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Report Title: Effect of riparian zone management on brook trout (Salvelinus fontinalis) The Hayward and Holmes Brook watershed study Final rapport for the period from 1994 to 1996

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Effect of riparian zone management on brook trout (Salvelinus fontinalis)

The Hayward and Holmes Brook watershed study

Final rapport for the period from 1994 to 1996

Submitted to the Fundy Model Forest

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by

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Introduction

In the case of aquatic studies the effects of forestry practices have tended to focused on hydrology, water chemistry, substrate, invertebrates and fish (Cunjak et al. 1993, Hartman and Scrivener 1990, MacDonald et al. 1992,). The evolution of Model Forests within Canada have placed such studies within a broader context by including biodiversity, recreational and landscape values. Insuring that biodiversity is maintained is a challenging problem. The approach has been to select key species whose requirements also meet the needs of a broader range of species. Fish hold a unique position in this respect, as their presence constitutes an important part of the biodiversity of stream and rivers. In New Brunswick, trout and salmon are also at the basis of an important recreational fishery. Forestry operations frequently occur in watersheds and create the potential to affect fish habitat. To effectively determine the effects of forestry practices on fish requires species that readily respond to change.

Coldwater salmonids such as brook trout (Salvelinus fontinalis) and Atlantic salmon (Salmo salar) have well defined habitat requirements, and are recognized as indicators of biodiversity. Decreases in the abundance of brook trout and salmon have been linked to environment damage. Adult salmon and trout require clean gravel of the appropriate size for spawning and adequate cover. Eggs and newly hatched fish require stable gravel and cool well oxygenated water, whereas juveniles require food and cover (Murphy and Meehan 1991). The band of vegetation that borders a river or stream (riparian zone) plays an important role in regulating and maintaining conditions essential for the survival of brook trout and salmon (Mullen and Moring 1988, Osborne and Kovacic 1993, Platt and Nelson 1989). Although, the importance of riparian zones to the aquatic environment is well recognized, the precise width or widths required to maintain viable populations of fish and terrestrial species are not known.

This study examines the effects of riparian zone widths on fish and their habitat in the Hayward and Holmes Brook watersheds, part of an experimental research site located in the Fundy Model Forest, New Brunswick, Canada. Fish abundance has been determined in all years of the study by electrofishing and live trapping. These brooks contain primarily brook trout. Since water quality monitoring is being conducted by Environment Canada, this study examines the remaining elements of critical importance to salmonids, specifically: 1) stream channel characteristics-width, depth, and length of pools runs and riffles, 2) composition of substrates in pools and 3) presence of large woody debris. Baseline data were collected in 1994 and 1995. The year 1996, marks the first year following harvest. Results of the study will be incorporated into the Fundy Model Forest Management Plan. In addition, the project is contributing to our understanding of the population dynamics of brook trout and the importance of small streams as refugia. The following sections provide an overview of the study since 1994, present preliminary findings and suggest avenues for further research.

Methods

Site description

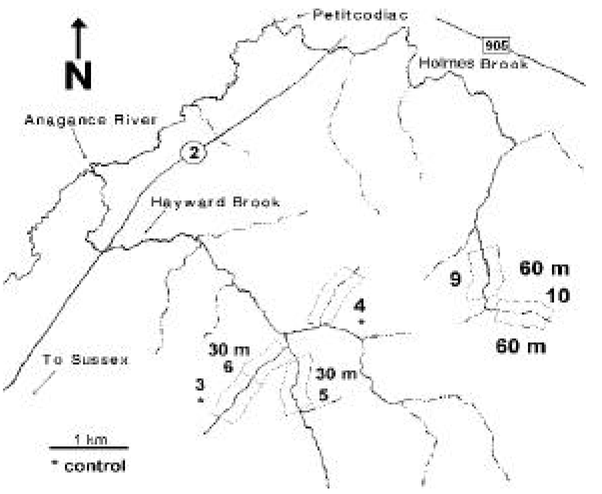

Figure 1. Map of study site, New Brunswick, Canada

The study area is located in the upper part of the Holmes and Hayward Brook watersheds located near Petitcodiac village in southeast New Brunswick, Canada (45°22'N, 65°09'W, Figure 1). The forest in this area consists primarily of second growth mixed species (80 yr). Sites were identified and flagged in 1993, one year prior to the fish studies, as part of an investigation to determine the effects of riparian zone width on birds communities. To provide uniformity, the nomenclature used to identify the terrestrial sites was maintained for the fish study. On Hayward Brook, sites 5 and 6 were assigned 30 m buffers and sites 3 and 4 the controls were subject to no treatment. On Holmes Brook, sites 9 and 10 were assigned 60 m buffers. Buffers extend equally on both sides of the watercourse. Each site was between 650 to 1000 m in length.

Roads were established in the autumn of 1994. Timber harvesting began in the summer of 1995 and continued into the winter of 1995/1996. There is therefore some question as to whether the summer of 1996 truly represents the full effects of harvesting on both the fish and their habitat.

Physical habitat

Since brook trout demonstrate habitat preference for pools (Chiasson 1990), the frequency of pools runs and riffles were recorded for each tributary in 1994. This was done by counting the number of each habitat type within each study site until a minimal count of 20 was obtained for any habitat type.

Substrate

Substrate composition was evaluated by placing a 1 m^2 frame subdivided into 625 cm^2 grids over the first ten pools in each study site (Figure 2). Substrate type in each square was recorded using a color code and categorized as follows: cobble > 5 cm, coarse cobble < 5 cm > 2 cm, gravel < 2 cm, sand, vegetation and small fragmented woody debris.

Large woody debris

Large woody debris was assessed in each year by sketching the first 50 m in the lower, middle and upper reaches of sites 5 (30 m buffer) and site 3 (control). Resources were not available to do the 60 m buffer sites, the 30 m replicate and control site 4. Angle and length were recorded for pieces larger than 0.5 m as well as their position in the stream. Logs were divided into three categories: pieces between 0-30°, 31-60° and 61-90° from the bank of the stream. Pieces lying within 61-90° are most likely to contribute to the formation of pools, a critical habitat feature for brook trout.

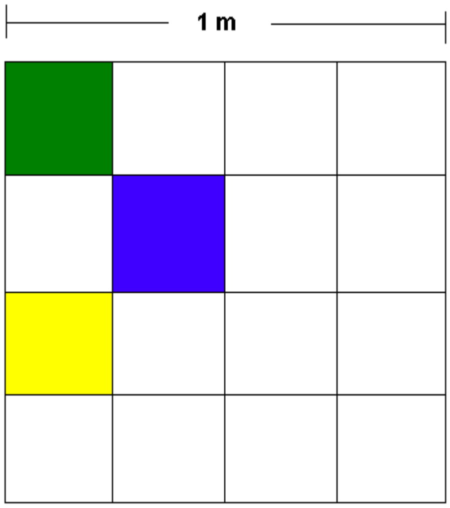

Figure 2. Grid design used to measure substrate composition in the first 10 pools of each study site.

Indices of fish abundance

Trapping

The abundance and distribution of fish were assessed using minnow traps (G-traps) and electrofishing (Smith Root Model 12B electrofisher). Tributaries were divided into a downstream (100 m), middle (100 m) and upstream (100 m) section.

A total of six minnow traps were distributed within each 100 m section, with two traps in each of the following habitat types: pools, runs and riffles (Figure 3). The length, depth and width of the pools runs and riffles were recorded at each trap location and the end of the summer sampling schedule. Sites were identified and flagged with colored tape. Sites were sampled twice during the summer (June-August) and once during the fall (October). Traps were set for two consecutive 24-hour periods and verified early each morning. Fish were identified as to species, counted, measured and released.

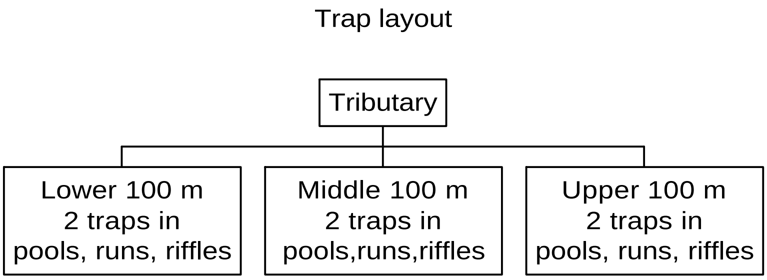

Figure 3. Layout of minnow traps.

In 1994, all the fish from traps set in late July and early August were marked with a Panjet dye-innoculator and adipose fin clipped. This Panjet dye-innoculator leaves a tattoo in the area of injection. Using this method fish were identified as to tributary and as to location in the lower, upper, or middle sections of each study site. This method permits detection of movement of fish both within and among sites for each watershed. In all years of the study the adipose fin was clipped. In 1995, fish were simply fin clipped. In 1996, all fish were uniquely marked with external Floy fingerling tags. Fish were anesthetized with CO_2 prior to tagging. To check for survival and loss of tags 9 fish were held for 24 hr after tagging. No loss of tags or mortality were noted.

Electrofishing

Surveys were conducted in 1994 at all sites except 10, which was difficult to access with heavy equipment. Site 10 was electrofished in 1995 and 1996, subsequent to road construction in the area. At each site a 50 m section of stream was selected outside the areas fished with traps. Barrier nets were erected at both upstream and downstream ends and a minimum of 3 sweeps were made. Fish were identified, measured, adipose fin-clipped and released. Number of fish captured was too low to permit population estimates. Electrofishing results therefore report the total number of fish caught per 100 m^2

Results

Physical habitat

The number of pools runs and riffles recorded in 1994 are reported in Table 1. Sites 9 and 10 which are located on Holmes Brook had the greater number of pools. In particular site 10 which was in the upper part of the watershed contained a high diversity of each habitat type. Site 4, also has habitat diversity but due to its small size, the upper reaches ran dry in late summer of 1995 and 1996.

Table 1. Numbers of pools, runs and riffles in each study site. Values in parentheses indicate the average distance covered before finding an occurrence of the habitat type in each column.

Site	**Distance**		**Number of**	
	(m)	pools	runs	riffles
3	350	34(10)	29(12)	20(18)
4	200	20(10)	23(9)	29(7)
5	300	20(15)	25(12)	26(12)
6	250	21(12)	26(10)	29(9)
9	250	28(9)	26(10)	20(13)
10	200	40(5)	22(9)	20(7)

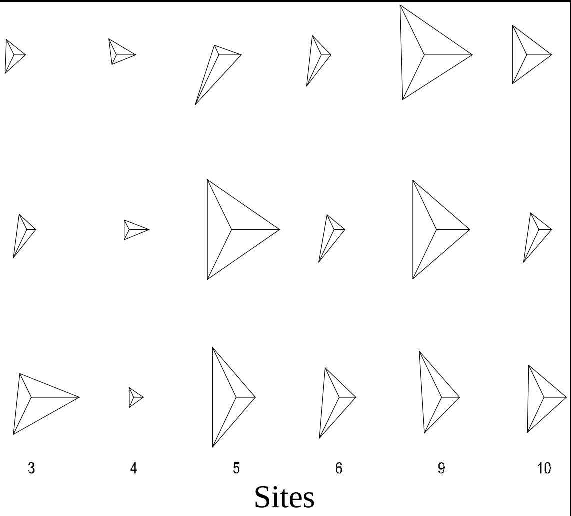

Figure 4. Star graphs of pools, runs and riffles in 1994.

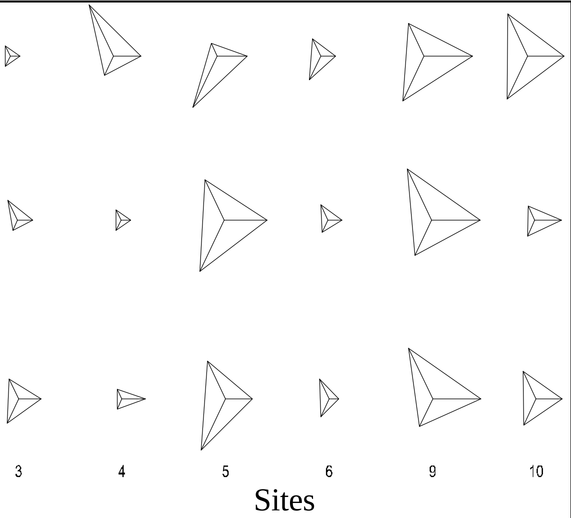

Figure 5. Star graphs of pools, runs and riffles in 1995.

The length, width and depth of pools are presented in the star graphs in Figure 4 to 6. The first variable, length is in the 3 o'clock position with the remaining variables of width and depths distributed in a counter clockwise fashion.

Results indicate a similar profile for sites 5 and nine which encompass greater volumes of habitat than any of the other sites in any year. Site 3, 4 and 6 have the smaller habitat volumes. Site 4 can be explained by its very small size, as previously noted it ran dry in late summer in 1995 and 1996. Site 3 is located in the most extreme upper section of the watershed followed by site 6 located on the same tributary immediately downstream. It is characterized by its small size but also has stable flow due to a large number of springs in the area. Profiles are similar in all years of the study. There is no evidence to conclude that volume of habitat available in 1996 was any different than in any of the previous years.

Substrate

Results obtained in 1994, demonstrate a different distribution of substrate types in comparison with the remaining two years. In 1994, substrate types other than sand were well represented at most of the other locations. In 1995 and 1996 sand became the most dominant substrate type at all locations, with reductions of other components. Road construction commenced in 1994. Analysis of turbidity and current velocity from Environment Canada may shed some light on the apparent increase in sand. Lower stream flows due to dry conditions in 1995 and 1996 may also explain a greater deposit of sand. The sand component recorded in all years was free from fine silts and mud that might make it unsuitable for spawning. All study sites have a certain amount of ground flow from springs which in many areas percolate through the sand. Although not confirmed by visual observations, sand may be a suitable area for spawning brook trout if supplied by a rich source of oxygen laden ground water.

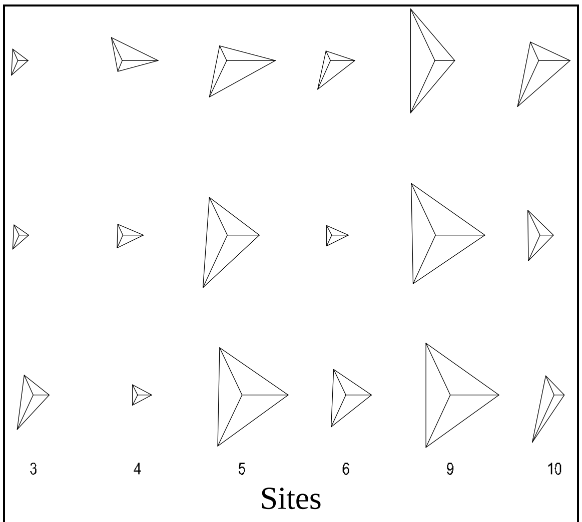

Figure 5. Star graphs of pools, runs and riffles in 1996.

Large woody debris

Woody debris, consisting of logs and large branches that have fallen into the river or stream. In the past, it was unknowing removed from many rivers and streams under the mistaken assumption that fish passage was being improved. Recent studies have identified the importance of woody debris in creating pools and in modulating water flow.

Results were consistent in all years and across sites, with the majority of pieces lying between 61 and 90°. One possible explanation for the dominance of the 61 to 90^{o} category may lie in the increased probability that it will wedge in the stream, whereas pieces lying parallel to the watercourse may tend be swept downstream. There is no suggestion that the pattern of woody debris has changed in 1996 compared to the previous two years.

Fish

Traps

Only three species have been captured since 1994, brook trout (Salvelinus fontinalis), slimy sculpin (Cottus cognatus), american eel (Anguilla rostrata) and threespine stickleback (Gasterosteus aculeatus). However, brook trout dominated all sites with less than 4 individuals of any other species being captured in any one year. Although a number of recaptures were made during the summer, returns were low. Since no within season decline in fish numbers was noted the data suggest a significant movement of untagged fish into the tributaries.

The total number of fish caught in traps is presented in Figure 10. At all sites but controls, there was a decrease in the number of fish captured. The decreases were most noticeable at sites 5, 9 and 10. There was no similar decrease at sites 3 or 4, the controls. The results suggest an effect due to cutting in the fall of 1995 and the winter of 1996.

However, a word of caution is advised. There is only one year of data following treatment and some degree of uncertainty as to the full effects being manifested in 1996. In addition, a decrease in salmonids in other streams was noted in 1996 (Chiasson 1996) and where there appears to be recruitment failure of younger age classes for Atlantic salmon in the same year. Site number 3 is in the upper part of the watershed and fed by ground water. There is the possibility that it may not have been subject to the same conditions as experienced by other streams in the province that experienced decline.

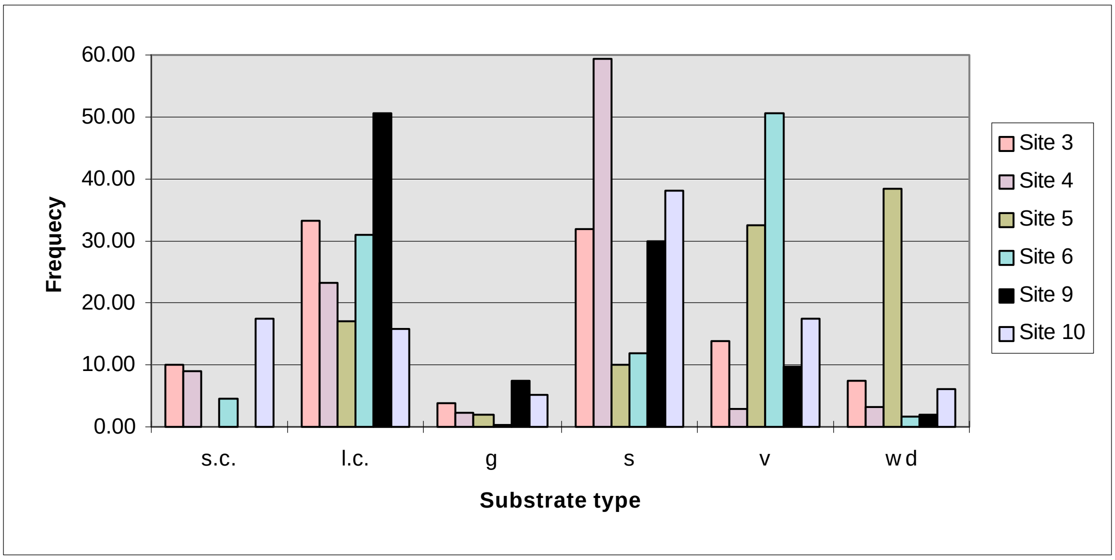

Figure 6. Substrate composition in the first 10 pools of each site in 1994. s.c. = small cobble, l.c. = large cobble, g = gravel, s. = sand, v = vegetation (submerged aquatic), wd = woody debris.

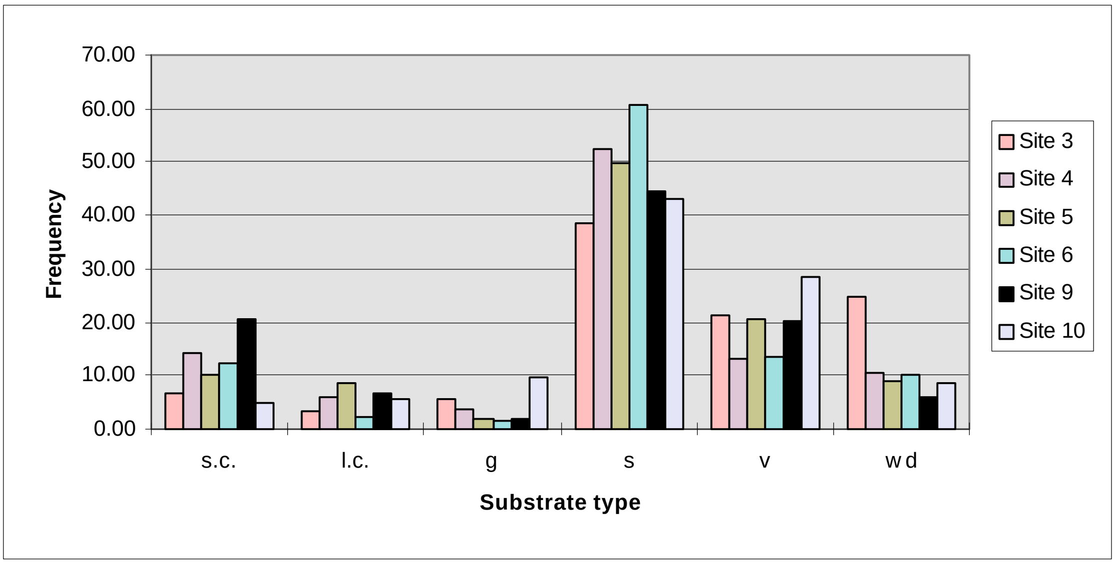

Figure 7. Substrate composition in the first 10 pools of each site in 1995. s.c. = small cobble, l.c. = large cobble, g = gravel, s. = sand, v = vegetation (submerged aquatic), wd = woody debris.

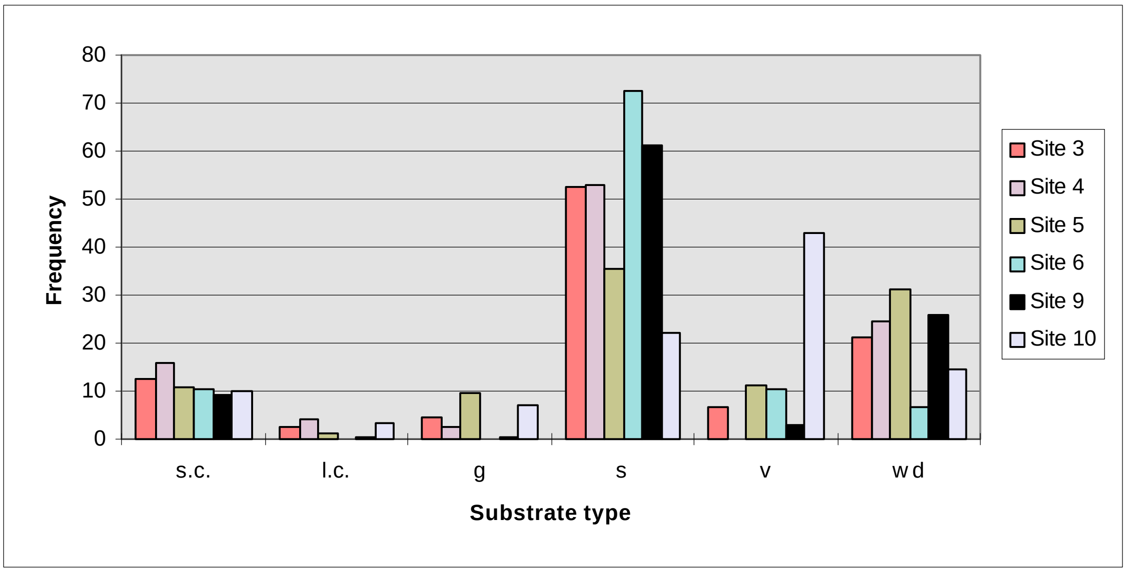

Figure 8. Substrate composition in the first 10 pools of each site in 1996. s.c. = small cobble, l.c. = large cobble, g = gravel, s. = sand, v = vegetation (submerged aquatic), wd = woody debris.

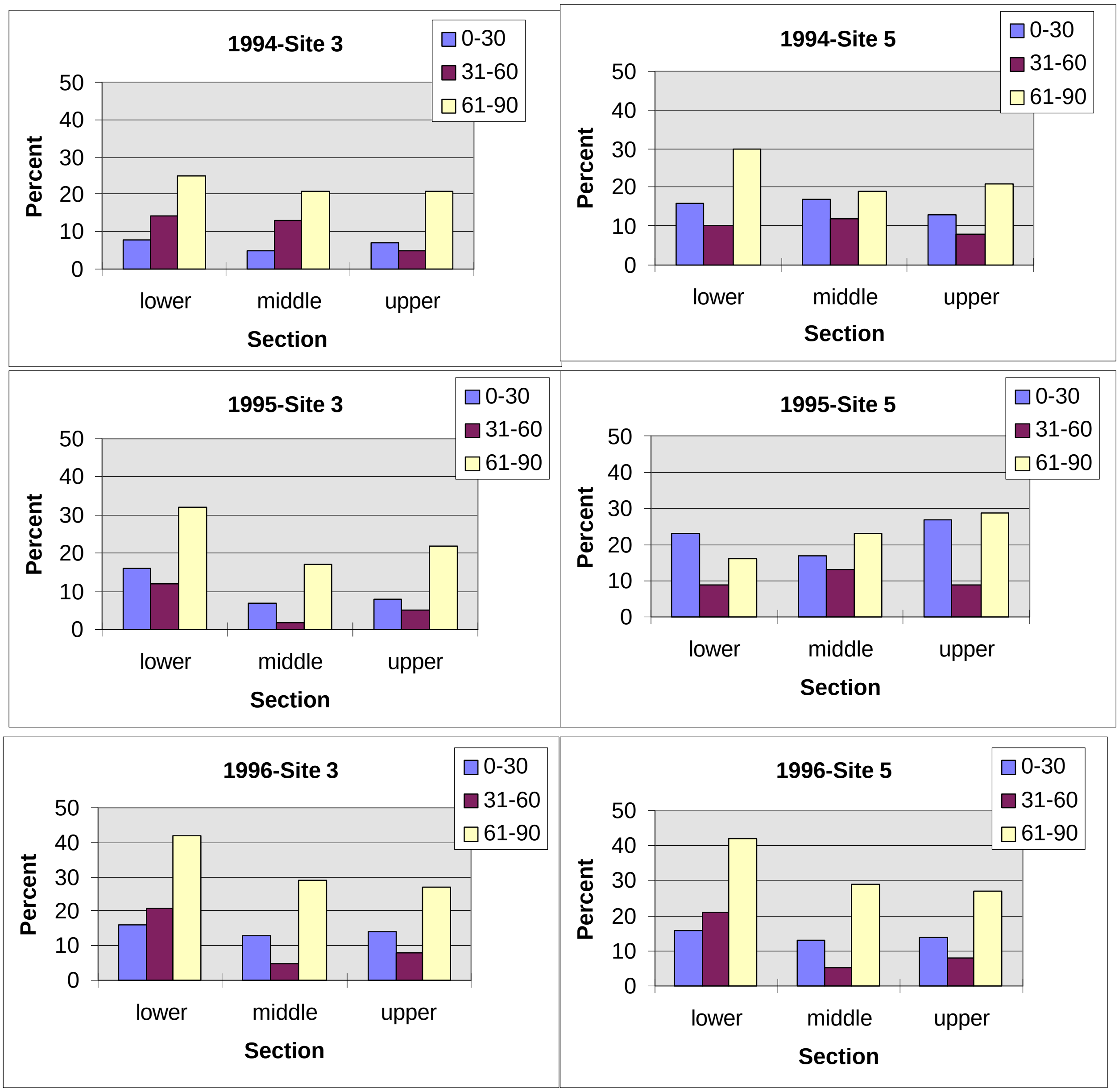

Figure 9. Woody debris at site 3 (control) and site 5 (30 m buffer) in 1994, 1995 and 1996.

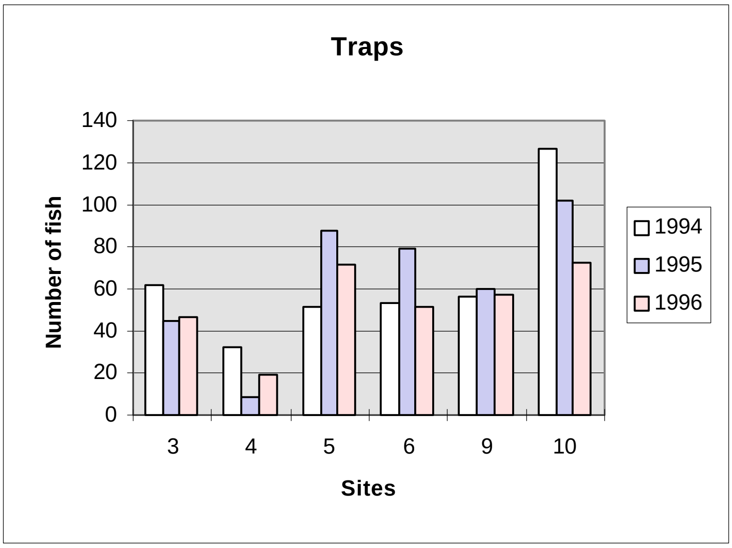

Figure 10. Total number of fish caught in minnow traps in 1994 to 1996.

There is a clear need for an additional year of data to determine if the decline is evident in 1997. This will enable two years of pre-harvest data to be compared with two years of post-harvest data.

Length of fish

Changes in the length distribution of brook trout can also serve as an indication of the effects of the various treatments employed in this study. Box whisker plots were constructed using the trap data as it contained a larger number of fish and was consistently sampled during the summer in all year (Figure 11 to 13). Box whisker plots give the median and quartile distributions. The notches indicate 95% confidence limits on the medians. Median size of brook trout was similar across sites with values between 8 to 10 cm. Distributions were usually skewed but there appears to be no consistent pattern. Some reservation may be warranted for site 4 as traps were removed from riffles and runs and placed in pools in 1994 as the stream became drier and in 1995 and 1996 they were totally removed from locations that went dry.

Electrofishing

In all years of the study electrofishing was conducted early in the summer (Figure 14). Results suggest a decline of fish at sites 6, 9 and 10 with an increase at the control site 3. Site 4 should be excluded due to low water levels. Again similar reservations to trap data are expressed. Decreases in salmonids have been noted in other parts of the province in 1996 and site 3 which is fed by ground water springs may be an exception. Another year of data would help to clarify the situation. Samples taken late in the summer (Figure 15) confirm the pattern observed at the earlier dates. This is important as it indicates that electrofishing efforts reflect actual population levels in the streams

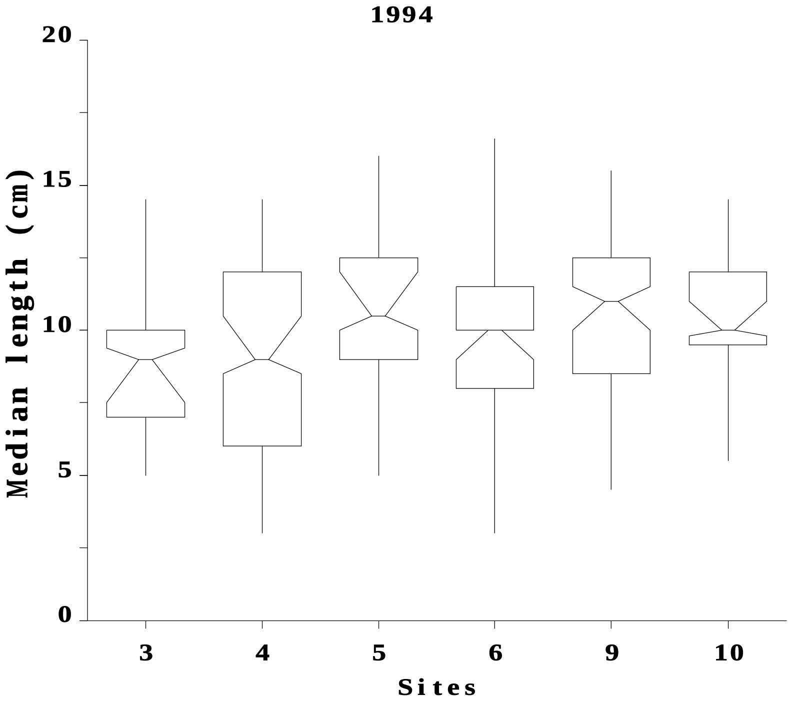

Figure 11. Box whisker plots of median lengths of brook trout in 1994. Sample size is 45.

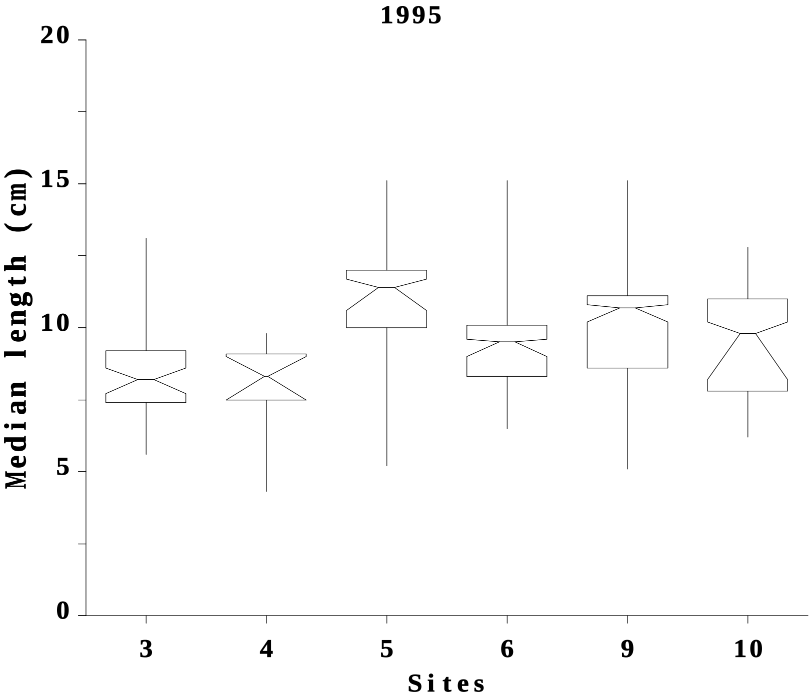

Figure 12. Box whisker plots of median lengths of brook trout in 1994. Sample size is 45, except for site 4 which is 9.

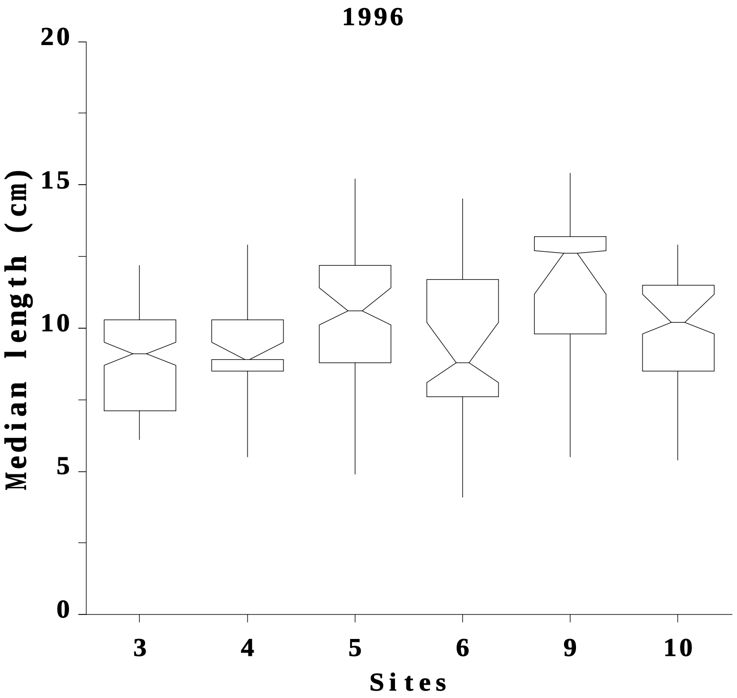

Figure 13. Box whisker plots of median lengths of brook trout in 1994. Sample size is 45, except for site 4 which is 17.

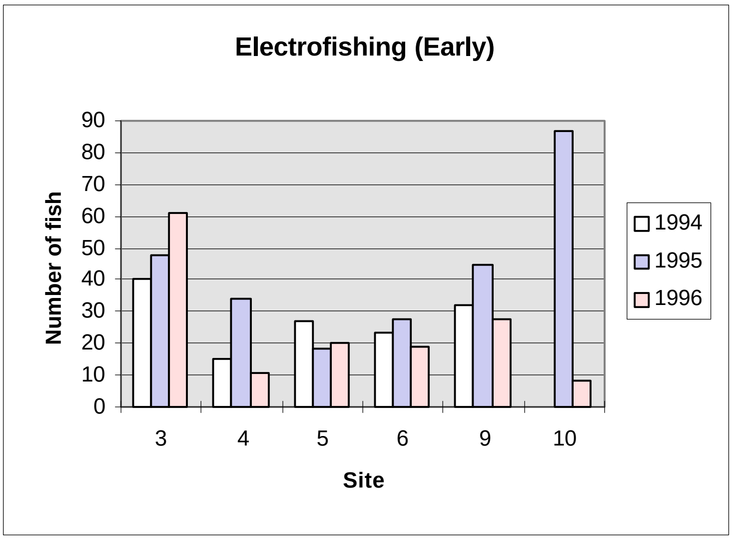

Figure 14. Electrofishing results for samples taken early in the summer.

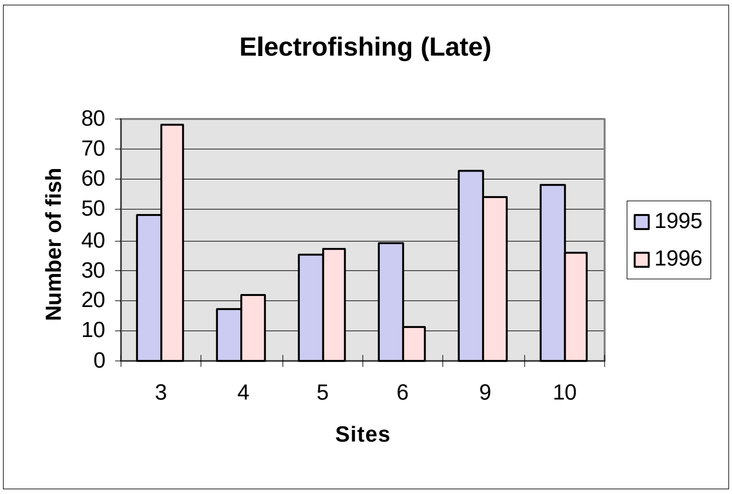

Figure 15. Electrofishing results for samples taken late in the summer.

Fall electrofishing

In 1994, electrofishing was conducted in August and again in October. There was a dramatic increase in the number of fish at all sites in the fall. Fish captured at this time were in spawning condition. Although not conclusive, there is the suggestion that fish may be moving into these tributaries in the fall to lay their eggs. Fish were actively spawning as both milt and eggs were being extruded from a number of captured fish. In addition, it suggests that fall sampling should be conducted when ever possible as low abundance in the summer may not be the case in the fall. Sampling during the summer period may under evaluate the importance of the tributary to brook trout production.

Sampling conducted in 1996 was conducted earlier in the fall than in 1994 due to lack of resources. Resources did not permit electrofishing in the fall of 1994. No increase in the abundance of fish was noted in September compared to August. However, fish may not have moved into the system at this early data. Although brook trout were in spawning coloration, gonads did not appear to be mature as in 1994. Sampling later in the season in October is recommended.

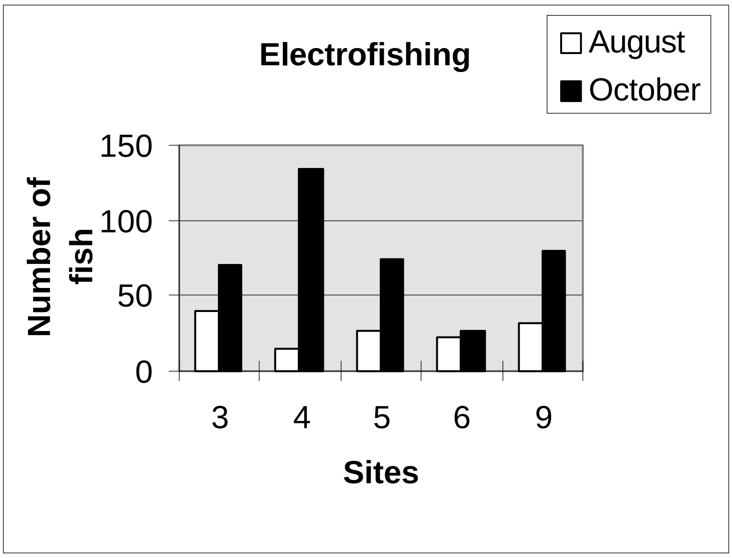

Figure 16. Number of fish captured by electrofishing in August and October of 1994.

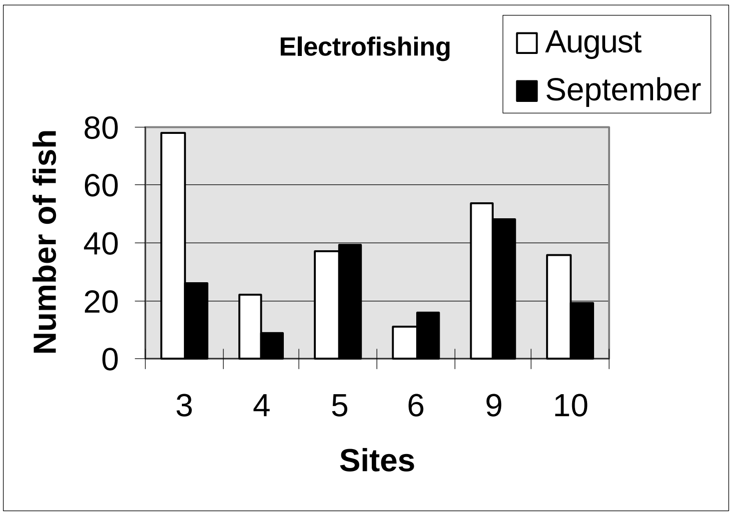

Figure 17. Electrofishing conducted in August and September of 1996.

Recaptures

Very low rate of recaptures were noted in all years of the study, either from tattoo marking, adipose fin clipping or tagging. No dead fish were found in any years of the study and fish were always captured live in the traps. No changes in catch rates were noted within season leading to the conclusion that fish are either highly mobile, with fish immigrating and emigrating during the season.

4.2.3 Discussion

The effects of forestry practices on fish requires an ecosystem approach. This includes all the biological communities of which a stream or river is composed, availability of resources and the physical and chemical composition of the environment (Murphy and Meehan 1991). The various studies taking place in the Hayward and Holmes Brook watershed address many of these aspects without focusing on a single species or feature of the environment. Riparian zones play a unique role in such ecosystems, providing a link between the terrestrial and the aquatic components.

On small to mid-size streams, riparian zones have been found to reduce temperatures, reduce sediment input, provide important sources of organic matter and stabilize the banks (Osborne and Kovacic 1993). A number of studies have shown that streamed vegetation minimizes damage to the habitat and helps to maintain the integrity of fish populations (Hicks et al. 1991). However, the question of width remains unresolved. In a review of various strategies to protect aquatic habitat, Piégay and Maridet (1994) cite a number of suggestions for riparian zone widths, ranging from 5 to 50 m. A study conducted Davis and Nelson (1994) on the impacts of logging of a Eucalyptus forest, only found significant effects at less than 30 m. None of these widths take into consideration soil conditions nor relief of the terrain.

The present study has found some evidence suggesting a decline in fish abundance in 1996 compared to 1995. What is less certain is the attributable cause as declines in juvenile salmon abundance in 1996 compared to 1995 have been noted in other areas of the province. Site 3 failed to show decreases observed at other sites but its location in the upper part of the watershed leaves some room for question. In addition, there is no evidence for dramatic changes in the physical habitat other than an increase in the quantity of sand located in pools. The final consideration is the time of the cuts. They commenced in late 1995 and continued through the winter months. The full effect of harvesting if any may not be evident until the following year. The recommendation is for another year of data. All fish captured in 1996 were tagged and will be easily identifiable in 1997 if captured. Other studies have also indicated a preference for long-term data on the effects of forestry harvesting. At minimum, all sites should be electrofished at least once during the following years.

In the future several other areas of research may be explored. The effects of selective cutting within riparian zones is not known. This extends not only to volume of wood removed but frequency of removal, and size and species selection. Riparian zones act as nutrient sinks (Osborne and Kovacic 1993). To what extent this capacity is reduced or remaining vegetation saturated by removal of vegetation bordering streams and rivers is unclear. Partial deforestation of a small watershed in Maine resulted in little effect in the year following the harvesting (Mullen and Moring 1988).

Selective removal within buffer zones may also affect supply of woody debris. Although, the importance of woody debris to salmonid habitat is well established (Hicks et al. 1991), the dynamics from season to season and year to year are poorly understood. Managers must ensure that a sufficient numbers of trees of the proper age class and species remaining standing to eventually fall into the stream or river.

To date little information is available on riparian zones and the protection of groundwater. Groundwater not only stabilizes temperatures in small streams but is critical to spawning areas, insuring that eggs deposited in the gravel do not freeze during the winter. Riparian zones may have to be extended in areas known to be important sources of groundwater. Conversely, overall riparian zones could be smaller in watersheds where groundwater sources are mainly responsible for the flow and adequately protected.

Watershed analysis would address may of the information gaps previously cited.
FEMAT (Forestry Ecosystem Management Team) defines watershed analysis as,

> “a systematic procedure for characterizing watershed and ecological processes to meet specific management social objectives. The information then may guide management prescriptions, including prescriptions, including setting and refining boundaries and other reserves, developing restoration strategies and priorities, and revealing the most useful indicators for monitoring environmental changes.”

Monitoring of fish communities is a valuable tool in determining the effects of different forestry harvesting practices on aquatic communities. Functionally, key species such as brook trout and Atlantic salmon can provide useful information on whether biodiversity goals are being met and as such should be included as part of future plans to evaluate the effectiveness of new forestry management practices on watersheds.

Acknowledgments

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Recommendations

Data collected in 1996, suggest a decline in brook trout compared to the previous two years of the study. However, the decline is based on only one year of data and there is some reason to believe that it may be part of a more wide spread phenomena in the province. In addition, samples collected in 1996, may have been exposed to different duration of post-harvest effects as cutting took place during a protracted period of time extending from the previous fall and into the winter months of the same year.

1. Based on one year of data following harvest there is no evidence to suggest that a 60 m buffer is better than a 60 m buffer.

2. To resolve the question of decline in brook trout abundance in 1996 it is recommended that monitoring of fish populations be conducted for at least another year. It is suggested that at minimum, electrofishing be conducted at least once during the summer months.

3. That tracking of substrate composition in pools be continued for at least another year and that previous data be compared with turbidity reading from Environment Canada at the same locations.

4. That potential poor recruitment in other areas of the province be examined and if possible a cause identified.

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