MS in the laboratory. Water temperature was monitored continuously during ice-free months using HOBO temperature recorders. Stream discharge was measured in each stream during the ice-free months using Solonist level recorders and stage/discharge regression relationships. Canopy cover was estimated at each reach with a spherical densiometer. Data for qualitative habitat evaluation index (QHEI) scores at the eight multiple-basin study sites were collected in August 2008. Substrate was quantified visually (silt, sand, gravel, pebble, cobble and boulder) at multiple transects in each reach. Current velocity and depth were also recorded at each reach. Data could not be collected at the control reach at Site 7 due to a beaver dam downstream of the reach.

Periphyton (algal) standing crop

We assessed differences in algal standing crop biomass by measuring chlorophyll *a* content of algae growing on three rocks at each site (upstream and within) in each plot at the single-basin location and within each of the multiple-basin reaches. Chlorophyll *a* was extracted from rocks and measured on a spectrophotometer using APHA (1995) methods. Rock area was measured to estimate algal biomass in grams of chlorophyll *a* per unit rock surface area.

Organic matter standing crop – FBOM, CBOM

We quantified the amount of detrital food resources (Fine Benthic Organic Matter – FBOM; Coarse Benthic Organic Matter – CBOM) available to aquatic consumers in summer 2007 (single-basin study sites) and June 2008 (multiple-basin study sites). CBOM and FBOM was collected with the quantitative macroinvertebrate samples (methods described below) was separated from the invertebrates and separated into organic matter types (e.g. leaves, wood). Each fraction was dried at 60ºC, weighed, ashed at 500 ºC, and reweighed to obtain ash-free dry mass (AFDM) per m^2. Samples could not be collected at the control reach at Site 7 due to a beaver dam downstream of the reach. We also collected CBOM according to previously established methods (Newman in Perry et al. 1998) at each single-basin plot.

Leaf and wood breakdown rates

Breakdown rates of sugar maple (*Acer saccharum*) and balsam popular (*Populus balsamifera* L.), the dominant tree species of the pre- and post-harvest overstory at the single-basin sites, respectively, were estimated within and above each plot during autumn 2008 to autumn 2009 using methods of Eggert and Wallace (2003). Litter bags were filled with 15 grams of dried leaves, deployed in the streams at peak leaf fall, and replicate bags picked up at approximately 200, 250, and 300 day intervals dependent on breakdown rates and access to bags (bags could be picked up from frozen streams or when cooperator closed access roads to plots during spring months). Ten litterbags of each species were taken out to the field, returned to the lab immediately, and reweighed to correct for handling loss. In the lab, litterbag contents were washed to remove invertebrates and sediments, oven dried at 60ºC, weighed, ashed at 500 ºC, and re-weighed to obtain AFDM remaining for each date. Breakdown rates were calculated using the exponential decay model (Petersen and Cummins 1974). Invertebrates associated with litterbag contents were saved for a portion of the litterbags and will be analyzed at a later date. Wood breakdown rates were measured using aspen veneers anchored in the stream bottom (Tank and Webster 1998). Wood veneers were placed in the streams in June 2008 and are being retrieved as long as sufficient material remains. Lab processing of wood veneers was similar to that for litterbags. Wood breakdown rates were calculated using the same exponential decay model described above.

Macroinvertebrate community

Qualitative samples were collected within each of the three reaches at each multiple-basin site in August 2008 using Atuke's (2007) methods. Using a 500 µm-mesh D-frame net, we sampled each reach 20 times approximately every 2.5 meters, taking care to include all habitats within a reach. Samples were preserved in alcohol and brought back to the lab for sorting and identification to the lowest practical taxonomic unit. Samples could not be collected at the control reach at Site 7 due to a beaver dam downstream of the reach. Our goal was to examine responses of those invertebrate taxa most likely to change with riparian harvesting. We calculated taxa richness, percent Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa, and percent scrapers, shredders, collector-gatherers, collector-filterers, and predators for each reach at each site. Four quantitative invertebrate samples were collected within each reach at the multiple-basin sites during June 2008 using Hess or Surber samplers. Invertebrates have been separated from the organic matter and will be identified at a later date. We will do more intensive analysis of invertebrates from these samples (e.g., biomass).

Two quantitative Surber samples from riffle habitat within and above each treatment plot at the single-basin site were collected in August 2006, June 2007, July 2007, and October 2007. Invertebrates from the August 2006, June 2007, and July 2007 collection periods were identified to the lowest practical taxonomic unit and classified by functional feeding group using methods of Lugthart and Wallace (1992). Substrate type, water depth, and current velocity at each Surber sample location were recorded at the time of sample collection. We calculated taxa richness, percent Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa, and percent scrapers and shredders for upstream and within plot reaches. Below we present results from the June 2007 data set.

Macroinvertebrate and fish diets

Macroinvertebrates for diet analyses were collected at the single-basin site in June and October 2007. Fish for diet analyses were collected in July 2007 at the single-basin plots by Eric Merten (UMN) and saved for diet analyses. Due to a prolonged drought, fish specimens were not found at each plot. Macroinvertebrates and fish samples for diet and isotope analyses were also collected during June and July 2008 at each of the multiple-basin reaches. A University of Minnesota graduate student (funded by the US Forest Service) initiated lab processing of the diet samples during fall 2008. No results are currently available.

Statistical analyses

Due to the lack of "before" data and possible upstream effects on downstream treatments, we used an upstream (reference) and downstream (within treatment) approach at the single-basin plots. We calculated differences between reaches, pooled the plot differences for each treatment and tested for differences among treatments using one-way ANOVA. For the multiple-basin data, we used one-way ANOVA to test for differences among control, riparian control, and treatment reaches for each of the treatment levels (control, riparian control, and low and medium RBA). Tukey's HSD test was run to test for differences between sites when significant ANOVA results were found.

Results

Water quality and habitat measurements

Multiple-basin sites

We hypothesized that the most likely differences in water chemistry between harvested and control sites at both the single- and multiple-basin study sites would be higher nutrient concentrations (nitrate and dissolved inorganic phosphorus [DIP]) at the harvested sites. Five years after harvest we found no significant differences in either NO_3-N or DIP among treatments during the months of June or July 2008 (Tables 2b.1A and 2b.1B). Nitrate-N was at or below detection limits (<0.02 mg/L) during June at most sites. During July there was a non-significant trend of higher nitrate-N concentrations at the riparian control and treatment reaches than controls at most sites. DIP generally was at or below detection limits (<0.03 mg/L) at all sites during both months (Tables 2b.1A and 2b.1B). Conductivity varied widely among the eight sites, and was highest at Shotley Brook and West Split Rock River, indicative of high productivity at those sites (Tables 2b.1A and 2b.1B). Baseflow turbidity levels were all low at each reach of each site during both months (Tables 2b.1A and 2b.1B). Dissolved oxygen concentrations in all reaches at all eight sites were all well above the threshold that limits aquatic life (5 mg/L).

Previous research showed that riparian timber harvesting may result in increased water temperatures at harvested sites due to increase exposure of stream water to sunlight. Light available for periphyton growth was estimated as percent open canopy (Figure 2b.1). We observed a trend (p=0.09) of higher light levels in the low RBA treatment reaches compared to control and riparian control reaches and no differences between medium RBA treatment and control reaches (Figure 2b.1). Water temperature and stream level loggers were removed from the multiple-basin study sites in early October 2008 and downloaded in the lab. During the downloading process it was determined that a number of loggers were not launched properly prior to installing them in the field. Those loggers were relaunched and redeployed at the multiple-basin study sites in late October. Data available for loggers that were deployed properly showed that temperatures were significantly higher in harvested reaches than in control reaches for two sites (one site each in low and medium RBA) (Table 2b.2). We found no statistically significant differences in mean summer and fall temperatures when data from low RBA and medium RBA sites were pooled by treatment. It should be noted that due to the high variability among the four sites for this and other parameters examined in this study, some trends were not found to be statistically significant at the p<0.05 level. We caution that statistically insignificant results may not necessarily be biologically insignificant. Remaining data will be analyzed from redeployed loggers at the end of summer 2009.

Single-basin sites

Ten years after riparian timber harvesting we found no significant differences among the four treatments for all chemical parameters analyzed. Nitrate-N was higher at some plots than others (plots 1 and 2), but there was no trend in increased nutrients within harvested reaches (Tables 2b.3A, 2b.3B, and 2b.3C). Conductivity and cation concentrations were high at all plots indicating high productivity in these low gradient streams. Baseflow turbidity was higher at the single-basin plots than at the multiple-basin sites, but still well below levels that impair aquatic life (approximately 25 NTU, R. Jackson unpublished data). We did not collect turbidity samples during storm events, which would be a better measure of sediment impacts on aquatic life. Dissolved oxygen concentrations in all reaches at all eight sites were all well above the threshold that limits aquatic life (5 mg/L).

Water temperature loggers at 3 plots were not deployed properly. Results will available at the end of summer 2009 after the redeployed temperature loggers are retrieved. Canopy cover was measured intensely (at ten meter intervals) upstream and within each single-basin plot in August 2007. Differences between upstream and within treatment measurements of percent open canopy were not significantly different ($p>0.05$), but were greatest for the cut-to-length and whole-tree harvest treatments (Figure 2b.2).

Periphyton standing crop

<u>Multiple-basin sites</u>

Long-term effects of riparian harvesting may result in increased in-stream algal levels. We did not observe significant ($p>0.05$) differences between harvested and control reaches at either harvesting level (Figure 2b.3). There was significantly higher periphyton levels at all of the low RBA reaches compared to the medium RBA reaches, which may be related to initial site selection. Periphyton standing crop was positively and significantly related to light levels in the treatment reaches of all sites, which suggests that periphyton is responding to light levels in the treatment reaches (Figure 2b.4). There was no relationship between periphyton and light in the control and riparian control reaches.

<u>Single-basin sites</u>

Periphyton standing crop at the single-basin plots in August 2006 was similar at upstream and within reaches for all treatments except whole-tree harvesting (Figure 2b.5). We observed no significant differences between upstream and downstream reaches for any treatment in June 2007 or October 2007, although high variability among plots may have prevented us from detecting small differences (Figures 2b.6 and 2b.7).

Litter inputs

<u>Multiple-basin sites</u>

We predicted that removal of timber from the riparian management zones would result in reduced leaf litter inputs to treatment reaches of streams (low RBA reaches would have lower leaf inputs than either medium RBA, riparian controls or control reaches) immediately following harvesting with recovery through time as vegetation regenerated. We also expected wood inputs to be higher in treatment plots most susceptible to blowdown (low RBA> medium RBA).

Five years after harvest, plots with the lowest RBA within the riparian zone had higher overhead wood inputs to streams (Figures 2b.8A and 2b.8B). Average wood inputs to all reaches were relatively small compared to leaf inputs, suggesting that the observed differences in wood inputs among reaches were due to differences in small woody debris (twigs) rather than large woody debris (stems). No differences were found for overhead or lateral leaf inputs, which dominated total organic matter inputs (Figures 2b.8A and 2b.8B).

Single-basin sites

Eleven years after harvest, overhead leaf inputs to low-gradient single-basin streams were significantly lower in the whole-tree harvest treatment compared to streams with unharvested RMZs (Figure 2b.9). We found no significant differences between leaf inputs to true control, riparian control, or cut-to-length treatment plots (Figure 2b.9). Increased wood inputs likely resulted from increased blowdown over time (Figure 2b.10 photo). Note that the limited area of the eight overhead traps per reach is not sufficient to accurately estimate wood inputs to these streams. The large input of wood for the whole-tree harvest treatment (1 kg/m^2) was a result of a large blown down stem in plot 4 that landed directly on an overhead litter trap between June and October 2008. Our estimates of wood inputs are clearly an underestimate of wood falling into the streams.

Organic matter standing crop – CBOM, FBOM, seston

Multiple-basin sites

Detrital food resources (Fine Benthic Organic Matter – FBOM; Coarse Benthic Organic Matter – CBOM; and seston – fine organic matter in transport) available to aquatic invertebrates were sampled at the multiple-basin sites June 2008. There were no significant differences in leaf or wood standing crop among reaches within the low and medium RBA treatment levels (Figures 2b.11A and 2b.11B). In general, leaf and wood standing crops were higher at the medium RBA sites than at the low RBA sites. These data along with the periphyton data (Figure 2b.3) suggest that food webs in the medium RBA sites are naturally more detrital based, while food webs within the low RBA sites are more autochthonous (algal) based. There were no significant differences in FBOM among reaches for either the low or medium RBA treatment sites (Figure 2b.12A). Fine Benthic Inorganic Matter (FBIM) is a quantitative measure of fine sediments in the stream bottom. Our estimates of FBIM in riffle habitats at the multiple-basin sites show that there is not significantly more sediment in the treatment reaches than control or riparian control reaches (Figure 2b.12B). It is worth noting that FBIM (Figure 2b.12B) and FBOM (Figure 2b.12A) closely relate to leaf standing crops (Figure 2b.11A) and wood standing crops (Figure 2b.11B), respectively, at the low and medium RBA sites. There were no differences in seston transport among sites, although we only measured seston in the water column during baseflow conditions. Future work should include measurements of storm transport of fine organic and inorganics.

Single-basin sites

We collected CBOM samples in August 2007 from riffle and depositional habitats at each single-basin plot using methods previously established by multiple-basin project researchers. We refined the method by separating collected CBOM into "leaf", "wood", and "other" categories rather than lumping all organic matter types together. We anticipated that differences in leaf and small wood standing crops among harvested treatments might exist due to differences in vegetation regeneration and blowdown in various treatments. These differences are ecologically relevant to invertebrate community structure and function, and in-stream organic matter dynamics. Leaf standing crop in August 2007 was lower than small wood in both habitats across all treatments (Figures 2b.13a and 2b.13b). More organic matter (leaf and small wood) was found in depositional habitat than in riffle habitat across all treatments. Differences between reaches (upstream - within) for leaf and wood standing crops appeared to be similar among treatments, except depositional wood in the whole-tree harvest treatment where more wood was found within the treatment reach (probably not statistically different due to very high variability among plots). There were no significant differences between upstream and within reaches for any treatment for either FBOM or FBIM (Figure 2b.14). The amount of sediment (mean of 45-90 g/m^2) found in the true control plots suggest that the increased sediment load associated with the culvert issues at the beginning of the study still remain and may be masking any riparian harvesting effects.

Leaf and wood breakdown rates

Single- and multiple-basin sites

We hypothesized that leaf and wood breakdown rates would either be higher in riparian harvested streams due to increased nutrient concentrations from runoff and the consequent increase in breakdown due to microbial stimulation, or lower due to the loss of shredder invertebrates associated with reduced leaf inputs from riparian harvesting.

The lack of access to the single-basin sites during spring 2009 delayed spring litterbag and wood veneer pickups until June 1-4, 2009. Preliminary data analyses of wood breakdown rates at the single-basin sites (based on available data points) suggest that breakdown rates are similar ($p > 0.05$) across treatments (Figure 15). Breakdown rates were extremely variable over all 12 plots and with treatments ranging from -0.0007 (cut-to-length) to -0.0027 (true control). Many of the sets of veneers were buried in sediments which may have accounted for the extreme variability among plots and within treatments. Additional veneers and litterbags will be picked up over summer and fall 2009. Final data analyses will be completed after remaining samples have been collected and processed in the lab.

Macroinvertebrate community

Multiple-basin sites

We collected, sorted, and identified 127,267 individuals of 157 different invertebrate taxa from the eight multiple-basin sites during August 2008 (Table 2b.4). Taxa richness was highest at the riparian control and the low RBA treatment sites (Figure 2b.16A). The percent EPT taxa, or those taxa most sensitive to low dissolved oxygen conditions, was greatest at each of the reaches associated with the medium RBA treatments (Figure 2b.16B). Although not significantly different at the $p<0.05$ level, there was a trend toward higher proportions of scraper taxa (invertebrates that scrape and feed on attached algae), in each of the treatment reaches (Figure 2b.16C). Shredders made up a minor portion of the communities at all sites (Figure 2b.16D). Collector-gatherers dominated (38-49%) the communities at all sites (Figure 2b.16E), which is not unexpected since most of the collector-gatherer taxa are small bodied organisms which have high turnover rates. We also observed a trend toward greater proportions of collector-filterers at each of the medium RBA reaches (Figure 2b.16F). Predators made up a significantly greater proportion of the community at the low RBA riparian control reaches than either the control or treatment reaches (Figure 162b.G). Further investigation revealed that the high numbers of predators at these reaches were composed of the small-bodied Acari (water mites), Tanypodinae (midge larvae), *Atherix* (water snipe larvae), and young instars of Gomphidae (dragonfly larvae) collected from Sites 4 (W. Split Rock R.) and 6 (East Br. Beaver River) (Table 2b.5).

Single-basin sites

We collected, sorted and, identified 65,688 individuals of 67 different invertebrate taxa from the twelve single-basin plots during June 2007 (Table 2b.5). Taxa richness was similar in upstream control reaches compared to within plot reaches for all treatments (Figure 2b.17A). Although not significantly different, we found higher total invertebrate abundances within the cut-to-length plots (Figure 2b.17B). The high abundances within this treatment was attributed to very high densities of the collector-filterer *Simulium* (blackfly larvae) and collector-gatherer Chironomidae (midge larvae) at plot 8 (Table 2b.5). Scrapers were more abundant (Figure 2b.17C) and proportionately more dominant (Figure 2b.17E) at the riparian control, cut-to-length, and whole-tree harvest plots, although not significantly so due to high plot-to-plot variability. Shredders were more abundant (Figure 2b.17D) and dominant at the control plots (upstream and within) than in the other treatments. Percent EPT taxa were similar between upstream and within reaches for all treatments except the upstream control plots (particularly plots 1 and 7) where we found large numbers of young instar stonefly larvae (Figure 2b.17G). Overall all of the plots were dominated by collector-gatherer and collector-filterer taxa (Chironomidae and *Simulium*) which made up 81% of the invertebrate community in some samples.

Conclusions

Multiple-basin sites

Five years after harvest, we observed no statistically significant differences in water chemistry between reaches for either the low or medium residual RBA treatments. It is likely that the elevated nitrate levels observed immediately after harvesting (Atuke 2005) have been mitigated through vegetative regeneration. Light levels were highest in the low RBA treatment reaches compared to all other reaches. Although not statistically significant, this result does not suggest that the difference is not biologically meaningful. We observed a significant relationship between light levels and periphyton standing crop in the treatment reaches but not the control or riparian control reaches. Despite the fact that we did not observe differences in leaf inputs to treatment plots, we did see higher leaf and wood standing crops at the medium RBA sites than at the low RBA sites. These data along with the periphyton results suggest that stream food webs within the medium RBA sites are naturally more detrital based, while food webs within the low RBA sites are more autochthonous (algal) based. The invertebrate results closely tracked available food resources at the multiple-basin sites. There were proportionately greater numbers of scrapers collected at sites with the highest periphyton levels and greater numbers of shredders found at sites with the highest leaf and wood standing crops. It is likely that the major reason why we did not see larger harvesting impacts on the aquatic invertebrate community either five years after harvest or at the beginning of the study (Atuke 2007), was due to the lack of uniform residual basal areas left across the harvested riparian areas at some sites (Palik, Result 1 of this report). It was visually obvious during site visits that riparian areas closest to the streams at some sites (e.g. Site 6 – East Baptism R.) had higher residual basal areas than riparian areas further away from the stream, thus reducing any potential impacts to the aquatic community.

Single-basin sites

The harvest method used in 1997 did not result in any statistically significant differences in water chemistry, light levels, periphyton levels, or invertebrate abundances among plots. However, based on the functional feeding characteristics of the invertebrate community we found that scraper taxa abundances tended to be higher in the harvested plots (corresponding to higher periphyton levels), while shredders were less abundant. We measured lower overhead leaf inputs to streams in the whole-tree harvest plots, but not the cut-to-length plots where shredder abundances were lowest. Those organisms that are morphologically able to utilize fine benthic organic matter (FBOM) as a food resource were also very abundant in most plots. This FBOM is likely the result of sediments deposited in the streams during road building/culvert failures earlier in the study, continuing bank erosion, and the breakdown of leaf litter inputs by microbes. Preliminary data suggested no differences in wood breakdown rates although many of the wood veneers became buried in sediment over the winter and spring months. It is possible that the continuing movement of sediment throughout the stream reaches may be masking any real harvesting impacts on the aquatic invertebrate food web. Ideally some sort of restoration/sediment removal effort should be undertaken (perhaps in the form of an experimental manipulation), which would allow the currently buried cobble substrates to surface and provide an opportunity to more accurately measure of harvesting effects.

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. The only unresolved problem relative to this Result was the water temperature loggers which were not deployed properly at 3 plots within the single-basis study. Data from those redeployed temperature loggers will available at the end of summer 2009 after they are retrieved. All other work was completed as planned. Additional analyses will be conducted during and after the summer of 2009 as additional data becomes available.

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Table 2b.1A. Water chemistry at the multiple-basin sites during June 2008. No data at Site 7 Control reach due to a beaver dam within the reach.

Site	Reach	pH	Conductivity uS/cm	Turbidity NTU	Alkalinity mg/L CaC03	Cl^- mg/L	NO_3^--N mg/L	Diss Inorg P mg/L	SO_4^{-2} mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	K+ mg/L	Na^+ mg/L	Fe^{2+} mg/L
1	Control	7.41	188.5	1.4	88.0	1.56	0.14	<0.03	10.29	30.80	8.68	1.30	3.93	0.83
1	Rip Control	7.35	186.1	1.7	81.5	1.58	0.09	<0.03	10.31	29.70	8.36	2.10	3.03	0.84
1	Tmt - Med RBA	7.86	188.1	1.4	86.3	1.57	<0.02	<0.03	10.26	29.90	8.57	1.10	2.79	0.84
2	Control	6.33	41.0	0.9	18.5	0.12	<0.02	<0.03	0.76	6.12	2.17	0.70	1.56	1.28
2	Rip Control	6.75	41.6	1.0	17.7	0.13	<0.02	<0.03	0.81	6.77	2.29	<0.08	1.44	0.76
2	Tmt - Med RBA	7.21	37.2	1.1	20.3	0.14	<0.02	<0.03	0.90	6.18	2.26	2.69	1.51	1.25
3	Control	7.41	77.4	4.5	34.5	0.20	<0.02	<0.03	3.16	9.67	2.87	0.62	1.61	1.05
3	Rip Control	7.41	75.9	4.5	32.7	0.23	<0.02	<0.03	3.19	9.41	2.74	0.23	1.63	1.02
3	Tmt - Med RBA	7.36	73.4	5.9	31.8	0.20	<0.02	<0.03	3.18	9.52	2.81	0.22	1.54	1.03
4	Control	7.34	94.1	1.1	43.5	0.26	0.09	<0.03	2.47	13.30	3.81	0.32	3.20	0.90
4	Rip Control	7.37	93.4	0.9	43.8	0.26	0.09	<0.03	2.46	12.40	3.63	0.20	3.53	0.83
4	Tmt - Low RBA	7.32	92.8	0.9	44.2	0.32	0.09	<0.03	2.46	12.70	3.65	<0.08	2.68	0.86
5	Control	7.20	47.5	0.8	28.0	0.28	<0.02	<0.03	2.99	7.24	2.54	1.29	2.19	2.05
5	Rip Control	7.40	48.2	0.9	27.0	0.23	<0.02	<0.03	2.98	6.96	2.34	3.87	3.07	0.82
5	Tmt - Med RBA	7.62	49.2	0.9	25.0	0.28	<0.02	<0.03	2.98	6.86	2.33	0.94	1.82	0.81
6	Control	7.05	35.2	0.4	15.2	0.48	<0.02	<0.03	2.64	5.58	1.82	2.20	1.60	0.86
6	Rip Control	7.13	36.8	0.4	15.1	0.50	<0.02	<0.03	2.65	5.63	1.81	0.82	1.73	0.87
6	Tmt - Low RBA	7.27	37.1	0.4	15.3	0.55	<0.02	<0.03	2.64	5.69	1.86	1.37	1.63	0.86
7	Control	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7	Rip Control	5.91	35.2	0.9	11.4	0.12	<0.02	<0.03	0.39	5.13	2.15	0.09	1.19	0.89
7	Tmt - Low RBA	6.31	35.1	0.7	9.5	0.13	<0.02	<0.03	0.48	5.07	2.13	0.08	1.20	0.89
8	Control	6.07	37.0	1.0	20.0	0.14	<0.02	<0.03	0.16	6.73	2.00	1.56	1.31	1.01
8	Rip Control	6.29	33.5	1.3	16.0	0.15	<0.02	<0.03	<0.02	5.34	1.59	3.36	1.16	1.08
8	Tmt - Low RBA	6.60	35.1	5.6	20.0	0.18	<0.02	<0.03	0.24	6.24	1.82	2.10	0.94	1.01

Table 2b.1B. Water chemistry at the multiple-basin sites during July 2008. No data at Site 7 Control reach due to a beaver dam within the reach.

Site	Reach	pH	Conductivity uS/cm	Turbidity NTU	Alkalinity mg/L CaC03	Cl^- mg/L	NO_3^--N mg/L	Diss Inorg P mg/L	SO_4^{-2} mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	K+ mg/L	Na^+ mg/L	Fe^{2+} mg/L
1	Control	7.43	344.0	2.7	185.0	1.48	<0.02	<0.03	0.85	51.40	14.40	0.61	3.96	1.01
1	Rip Control	7.43	342.0	2.0	186.9	1.56	0.08	<0.03	0.91	55.20	15.40	0.51	5.02	0.90
1	Tmt - Med RBA	7.46	334.0	2.2	189.0	1.48	0.08	<0.03	1.05	55.20	15.60	0.46	3.63	0.96
2	Control	6.36	109.8	9.7	53.2	0.35	<0.02	<0.03	0.39	16.00	5.61	0.16	2.58	2.84
2	Rip Control	6.95	101.5	6.3	49.8	0.26	0.08	<0.03	0.53	14.80	5.30	0.21	8.20	2.17
2	Tmt - Med RBA	6.86	96.8	4.9	48.0	0.31	0.09	<0.03	0.86	15.00	5.37	0.68	4.32	1.90
3	Control	7.25	101.6	2.9	46.2	0.25	0.09	<0.03	2.37	13.30	3.77	0.20	3.77	1.23
3	Rip Control	7.45	101.9	2.6	45.9	0.38	0.11	<0.03	2.42	13.30	3.84	0.37	2.28	1.15
3	Tmt - Med RBA	7.38	102.0	2.4	45.4	0.33	0.13	<0.03	2.47	13.30	3.86	0.44	3.71	1.11
4	Control	7.36	129.1	2.0	60.2	0.38	0.14	<0.03	2.79	17.90	5.07	0.60	2.83	0.91
4	Rip Control	7.47	128.8	1.6	63.8	0.42	0.15	<0.03	2.77	18.20	5.16	0.33	3.82	0.91
4	Tmt - Low RBA	7.40	134.4	1.5	64.3	0.41	0.15	<0.03	2.85	18.40	5.22	0.36	2.76	0.91
5	Control	7.29	79.4	1.2	37.1	0.28	<0.02	<0.03	1.60	10.90	3.52	0.14	2.38	1.23
5	Rip Control	7.32	80.3	1.1	38.2	0.28	<0.02	<0.03	1.64	10.40	3.45	<0.08	2.88	1.21
5	Tmt - Med RBA	7.24	82.7	1.9	37.7	0.29	<0.02	<0.03	1.66	10.90	3.59	0.14	6.31	1.20
6	Control	7.08	59.6	0.3	26.6	0.43	<0.02	<0.03	2.14	7.86	2.59	0.27	2.04	0.99
6	Rip Control	7.22	60.6	0.3	26.3	0.48	0.08	<0.03	2.18	7.74	2.58	<0.08	1.88	0.97
6	Tmt - Low RBA	7.37	62.5	0.3	27.2	0.63	0.09	<0.03	2.25	8.26	2.63	0.37	2.13	1.01
7	Control	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7	Rip Control	7.17	62.2	1.6	30.0	0.18	0.10	<0.03	0.47	7.33	3.15	1.37	1.74	2.40
7	Tmt - Low RBA	6.54	47.9	1.4	30.0	0.18	0.11	<0.03	0.50	6.44	2.68	0.17	1.16	1.92
8	Control	6.21	44.5	0.9	22.7	0.20	<0.02	<0.03	<0.02	9.18	2.68	0.35	1.12	1.27
8	Rip Control	7.04	47.9	1.8	13.6	0.20	0.15	0.12	0.19	8.28	2.36	0.69	0.65	1.86
8	Tmt - Low RBA	6.20	48.6	1.8	16.0	0.16	0.12	<0.03	0.19	8.20	2.40	0.47	0.74	1.61

Table 2b.2. Water temperature at the multiple-basin control, riparian control, and treatment reaches from 24 June 2008 to 23 October 2008. No data available from Reservation Trib. (Medium residual basal area [RBA] site) and Cloquet Trib. (Low RBA site). Letters indicate significant differences ($p<0.05$) between reaches within a site.

Low Residual Basal Area

	West Split Rock R.			East Br. Baptism R.			St. Louis Trib.		
	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt
mean (ºC)	13.9[a]	14.2[b]	14.1[a,b]	15.8[a]	15.2[b]	15.1[c]	14.0[a]	13.7[b]	13.7[b]
se (ºC)	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
max (ºC)	23.2	23.2	23.2	26.0	25.6	24.8	23.6	20.6	20.6
min (ºC)	2.9	5.0	3.3	4.6	4.2	4.6	2.9	5.0	5.0
range (ºC)	20.4	18.3	19.9	21.4	21.4	20.2	20.7	15.6	15.6

Medium Residual Basal Area

	Shotley Bk.			Nemadji Trib.			East Br. Beaver R.		
	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt
mean (ºC)	15.8[a]	15.4[b]	15.3[b]	13.1[a]	13.5[b]	13.7[c]	15.9[a]	15.6[b]	15.1[c]
se (ºC)	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1
max (ºC)	25.2	23.6	22.9	18.7	19.0	21.0	26.7	26.3	26.0
min (ºC)	5.0	4.6	3.7	5.4	3.7	3.7	4.2	3.7	3.7
range (ºC)	20.2	19.1	19.1	13.3	15.3	17.2	22.6	22.6	22.2

Table 2b.3A. Water chemistry at the single-basin plots during August 2006.

Tmt	Plot	Reach	pH	Conductivity uS/cm	Turbidity NTU	Alkalinity mg/L CaC03	Total P mg/L	Total N mg/L	Cl^- mg/L	NO_3^--N mg/L	Diss Inorg P mg/L	SO_4^{-2} mg/L	NH_3N mg/L	NO_3 $+NO_2N$ mg/L	Tot Org C mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	K+ mg/L	Na^+ mg/L	Fe^{2+} mg/L
True Control	1	Up	7.09	267	7.4	148	0.08	0.67	1.12	0.27	<.03	1.58	0.09	0.27	11.53	38.70	10.70	2.37	5.54	0.08
True Control	1	Down	7.25	270	6.2	155	0.06	0.56	1.33	0.30	<.03	1.77	<.02	0.29	11.77	36.20	10.10	2.10	5.34	0.08
True Control	7	Up	7.88	246	2.2	127	0.07	0.45	0.59	0.17	<.03	6.71	<.02	0.14	12.76	27.10	9.90	0.74	4.73	0.10
True Control	7	Down	7.92	294	1.8	146	0.04	0.38	0.47	0.16	<.03	7.25	<.02	0.13	10.12	28.10	11.10	0.86	5.41	0.10
True Control	9	Up	8.14	478	0.9	242	0.06	0.26	0.45	0.18	<.03	9.16	<.02	0.15	5.87	14.30	15.00	0.91	5.07	0.07
True Control	9	Down	8.22	483	0.3	249	0.05	0.24	0.45	0.17	<.03	8.71	<.02	0.14	2.10	14.00	13.90	0.75	4.45	0.06
Rip Control	3	Up	8.06	224	2.0	118	0.05	0.27	1.15	0.09	<.03	7.59	<.02	0.06	13.65	19.50	9.39	0.96	2.70	0.15
Rip Control	3	Down	8.13	232	2.9	126	0.07	0.26	1.11	0.10	<.03	7.67	<.02	0.06	12.77	24.60	9.09	0.95	2.63	0.12
Rip Control	5	Up	8.10	244	5.7	125	0.07	0.31	1.12	0.10	<.03	7.56	<.02	0.06	11.42	33.20	11.60	1.25	3.38	0.13
Rip Control	5	Down	8.13	249	5.7	122	0.07	0.30	1.07	0.09	<.03	7.18	<.02	0.06	11.01	30.10	10.30	1.04	2.93	0.12
Rip Control	12	Up	7.82	415	0.4	224	0.08	0.12	0.51	0.13	<.03	8.95	<.02	0.11	4.54	39.00	18.20	1.11	4.02	0.07
Rip Control	12	Down	7.74	407	0.4	214	0.06	0.16	0.49	0.14	<.03	8.62	<.02	0.11	4.87	32.00	16.20	1.04	3.69	0.07
Cut-to-length	2	Up	7.20	254	2.8	147	0.06	0.45	1.26	0.22	<.03	1.64	<.02	0.20	7.78	35.30	9.94	1.81	5.02	0.08
Cut-to-length	2	Down	6.99	263	1.2	139	0.05	0.27	1.24	0.12	<.03	2.11	<.02	0.09	6.45	35.80	9.82	2.05	5.07	0.07
Cut-to-length	8	Up	7.84	308	1.8	151	0.07	0.37	0.50	0.16	<.03	8.02	<.02	0.13	8.86	27.30	11.10	0.80	5.21	0.09
Cut-to-length	8	Down	7.97	313	1.7	158	0.06	0.37	0.58	0.15	<.03	7.91	<.02	0.13	10.57	19.10	12.40	0.99	5.87	0.08
Cut-to-length	11	Up	7.68	422	0.8	232	0.08	0.13	0.50	0.12	<.03	8.63	<.02	0.09	4.31	23.10	17.90	1.08	3.98	0.07
Cut-to-length	11	Down	7.68	417	0.7	224	0.06	0.12	0.49	0.13	<.03	8.68	<.02	0.10	4.49	27.50	18.10	1.14	3.96	0.07
Whole-tree harvest	4	Up	8.08	242	3.6	122	0.05	0.23	1.12	0.09	<.03	7.58	<.02	0.06	11.86	32.60	11.10	1.32	3.38	0.14
Whole-tree harvest	4	Down	8.02	250	3.8	127	0.06	0.32	1.12	0.09	<.03	7.84	<.02	0.06	11.50	34.50	11.60	1.28	3.45	0.14
Whole-tree harvest	6	Up	7.41	179	3.4	82	0.06	0.74	0.48	0.21	<.03	12.02	0.04	0.19	21.82	26.00	7.55	0.59	2.72	0.26
Whole-tree harvest	6	Down	7.58	190	3.6	96	0.05	0.64	0.39	0.19	<.03	9.93	<.02	0.17	19.52	26.60	8.03	0.65	3.05	0.17
Whole-tree harvest	10	Up	7.94	479	1.2	239	0.07	0.19	0.47	0.13	<.03	8.49	<.02	0.11	0.86	22.00	18.80	1.02	5.77	0.07
Whole-tree harvest	10	Down	7.63	442	1.0	247	0.05	0.16	0.49	0.12	<.03	8.77	<.02	0.08	3.94	23.80	19.10	1.16	4.93	0.07

Table 2b.3B. Water chemistry at the single-basin plots during June 2007.

Tmt	Plot	Reach	pH	Conductivity uS/cm	Turbidity NTU	Alkalinity mg/L CaC03	Cl^- mg/L	NO_3^--N mg/L	Diss Inorg P mg/L	SO_4^{-2} mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	K+ mg/L	Na^+ mg/L	Fe^{2+} mg/L
True Control	1	Up	6.99	229	2.17	116	1.15	0.24	<.03	1.37	30.80	8.24	1.93	4.92	0.10
True Control	1	Down	7.2	222	2.11	124	1.17	0.29	<.03	1.09	24.00	6.38	1.69	4.14	0.09
True Control	7	Up	6.94	163	1.23	85	0.35	0.17	<.03	2.93	19.70	5.86	0.75	2.94	0.32
True Control	7	Down	7.12	158	0.67	91	0.38	0.16	<.03	2.86	23.40	6.86	0.71	3.51	0.35
True Control	9	Up	7.34	417	0.16	241	0.55	0.13	<.03	7.00	34.30	16.70	1.01	6.59	0.07
True Control	9	Down	7.26	417	0.25	247	0.52	0.12	<.03	6.07	37.90	15.40	0.89	5.60	0.07
Rip Control	3	Up	7.38	256	0.38	130	1.92	0.12	<.03	5.60	31.50	9.11	0.82	3.09	0.13
Rip Control	3	Down	7.23	267	0.39	152	1.51	0.10	<.03	5.84	25.40	8.48	0.85	3.06	0.09
Rip Control	5	Up	7.35	247	0.69	141	1.38	0.08	<.03	5.88	35.00	10.40	0.87	3.34	0.11
Rip Control	5	Down	7.39	266	0.46	141	1.41	0.09	<.03	5.91	25.90	8.37	0.77	3.13	0.10
Rip Control	12	Up	7.53	386	0.12	221	0.67	0.10	<.03	8.83	53.20	19.00	1.12	4.40	0.06
Rip Control	12	Down	7.54	396	0.25	222	0.65	0.09	<.03	9.32	39.90	17.40	1.14	5.89	0.07
Cut-to-length	2	Up	7.13	230	2.11	121	1.24	0.28	<.03	0.98	18.00	5.21	1.56	3.69	0.08
Cut-to-length	2	Down	7.4	228	0.93	129	1.23	0.27	<.03	1.48	25.10	7.03	1.74	4.68	0.08
Cut-to-length	8	Up	6.98	175	0.47	90	0.37	0.14	<.03	2.68	19.70	5.86	0.66	2.83	0.22
Cut-to-length	8	Down	7.07	186	0.78	101	0.42	0.13	<.03	3.43	22.90	7.57	0.80	3.92	0.24
Cut-to-length	11	Up	7.53	409	0.31	224	0.58	0.10	<.03	9.51	39.20	17.20	1.02	3.94	0.07
Cut-to-length	11	Down	7.52	392	0.31	225	0.57	0.09	<.03	9.25	43.40	18.80	1.07	4.73	0.07
Whole-tree harvest	4	Up	7.39	246	0.25	138	1.46	0.09	<.03	5.89	28.50	8.90	0.83	3.10	0.11
Whole-tree harvest	4	Down	7.23	244	0.77	141	1.49	0.09	<.03	6.07	25.10	7.34	0.71	3.14	0.10
Whole-tree harvest	6	Up	6.6	114	4.25	59	0.26	0.20	<.03	1.34	13.50	4.03	0.63	1.79	0.44
Whole-tree harvest	6	Down	6.7	124	2.15	63	0.36	0.19	<.03	1.50	15.40	4.74	0.62	2.18	0.46
Whole-tree harvest	10	Up	7.36	419	0.43	231	0.61	0.09	<.03	10.34	37.40	18.50	1.04	5.09	0.07
Whole-tree harvest	10	Down	7.48	426	0.19	240	0.55	<.02	<.03	10.35	36.30	17.90	1.01	4.77	0.07

Table 2b.2C. Water chemistry at the single-basin plots during July 2007.

Tmt	Plot	Reach	pH	Conductivity uS/cm	Turbidity NTU	Alkalinity mg/L CaC03	Cl^- mg/L	NO_3^--N mg/L	Diss Inorg P mg/L	SO_4^{-2} mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	K+ mg/L	Na^+ mg/L	Fe^{2+} mg/L
True Control	1	Up	7.11	244	7.8	140	1.25	0.33	<.03	0.70	29.40	9.52	1.74	5.83	0.08
True Control	1	Down	7.27	245	4.1	141	1.20	0.30	<.03	0.66	31.00	9.41	1.70	5.20	0.09
True Control	7	Up	7.43	285	1.6	149	0.62	0.12	<.03	4.60	31.60	10.70	0.99	6.12	0.11
True Control	7	Down	7.22	275	1.8	140	0.72	0.13	<.03	4.17	26.50	10.50	0.85	5.99	0.11
True Control	9	Up	7.54	429	1.1	239	0.80	0.13	<.03	8.67	26.70	14.90	0.64	4.60	0.07
True Control	9	Down	7.30	462	0.6	260	0.77	0.20	<.03	5.38	46.10	18.50	0.90	5.75	0.07
Rip Control	3	Up	7.56	343	1.4	184	1.82	0.17	<.03	5.18	27.00	13.30	1.08	4.39	0.08
Rip Control	3	Down	7.53	334	0.7	178	1.09	0.11	<.03	5.82	27.70	12.70	1.07	4.50	0.07
Rip Control	5	Up	7.58	318	1.3	169	1.54	0.17	<.03	5.48	35.10	12.20	1.18	4.16	0.08
Rip Control	5	Down	7.50	313	1.5	170	1.19	0.14	<.03	4.15	37.80	12.30	1.05	4.07	0.09
Rip Control	12	Up	7.65	416	0.4	228	0.72	0.15	<.03	7.86	21.90	16.00	1.16	3.78	0.07
Rip Control	12	Down	7.72	421	0.6	239	0.78	0.16	<.03	7.75	25.20	17.80	1.26	4.16	0.07
Cut-to-length	2	Up	7.20	238	2.8	129	1.23	0.22	<.03	1.23	32.60	9.27	1.49	5.02	0.09
Cut-to-length	2	Down	7.40	249	1.2	137	1.28	0.24	<.03	1.24	26.20	8.97	1.57	5.24	0.08
Cut-to-length	8	Up	7.10	291	2.9	151	0.59	0.14	<.03	3.96	34.80	11.50	0.98	5.89	0.11
Cut-to-length	8	Down	7.34	300	2.8	150	0.54	0.13	<.03	3.83	34.80	11.60	1.03	5.24	0.09
Cut-to-length	11	Up	7.63	425	0.8	226	0.76	0.14	<.03	7.88	33.70	18.00	1.15	3.80	0.06
Cut-to-length	11	Down	7.70	428	1.2	234	0.75	0.13	<.03	8.30	28.80	17.80	1.10	3.84	0.07
Whole-tree harvest	4	Up	7.39	320	2.1	170	1.45	0.14	<.03	5.02	37.00	12.50	0.98	4.42	0.10
Whole-tree harvest	4	Down	7.64	371	1.7	171	1.24	0.14	<.03	5.22	38.50	12.60	1.17	4.35	0.10
Whole-tree harvest	6	Up	6.89	127	5.6	70	0.29	0.18	<.03	0.52	17.90	5.46	0.43	2.17	0.49
Whole-tree harvest	6	Down	7.08	184	3.2	96	0.42	0.10	<.03	1.36	25.30	7.91	0.62	3.29	0.38
Whole-tree harvest	10	Up	7.36	434	0.9	252	0.80	0.09	<.03	10.40	38.60	18.10	1.00	4.47	0.07
Whole-tree harvest	10	Down	7.63	435	1.0	241	0.68	0.09	<.03	9.59	30.30	18.40	1.00	4.34	0.07

Table 2b.3. Water temperature at the multiple-basin control, riparian control, and treatment reaches from 24 June 2008 to 23 October 2008. No data available from Reservation Trib. (Medium residual basal; area [RBA] site) and Cloquet Trib. (Low RBA site).

Low Residual Basal Area

	West Split Rock R.			East Br. Baptism R.			St. Louis Trib.		
	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt
mean (ºC)	13.9	14.2	14.1	15.8	15.2	15.1	14.0	13.7	13.7
se (ºC)	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
max (ºC)	23.2	23.2	23.2	26.0	25.6	24.8	23.6	20.6	20.6
min (ºC)	2.9	5.0	3.3	4.6	4.2	4.6	2.9	5.0	5.0
range (ºC)	20.4	18.3	19.9	21.4	21.4	20.2	20.7	15.6	15.6

Medium Residual Basal Area

	Shotley Bk.			Nemadji Trib.			East Br. Beaver R.		
	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt	Control	Riparian Control	Tmt
mean (ºC)	15.8	15.4	15.3	13.1	13.5	13.7	15.9	15.6	15.1
se (ºC)	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1
max (ºC)	25.2	23.6	22.9	18.7	19.0	21.0	26.7	26.3	26.0
min (ºC)	5.0	4.6	3.7	5.4	3.7	3.7	4.2	3.7	3.7
range (ºC)	20.2	19.1	19.1	13.3	15.3	17.2	22.6	22.6	22.2

Table 2b.4. Invertebrate taxa list for the multiple-basin sites during August 2008.

Insects

Order	Family	Lowest taxonomic level	Functional Feeding Group
Coleoptera	Dryopidae	Helichus (**adult** and **larva**)	Scraper
Coleoptera	Dytiscidae	Acilius (adult)	Predator
Coleoptera	Dytiscidae	Agabus (**adult** and larva)	Predator
Coleoptera	Dytiscidae	Dytiscus (larva)	Predator
Coleoptera	Dytiscidae	Hydrocolus (adult)	Predator
Coleoptera	Dytiscidae	Hygrotus (adult)	Predator
Coleoptera	Dytiscidae	Neoporus (adult)	Predator
Coleoptera	Elmidae	Dubiraphia (adult and **larva**)	Collector-gatherer
Coleoptera	Elmidae	Macronychus (adult and **larva**)	Collector-gatherer
Coleoptera	Elmidae	Optioservus (adult and **larva**)	Scraper
Coleoptera	Elmidae	Promoresia (adult and larva)	Collector-gatherer
Coleoptera	Elmidae	Stenelmis (adult and **larva**)	Scraper
Coleoptera	Haliplidae	Haliplus (adult and **larva**)	Shredder
Coleoptera	Hydraenidae	Gymnochthebius (adult)	Scraper
Coleoptera	Hydraenidae	Hydraena (adult)	Scraper
Coleoptera	Hydrophilidae	Anacaena (adult)	Collector-gatherer
Coleoptera	Hydrophilidae	Crenitis (adult)	Collector-gatherer
Coleoptera	Hydrophilidae	Cymbiodyta (adult)	Collector-gatherer
Coleoptera	Hydrophilidae	Enochrus (adult)	Collector-gatherer
Coleoptera	Hydrophilidae	Helophorus (adult)	Collector-gatherer
Diptera	Athericidae	Atherix	Predator
Diptera	Ceratopogonidae	Ceratopogoninae	Predator
Diptera	Ceratopogonidae	Forcipomyiinae	Collector-gatherer
Diptera	Chironomidae	Chironomidae (non-Tanypodinae)	Collector-gatherer
Diptera	Chironomidae	Tanypodinae	Predator
Diptera	Dixidae	Dixella	Collector-gatherer
Diptera	Dolichopodidae	Dolichopodidae	Predator
Diptera	Empididae	Hemerodromia	Predator
Diptera	Empididae	Neoplasta	Predator
Diptera	Empididae	Roederiodes	Predator
Diptera	Ephydridae	Ephydridae	Collector-gatherer
Diptera	Psychodidae	Pericoma	Collector-gatherer
Diptera	Ptychopteridae	Bittacomorpha	Collector-gatherer
Diptera	Sciomyzidae	Sciomyzidae	Predator
Diptera	Simuliidae	Simulium	Collector-filterer
Diptera	Stratiomyidae	Nemotelus	Collector-gatherer
Diptera	Stratiomyidae	Odontomyia	Collector-gatherer
Diptera	Tabanidae	Tabanidae	Predator
Diptera	Tipulidae	Antocha	Collector-gatherer
Diptera	Tipulidae	Dicranota	Predator
Diptera	Tipulidae	Hexatoma	Predator
Diptera	Tipulidae	Limonia	Shredder
Diptera	Tipulidae	Ormosia	Collector-gatherer
Diptera	Tipulidae	Pedicia	Predator

Table 2b.4 (continued). Invertebrate taxa list for the multiple-basin sites during June 2008.

Diptera	Tipulidae	Tipula	Shredder
Ephemeroptera	Baetidae	Acentrella	Collector-gatherer
Ephemeroptera	Baetidae	Acerpenna	Collector-gatherer
Ephemeroptera	Baetidae	Baetis	Scraper
Ephemeroptera	Baetidae	Centroptilum	Collector-gatherer
Ephemeroptera	Baetidae	Diphetor	Collector-gatherer
Ephemeroptera	Baetidae	Procloeon	Collector-gatherer
Ephemeroptera	Baetidae	Pseudocentroptiloides	Collector-gatherer
Ephemeroptera	Baetidae	Pseudocloeon	Collector-gatherer
Ephemeroptera	Baetiscidae	Baetisca	Collector-gatherer
Ephemeroptera	Caenidae	Brachycercus	Collector-gatherer
Ephemeroptera	Caenidae	Caenis	Collector-gatherer
Ephemeroptera	Ephemerellidae	Ephemerella	Collector-gatherer
Ephemeroptera	Ephemerellidae	Eurylophella	Collector-gatherer
Ephemeroptera	Ephemerellidae	Serratella	Collector-gatherer
Ephemeroptera	Ephemeridae	Ephemera	Collector-gatherer
Ephemeroptera	Ephemeridae	Hexagenia	Collector-gatherer
Ephemeroptera	Heptageniidae	Epeorus	Scraper
Ephemeroptera	Heptageniidae	Leucrocuta	Scraper
Ephemeroptera	Heptageniidae	Maccaffertium	Scraper
Ephemeroptera	Heptageniidae	Stenacron	Scraper
Ephemeroptera	Isonychiidae	Isonychia	Collector-filterer
Ephemeroptera	Leptohyphidae	Tricorythodes	Collector-gatherer
Ephemeroptera	Leptophlebiidae	Paraleptophlebia	Collector-gatherer
Hemiptera	Corixidae	Sigara (adult)	Collector-gatherer
Hemiptera	Gerridae	Aquarius (**adult** and larva)	Predator
Hemiptera	Gerridae	Trepobates (larva)	Predator
Hemiptera	Nepidae	Ranatra (larva)	Predator
Hemiptera	Veliidae	Rhagovelia (**adult** and larva)	Predator
Megaloptera	Corydalidae	Nigronia	Predator
Megaloptera	Sialidae	Sialis	Predator
Odonata	Aeshnidae	Aeshna	Predator
Odonata	Aeshnidae	Boyeria	Predator
Odonata	Calopterygidae	Calopterygidae	Predator
Odonata	Cordulegastridae	Cordulegaster	Predator
Odonata	Cordulegastridae	Epitheca	Predator
Odonata	Corduliidae	Corduliidae	Predator
Odonata	Corduliidae	Somatochlora	Predator
Odonata	Gomphidae	Ophiogomphus	Predator
Odonata	Libellulidae	Perithemis	Predator
Plecoptera	Capniidae	Capniidae	Shredder
Plecoptera	Leuctridae	Leuctra	Shredder
Plecoptera	Nemouridae	Amphinemura	Collector-gatherer
Plecoptera	Perlidae	Acroneuria	Predator
Plecoptera	Perlidae	Paragnetina	Predator
Plecoptera	Perlidae	Perlesta	Predator

Table 2b.4 (continued). Invertebrate taxa list for the multiple-basin sites during June 2008.

Plecoptera	Perlodidae	Isogenoides	Predator
Plecoptera	Pteronarcyidae	Pteronarcys	Shredder
Trichoptera	Apataniidae	Apatania	Scraper
Trichoptera	Brachycentridae	Brachycentrus	Collector-filterer
Trichoptera	Brachycentridae	Micrasema	Shredder
Trichoptera	Dipseudopsidae	Phylocentropus	Collector-filterer
Trichoptera	Glossosomatidae	Glossosoma	Scraper
Trichoptera	Glossosomatidae	Protoptila	Scraper
Trichoptera	Goeridae	Goera	Scraper
Trichoptera	Helicopsychidae	Helicopsyche	Scraper
Trichoptera	Hydropsychidae	Ceratopsyche	Collector-filterer
Trichoptera	Hydropsychidae	Cheumatopsyche	Collector-filterer
Trichoptera	Hydropsychidae	Diplectrona	Collector-filterer
Trichoptera	Hydropsychidae	Hydropsyche	Collector-filterer
Trichoptera	Hydroptilidae	Hydroptila	Scraper
Trichoptera	Hydroptilidae	Ithytrichia	Scraper
Trichoptera	Hydroptilidae	Leucotrichia	Scraper
Trichoptera	Hydroptilidae	Mayatrichia	Scraper
Trichoptera	Hydroptilidae	Neotrichia	Scraper
Trichoptera	Hydroptilidae	Oxyethira	Collector-gatherer
Trichoptera	Lepidostomatidae	Lepidostoma	Shredder
Trichoptera	Leptoceridae	Ceraclea	Collector-gatherer
Trichoptera	Leptoceridae	Mystacides	Collector-gatherer
Trichoptera	Leptoceridae	Oecetis	Predator
Trichoptera	Limnephilidae	Hydatophylax	Shredder
Trichoptera	Limnephilidae	Pycnopsyche	Shredder
Trichoptera	Philopotamidae	Chimarra	Collector-filterer
Trichoptera	Philopotamidae	Dolophilodes	Collector-filterer
Trichoptera	Phryganeidae	Ptilostomis	Shredder
Trichoptera	Polycentropodidae	Neureclipsis	Collector-filterer
Trichoptera	Polycentropodidae	Polycentropus	Collector-filterer
Trichoptera	Psychomyiidae	Psychomyia	Collector-gatherer
Trichoptera	Rhyacophilidae	Rhyacophila	Predator
Trichoptera	Uenoidae	Neophylax	Scraper
Other aquatic invertebrates			
		Subclass Acari	Predator
		Class Branchiopoda (Cladocera)	Collector-gatherer
		Order Collembola	Collector-gatherer
		Class Copepoda	Collector-gatherer
		Class Hydrozoa	Predator
		Phylum Nematoda	Collector-gatherer
		Class Ostracoda	Collector-gatherer
		Class Turbellaria	Predator
Amphipoda	Hyalellidae	Hyalella	Shredder
Arhynchobdellida	Erpobdellidae	Dina	Predator

Table 2b.4 (continued). Invertebrate taxa list for the multiple-basin sites during June 2008.

Arhynchobdellida	Erpobdellidae	Mooreobdella	Predator
Basommatophora	Ancylidae	Ancylidae	Scraper
Basommatophora	Ancylidae	Ferrissia	Scraper
Basommatophora	Lymnaeidae	Fossaria	Scraper
Basommatophora	Lymnaeidae	Lymnaeidae	Scraper
Basommatophora	Physidae	Physa	Scraper
Basommatophora	Planorbidae	Gyraulus	Scraper
Basommatophora	Planorbidae	Helisoma	Scraper
Basommatophora	Planorbidae	Planorbidae	Scraper
Veneroida	Sphaeriidae	Musculium	Collector-filterer
Veneroida	Sphaeriidae	Pisidium	Collector-filterer
Veneroida	Sphaeriidae	Sphaerium	Collector-filterer
Rhynchobdellida	Glossiphoniidae	Glossiphonia	Predator
Rhynchobdellida	Glossiphoniidae	Helobdella	Predator
Rhynchobdellida	Glossiphoniidae	Placobdella	Predator
Rhynchobdellida	Glossiphoniidae	Theromyzon	Predator
Neotaenioglossa	Hydrobiidae	Hydrobiidae	Scraper
Lumbriculida	Lumbriculidae	Lumbriculidae	Collector-gatherer
Haplotaxida	Naididae	Naididae (Naidinae)	Collector-gatherer
Haplotaxida	Naididae	Naididae (Tubificinae) - with capillary setae	Collector-gatherer
Haplotaxida	Naididae	Naididae (Tubificinae) - without capillary setae	Collector-gatherer
Decapoda	Cambaridae	Orconectes	Shredder

Table 2b.5. Invertebrate taxa list for the single-basin plots during June 2007.

Insects

Order	Family	Lowest taxonomic level	Functional Feeding Group
Coleoptera	Dryopidae	Helichus (adult)	Scraper
Coleoptera	Dytiscidae	Agabus (adult and **larva**)	Predator
Coleoptera	Elmidae	Optioservus (adult and **larva**)	Scraper
Diptera	Ceratopogonidae	Ceratopogoninae	Predator
Diptera	Chironomidae	Chironomidae (non-Tanypodinae)	Collector-gatherer
Diptera	Chironomidae	Tanypodinae	Predator
Diptera	Dixidae	Dixa	Collector-filterer
Diptera	Empididae	Neoplasta	Predator
Diptera	Empididae	Roederiodes	Predator
Diptera	Psychodidae	Pericoma	Collector-gatherer
Diptera	Simuliidae	Simulium	Collector-filterer
Diptera	Stratiomyidae	Oxycera	Scraper
Diptera	Tabanidae	Tabanidae	Predator
Diptera	Tipulidae	Dicranota	Predator
Diptera	Tipulidae	Hexatoma	Predator
Diptera	Tipulidae	Limnophila	Predator
Diptera	Tipulidae	Pedicia	Predator
Diptera	Tipulidae	Tipula	Shredder
Ephemeroptera	Baetidae	Acentrella	Collector-gatherer
Ephemeroptera	Baetidae	Baetis	Scraper
Ephemeroptera	Leptophlebiidae	Leptophlebiidae	Collector-gatherer
Hemiptera	Gerridae	Trepobates (adult)	Predator
Hemiptera	Pleidae	Neoplea (adult)	Predator
Odonata	Aeshnidae	Boyeria	Predator
Odonata	Calopterygidae	Calopterygidae	Predator
Odonata	Cordulegastridae	Cordulegaster	Predator
Plecoptera	Capniidae	Capniidae	Shredder
Plecoptera	Nemouridae	Amphinemura	Collector-gatherer
Plecoptera	Nemouridae	Nemoura	Collector-gatherer
Trichoptera	Brachycentridae	Micrasema	Shredder
Trichoptera	Glossosomatidae	Glossosoma	Scraper
Trichoptera	Hydropsychidae	Ceratopsyche	Collector-filterer
Trichoptera	Hydropsychidae	Cheumatopsyche	Collector-filterer
Trichoptera	Hydropsychidae	Hydropsyche	Collector-filterer
Trichoptera	Hydropsychidae	Parapsyche	Collector-filterer
Trichoptera	Lepidostomatidae	Lepidostoma	Shredder
Trichoptera	Limnephilidae	Hesperophylax	Shredder
Trichoptera	Limnephilidae	Ironoquia	Shredder
Trichoptera	Limnephilidae	Limnephilus	Shredder
Trichoptera	Limnephilidae	Pycnopsyche	Shredder
Trichoptera	Molannidae	Molanna	Scraper
Trichoptera	Philopotamidae	Dolophilodes	Collector-filterer
Trichoptera	Polycentropodidae	Neureclipsis	Collector-filterer
Trichoptera	Polycentropodidae	Polycentropus	Collector-filterer

Table 2b.5 (continued). Invertebrate taxa list for the single-basin plots during June 2007.

Trichoptera	Psychomyiidae	Lype	Scraper
Trichoptera	Rhyacophilidae	Rhyacophila	Predator
Trichoptera	Uenoidae	Neophylax	Scraper

Other aquatic invertebrates

		Subclass Acari	Predator
		Order Collembola	Collector-gatherer
		Class Copepoda	Collector-gatherer
		Phylum Nematoda	Collector-gatherer
		Phylum Nematomorpha	Predator
		Class Ostracoda	Collector-gatherer
		Class Turbellaria	Predator
Amphipoda	Gammaridae	Gammarus	Shredder
Arhynchobdellida	Erpobdellidae	Mooreobdella	Predator
Arhynchobdellida	Erpobdellidae	Nephelopsis	Predator
Basommatophora	Lymnaeidae	Fossaria	Scraper
Basommatophora	Lymnaeidae	Lymnaeidae	Scraper
Basommatophora	Physidae	Physa	Scraper
Basommatophora	Planorbidae	Gyraulus	Scraper
Basommatophora	Planorbidae	Planorbidae	Scraper
Veneroida	Sphaeriidae	Pisidium	Collector-filterer
Lumbriculida	Lumbriculidae	Lumbriculidae	Collector-gatherer
Haplotaxida	Naididae	Naididae (Naidinae)	Collector-gatherer
Haplotaxida	Naididae	Naididae (Tubificinae) - with capillary setae	Collector-gatherer
Haplotaxida	Naididae	Naididae (Tubificinae) - without capillary setae	Collector-gatherer

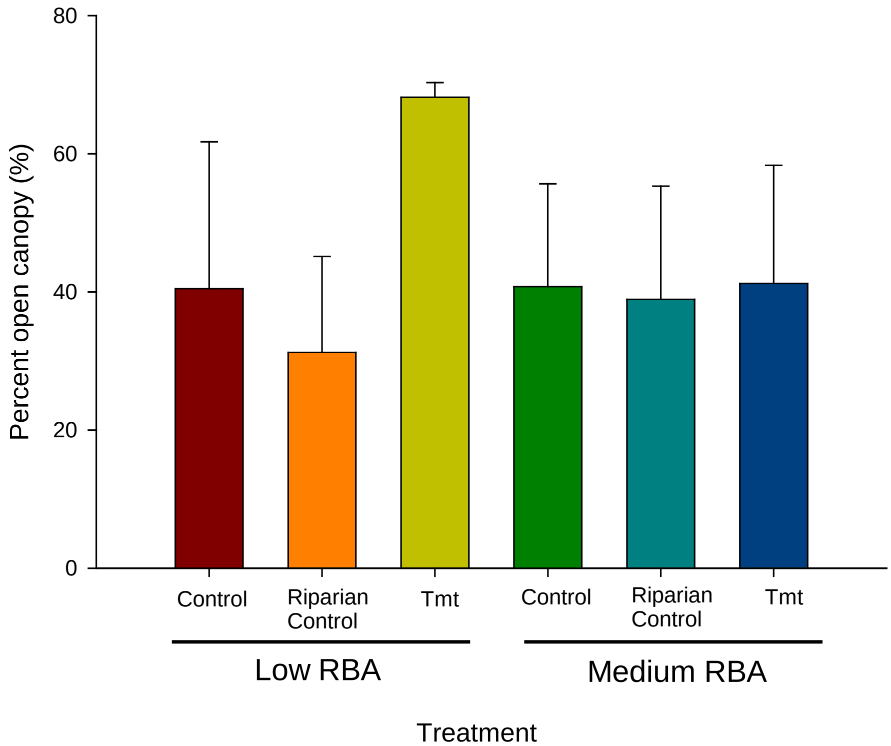

Figure 2b.1. Mean (± standard error) percent open canopy within control, riparian control, and low and medium residual basal area (RBA) treatments at the multiple-basin sites in June 2008.

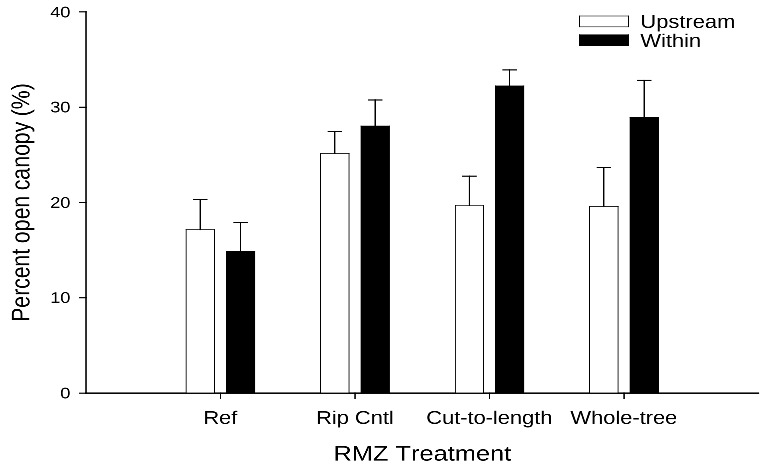

Figure 2b.2. Mean (± standard error) percent open canopy upstream and within RMZ treatments at the single-basin plots in August 2007.

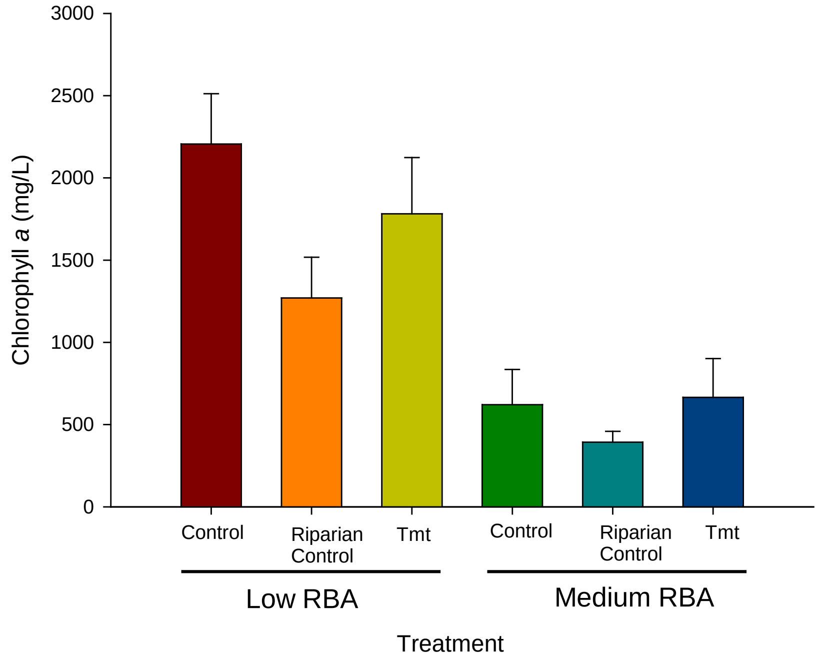

Figure 2b.3. Mean (± standard error) algal biomass standing crop within control, riparian control and low and medium residual basal area (RBA) treatments at the multiple-basin sites in June 2008.

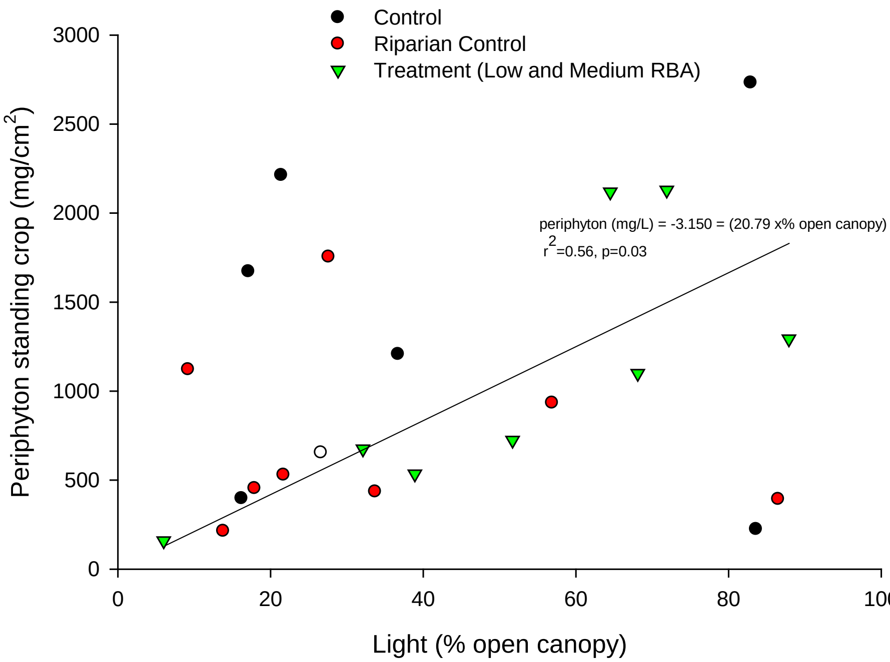

Figure 2b.4. Relationship between light levels within the stream and periphyton standing crop for treatment reaches (control, riparian control, and harvested RMZs) at the multiple-basin sites during June 2008. No significant relationship between light and periphyton at control reaches.

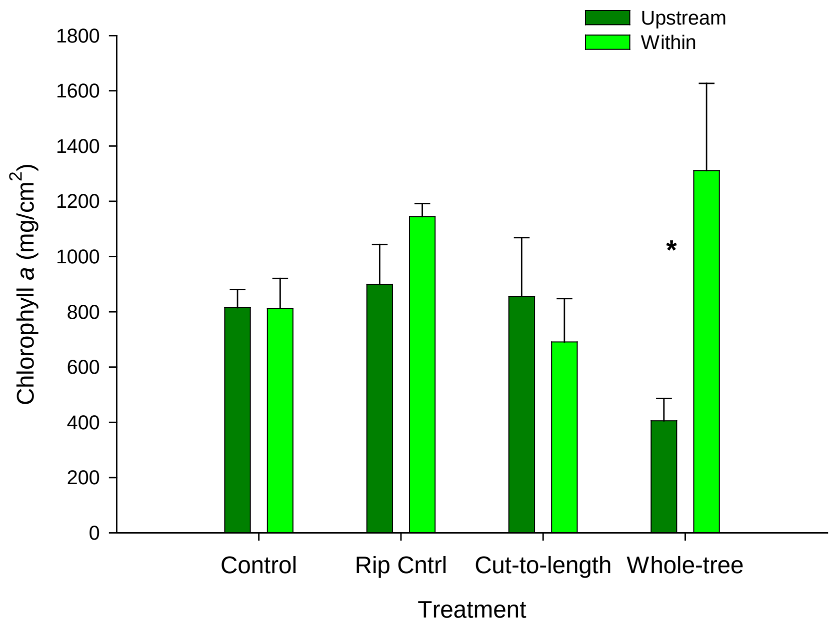

Figure 2b.5. Mean (± standard error) algal biomass standing crop upstream and within RMZ treatments at the single-basin plots in August 2006.

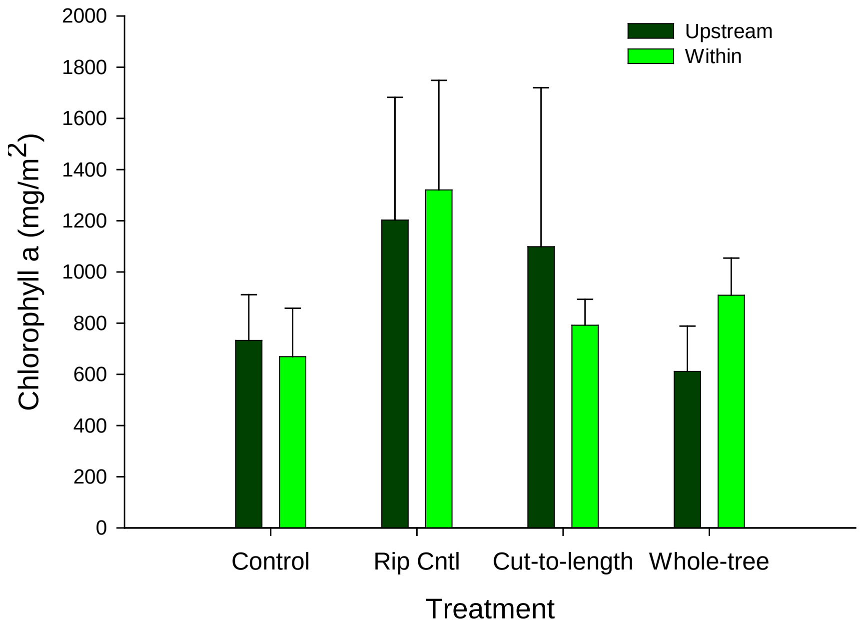

Figure 2b.6. Mean (± standard error) algal biomass standing crop upstream and within RMZ treatments at the single-basin plots in June 2007.

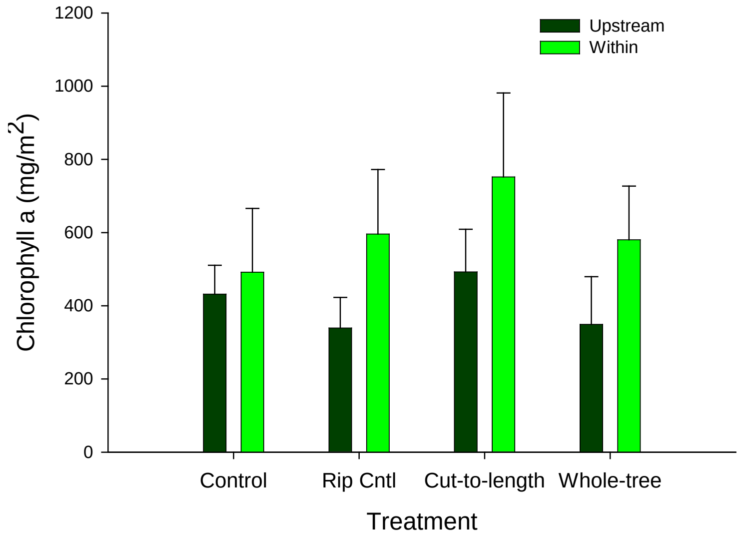

Figure 2b.7. Mean (± standard error) algal biomass standing crop upstream and within RMZ treatments at the single-basin plots in October 2007.

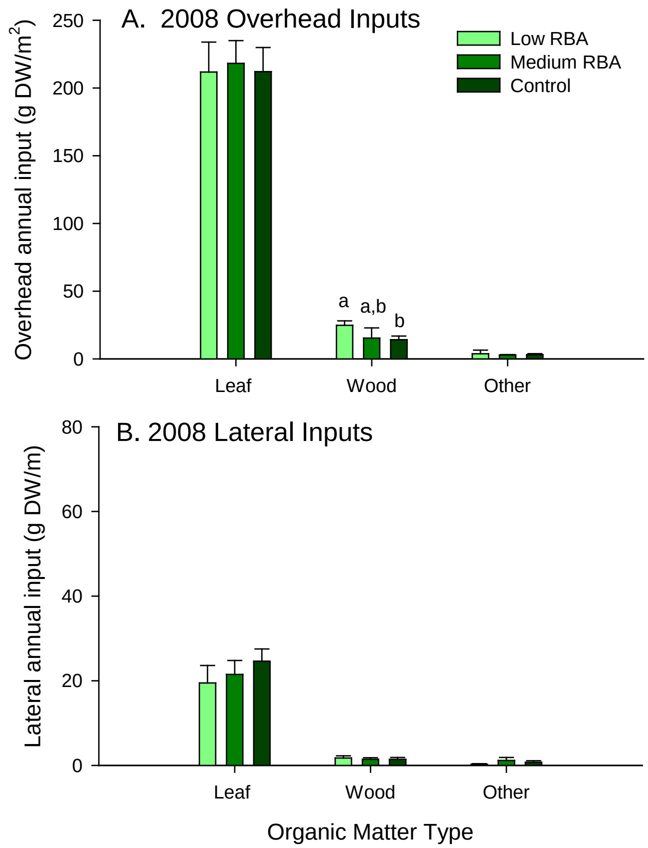

Figure 2b.8. Annual litter inputs by organic matter type during 2008 at the multiple-basin sites. Letters indicate significant differences at $p<0.05$.

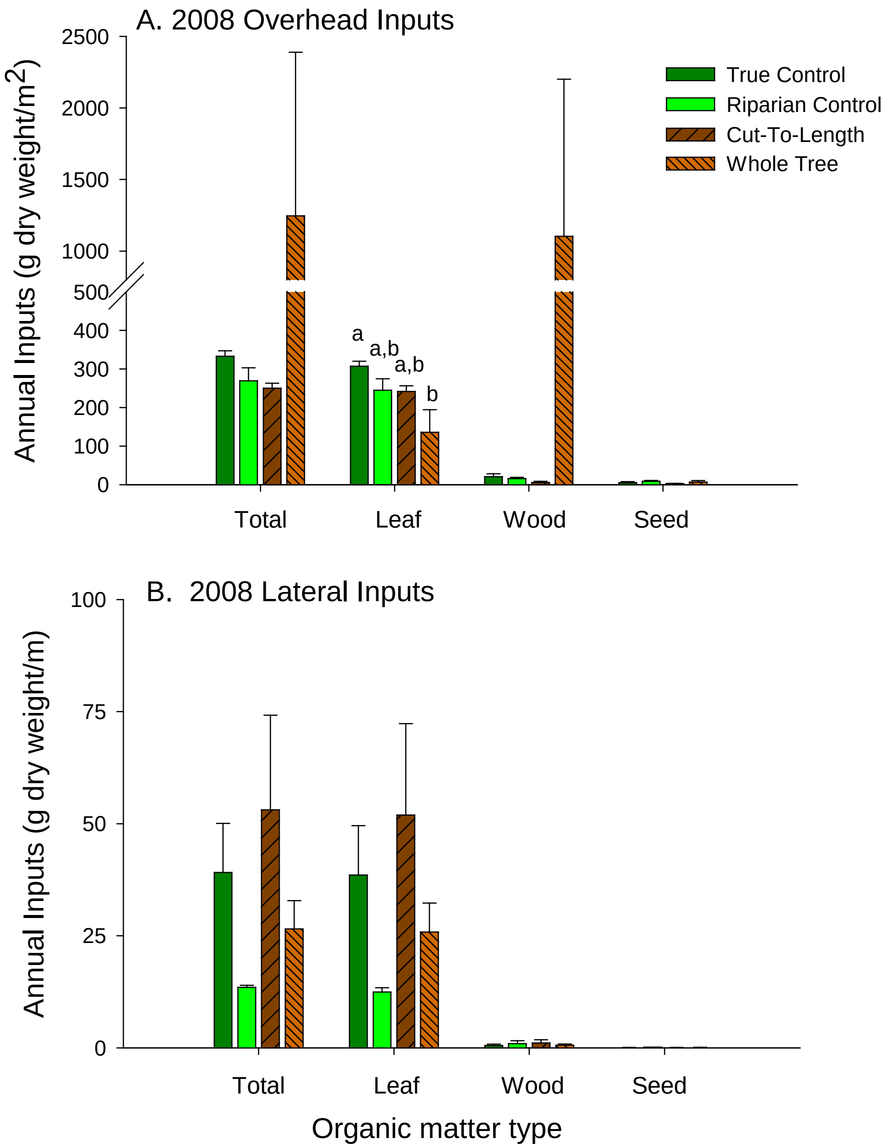

Figure 2b.9. Annual litter inputs by organic matter type at the single-basin sites in 2008. Letters indicate significant differences at $p<0.05$.

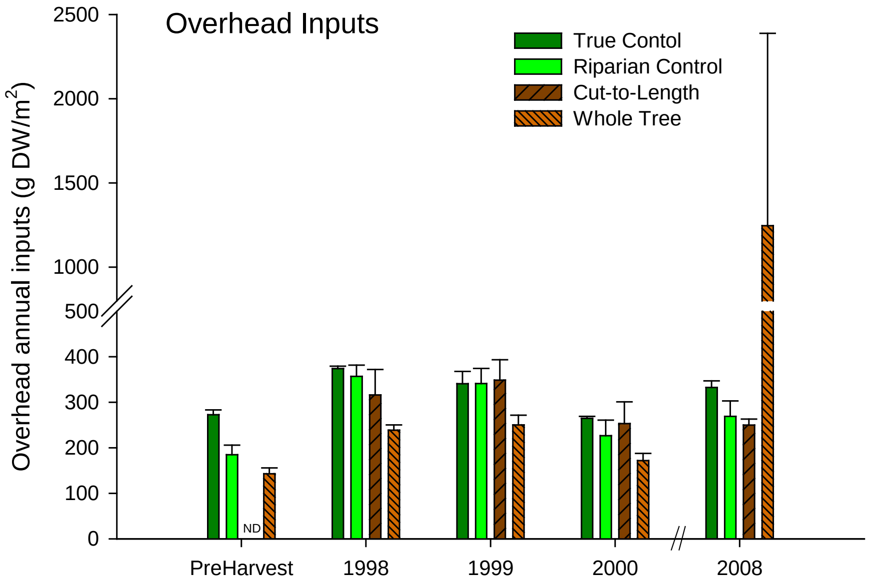

Figure 2b.10. Total litter inputs during pre-harvest year, early post-harvest years and year 11 post-harvest at the single-basin sites. Photo shows blowdown into overhead litter trap at plot 4 (Whole-tree harvest) during 2008.

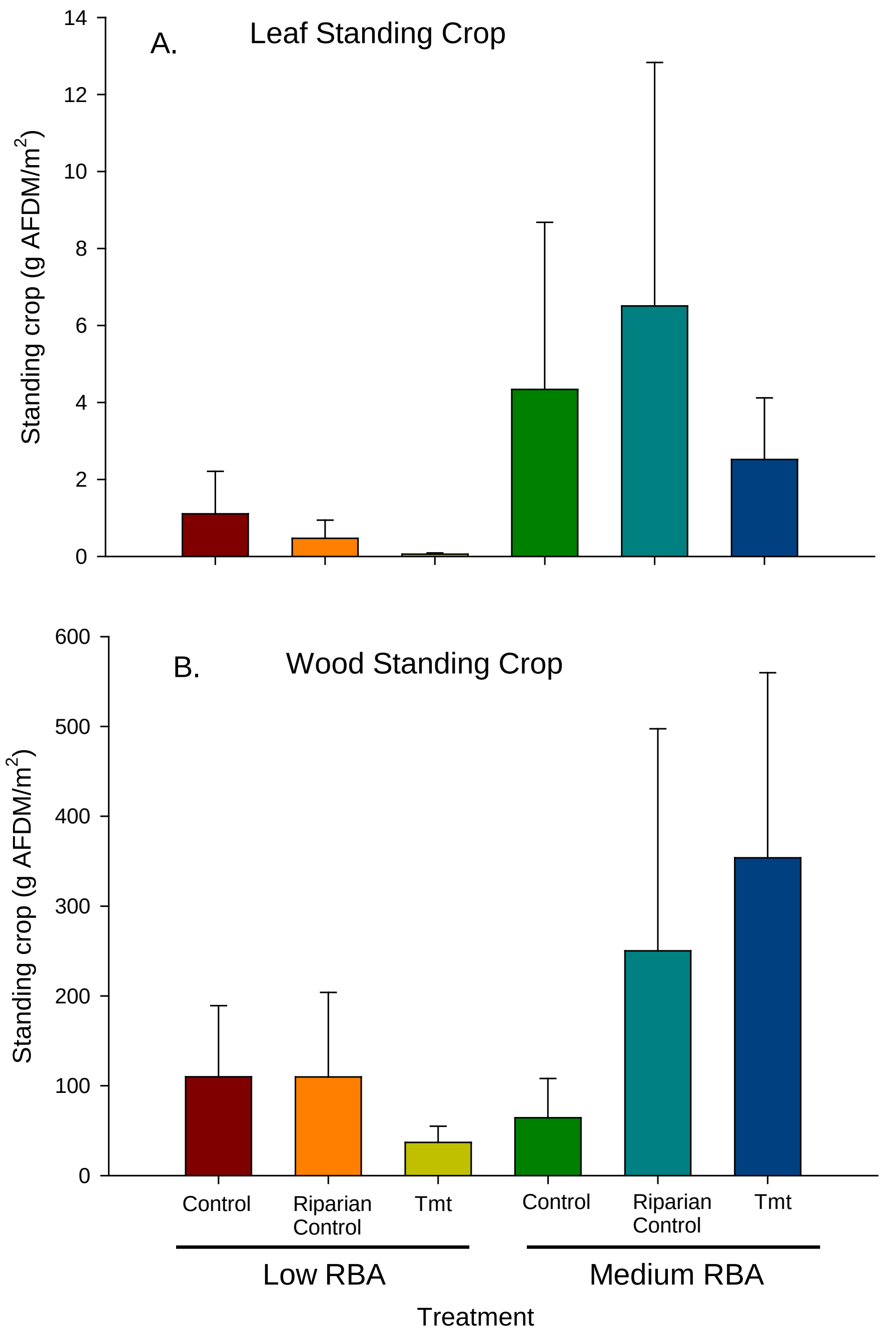

Figure 2b.11. Mean (± standard error) standing crop of leaf A.) and small wood B.) within control, riparian control, and low and medium residual basal area (RBA) treatments at the multiple-basin sites in June 2008.

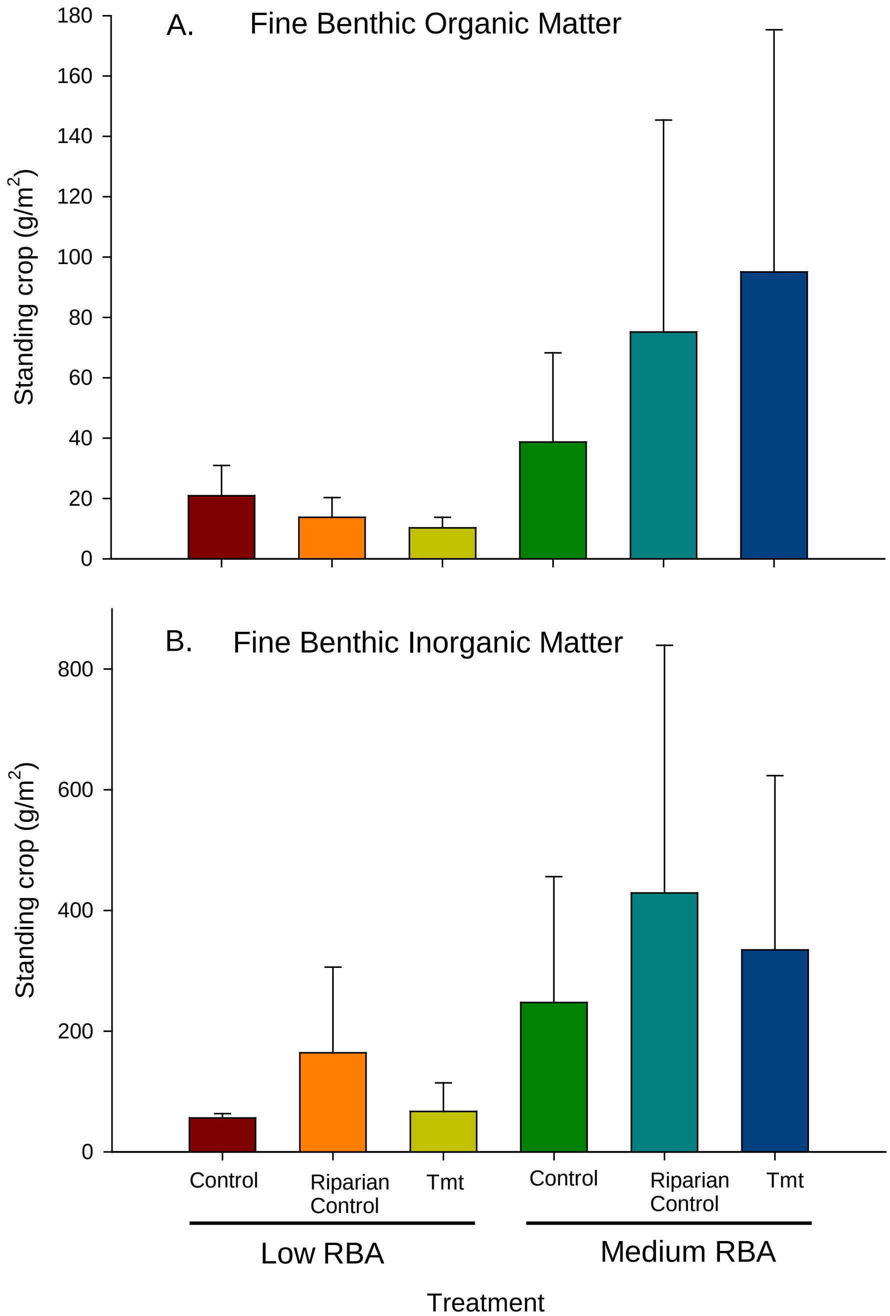

Figure 2b.12. Mean (± standard error) standing crop of Fine Benthic Organic Matter (FBOM) and Fine Benthic Inorganic Matter (FBIM) within control, riparian control, and low and medium residual basal area (RBA) treatments at the multiple-basin sites in June 2008.

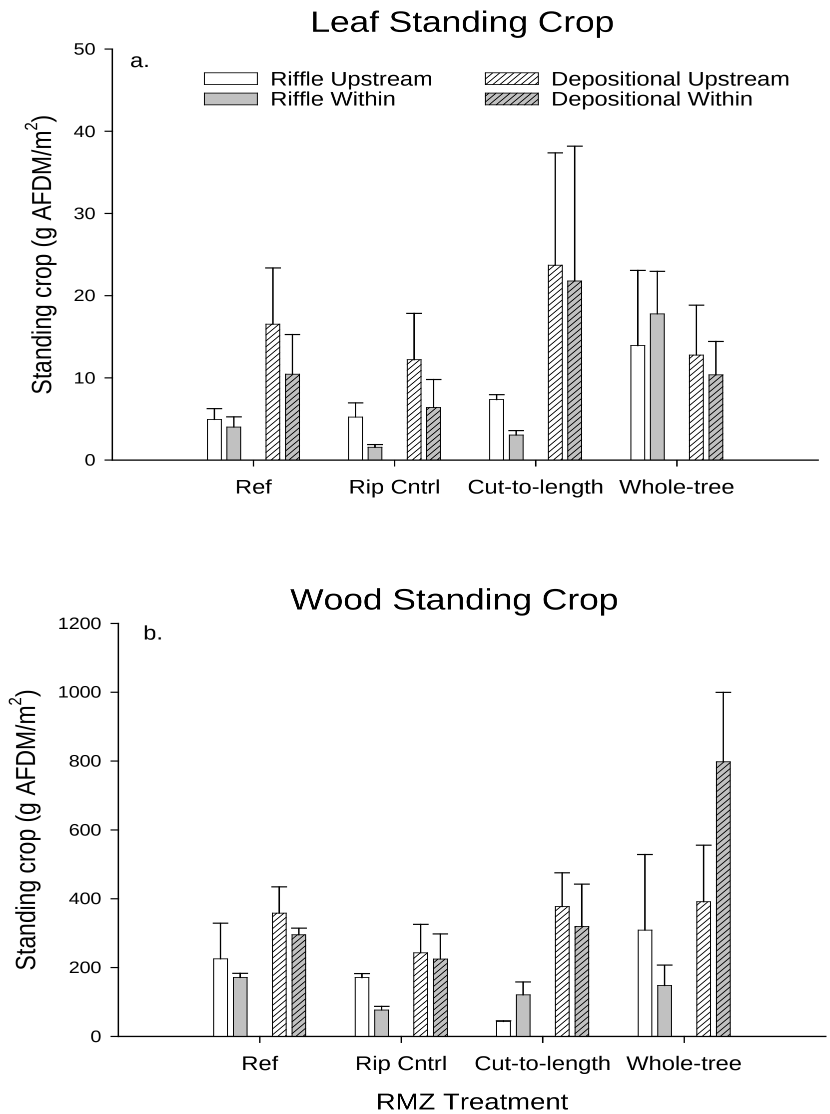

Figure 2b.13. Mean (± standard error) standing crop of a.) leaf and b.) wood upstream and within RMZ treatment reaches at the single-basin plots in August 2007.

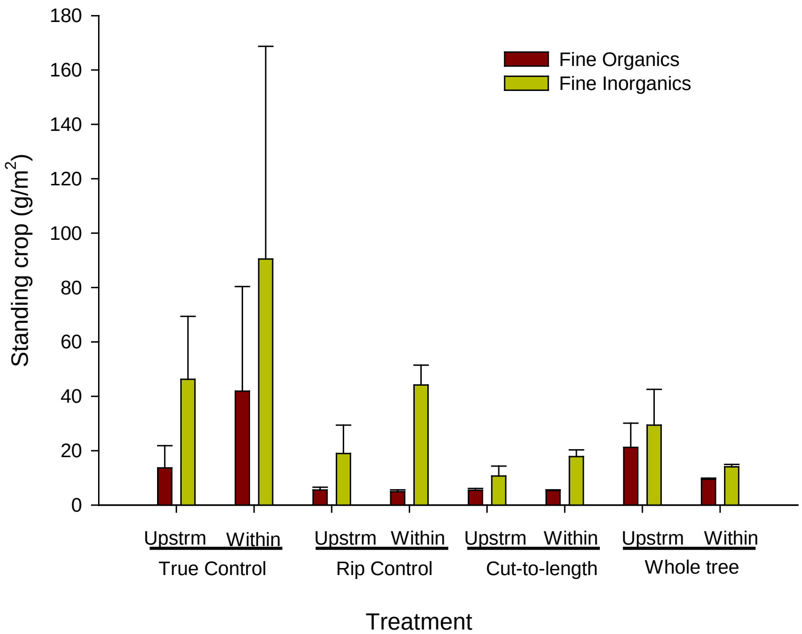

Figure 2b.14. Mean (± standard error) standing crop of Fine Benthic Organic Matter (FBOM) and Fine Benthic Inorganic Matter (FBIM) upstream and within RMZ treatment reaches at the single-basin plots in October 2007.

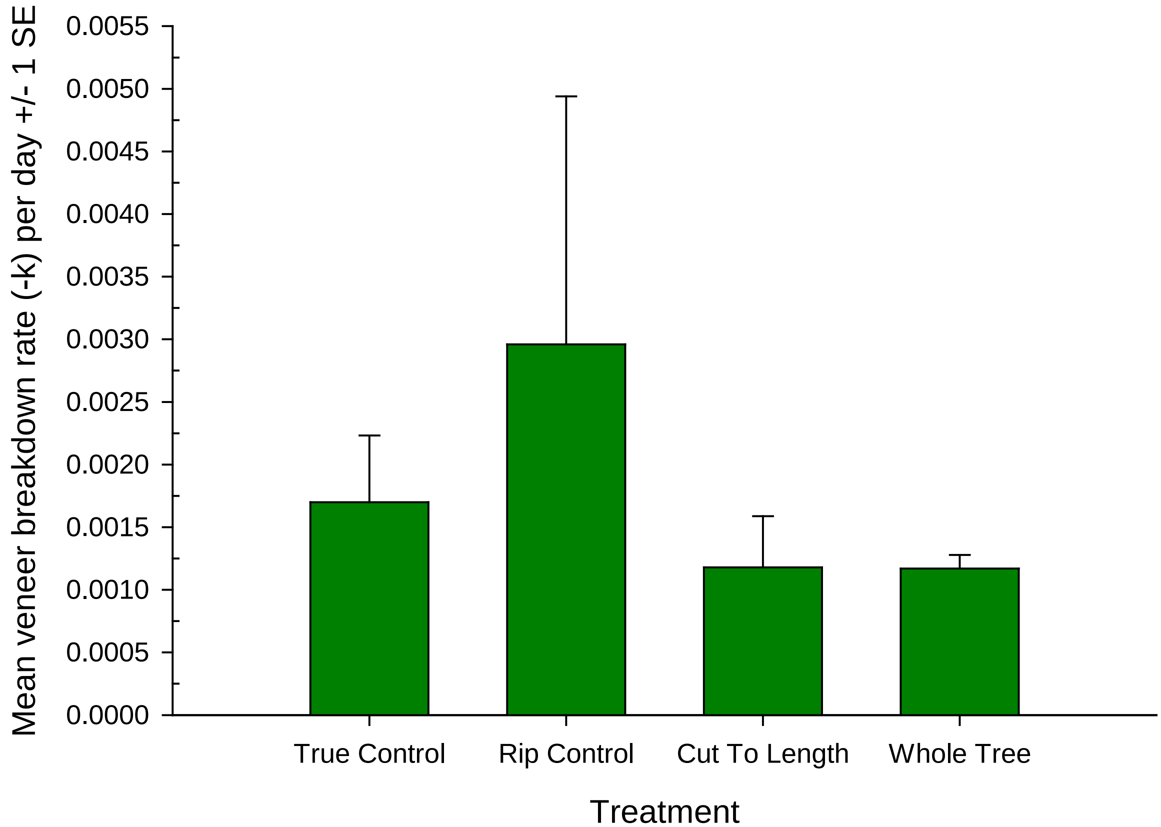

Figure 2b.15. Mean wood veneer breakdown rates (-k) +/- 1 SE from June 2008 to June 2009 at the single-basin plots. No significant ($p > 0.05$) difference among treatments.

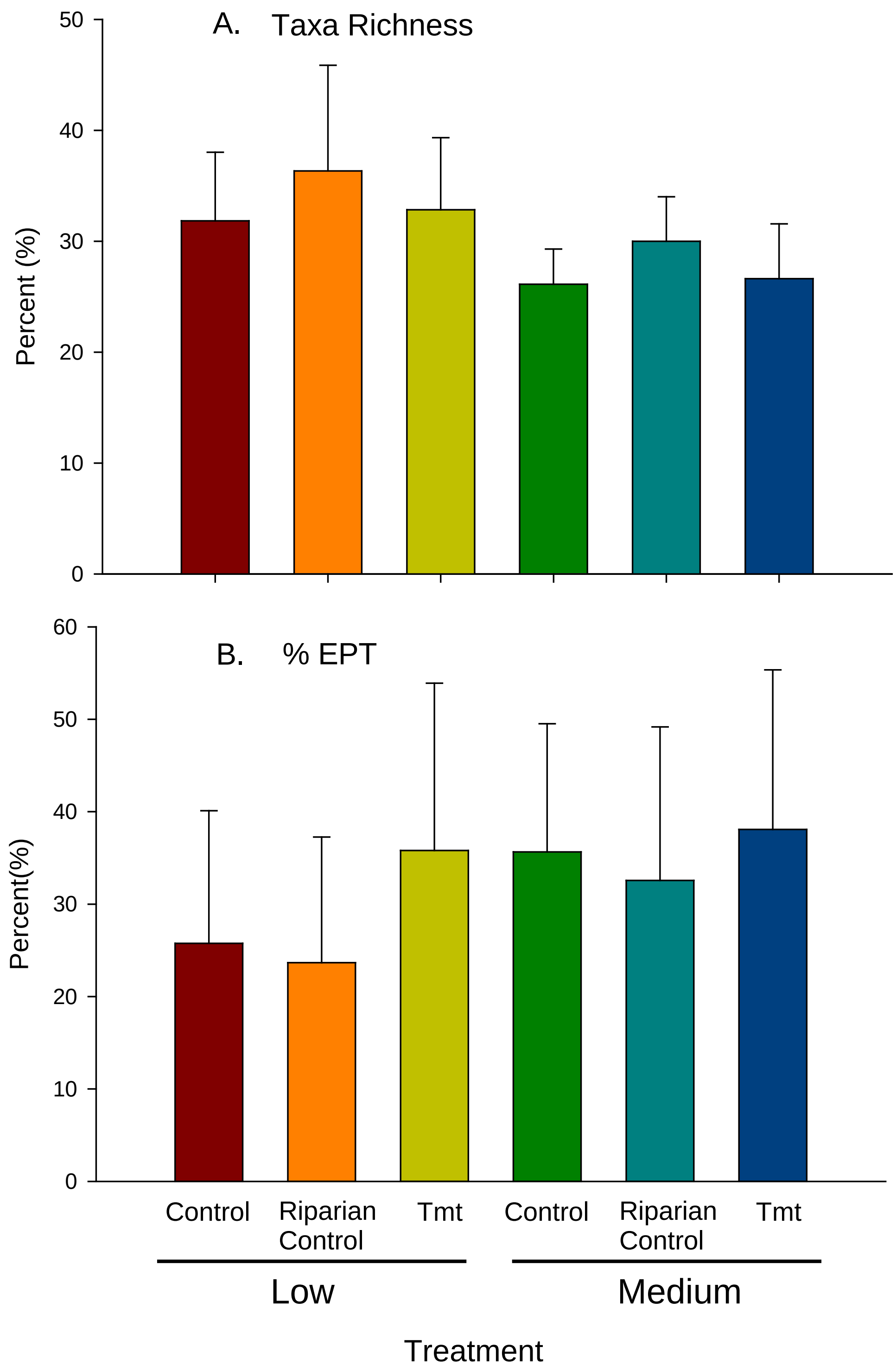

Figure 2b.16. Mean (+/- 1 SE) Taxa richness A), and Percent Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa B) during August 2008 at the multiple-basin sites. No significant ($p > 0.05$) differences among control, riparian control, and treatment reaches at low or medium residual basal area (RBA) levels.

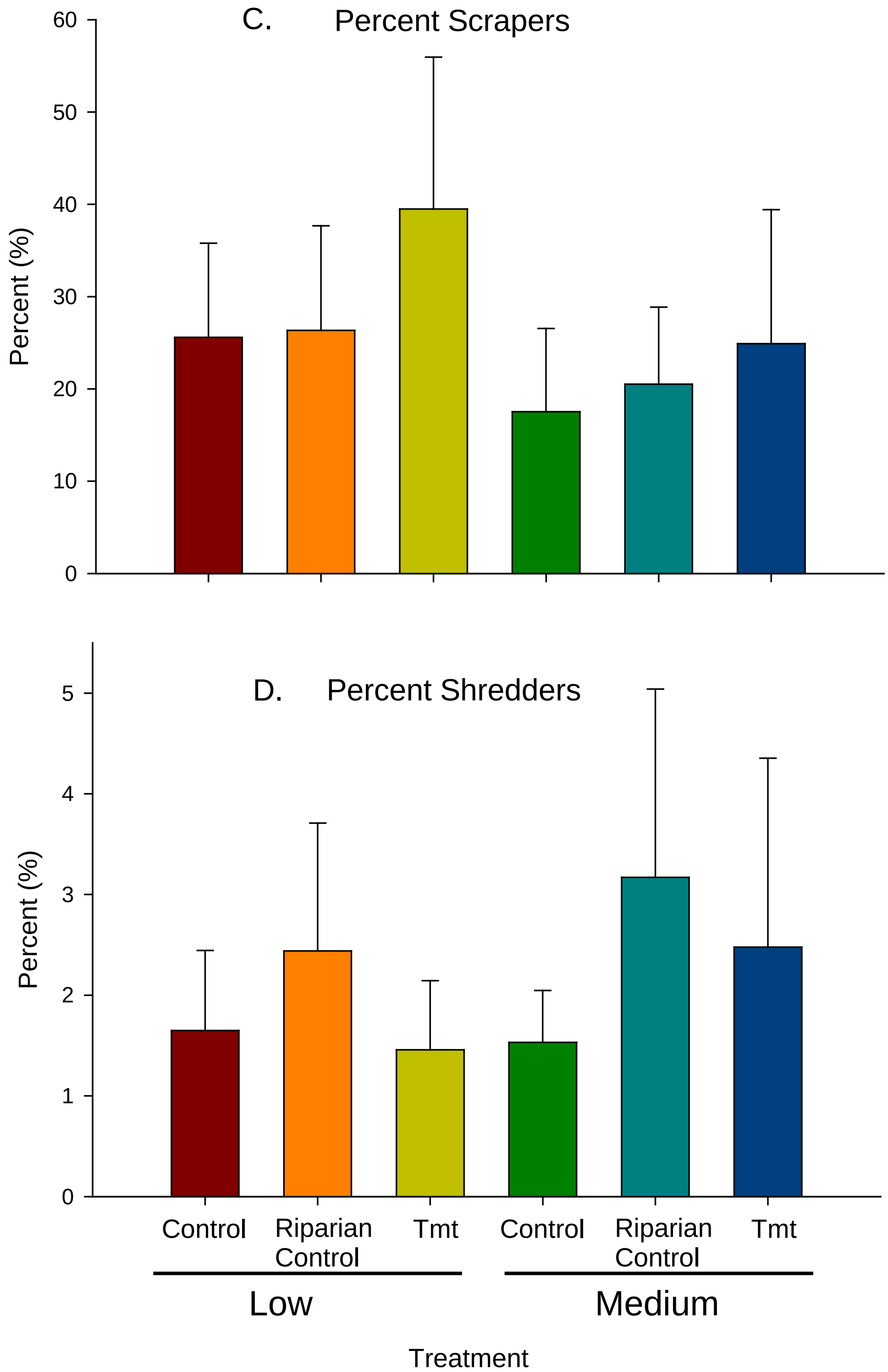

Figure 2b.16 (continued). Mean (+/- 1 SE) Percent scrapers C) and Percent shredders D) during August 2008 at the multiple-basin sites. No significant ($p > 0.05$) differences among control, riparian control, and treatment reaches at low or medium residual basal area (RBA) levels.

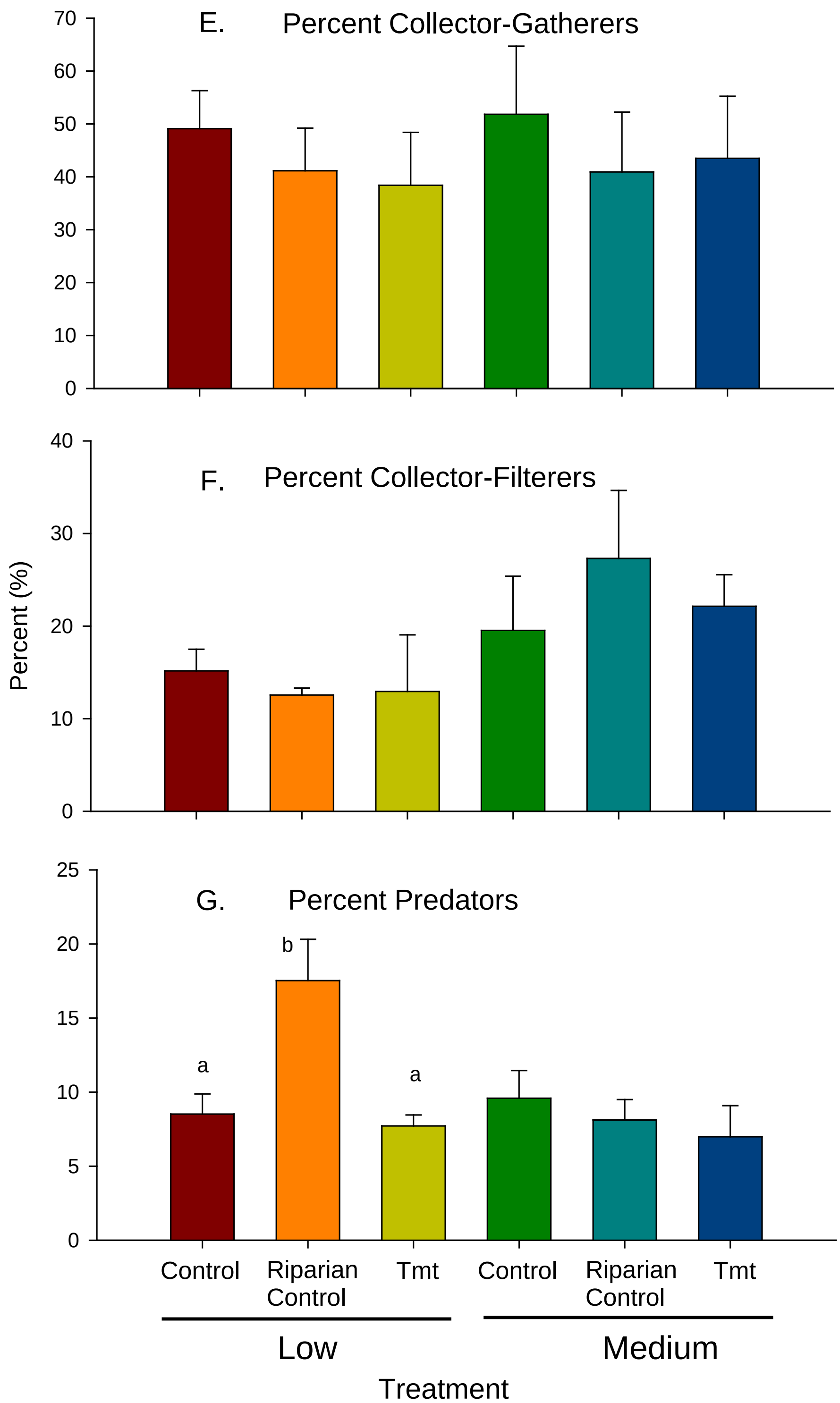

Figure 2b.16 (continued). Mean (+/- 1 SE) Percent collector-gatherers E), Percent collector-filterers F), and Percent predators G) during August 2008 at the multiple-basin sites. Significant ($p < 0.05$) differences among control, riparian control, and treatment reaches indicated by letters.

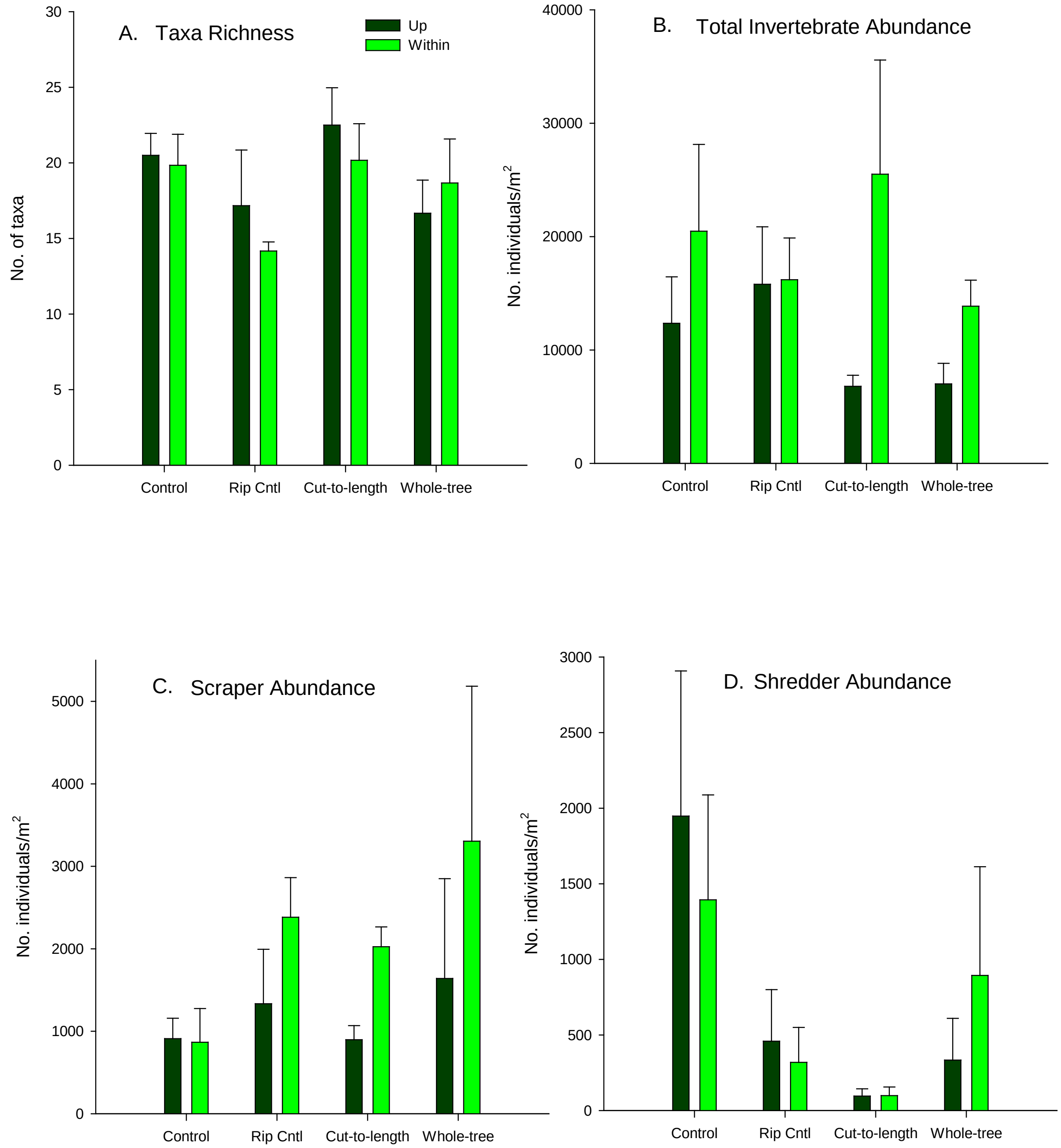

Figure 2b.17. Mean (+/- 1 SE) Taxa richness A), Total invertebrate abundance B), Scraper abundance C), and Shredder Abundance D) during June 2007 at the single-basin plots. No significant ($p > 0.05$) upstream-within plot differences among treatments.

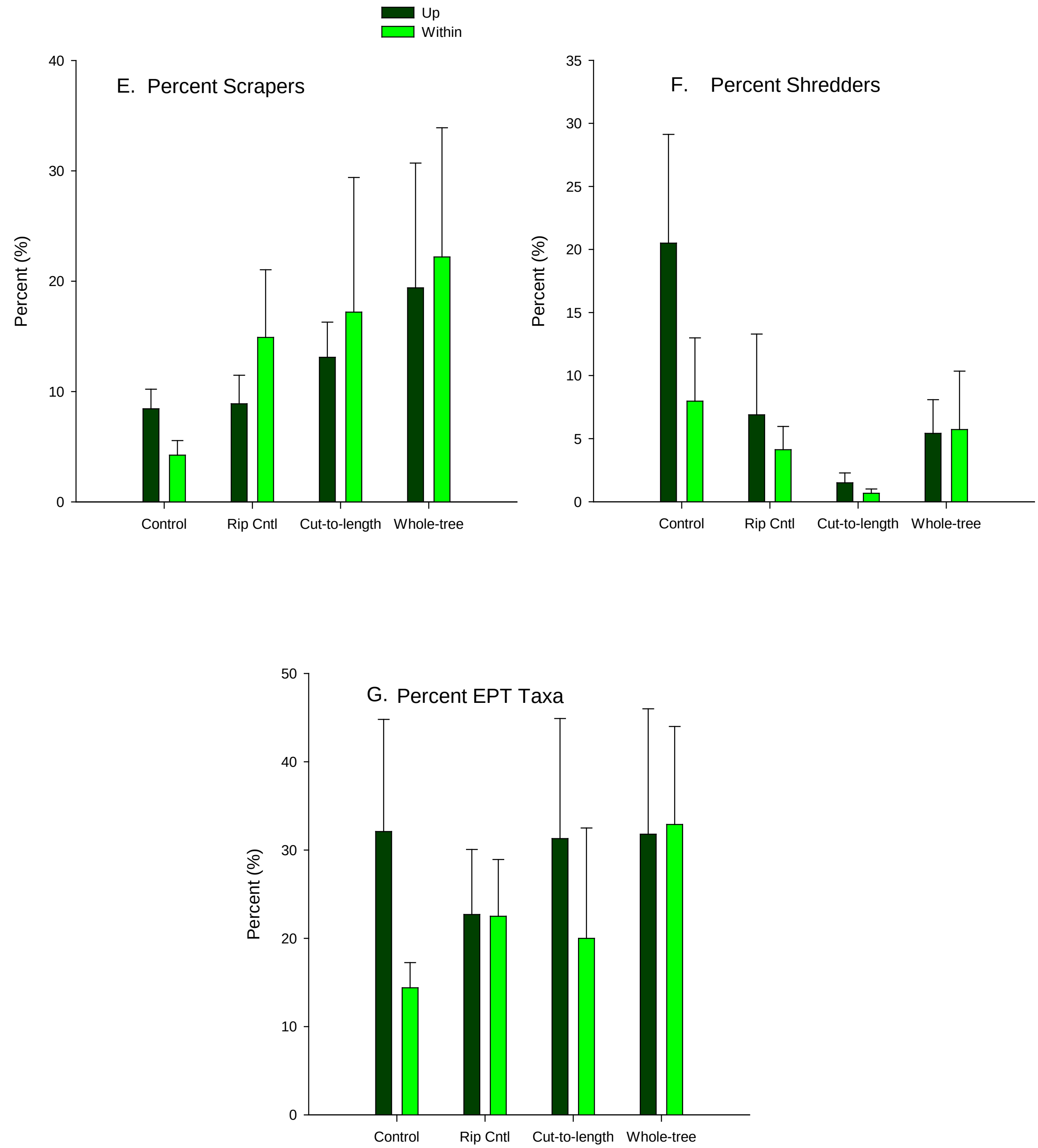

Figure 2b.17 (continued). Mean (+/- 1 SE) Percent scrapers E), Percent shredders F), and Percent Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa G) during June 2007 at the single-basin plots. No significant ($p > 0.05$) upstream-within plot differences among treatments.

Result 3: Evaluate bird impacts

Description: We evaluated the effects of our treatments on breeding birds in northern Minnesota. Breeding bird response to habitat elements within these treated sites such as conifers, snags, long-lived tree species and mast-producing trees and shrubs were evaluated. We evaluated these response variables in 2007 and 2008.

Summary Budget Information for Result 3: **Trust Fund Budget: $5,570.18**
Amount Spent: $5,570.18
Balance: $ 0.00

Deliverable	Completion date	Budget	Status
1. Census riparian -associated bird species and habitat elements at treated and control sites in northern Minnesota. Summarize data and submit progress report.	1/31/08	$1,392	Completed
2. Census riparian-associated bird species and habitat elements at treated and control sites. Summarize data and submit progress report.	6/30/08	$1,392	Completed
3. Analysis of field data gathered in summer 2007 and 2008. Submit progress report**.**	1/31/09	$1,392	Completed
4. Summarization of data gathered and prepare and submit final report	6/30/09	$1,394.18	Completed

Completion Date: June 2009

Final Report Summary:

Introduction

Of the seven components of Minnesota's forest management guidelines, the riparian guidelines have been among the most controversial. Research addressing the long-term effectiveness of riparian guidelines is critical to resolving riparian management conflicts, informing the ongoing revisions of riparian guidelines, and sustaining Minnesota's forest resources. The objective of this study was to examine the population response of forest birds to riparian harvest and to assess the effectiveness of Minnesota's riparian guidelines. In 1997 a riparian harvest project began near Grand Rapids, Minnesota in which 12 study sites along single-basin tributaries on Pokegama Creek were subjected to different harvest types and regimes. Hanowski et al. (2003) documented breeding bird response to riparian forest harvest using 2 types of harvest equipment at these study sites and Hanowski et al. (2007) reported on bird response to riparian harvest at 9 years post-harvest. This report synthesizes overall breeding bird response to riparian harvest at single-basin tributary sites to 11-years post-harvest and complements previous research on forest birds including additional publications by Hanowski et al. (2002 and 2005). For a more comprehensive review of general riparian and riparian breeding bird literature see Wegner (1999) and Hanowski et al. (2002, 2003).

Methods

During May, June, and July breeding birds were sampled at the 12 single-basin sites near Grand Rapids, Minnesota. Study sites were located in areas where no upland or riparian harvest occurred (Control), riparian control sites in which uplands were harvested with no riparian buffer harvest (Cut/Control), or treatment sites in which upland areas were harvested and riparian buffers harvested with a goal of 25 ft^2/acre residual basal area (Cut). Although the initial study purpose was to compare two harvest treatments (full-tree and cut-to-length harvesting), analyses here combine all treatments as a single treatment (Cut). Breeding birds were sampled using standard point counts along transects within these areas (Hanowski *et al.* 1990). Study survey years included one pre-harvest year (1997), three initial post-harvest years (1999-2000), and 3 late post-harvest years (2006-2008). Surveys were not conducted during the years 2001 to 2005. Surveys were completed by experienced observers who passed a bird identification test, a 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) with little wind <20 kph and little to no precipitation. During 2007 and 2008 breeding bird surveys occurred exclusively in June, therefore analyses here incorporate only mid-season (June) breeding bird data.

To understand the effects of riparian harvest on the bird community, individual bird species as well as bird guilds based on life history traits (nesting substrate, migration strategy, and broad habitat type use) were utilized and compared among study sites and years. Bird species and associated guilds are listed in Appendix 3.1. Total bird species abundance by year is reported in Appendix 3.2. These data were compared graphically and using t-statistical tests at a significance level of 0.05. Study years were analyzed individually and combined into three time stages, pre-harvest (1997), 1-3 years post-harvest (1998-2000) and 9-11 years post-harvest (2006-2008) to better examine large-scale changes in relative abundances of the bird community over time. Results are reported as a synthesis of riparian harvest effects on bird community dynamics.

Results

A total of 58 bird species were recorded at the single-basin sites throughout the study period from 1997 – 2008 (Appendix 2). The five most abundant bird species present at all sites pre-harvest were (in order of decreasing abundance) the Ovenbird, Red-eyed Vireo, Least Flycatcher, Black-throated Green Warbler, and Veery (Appendix 3.2). All of these species are associated with mature forest habitat (Lind et al. 2006, Appendix 3.1). At one-year post harvest Ovenbirds, Red-eyed Vireos, and Least Flycatchers remained the most abundant species but were followed in abundance by Mourning Warblers and White-throated Sparrows, two early successional species. Two-years post harvest, the Chestnut-sided Warbler, an early successional species, had become the most dominant bird at the single-basin study sites followed by the

Ovenbird and Mourning Warbler. At 4-years, 9-years, and 10-years post-harvest, the Chestnut-sided Warbler remained the most abundant bird at the study sites. It was not until 11-years post-harvest that the Chestnut-sided Warbler's relative abundance decreased and was replaced by the abundance of a mature forest species, the Red-eyed Vireo. Chestnut-sided Warbler abundance on Cut/Control and Cut plots did not begin to increase until 2-years post harvest (Figure 3.1) but remained significantly higher on Cut/Control and Cut sites when compared to Control sites post-harvest ($p<0.01$, $p<0.00$, respectively). Chestnut-sided Warbler abundance decreased at 10 and 11-years post-harvest. Ovenbirds remained relatively high in abundance throughout the study, however abundance on Cut/Control and Cut sites decreased significantly after harvest and remained significantly less than abundances on Control plots throughout the study ($p<0.00$, Figure 3.2). Ovenbird abundance remained relatively constant on Control plots throughout the study.

At the single-basin pre-harvest sites, the relative abundance of mature forest species ranged from 0.97-1.0 indicating an overall bird composition comprised of nearly all mature forest birds. In contrast, the relative abundance of early successional species ranged from 0-0.03 indicating these birds were nearly absent at the single-basin study sites pre-harvest. Mature and early successional species abundance changed drastically in the years post-harvest (Figure 3.3a-b). The relative abundance of mature forest species on both Cut/Control and Cut plots decreased at 1-3 years post-harvest and remained low at 9-11 years post-harvest and were significantly different than Control plot abundance at both post-harvest stages ($p<0.01$, Figure 3.3a). The relative abundance of early successional species increased on Cut/Control and Cut plots 1-3 years post-harvest and remained significantly higher than Control abundance at 9-11 years post-harvest ($p<0.00$, Figure 3.3b). As expected, abundances of mature and early successional species remained stable at Control plots throughout the study.

Long-distance and short-distance migrant birds exhibited opposing trends in relative abundance throughout the study period (Figures 3.4a-b). Relative abundance measurements showed long-distance migrants to be a dominant guild during the pre-harvest year with an abundance range of 0.80-0.89 as opposed to the relative abundance of short-distance migrants which ranged from 0.07-0.13 of total bird abundance. However, at 1-3 years post-harvest long-distance migrant abundance had decreased on both Cut/Control and Cut sites while short-distance migrant abundance increased on these two sites. The relative abundance of short-distance migrants returned to Control site levels at 9-11 years post-harvest as did the relative abundance of long-distance migrants on Control/Cut sites. However, the relative abundance of long-distance migrants continued to decrease on Cut sites at 9-11 years post-harvest. The relative abundance of these two migration guilds remained constant on Control sites throughout the study period.

Among the nesting guilds, no significant differences between sites at different years were detected. However trends in relative abundance did occur throughout the study period (Figure 3.5a-d). Canopy nesters declined in relative abundance throughout the study at all sites, including Controls sites. Cavity nesters slightly decreased in relative abundance on Cut/Control and Cut sites and increased on Control sites. Shrub nesters slightly decreased in relative abundance on Control sites throughout the study but increased on both Cut/Control and Cut sites and 1-3 years post-harvest. At 9-11 years post-harvest, the relative abundance of shrub nesters was similar on both Control and Cut/Control sites but decreased substantially at Cut sites.

Ground nesters increased very slightly in relative abundance at all sites throughout the study period.

Discussion

The results of the single-basin riparian study showed riparian bird community change at two time periods after upland and riparian harvest events. The riparian bird community was affected by both of these harvest events when compared to unharvested control sites. Maintaining an intact riparian buffer did not alleviate upland harvest effects on the riparian bird community. Only long-distance migrant birds increased to pre-harvest levels on the unharvested riparian buffers which may be a result of an increase of shrub nesting and early successional bird species with long-distance migrant life histories (Red-eyed Vireo, American Redstart, Mourning Warbler). Most harvest effects continued to be evident on unharvested riparian buffers at 9-11 years post harvest including the low abundance of cavity nesters, canopy nesters, and Ovenbirds. Ovenbirds are a high priority "watch list" species of northern Minnesota forests (Rich et al. 2004, Lind et al. 2006). This study showed that retaining an unharvested riparian buffer was not sufficient in maintaining pre-harvest abundance of canopy and cavity nesters, or maintaining Ovenbird populations in northern Minnesota.

Early successional species were virtually absent from study sites pre-harvest due to the dominant mature forest type which supported a bird community of nearly all mature forest associated species. The abundance of early successional species, including the Chestnut-sided Warbler, increased to highest study abundance by the first post-harvest time stage. Although Chestnut-sided Warbler abundance decreased towards the end of the study period, the relative abundance of early successional species remained high at 9-11 years post-harvest at both Cut/Control and Cut sites. Early successional species were the dominant habitat guild in Cut/Control sites throughout the post-harvest period. This reveals that retaining an unharvested riparian buffer is not sufficient to support the mature forest associated species population that was predominant in the area pre-harvest. This also reveals that riparian areas are affected by harvest in the landscape illustrated by the increase of early successional species in unharvested riparian areas.

Results of this study show that the pre-harvest bird community is neither maintained nor able to reestablish on unharvested riparian buffers at 9-11 years after an upland harvest event. These results suggest that riparian guidelines need to be flexible, the population status and life history of bird species of conservation priority should be fully considered in riparian management, and that management plans for riparian areas should be done on a landscape level.

The results from this study only reflected relatively short-term 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.

Result expenditures

Funds in the amount of $1.18 were shifted from Result 4 to get the Result 3 budget to a zero balance.

Unanticipated and unresolved problems
The procedures used to meet the objectives of this Result were adequate and sufficient. There were no unresolved problems relative to this Result. All work was completed as planned.

Literature cited

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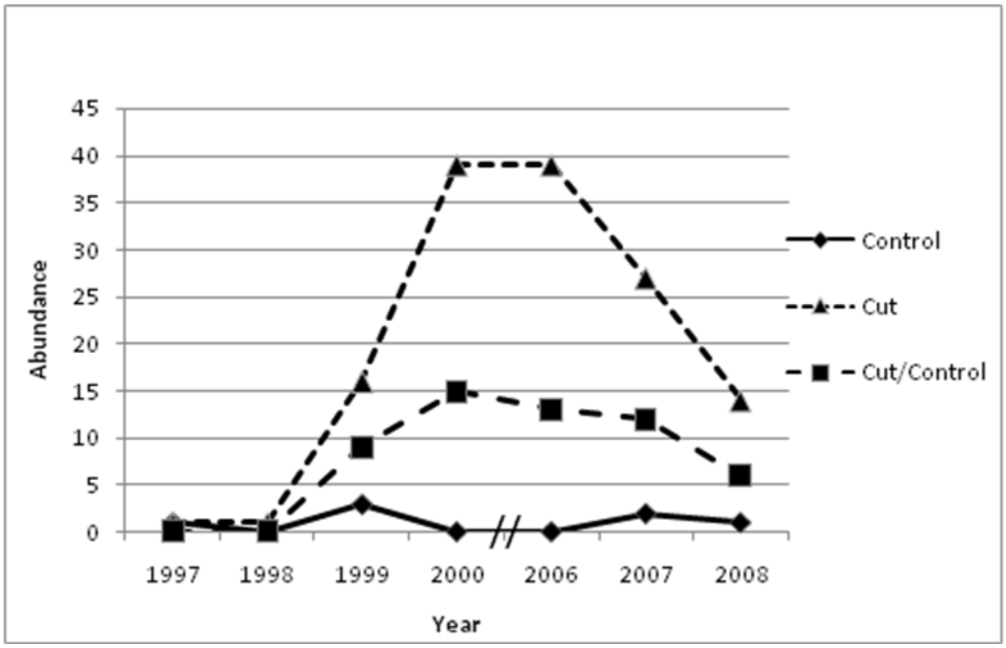


Figure 3.1. Chestnut-sided Warbler abundance at the single-basin Control, Cut/Control, and Cut sites during June over all survey years.

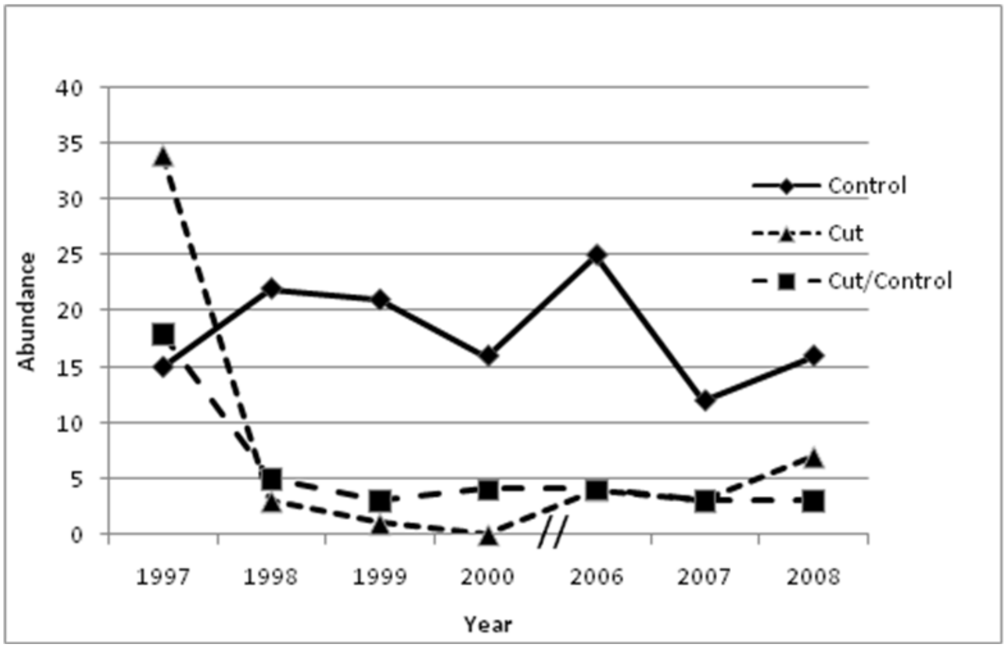


Figure 3.2. Ovenbird abundance at the single-basin Control, Cut/Control, and Cut sites during June over all survey years.

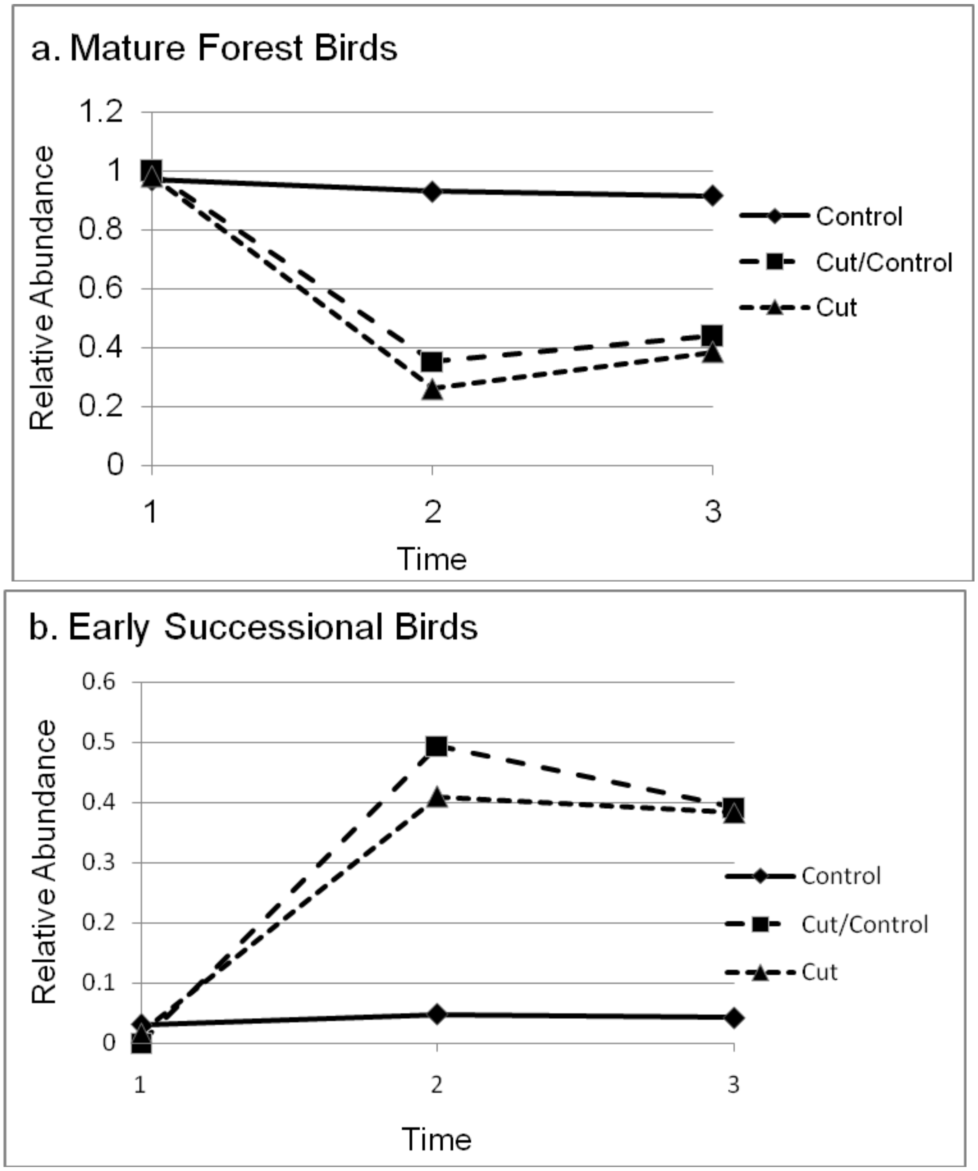


Figure 3.3a and b. Mature and early successional forest associated bird guild relative abundances at the single-basin Control, Cut/Control, and Cut sites at pre-harvest (Time 1), post-harvest 1-3 years (Time 2), and post-harvest 9-11 years (Time 3).

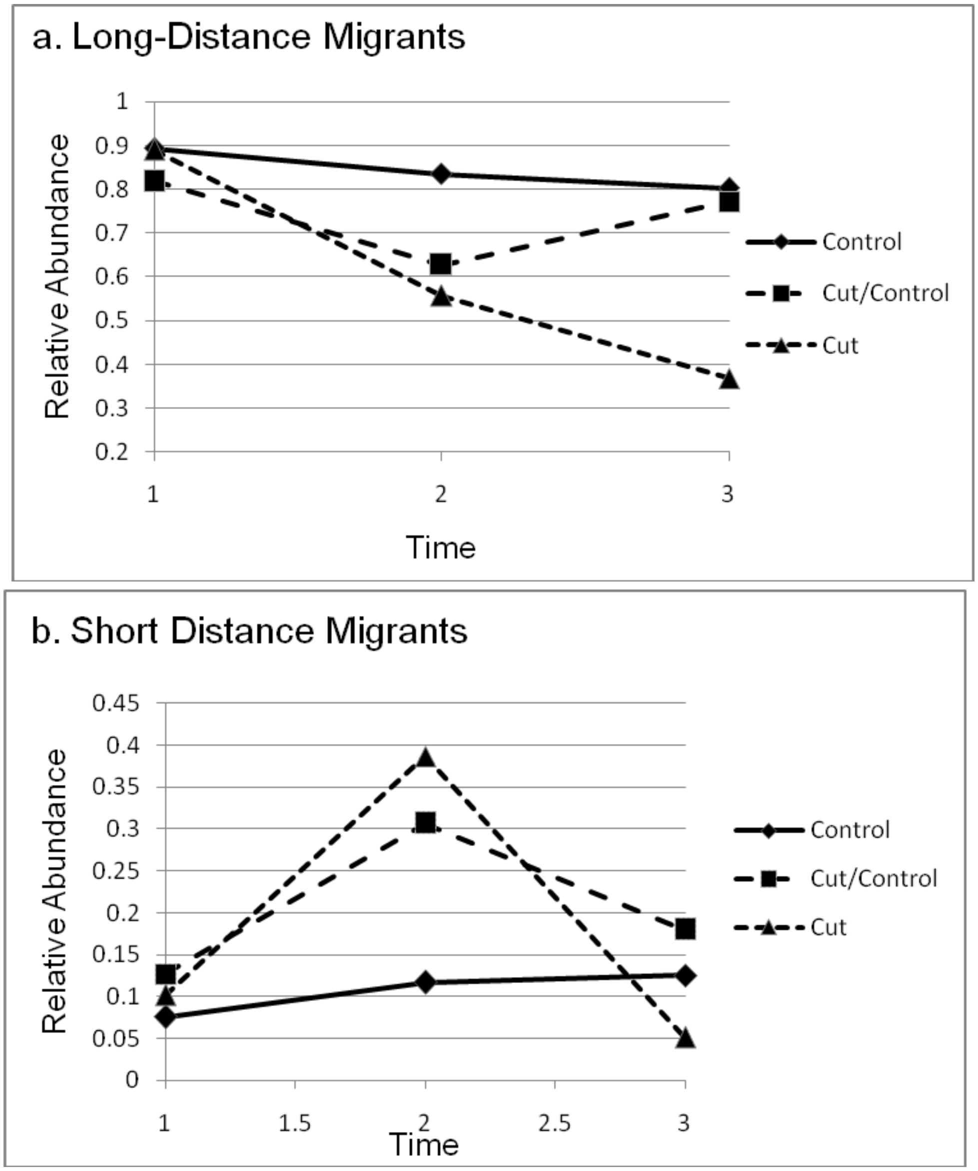
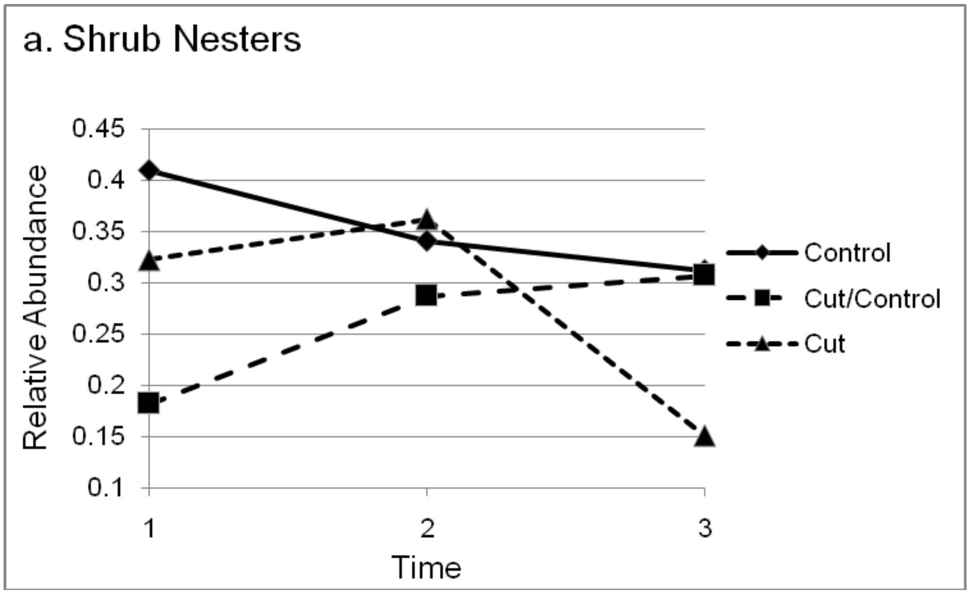


Figure 3.4a and b. Long-distance and short-distance migrant relative abundances at the single-basin Control, Cut/Control, and Cut sites at Pre-harvest (Time 1), Post-harvest 1-3 years (Time 2), and Post-harvest 9-11 years (Time 3).



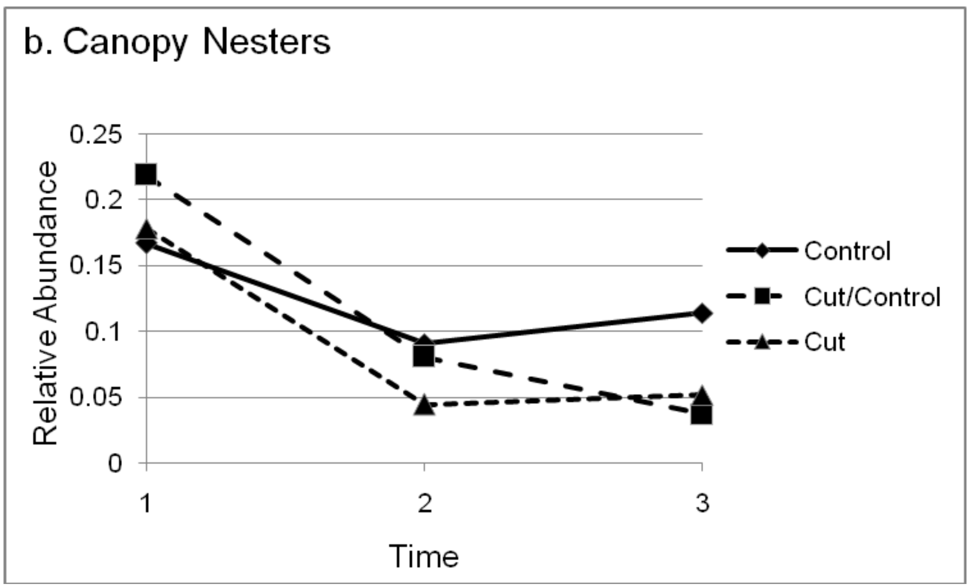


Figure 3.5a-d. Nesting guild relative abundances at the single-basin Control, Cut/Control, and Cut sites at pre-harvest (Time 1), post-harvest 1-3 years (Time 2), and post-harvest 9-11 years (Time 3).

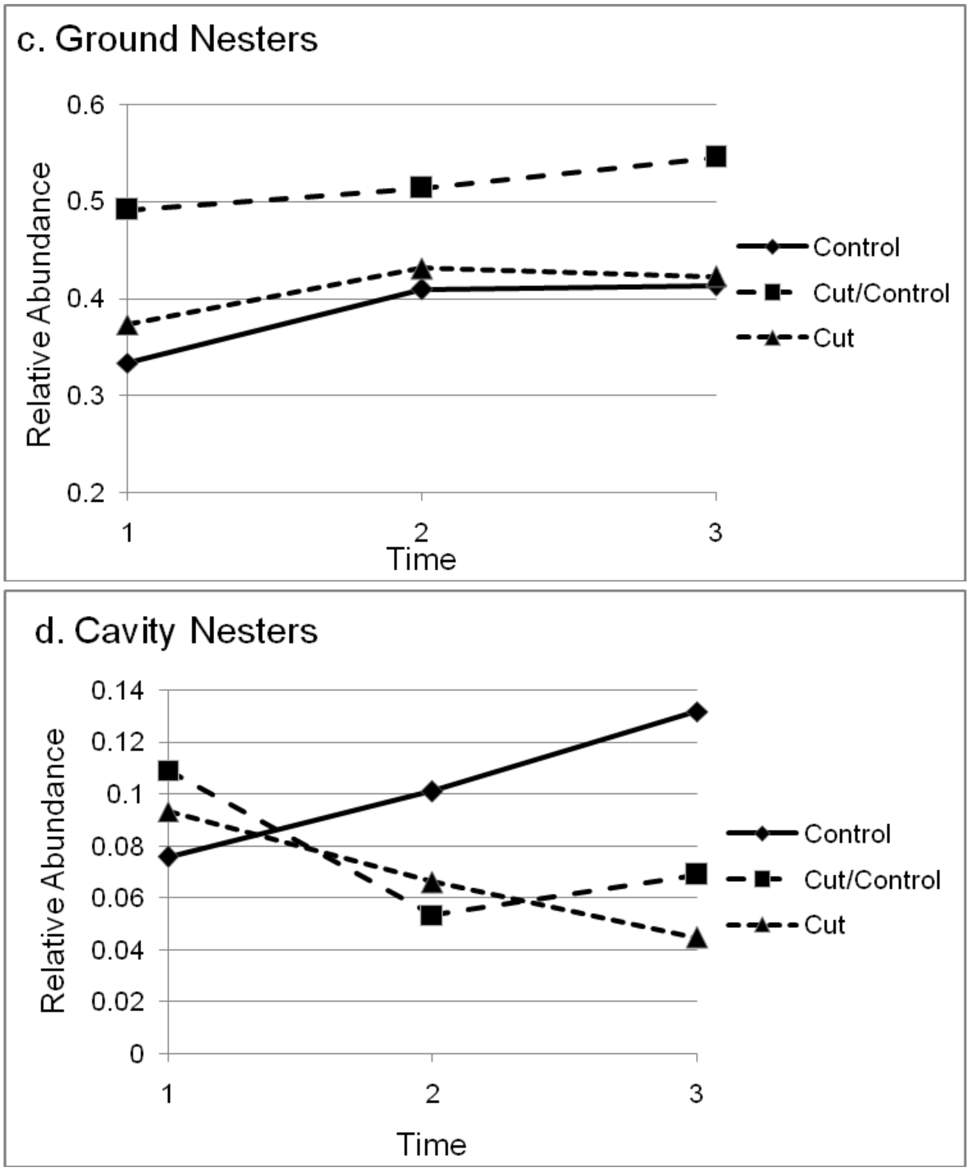


Figure 3.5a-d (continued). Nesting guild relative abundances at the single-basin Control, Cut/Control, and Cut sites at pre-harvest (Time 1), post-harvest 1-3 years (Time 2), and post-harvest 9-11 years (Time 3).

Appendix 3.1a. English and taxonomic bird species names and guild associations for species recorded at the single-basin study sites for all study years 1997 – 2008. Guild associations are taken from Lind et al. (2006). Migration Guild: Long = Long Distance Migrant, SHRT = Short Distance Migrant, PERM = Permanent Resident. Nesting Guild: CNPY = Canopy, CVTY = Cavity, GRND = Ground, PRST = Nest Parasite, SCPY = Subcanopy, SHRB = Shrub. Habitat Guild: ES = Early Successional, FLME = Fields and Meadows, MAT = Mature, UBIQ = Ubiquitous, URBN = Urban.

English Name	**Taxonomic Name**	**Migration Guild**	**Nesting Guild**	**Habitat Guild**
Alder Flycatcher	*Empidonax alnorum*	LONG	SHRB	ES
American Goldfinch	*Carduelis tristis*	SHRT	SHRB	FLME
American Redstart	*Setophaga ruticilla*	LONG	SHRB	ES
American Robin	*Turdus migratorius*	SHRT	SCPY	FLME
Black-and-white Warbler	*Mniotilta varia*	LONG	GRND	MAT
Black-capped Chickadee	*Poecile atricapillus*	PERM	CVTY	MAT
Brown-headed Cowbird	*Molothrus ater*	SHRT	PRST	FLME
Blackburnian Warbler	*Dendroica fusca*	LONG	CNPY	MAT
Blue Jay	*Cyanocitta cristata*	PERM	CNPY	MAT
Brown Creeper	*Certhia americana*	SHRT	CVTY	MAT
Black-throated Blue Warbler	*Dendroica caerulescens*	LONG	SHRB	MAT
Black-throated Green Warbler	*Dendroica virens*	LONG	CNPY	MAT
Broad-winged Hawk	*Buteo platypterus*	LONG	CNPY	MAT
Canada Warbler	*Wilsonia canadensis*	LONG	GRND	MAT
Cedar Waxwing	*Bombycilla cedrorum*	SHRT	SHRB	UBIQ
Chipping Sparrow	*Spizella passerina*	SHRT	CNPY	MAT
Chimney Swift	*Chaetura pelagica*	LONG	CNPY	URBN
Common Raven	*Corvus corax*	PERM	CNPY	MAT
Common Yellowthroat	*Geothlypis trichas*	SHRT	GRND	SBSW
Chestnut-sided Warbler	*Dendroica pensylvanica*	LONG	SHRB	ES
Downy Woodpecker	*Picoides pubescens*	PERM	CVTY	MAT
Eastern Phoebe	*Sayornis phoebe*	SHRT	SHRB	URBN
Eastern Wood-pewee	*Contopus virens*	LONG	SCPY	MAT
Evening Grosbeak	*Coccothraustes vespertinis*	PERM	CNPY	MAT
Great Crested Flycatcher	*Myiarchus crinitus*	LONG	CVTY	MAT
Golden-crowned Kinglet	*Regulus satrapa*	SHRT	CNPY	MAT
Gray Catbird	*Dumetella carolinensis*	LONG	SHRB	UBIQ
Golden-winged Warbler	*Vermivora crysoptera*	LONG	GRND	ES
Hairy Woodpecker	*Picoides villosus*	PERM	CVTY	MAT
Hermit Thrush	*Catharus guttatus*	SHRT	GRND	MAT

Appendix 3.1b. English and taxonomic bird species names and guild associations for species recorded at the single-basin study sites for all study years 1997 – 2008. Guild associations are taken from Lind et al. (2006). Migration Guild: Long = Long Distance Migrant, SHRT = Short Distance Migrant, PERM = Permanent Resident. Nesting Guild: CNPY = Canopy, CVTY = Cavity, GRND = Ground, PRST = Nest Parasite, SCPY = Subcanopy, SHRB = Shrub. Habitat Guild: ES = Early Successional, FLME = Fields and Meadows, MAT = Mature, UBIQ = Ubiquitous, URBN = Urban.

English Name	**Taxonomic Name**	**Migration Guild**	**Nesting Guild**	**Habitat Guild**
House Wren	*Troglodytes aedon*	SHRT	CVTY	MAT
Indigo Bunting	*Passerina cyanea*	LONG	SHRB	FLME
Least Flycatcher	*Empidonax minimus*	LONG	SHRB	MAT
Mourning Warbler	*Oporornis philadelphi*	LONG	GRND	ES
Nashville Warbler	*Vermivora ruficapilla*	LONG	GRND	MAT
Northern Flicker	*Colaptes auratus*	SHRT	CVTY	FLME
Northern Parula	*Parula americana*	LONG	CNPY	MAT
Northern Waterthrush	*Seiurus noveboracensis*	LONG	GRND	MAT
Ovenbird	*Seiurus aurocapilla*	LONG	GRND	MAT
Pileated Woodpecker	*Dryocopus pileatus*	PERM	CVTY	MAT
Purple Finch	*Carpodacus purpureus*	PERM	CNPY	MAT
Rose-breasted Grosbeak	*Pheuctuicus ludovicia*	LONG	SHRB	MAT
Red-breasted Nuthatch	*Sitta canadensis*	PERM	CVTY	MAT
Red-eyed Vireo	*Vireo olivaceus*	LONG	SHRB	MAT
Ruby-throated Hummingbird	*Archilochus colubris*	LONG	CNPY	MAT
Ruffed Grouse	*Bonasa umbellus*	PERM	GRND	ES
Scarlet Tanager	*Piranga olivacea*	LONG	CNPY	MAT
Song Sparrow	*Melospiza melodia*	SHRT	GRND	FLME
Swamp Sparrow	*Melospiza georgiana*	SHRT	SHRB	FLME
Tennessee Warbler	*Vermivora peregrina*	LONG	GRND	MAT
Veery	*Catharus fuscescens*	LONG	GRND	MAT
White-breasted Nuthatch	*Sitta carolinensis*	PERM	CVTY	MAT
Winter Wren	*Troglodytes troglodytes*	SHRT	GRND	MAT
Wood Thrush	*Hylocichla mustelina*	LONG	CNPY	MAT
White-throated Sparrow	*Zonotrichia albicollis*	SHRT	GRND	ES
Yellow-bellied Sapsucker	*Sphyrapicus varius*	SHRT	CVTY	MAT
Yellow-rumped Warbler	*Dendroica coronata*	LONG	CNPY	MAT
Yellow-throated Vireo	*Vireo flavifrons*	LONG	CNPY	MAT

Appendix 3.2a. Total abundance of bird species recorded by year at the single-basin sites for 1997 – 2000 and 2006 – 2008.

English Name	1997	1998	1999	2000	2006	2007	2008
Alder Flycatcher			3	1			
American Goldfinch				15	5		
American Redstart					20	12	9
American Robin		2	1	5	3	1	
Black-and-white Warbler	2	1			5	15	18
Black-capped Chickadee	1	3	1	9	13	6	5
Brown-headed Cowbird		6	8	6	2		2
Blackburnian Warbler	6					2	
Blue Jay		2	3	2	5	1	4
Brown Creeper	6	3	1		2	2	4
Black-throated Blue Warbler	1						
Black-throated Green Warbler	24	4	3	3	6	2	3
Broad-winged Hawk					2		
Canada Warbler					3	1	4
Cedar Waxwing				6	6	1	1
Chipping Sparrow	1						
Chimney Swift		1					
Common Raven				1			
Common Yellowthroat	1		6	17	6	4	3
Chestnut-sided Warbler	2	1	28	54	52	41	21
Downy Woodpecker		1		1		1	
Eastern Phoebe				1			
Eastern Wood-pewee	4	1	1	5	2		3
Evening Grosbeak				6			
Great Crested Flycatcher	6	2	4				4
Golden-crowned Kinglet	1						
Gray Catbird				1	4		1
Golden-winged Warbler			6	16	4	9	17
Hairy Woodpecker							1
Hermit Thrush	6	3	3	3		1	4

Appendix 3.2b. Total abundance of bird species recorded by year at the single-basin sites for 1997 – 2000 and 2006 – 2008.

English Name	**1997**	**1998**	**1999**	**2000**	**2006**	**2007**	**2008**
House Wren				1			
Indigo Bunting			2	6	1		
Least Flycatcher	26	15	6	8	5	5	3
Mourning Warbler	1	13	21	40	16	8	9
Nashville Warbler	4				2	3	20
Northern Flicker		1					1
Northern Parula	2			1	1	2	
Northern Waterthrush						1	
Ovenbird	67	30	25	20	33	18	26
Pileated Woodpecker					2		
Purple Finch			1		1		
Rose-breasted Grosbeak	2	2	1	10	17	7	13
Red-breasted Nuthatch	3						2
Red-eyed Vireo	44	20	18	24	26	18	27
Ruby-throated Hummingbird		2		8	2		2
Ruffed Grouse	1			3			4
Scarlet Tanager	5	3	2	3	1	1	3
Song Sparrow		3	21	22	2		
Swamp Sparrow			1			1	
Tennessee Warbler							1
Veery	8	4	3	4	38	30	26
White-breasted Nuthatch	1			4	4		
Winter Wren	4	6	3	4	4	1	3
Wood Thrush	2				3		6
White-throated Sparrow		7	9	11	8	6	8
Yellow-bellied Sapsucker	5	6	4	7	6	4	6
Yellow-rumped Warbler	2						1
Yellow-throated Vireo	1	1			1		

Result 4: Meta-analysis of terrestrial and aquatic results

Description: We evaluated the effects of our management treatments through time on both the terrestrial (trees and understory species) and aquatic habitat components, as well as changes of terrestrial and aquatic communities (fish and invertebrate) in a meta-analysis. We evaluated the response variables collected in previous years on the single- and multiple-basin study sites.

Summary Budget Information for Result 4: **Trust Fund Budget: $71,026.08**
Amount Spent: $70,123.44
Balance: $ 902.64

Deliverable	Completion date	Budget	Status
1. Assemble datasets for meta-analysis	4/30/08	$38,400	Completed
2. Analyze and synthesize datasets	9/30/08	$30,626.08	Completed
3. Prepare and publish meta-analysis; prepare and submit final report	6/30/09	$2,000	Completed

Completion Date: June 2009

Final Report Summary:

Introduction
Relatively few evaluations of bird communities, terrestrial vegetation, aquatic macroinvertebrate and fish communities have been published in peer-reviewed literature that detail the effect of varying RBA after timber harvesting in RMZs. This study evaluates data from two experiments in northern Minnesota, comparing the response of these riparian communities to partially harvested RMZs and riparian control plots for three years following harvest. The primary objectives were to: 1) evaluate the effectiveness of partial harvesting within the RMZ at mitigating disturbances to aquatic macroinvertebrate and fish communities; 2) identify similarities or differences in responses between invertebrate and fish communities, 3) examine the response of the avian community to different levels of RBA following harvest, and 4) identify the vegetative components affecting the avian community response after harvest.

Methods
Each experiment (single-basin and multiple-basin experiment) included one-year of pre-harvest data and three years of post-harvest data. In both experiments, the stream in each plot was divided into three reaches: upstream, within, and downstream of treatment to assess the aquatic communities. For the purpose of this study, only the within reach was used in the analysis. Initial analyses indicated few differences among reaches at a plot (Atuke, 2008; Hemstad et al., 2008), so the within-plot location was viewed as representative of the plot.

Aquatic macroinvertebrates

In the single-basin experiment plots, invertebrate samples were taken mid-summer (late July or early August) in each year at random locations within two consecutive riffles using a $0.1 m^2$ Waters-Knapp Hess sampler in the within-plot location. Invertebrate samples from the single-basin experiment plots were preserved in 95% ethanol and returned to the laboratory, where they were identified to the lowest practical taxon, typically genus (Merritt and Cummins, 1996). In the multiple-basin experiment plots, macroinvertebrates were sampled mid-summer (late July or early August) using a 30.4-cm wide kicknet with 500 µm mesh. Sampling started downstream of the plot and moved upstream to avoid impacting subsequent samples. Samples were collected after every 2.5 m of stream channel length for a total of 20 sampling points per 50-m reach length. Generally, two leg kicks were made per sampling point and all habitats available in the reach were sampled. Invertebrate samples from the multiple-basin experiment plots were preserved in 80% ethanol and returned to the laboratory where they were identified to the lowest practical taxon, typically genus.

Fish

In the single-basin experiment plots, fish were sampled in August with a Wisconsin™ Abp-3 pulsed DC backpack electrofisher (Engineering Technical Services). At each site, fish were collected from a 50-m reach within the treatment plot with a single pass. Fish were identified to species and returned to the stream. In the multiple-basin experiment plots, fish were sampled once a year (August) with the backpack electrofisher. Fish were collected from a 100-m reach with a single pass. Fish were identified to species and returned to the stream. The number of fish per sample was standardized by 50-m reach of the stream ($n \cdot 50\ m^{-1}$). Further detailed descriptions of fish collection methods can be found in Atuke (2008) for the multiple-basin experiment.

Birds

Before- and after-harvest data on breeding birds were collected using standardized methods in seven riparian study areas (multiple-basin experiment) 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).

Terrestrial data
Terrestrial data for each site in the multiple-basin experiment was obtained from Olszewski (2009). The data included understory woody biomass (W_{bio}), herbaceous biomass (H_{bio}), and tree basal area (T_{ba}). Above ground biomass for each structural layer was obtained by either destructive sampling (herbaceous and woody regeneration layers) or by the use of published allometric biomass equations (trees and shrubs) from study areas with similar species composition in Minnesota (see list of references in Kastendick [2005]). Biomass samples of herbaceous and woody regeneration less than 0.76 m tall were collected using destructive sampling techniques in two subplots, (0.61 by 0.61 m each) adjacent to the regeneration plots. Vegetation was clipped at the time of peak standing crop biomass, separated, and oven-dried at 70º C to a constant weight. Total basal area was calculated for all tree species > 12.7 cm dbh. There were a total of 56 samples that included both vegetation and avian community data. Further detail on the vegetation data collection methods can be found in Kastendick (2005) and Olszewski (2009). Vegetation data was not collected in 2005 so missing values were estimated by linear interpolation data from one year prior (2004) and one year after (2006).

Analysis
We compared aquatic macroinvertebrate and fish metrics between treatments using mixed models in R using the *nlme* package (Pinheiro et al. 2009) for each experiment separately. For the analysis of aquatic macroinvertebrates, we focused on commonly reported aquatic macroinvertebrate metrics (taxa richness, percent Ephemoptera, Plecoptera, and Trichopetera [EPT], and diversity [Shannon H']). For the analysis of fish, we focused on commonly-reported metrics (abundance, taxa richness, and diversity). Analyses were separated between experiments because of the different experimental designs that required different blocking protocols. For the single-basin experiment plots, we modeled the community metrics as a function of treatment (TRT) and year since harvest (YearSince) as a covariate. In this analysis, we blocked by stream, which was included as a random effect. In the multiple-basin experiment, the main effects were identical to the single-basin experiment but each treatment was nested by site (a random effect). We assessed significance of all analyses at • = 0.05 but assumed weak evidence at • = 0.10.

We examined the response of avian abundance, avian diversity (Shannon H'), species richness, community composition, mature forest species (total abundance) and early successional species (total abundance). We modeled site means with reduced maximum likelihood (REML). The main effects in these models were treatment (riparian control [RC], a "medium" level of residual basal area [MED RBA], and a low level of residual basal area [LOW RBA]), year (YEAR) since harvest, and intercept, which was included as a random factor. The repeated measure was treatment nested within site. We also tested for a treatment by year interaction, where a significant interaction would indicate an effect of the RMZ, and tested for the simple effects of year on each harvest level (SAS; SLICE option). We assessed significance of all analyses at • = 0.05 but assumed weak evidence at • = 0.10.

Results

Aquatic macroinvertebrate community following timber harvesting
Individual macroinvertebrate metrics displayed variable responses to treatment and temporal effects in the two experiments. We observed a general decline in the invertebrate taxa diversity throughout the single-basin experiment (Figure 4.1), but we did not observe significant (P > 0.05) treatment effects (Table 4.1). Likewise, in the multiple-basin experiment, we did not observe significant treatment effect on invertebrate diversity (P > 0.05) for all treatments, as the invertebrate diversity increased after harvest (Figure 4.1). Invertebrate richness in the single-basin experiment displayed a marginally significant temporal effect (P = 0.067), whereas in the multiple-basin experiment displayed a significant temporal effect (P < 0.001) as the number of taxa increased immediately following harvest. After the initial post-harvest increase in invertebrate richness observed in both experiments, there was a general decline in taxa richness in the single-basin experiment, whereas invertebrate richness in the RC and MED RBA treatments continued to increase in the multiple-basin experiment. However, taxa richness declined in the LOW RBA treatment (Figure 4.1).

Fish community following timber harvesting
As with the invertebrate metrics, fish metrics indicated a variable response to treatment and temporal effects. Fish diversity and richness tended to increase following harvest in both experiments (P < 0.05) (Table 4.2; Figure 4.2). Catch per 50 m indicated a significant treatment-by-year effect in the single-basin experiment (Table 2). Catch per 50 m increased two years after harvest in the multiple-basin experiment (Figure 4.2), reflecting the significant temporal effect (Table 4.2).

Bird community composition following timber harvesting
Mean avian abundance (± SE) was from 25.2 ± 5.7 birds in the riparian control plots, 20.4 ± 4.2 in the MED RBA treatment sites, and 19.8 ± 3.5 in the LOW RBA treatment sites (Figure 3) prior to harvest. There were no indications of significant treatment ($F_{2,11}$ = 0.64, P = 0.55), temporal ($F_{3,33}$ = 1.75, P = 0.18), or associated interaction ($F_{6,33}$ = 1.27, P = 0.30) effects on species richness (Table 4.3). Likewise, mean species richness ranged from 10.8 - 11.8 in the riparian control sites, from 9.8 – 11.8 in the MED RBA treatment sites, and 9.5 – 11.5 in the LOW RBA treatment sites (Figure 4.3). There were no indications of significant treatment ($F_{2,11}$ = 0.51, P = 0.61), temporal ($F_{3,33}$ = 0.62, P = 0.61), or associated interaction ($F_{6,33}$ = 0.64, P = 0.70) effects on species richness. In addition, mean species diversity did not indicate significant treatment ($F_{2,11}$ = 0.74, P = 0.50), temporal ($F_{3,33}$ = 0.82, P = 0.49), or associated interaction ($F_{6,33}$ = 1.08, P = 0.39) effects.

There was a significant response of the avian community to harvesting in the RMZ. The environmental variables accounted for 15.6% of the variation in the avian community data set. The significant environmental variables were log woody biomass (• = 0.05, P < 0.01), log herbaceous biomass (• = 0.03, P < 0.01), and log tree basal area (• = 0.02 P < 0.01). Partitioning the variance into understory (woody biomass and herbaceous biomass) and overstory biomass (tree basal area) components indicated that the understory component explained 48.1% (P < 0.01) of the constrained variation and the overstory component explained 32.5% (P < 0.01) of the constrained variation. Variation that could not be effectively portioned as either understory or overstory components was 19.4%.

The first RDA axis (RDA1) was correlated with decreased log transformed tree basal area (r = -0.82) and positively associated with woody biomass (r = 0.88) and herbaceous biomass (r = 0.79) (Figure 4.4). Hence, RDA1 was closely associated with harvested RMZs. The five avian species most associated with this axis (positive RDA1 values; decreasing strength of association [i.e., correlation]) were White-throated Sparrow (*Zonotrichia albicollis*) (r = 0.60), Chestnut-sided Warbler (*Dendroica pensylvanica*) (r = 0.54), Mourning Warbler (*Oporornis philadelphia*) (r = 0.42), Veery (*Catharus fuscescens*) (r = 0.29), and White-breasted Nuthatch (*Sitta carolinensis*) (r = 0.18). Alternatively, the five avian species most negatively associated with this axis (negative RDA1 values; decreasing strength of association) were Ovenbird (*Seiurus aurocapillus*) (r = -0.50), Black-throated Green Warbler (*Dendroica virens*) (r = -0.50), Red-eyed Vireo (*Vireo olivaceus*) (r = -0.28), Nashville Warbler (*Verivora ruficapilla*) (r = -0.21), and Red-breasted Nuthatch (*Sitta canadensis*) (r = -0.19).

The second RDA axis (RDA2) was primarily associated with increased herbaceous biomass (r = 0.51) but also increased tree basal area (r = 0.54). Avian species associated with this axis (positive axis 2 values; decreasing strength of association) were White-breasted Nuthatch (r = 0.43), Ovenbird (r = 0.39), American Redstart (*Setophaga ruticilla*) (r = 0.39), Red-eyed Vireo (r = 0.37), and Chestnut-sided Warbler (r = 0.30). Alternatively, the five avian species most negatively associated with this axis (negative RDA2 values; decreasing strength of association) were White-throated Sparrow (r = -0.25), Black-throated Green Warbler (r = -0.23), American Robin (*Turdus migratorius*) (r = -0.21), Northern Flicker (*Colaptes auratus*) (r = -0.18), and Ruby-throated Hummingbird (*Archilochus colubris*) (r = -0.15).

Treatment and site-specific avian community changes were apparent following harvest (Figure 4.4). Riparian control sites displayed temporal changes but there was little pattern in the community changes over the period of the study. Alternatively, we did observe changes in the vegetative community following harvest. Following harvest, there was a marked decrease in basal area and a general increase in the amount of woody biomass. With the increase in woody biomass, the avian communities shifted toward an association with early successional species (White-throated sparrow and Chestnut-sided Warbler). One MED RBA treatment and one LOW RBA treatment indicated a shift toward increased herbaceous biomass and greater association with the Chestnut-sided Warbler.

Discussion and conclusions

Macroinvertebrate and fish communities

Stream fish communities, as with macroinvertebrates communities, typically display large temporal variation, depending on the scale observed (Lohr and Fausch, 1997). Because lotic systems are open systems, stream fishes are subjected to many temporally changing factors that can influence their community dynamics, such as weather, migration, variation in competition (Oberdorff et al., 2001), or instream habitat cover and refugia (Pusey et al., 1993). Community stability often depends on the physical and temporal stability of habitats and on the interactions between the species in the community (Collins, 2000). In our analysis, we observed a strong temporal effect on diversity and species richness of the fish communities in the single-basin experiment but less so in the multiple-basin experiment. Interestingly, temporal variation was observed on instream habitat variables in the single-basin experiment (Hemstad et al., 2008) and in the multiple-basin experiment (Atuke, 2008). There are two explanations for this difference in the extent of temporal variation. The greater temporal variation in the single-basin experiment could be an artifact of the differences in the spatial extent between the two experiments, where the variability of any single stream would likely be minimized from the other sites across the large spatial extent. Another possible explanation for the high temporal variation of instream habitat in the single-basin experiment is that it may be a more dynamic and disturbed watershed than the multiple-basin plots. The history of logging within the two experiments was similar. The multi-basin experiment consisted of even-aged stands originating after an initial cutover 60-70 years ago and the single-basin experiment consisted of even aged stand originating 70-80 years ago (B. Palik, unpubl. data). The single-basin experiment streams were not as wide on average as in the multiple-basin experiment, potentially making these smaller streams more susceptible to disturbance (Gomi et al., 2002). Initial macroinvertebrate richness, diversity, and abundance in the single-basin experiment were much less than observed in the pre-harvest collection in the multiple-basin experiment.

The inherent variation observed in stream communities poses a significant challenge for resource managers, because this variation makes detection of anthropogenic disturbances difficult (Grossman et al., 1990). Regardless of the temporal variation in the fish communities in these experiments, we were able to detect some changes in the communities as a result of the partially harvested RMZs. In both experiments, fish community turnover in the medium RBA treatment was the greatest as brook sticklebacks and central mudminnows, two relatively tolerant fish species, increased. Interestingly, the low RBA treatment in the multiple-basin experiment had lower community turnover than the RC. The RAC for low RBA treatments indicated that the change in communities was primarily due to the increase in abundance of brook stickleback, whereas the relative ranking of the fish in the less common species changed. Increases in the slope of the RAC following harvest suggests that the fish community became more dominated by a single species one year after harvest, but resembled pre-harvest community rankings three years after harvest. In addition, measures of diversity and richness did not indicate significant treatment effects. The lack of significant responses to treatments by the fish communities indicated that the presence of partially harvested RMZs did not result in large changes in the fish communities.

Bird community

Mature forest species, such as the Ovenbird and Red-eyed Vireo, declined with increasing rates of timber removals from the RMZs, yet continued to be abundant in the riparian control sites. This result is also consistent with other studies (Hanowski et al., 2005; Holmes and Pitt, 2007) that observed similar responses of the mature forest species to timber harvesting. The Ovenbird, a species that we observed to have a significant decline following harvest in all treatment plots, is a "species of greatest conservation need" in the Minnesota Department of Natural Resources' Comprehensive Wildlife Conservation Plan (Minnesota Department of Natural Resources, 2006). The Ovenbird is dependent on mature forests and forest interior habitat and thus, very sensitive to timber harvesting (Lambert and Hannon, 2000; Manolis et al., 2002). Bourque and Villard (2001) observed not only lower densities of Ovenbirds in selection cuts than in uncut plots, but also significantly lower reproductive performance of Ovenbirds. Bourque and Villard (2001) suggested that the effects of selection cutting (i.e., removal of approximately 30% of the basal area) on demography are species-specific and that Ovenbird persistence in selection cuts may be compromised unless the intensity (i.e., degree to which basal area is reduced) is decreased or frequency (i.e., time between harvest) of cutting is maximized. The decline of mature forest species in the partially harvested treatments indicates that maintaining an unharvested riparian buffer adjacent to an upland harvest may aid in maintaining abundance of "species of greatest conservation need" in northern Minnesota.

The response of the avian community within the MED RBA treatment differed little from the avian community within the riparian control plots, both of which indicated striking differences to the LOW RBA treatments. In an analysis of the vegetation response in these experimental treatments, Kastendick (2005) observed that regeneration layer biomass increased with increasing harvest intensity, resulting in clearcut uplands and LOW RBA treatment biomasses that were more than double those of MED RBA or riparian control treatments. He noted that there was a rapid response after harvest of early-seral, shade-intolerant species in both the shrub and woody regenerations layers in the RMZ. Multivariate analysis of our sites in the RDA, indicated the same response of a movement from greater influence of tree basal area to that dominated by woody biomass, of which the LOW RBA treatments appeared to indicate the greatest change. The connection of avian communities to the vegetation structure is well-established (DeGraaf et al., 1998; Sanders and Edge, 1998; Pey-Yi and Rotenberry, 2005) and is one of the unifying theories in avian biology (Block and Brennan, 1993). This analysis suggests that maintaining a basal area • 11.5 m2/ha may have retained enough overstory vegetation and minimized the increase in understory woody biomass to mitigate the significant changes in the avian community that were observed in the LOW RBA treatments, although the decrease in Ovenbird numbers was still evident.

Management implications

Overall, our analyses suggest that timber harvesting on both sides of the stream that leaves RBA • 12.4 ± 1.3 m2• ha-1 along reaches • 200 m in length or timber harvesting that retains RBA • 8.7 ± 1.6 m2• ha-1 on a single side of the stream may be adequate to protect instream habitat and invertebrate and fish communities. The large temporal variation observed in the instream habitat and invertebrate and fish communities were typical of these systems, but could have confounded treatments effects (Grossman et al., 1990). This difficulty may have been influenced by only having one year pre-harvest data for both sites. While studies that only include one year pre-harvest data in the published literature are common (e.g., Wang et al. 2006; Wilkerson et al., 2006, de Graaf et al. 2008), we attempted to overcome this limitation by examining across a larger spatial extent. The large number of plots included in our study and the relative consistency of our analysis suggest that the treatment effects were minimal. However, the relatively small size of our treatment plots and short lengths of stream reach harvested (although the sizes of harvest blocks are typical for the region) may have limited the impacts of harvest as compared to what has been observed in larger harvest treatments (Barton et al., 1985; Carroll et al., 2004). For example, Carroll et al. (2004) observed significant increases in stream water temperatures where timber harvesting occurred on both sides of the stream although there were no significant changes in stream temperature observed where harvesting occurred on a single side. Further studies that examine the effect of partially harvested RMZ on low-gradient stream systems should consider the effects of larger harvested plots and harvest along longer reaches and include multiple years of pre-harvest data to identify the natural temporal variation observed in the communities. Finally, although the invertebrate and fish communities appeared to return to pre-harvest conditions within three years post-harvest, a longer term assessment of the dynamics of partially harvested RMZs should be undertaken.

The changes in the avian community following timber harvesting within RMZs differed from the macroinvertebrate and fish communities. The choice of taxa is an important question in assessing the effects of timber harvesting in riparian communities (Lindenmayer, 1999; Lindenmayer et al., 2000), and can lead to differing and sometimes conflicting results accenting the different needs of the groups. For example, windthrow can recruit trees into the stream channel to provide a variety of ecosystem functions, such as high quality aquatic habitat for fish and macroinvertebrates (Hemstad et al., 2008). Alternatively, increased windthrow from management practices decreases the amount of habitat for bird species requiring mature forest stands. The difference in the response of the aquatic and terrestrial communities in this study highlights the need to assess multiple taxa communities when trying to understand the effects on organisms within riparian ecosystem communities.

Overall, breeding bird species management should occur at a landscape scale, attempting to provide a maximum level of forest stand types to provide habitat for breeding bird species across a broad geographic scale. At the stand-level, management decisions should not overlook the impacts of windthrow. However, simply leaving an unharvested buffer is not always the best solution. Thinning an RMZ adjacent to clearcut uplands may make trees in the RMZs more susceptible to windthrow (Ruel, 2000; Ruel, Pin & Cooper, 2001) and influence the structure of the mature forest stands and hence, mature forest bird species. The decision about how to design an RMZ to minimize windthrow should consider management objectives as well as stand and site conditions for the area. Items to consider include, but are not limited to 1) development of a site inventory to assess stand and site conditions for windthrow hazards; 2) minimization of potential hazards such as high topographic exposure, soil conditions that create weak or shallow rooting patterns, and prevailing wind direction; 3) providing a wider RMZ, reserve more windfirm species, and a gradual increase in residual basal area as you approach the water's edge (i.e., feather the cut edge) where windthrow hazards exist; and 4) reserving super-canopy trees that have become acclimated to wind. Susceptible species such as balsam fir, white spruce, black spruce, and aspen should be considered first for removal near the RMZ edge adjacent to the clearcut.

To truly understand the effect of forest timber harvest in the RMZ on these communities it is essential that continued monitoring of these experimental sites continues. Hanowski et al. (2007) indicated that breeding bird communities only began to resemble pre-harvest conditions 10 years following harvest. It is likely that such a time frame would be required in the multiple-basin experiment to observe these communal shifts.

Result expenditures

Funds in the amount of $866.78, $1.18, and $1,805.96 were shifted from Result 4 to get the Result 2a, Result 3 and Result 5 budgets, respectively, to a zero balance.

Unanticipated and unresolved problems

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

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Table 4.1. Fixed effects from mixed model analyses on invertebrate community metrics for the single- and multiple-basin experiments. Treatment effects within the riparian management zone (RMZ) were riparian control (unharvested RMZ) and medium residual basal area (RBA) for the single-basin experiment and riparian control and low and medium RBA for the multiple-basin experiment. Abundance, total invertebrate abundance; Diversity (H'), Shannon diversity index; Richness (r), total species richness; Percent EPT, percent Ephemeroptera, Plecoptera and Trichoptera (EPT) richness. Abundance, total fish abundance adjusted for effort and distance (50 m^2). All proportions were arcsine square-root transformed and abundance was log(x+1) transformed.

Effect	Parameter	Value	Std.Error	DF	t-value	p-value
	Single-basin experiment (1997 - 2000)					
Abundance	Intercept	4.176	0.458	30	9.116	< 0.001
	TRT-MED	0.672	0.444	30	1.516	0.140
	YearSince	0.464	0.187	30	2.483	0.019
Diversity (H')	Intercept	1.868	0.117	30	16.006	< 0.001
	TRT-MED	0.010	0.113	30	0.086	0.932
	YearSince	-0.147	0.048	30	-3.079	0.004
Richness (r)	Intercept	15.688	1.640	30	9.564	< 0.001
	TRT-MED	1.158	1.464	30	0.791	0.435
	YearSince	-1.089	0.572	30	-1.903	0.067
Percent EPT	Intercept	0.969	0.033	30	29.172	< 0.001
	TRT-MED	-0.031	0.032	30	-0.978	0.336
	YearSince	0.000	0.014	30	-0.019	0.985
	Multiple basin experiment (2003- 2006)					
Abundance	Intercept	5.793	0.075	36	77.129	< 0.001
	TRT-MED	0.147	0.100	5	1.466	0.203
	TRT-LOW	0.052	0.095	5	0.553	0.604
	YearSince	-0.003	0.033	36	-0.107	0.916
Diversity (H')	Intercept	1.423	0.123	36	11.577	< 0.001
	TRT-MED	-0.004	0.139	5	-0.029	0.978
	TRT-LOW	-0.105	0.132	5	-0.794	0.463
	YearSince	0.182	0.046	36	3.910	0.000
Richness (r)	Intercept	16.313	2.011	36	8.111	< 0.001
	TRT-MED	0.460	1.303	5	0.353	0.738
	TRT-LOW	-2.131	1.233	5	-1.728	0.145
	YearSince	1.574	0.413	36	3.810	0.001
Percent EPT	Intercept	0.795	0.020	36	39.745	< 0.001
	TRT-MED	-0.043	0.024	5	-1.798	0.132
	TRT-LOW	0.000	0.022	5	-0.015	0.988
	YearSince	0.020	0.008	36	2.550	0.015

Table 4.2. Fixed effects from mixed model analyses on fish community metrics for the single- and multiple-basin experiments in northern Minnesota following timber harvest. Treatment effects within the riparian management zone (RMZ) were riparian control (unharvested RMZ) and medium residual basal area (RBA) for the single-basin experiment and riparian control and low and medium RBA for the multiple-basin experiment. Abundance, total fish abundance adjusted for effort and distance (50 m); Diversity (H'), Shannon diversity index; and Richness (r), total species richness. Proportions were arcsine square-root transformed and abundance was log(x+1) transformed.

Effect	Parameter	Value	Std.Error	DF	t-value	p-value
		Single-basin experiment (1997 - 2000)				
Abundance	Intercept	-0.140	0.322	40	-0.434	0.666
	TRT-MED	-0.263	0.341	40	-0.771	0.445
	YearSince	-0.153	0.040	40	-3.855	< 0.001
Diversity (H')	Intercept	0.647	0.195	40	3.315	0.002
	TRT-MED	-0.053	0.138	40	-0.388	0.700
	YearSince	-0.018	0.015	40	-1.152	0.256
Richness (r)	Intercept	2.877	0.537	40	5.353	< 0.001
	TRT-MED	-0.168	0.370	40	-0.454	0.653
	YearSince	-0.082	0.041	40	-1.991	0.053
		Multiple-basin experiment (2003- 2006)				
Abundance	Intercept	-0.278	0.242	35	-1.149	0.258
	TRT-MED	0.034	0.304	5	0.112	0.915
	TRT-LOW	-0.112	0.289	5	-0.388	0.714
	YearSince	0.301	0.108	35	2.773	0.009
Diversity (H')	Intercept	1.036	0.167	35	6.219	< 0.001
	TRT-MED	-0.308	0.140	5	-2.203	0.079
	TRT-LOW	-0.205	0.135	5	-1.520	0.189
	YearSince	0.112	0.045	35	2.468	0.019
Richness (r)	Intercept	5.095	0.840	35	6.067	< 0.001
	TRT-MED	-0.913	0.648	5	-1.410	0.218
	TRT-LOW	-0.777	0.625	5	-1.243	0.269
	YearSince	0.463	0.208	35	2.224	0.033

Table 4.3. Results of the repeated measures ANOVA. "H" =Shannon diversity index); Richness= total species richness; Abundance= log transformed abundance; %Mature= proportional abundance of species within the mature forest habitat guild; and %Early= proportional abundance of species within the early successional habitat. F-value (*P*-value). NDF are the numerator degrees of freedom and DDF are the denominator degrees of freedom. Values in **bold** indicate a significant (*P* < 0.05) effect.

Effect	NDF	DDF	H	Richness	Abundance	% Mature	%Early
Treatment	2	11	0.74 (0.501)	0.51 (0.612)	0.64 (0.547)	**5.55 (0.022)**	3.11 (0.085)
Year	3	33	0.82 (0.494)	0.62 (0.605)	1.75 (0.176)	**11.19 (<0.001)**	**7.19 (<0.001)**
Treatment x year	6	33	1.08 (0.394)	0.64 (0.699)	1.27 (0.297)	1.47 (0.220)	0.28 (0.743)

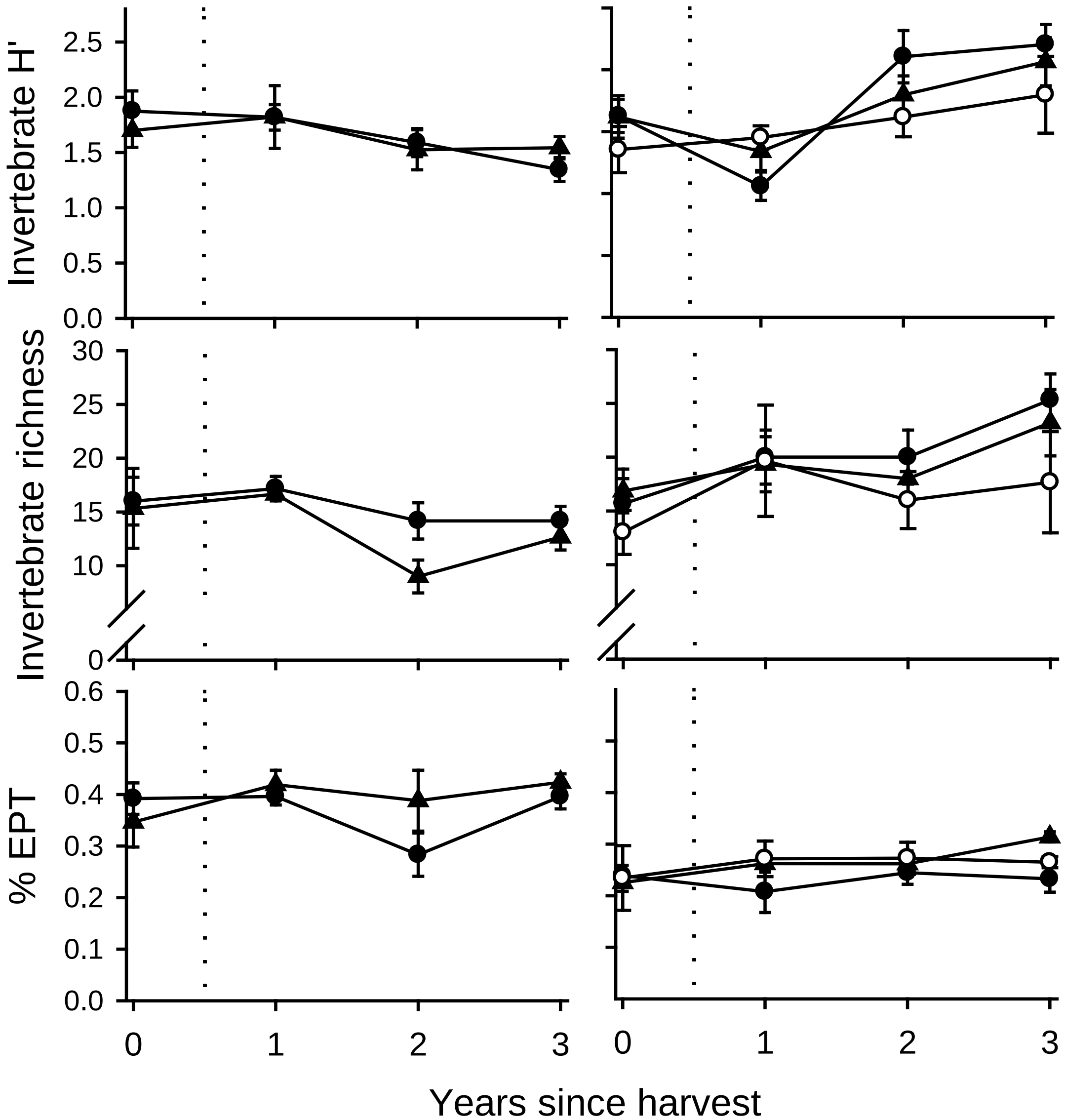

Figure 4.1. Mean (± standard error) invertebrate metrics (diversity, richness, and % EPT) in the single- (left column) and multiple-basin (right column) experiments following harvest in the riparian management zones. Triangles, riparian control; closed circle, medium residual basal area (RBA) treatment; and open circle, low RBA treatment.

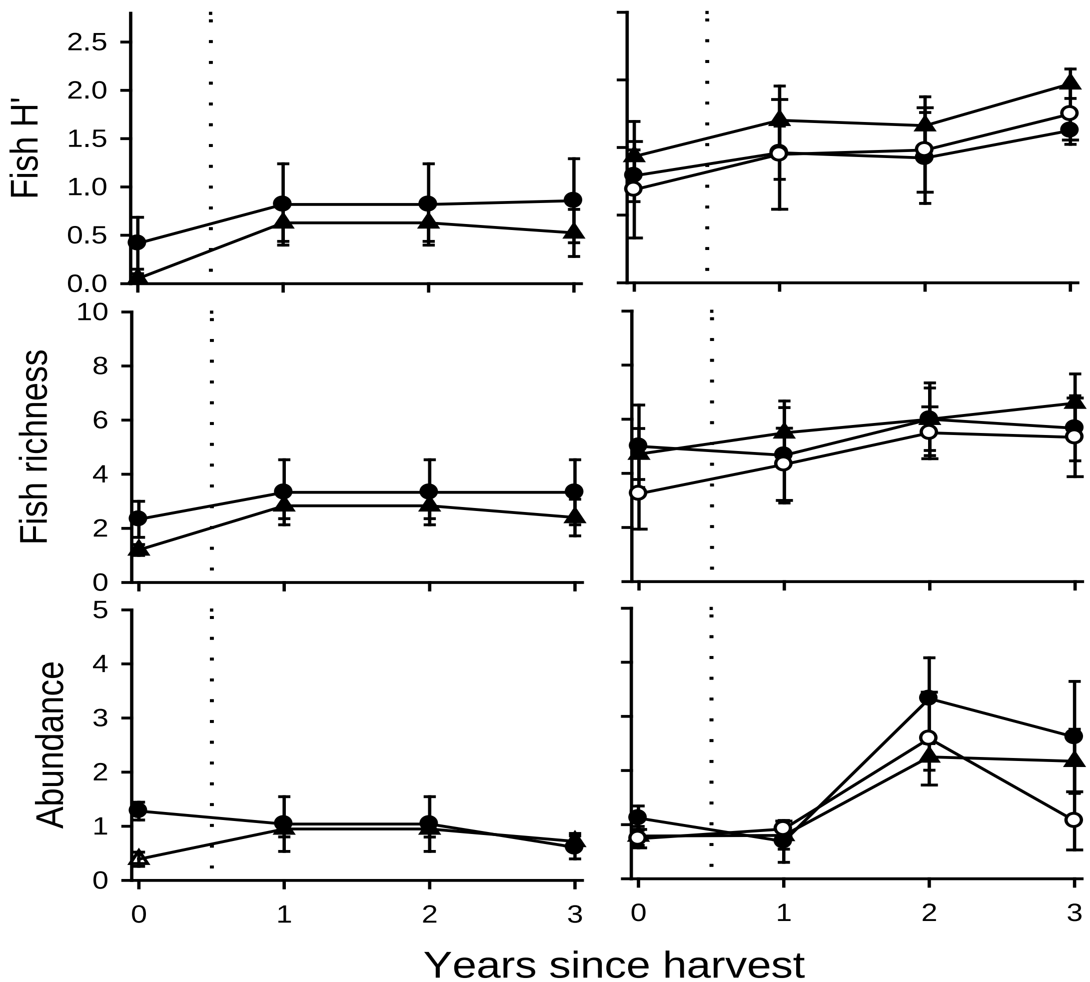

Figure 4.2. Mean (± standard error) fish metrics (diversity, richness, and catch per 50 m in the single- (left column) and multiple-basin (right column) experiments after harvest in the riparian management zones. Triangles, riparian control; closed circle, medium residual basal area (RBA) treatment; and open circle, low RBA treatment.

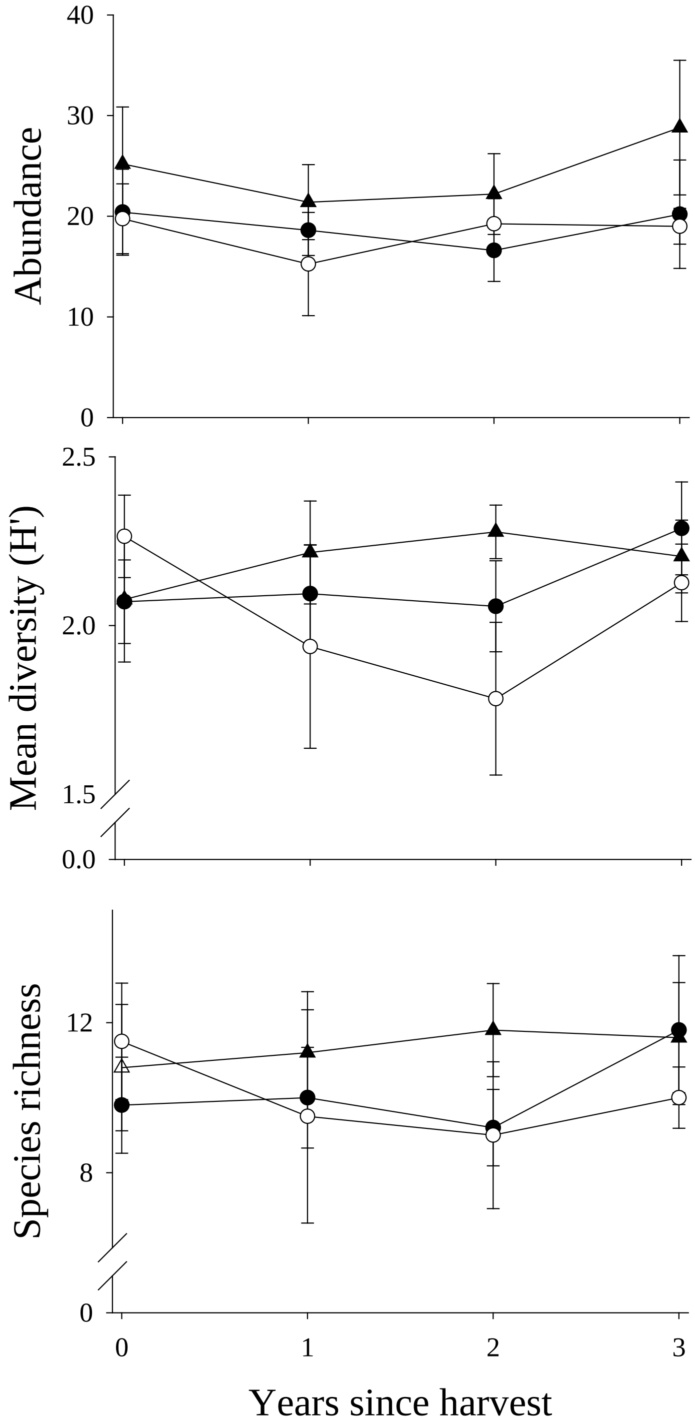

Figure 4.3. Mean (± standard error) abundance, Shannon diversity index (H'), and species richness for birds in experimental plots in northern Minnesota. The riparian control = triangles, medium residual basal area (RBA) treatment = closed circles, and low RBA treatment = open circles.

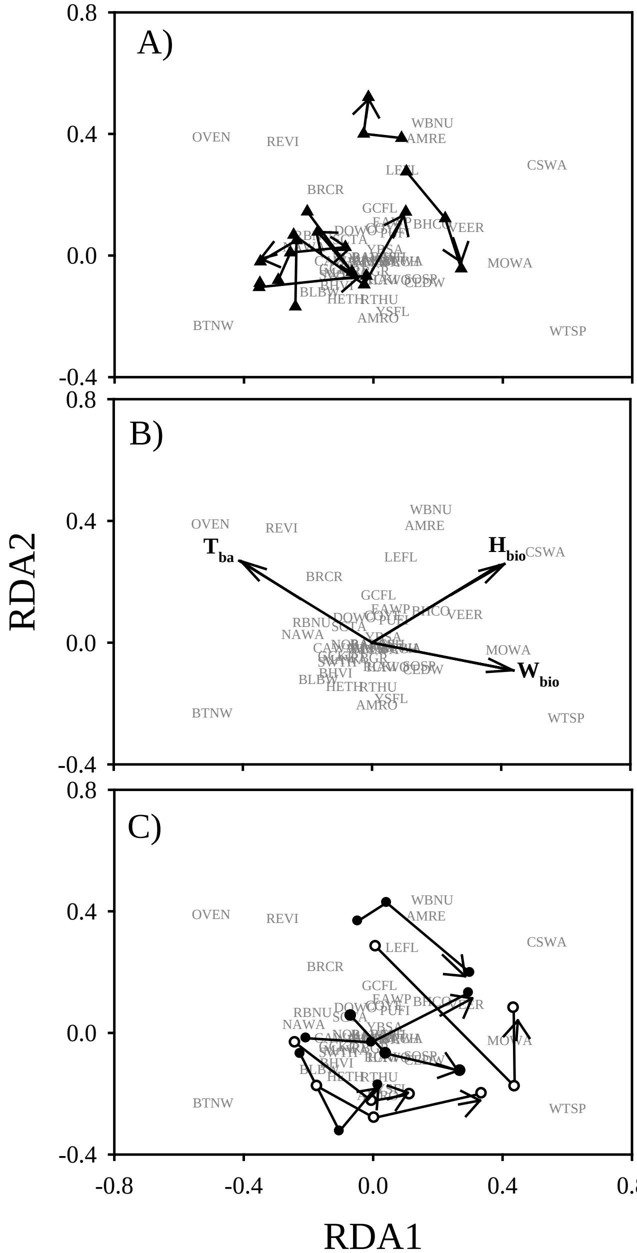

Figure 4.4. Ordination plot of the redundancy analysis (RDA) showing the first and second axis. Lines connect the sequential plots through time and arrows indicate the direction of change. Four letter avian abbreviations can be found in Appendix A. A) Riparian control sites in years 2003 (pre-harvest), 2004, and 2006 (3 years post-harvest). B) Significant vegetation factors: Hbio = log transformed herbaceous biomass, Wbio = log transformed woody biomass and Tba = log transformed tree basal area. C) Medium basal area treatment (closed circle) and low basal area treatment (open circle) in years 2003, 2004, and 2006.

Result 5: Outreach riparian research information

Description: We conducted three one-day workshops for natural resource professionals to present information from our research as well key findings from the Minnesota Forest Resource Council's Riparian Science Technical Committee process. Each workshop included indoor and on-site components. A website was developed. Data and photographs were processed to facilitate communication and additional analyses in the future.

Summary Budget Information for Result 5: **Trust Fund Budget: $9,911.96**
Amount Spent: $9,911.96
Balance: $ 0.00

Deliverable	Completion date	Budget	Status
1. Develop and promote workshop agenda	6/30/08	$5,000	Completed
2. Conduct two workshops and create project website	10/31/08	$2,106	Completed
3. Process data and photographs. Prepare and submit final report	6/30/09	$2,805.96	Completed

Completion Date: June 2009

Final Report Summary:

Introduction

A variety of data has been collected and analyzed from the two study areas (single- and multiple-basin study sites) since their inception. In addition, the Minnesota Forest Resource Council's Riparian Science Technical Committee synthesized relevant literature to provide unbiased scientific information about riparian areas and timber management practices necessary to protect riparian functions on the site level. Field managers need updated information about management within forested riparian management zones to provide appropriate protection during management activities.

Results

A one-day workshop entitled "At the Water's Edge: Current State of Riparian Forest Management Research in Minnesota" was presented in Grand Rapids on May 20, 21, and 22, 2008. The purpose of the workshop was to interpret research results from the single- and multiple-basin riparian effectiveness monitoring studies as well as the Minnesota Forest Resource Council's Riparian Science Technical Committee findings for natural resource managers and loggers. The program included both indoor and outdoor components. There were 102 participants over the course of the three days. Overall, participants indicated that they learned a bit more than they expected to learn. Both the indoor and outdoor components received positive reviews.

A website was developed to provide information about the project, including a project overview, more detailed descriptions of our research, information about project personnel, a listing of project cooperators, project publications, and information presented during our workshop. The url for that website is http://rmzharvest.cfans.umn.edu/. A second website was created to allow project researchers to access data (http://rmzharvest.cfans.umn.edu/login).

To facilitate better communication with outside individuals and researchers within the project, all available data was entered electronically, data codes and spreadsheet formatting were made consistent across all the data files from all the disciplines, and thoroughly error checked. In addition, meta-data were created for all the data files that described who collected the data and explained all codes used in the data file. Finally, all photographs from the sites were catalogued to describe the subject of the photo, who, when and where the photo was taken. Each image was edited to allow easier upload to the website. These files and photos were added to the website to enhance its utility for project researchers and to allow for easier dissemination of the information.

Result expenditures

Funds in the amount of $1,805.96 were shifted from Result 4 to get the Result 5 budget to a zero balance.

Unanticipated and unresolved problems

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

V. TOTAL TRUST FUND PROJECT BUDGET

Staff or Contract Services: $336,772 One post-doctoral research associate (1 FTE for 1 year), graduate students (0.5 FTE for 16 months), four undergraduate research assistants (6 weeks during 2 summers for three individuals and 12 weeks during one Spring Semester for one individual) were employed by the University of Minnesota. Two technicians (1 FTE for 1 year and 1 FTE for 2 years) and two undergraduate research assistants (0.4 FTE for 1 year) were employed by the US Forest Service because that is the most cost-effective approach and our need to have personnel dedicated to this research study who are located close to the field sites. Three technicians (1.5 FTE for 1 year) were employed through the US Forest Service to assist with sample processing.

Equipment: $26,659 Digital clinometer ($1,000), miscellaneous expendable supplies (including flagging, paint, binoculars, tree tags, field notebooks and paper, pens, ethanol, sampling bottles, sampling nets, GPS receiver, chemicals for water quality assessment, replacement temperature loggers, and batteries – $25,059), computer software for data analysis ($600).

Development: $0

Restoration: $0

Acquisition, including easements: $0

Other: $36,569 Lodging/per diem/mileage ($13,104), vehicle rental with mileage ($21,500), bus rental for workshops ($365), publication page charges ($1,600).

TOTAL TRUST FUND PROJECT BUDGET: $400,000

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

V. 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 Gerald Niemi (received $5,570 from the request); Ray Newman and Bruce Vondracek (USGS) (received $40,965 from the request); and Charlie Blinn (received $80,938 from the request). Randy Kolka and Susan Eggert (received $134,231 from the request through a subcontract with University of Minnesota) and Brian Palik (received $138,296 from the request through a subcontract with University of Minnesota) from the US Forest Service contributed $144,000 worth of time, effort, and equipment to the project. The Minnesota Department of Natural Resources, St. Louis County Land Department, Lake County Land Department, and Blandin UPM-Kymmene cooperated by providing their lands for study treatments. Dr. Casey Huckins, Department of Biological Sciences, Michigan Technological University, Houghton, MI and Dr. Jacques Finlay, Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul, MN assisted with Result 2b.

B. Other Funds being Spent during the Project Period

Project partners solicited additional funds from outside sources during the biennium. The US Forest Service and Minnesota Forest Resources Council each committed $10,000 to Result 3. In-kind support of $144,000 was provided from the US Forest Service. Workshop income ($2,100) was used to defray expenses for catering and photocopying.

C. Past Spending

The LCMR provided $333,000 during the 2005 biennium to collect 2- and 3-year post-harvest data from the multiple-basin watersheds. The US Forest Service provided $75,000 worth of time and effort to the project and $80,400 to partially fund graduate research assistants. The National Council for Air and Stream Improvement provided $60,000 and the Minnesota Department of Natural Resources Section of Fisheries provided $18,000 in support of data collection and analysis at Pokegama Creek (single-basin location).

D. Time
It is anticipated that the entire project will be completed in 2013. The post-harvest assessment would continue through 2011 with increasing focus on longer-term data collection, analysis, reporting, and dissemination of study results. Additional funds would be requested from LCCMR 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.

VII. **DISSEMINATION:**

Presentations
Blinn, C. R. May 20, 21 and 22, 2008. What is a riparian area and why are they important? At the water's edge: Current state of riparian forest management research in Minnesota. Conference for general public. Grand Rapids, MN.

Chizinski, C. J., D. Atuke, N. Hemstad, E. Merten, B. Vondracek, R.M.Newman, and C. Blinn. August 7, 2008. Effects of riparian forest harvesting on the aquatic ecosystem in northern Minnesota streams. Milwaukee, WI. 93rd Annual Meeting of the Ecological Society of America.

Chizinski, C. J., A. C. Peterson, and C. R, Blinn. December 17, 2008. The influence of riparian buffers on bird, aquatic invertebrate, and fish assemblages. 69th Midwest Fish and Wildlife Conference, Columbus, Ohio.

Eggert, S .L. 2007. Stream ecosystem response to a changing environment. Natural Resources Research Institute, University of Minnesota, Duluth, MN.

Eggert, S. L. 2008. The stream and its valley: Small streams as integrators of the landscape. Michigan Technological University, Houghton, MI.

Eggert, S. L., B. Palik, D. Kastendick, J. Kragthorpe, R.K. Kolka, and J.N. Baldauf. 2009. Organic matter inputs to northern Minnesota headwater streams following riparian timber harvesting. North American Benthological Society Meeting, Grand Rapids, MI.

Kolka, R. May 20, 21 and 22, 2008. Overview of effectiveness monitoring studies. At the water's edge: Current state of riparian forest management research in Minnesota. Grand Rapids, MN.

Merten, E. C. N. A. Hemstad, R. M. Newman, B. Vondracek, L. B. Johnson, R. K. Kolka, E. S. Verry, and S. L. Eggert. August 7, 2008. Forest harvest effects on a northern Minnesota stream system: A study spanning 11 years. Annual Meeting of the Ecological Society of America, Milwaukee, WI.

Palik, B. J. May 20, 21 and 22, 2008. Evaluating riparian timber harvesting guidelines: Terrestrial vegetation responses. At the water's edge: Current state of riparian forest management research in Minnesota. Conference for general public. Grand Rapids, MN.

Peterson, A. May 20, 21 and 22, 2008. Evaluating riparian timber harvesting guidelines: Wildlife responses. At the water's edge: Current state of riparian forest management research in Minnesota. Conference for general public. Grand Rapids, MN.

Peterson, A. C., C .J. Chizinski, and G. J. Niemi. August 4-9, 2008. Breeding bird community response to harvest in riparian buffers in northern Minnesota, USA. 126th Meeting of the American Ornithologists' Union. Portland, OR.

Vondracek, B. May 20, 21 and 22, 2008. Evaluating riparian timber harvesting guidelines: Aquatic responses. At the water's edge: Current state of riparian forest management research in Minnesota. Conference for general public. Grand Rapids, MN.

Vondracek, B. and S. Eggert. May 20, 21 and 22, 2008. Aquatic system response to harvesting in northern Minnesota riparian management zones. At the water's edge: current state of riparian forest management research in Minnesota. Grand Rapids, MN.

Vondracek, B. and S. Eggert. 2007. Northeast Forest Soils Conference. Presentation at the East Beaver River site near Silver Bay, MN.

Publications

Olszewski, S. L. 2009. 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. 41 p.

Steil, J. C., C. R. Blinn, and R. K. Kolka. 2009. Foresters' perceptions of windthrow dynamics in northern Minnesota riparian management zones. Northern Journal of Applied Forestry. 26(2):76-82.

Manuscripts submitted

Chizinski, C.J., B. Vondracek, C.R. Blinn, R.M. Newman, D. Atuke, K. Fredricks, N. Hemstad, E. Merten, and N. Schlesser. (Submitted 6/25/09). The influence of partial harvest in riparian management zones on macroinvertebrate and fish assemblages on small streams. Forest Ecology and Management

Chizinski, C.J., A. Peterson, C.R. Blinn, G. Niemi, B. Vondracek.(Submitted 6/25/09) Breeding bird response to partially harvested riparian management zones in northern Minnesota. Forest Ecology and Management.

Manuscripts in preparation

Chizinski, C.J., B. Vondracek, C.R. Blinn, Palik, B.J., Ozslewski, S.L., Kastendick, D.N., and Martin, M. Woody regeneration on clearcut and partial-cut riparian management zones. Proposed outlet: Forest Ecology and Management.

Eggert, S. and R. Kolka, B. Vondracek, E. Merten, L. Johnson, R. Newman, K. Fredrick, M. Fox and J. Perry. Long-term effects of riparian timber harvesting on stream function in northern Minnesota. Proposed outlet: Fundamental and Applied Limnology.

Eggert, S, B. Palik, D. Kastendick, J. Kragthorpe, R. Kolka. Organic matter inputs to northern Minnesota aquatic ecosystems following riparian timber harvesting. Proposed outlet: Canadian Journal of Forest Research.

Project website

Information about the research project (project overview, current research, project personnel, cooperators, publications) and the 2008 workshop are available at: http://rmzharvest.cfans.umn.edu/

Other products

A reference collection of voucher invertebrate specimens has been assembled for the single- and multiple-basin sites. The collection is being maintained by the USDA Forest Service, Northern Research Station, Aquatics Laboratory, Grand Rapids, MN.

Available data have been made available to project personnel through the internal project website (http://rmzharvest.cfans.umn.edu/login).

VI. REPORTING REQUIREMENTS: Periodic workprogram progress reports were submitted in January 2008, July 2008, and January 2009. A final workprogram report and associated products was submitted by August 17, 2009 as requested by the LCCMR.

VII. RESEARCH PROJECTS: N/A

Attachment A: Budget Detail for 2007 Projects

Project Title: *Evaluating Riparian Timber Harvesting Guidelines: Phase 3 5(f)*

Project Manager Name: *Charles R. Blinn*

Trust Fund Appropriation: $ *400,000*

2007 Trust Fund Budget	**Result 1 Budget:**	**Amount Spent** *(date)*	**Balance** *(6/09)*	**Result 2a Budget:**	**Amount Spent** *(date)*	**Balance** *(6/09)*	**Result 2b Budget:**	**Amount Spent** *(date)*	**Balance** *(6/09)*	**Result 3 Budget:**	**Amount Spent** *(date)*	**Balance** *(6/09)*	**Result 4 Budget:**	**Amount Spent** *(date)*	**Balance** (6/09)	**Result 5 Budget:**	**Amount Spent** *(date)*	**Balance** *(6/09)*	**TOTAL BUDGET**	**TOTAL BALANCE**
	Evaluate terrestrial impacts			Evaluate long-term effects on fish habitats and communities			Evaluate macroinvertebrates and organic matter dynamics			Evaluate bird impacts			Meta-analysis of terrestrial and aquatic results			Outreach riparian research information				
BUDGET ITEM																				
PERSONNEL: Staff Expenses, wages, salaries and fringe – *Personnel employed through University of Minnesota to collect, process, and report data*	0	0	0	39,372.93	39,372.93	0	0	0	0	5,558.21	5,558.21	0.00	67,641.44	67,641.44	0.00	8,104.91	8,104.91	0	120,677.49	0.00
Contracts																				
Professional/technical *(University of Minnesota subcontract with US Forest Service to collect, process, and report data) (7901)*	138,296	134,971.93	3,324.07	0	0	0	134,231	131,952.67	2,278.33	0	0	0	0	0	0			0	272,527	5,602.40
Printing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other supplies *(list specific categories)*																				
Lab/field supplies (7320)	0	0	0	514.25	514.25	0	0	0	0	11.97	11.97	0	0	0	0	0	0	0	526.22	0
Computer software (7330)	0	0	0	0	0	0	0	0	0	0	0	0	600	545	55	0	0	0	600	55
Courier and mailing services (7340)*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Travel expenses in Minnesota	0	0	0	1,077.60	1,077.60	0	0	0	0	0	0	0	2,784.64	1,937.00	847.64	1,442.25	1,442.25	0	5,304.49	847.64
Other *(Describe the activity and cost) be specific*																				
Sponsored publication costs (7311)**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Postage (7341)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Short-term lease (7702)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	364.80	364.80	0	364.80	0
COLUMN TOTAL	$138,296	$134,971.93	$3,324.07	$40,964.78	$40,964.78	$0.00	$134,231	$131,952.67	$2,278.33	$5,570.18	$5,570.18	$0.00	$71,026.08	$70,123.44	$902.64	$9,911.96	$9,911.96	$0.00	$400,000	$6,505.04

*Mailing reports, manuscripts, communications

**Page charges for 2 papers x 10 pages x $100/page