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The Fundy Model Forest…
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"The Fundy Model Forest (FMF) is a partnership of 38 organizations that are promoting sustainable forest management practices in the Acadian Forest region."

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Canadian Institute of Forestry
Canadian Forest Service
City of Moncton
Conservation Council of New Brunswick
Fisheries and Oceans Canada
Indian and Northern Affairs Canada
Eel Ground First Nation
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HAYWARD BROOK WATERSHED STUDY (ANNUAL REPORT-1994-1995)

95-39

The Hayward Brook Watershed Study

(Annual Report - 1994-1995)

Participants

Gerry Parker	-	Canadian Wildlife Service
Alyre Chaisson	-	Université de Moncton
Denis Haché	-	" "
Denis Doucette	-	" "
Joe Pomeroy	-	Waters Section, Environment Canada
Jean-Guy Deveaux	-	" "
Tom Pollock	-	" "
Helmut Krause	-	University of New Brunswick

To: Biodiversity Committee
Fr. Peter Etheridge
This is a 100+ page report. If you want to see or review the complete report please call.
Peter.

Compiled by: Gerry Parker
March 1, 1995.

Abstract:

The second year of the 5-year Hayward Brook Watershed Study, and the final year of predisturbance calibration, will be completed in 1994-95. The study treatment, or timber harvest, will be done in summer/autumn, 1995. The Hayward Brook project has developed into an integrated interdisciplinary study of both biotic and abiotic resources. The objective is to measure the responses of specific components of both the terrestrial and aquatic ecosystems to forested stream buffers following harvest of timber on the adjacent landscape. Pretreatment inventories of breeding birds, small mammals, aquatic invertebrates, winter birds and mammals, vegetation communities and water quality and flow are near completion (several measurements will continue up to the time of cutting in 1995). Pretreatment data will be summarized and represent benchmarks with which posttreatment measurements will be compared. Two undisturbed sites will provide controls. Some predisturbance measurements represent original research and will be used by students towards graduate degrees in biology (e.g. habitat selection by breeding birds; selection and use of cavity nest trees; population characteristics of small mammals; abundance and spatial use patterns of wintering birds and mammals) while other data sets await treatment and subsequent response measurements (e.g. water parameters; best management practices; fish and aquatic invertebrates). The project remains on schedule. Much of the success of the study now depends on the full cooperation of the landowner and adherence of timber harvest operations to the proposed cutting plans.

Original Objectives:

The following objectives come from the original proposal submitted to the Fundy Model Forest in 1993. The riparian study, as it was called, received high endorsement from the FMF partnership. It may be useful for reviewers to assess the first 2 years of the study relative to these original objectives.

1. to describe breeding bird and small mammal communities associated with a representative selection of riparian ecosystems and adjacent forests within the FMF.
2. to relate presence and abundance of breeding bird and small mammal species with structural components of the riparian and forested ecosystem.
3. to relate diversity of breeding bird and small mammal species and populations with structural diversity of site-specific habitats and forest stands.
4. to predict functional responses of breeding birds and small mammals (direction and intensity of change in richness, abundance and diversity) to specific habitat management prescriptions eg timber removal; habitat alteration and modification.
5. to develop "tolerance indices", relative to habitat change, for breeding birds and small mammals.

6. to field test predictions by implementing specific habitat changes and measuring functional responses of bird and mammal species.
7. to measure changes to water flow and quality from specific timber management prescriptions.
8. to develop recommendations/guidelines for forest management prescriptions within riparian buffer zones which would mitigate adverse impacts on certain species, and/or enhance responses by other species to habitat modification.
9. to find and describe nest trees used by primary and secondary cavity nesters in the riparian and forested buffer study areas.
10. to sample and describe habitats in the immediate area of occupied cavity nests.
11. to isolate structural habitat components which most influence use of trees by cavity nesting species.
12. to measure the impact of different intensities of timber removal within buffer strips on use of nest trees by cavity nesters.
13. to experiment with techniques for maintaining or enhancing use of buffer strips by cavity nesting species following various intensities of timber removal.
14. to establish winter track survey transects within established riparian and forested buffer zone study sites.
15. to conduct periodic track surveys to measure use (track indices) of habitats in winter by mammals.
16. to measure characteristics of ground snow cover within various habitats during winter track surveys.
17. to evaluate the impact of various forest management prescriptions on use of habitat types by mammals in winter.
18. to establish winter bird survey transects within riparian and forested buffer zone study sites.
19. to obtain indices of use of various habitat types by bird species in winter.
20. to evaluate the impacts of various forest management prescriptions on use of habitat types by birds in winter.
21. to install water measurement stations downstream from study sites to monitor flow and water quality before, during and after forest harvest prescriptions.

We had originally intended to include amphibians with those wildlife forms inventoried and assessed relative to timber harvesting and forested buffer strips. Amphibians, mainly salamanders, were inventoried with random time searches in 1993-94. However,the process was very time demanding and excluded many other important amphibian species. Amphibian searches were not continued in 1994-95. However, the data from 1993-94 is being analyzed by an Honour's student at University of Moncton and can be used for posttreatment assessment of response by salamanders if resources allow.

Since the above original objectives, Dr. Alyre Chaisson has joined the project and provides an important fishery dimension to the scope of the study. Dr. Helmut Krause is also using 2 of the study plots to assess the merits of site specific "best management practices". Water sampling data includes both permanent water gauges and scheduled year round bottle samples. The aquatic invertebrate sampling will be important when assessing responses of physical parameters of the aquatic environment and fish populations.

Study Area:

Hayward Brook crosses the Trans Canada Highway near Petitcodiac, joins the Anagance River and thence into the Petitcodiac River. The study area includes the upper tributaries, and adjacent forests, of Hayward Brook situated to the east of the Trans Canada Highway. The drainage basin east of the TCH is approximately 30 km2 (2400 ha). Several of the feeder streams are spring fed, and the brook contains running water all year. Several other feeder streams may be ephemeral during dry summers. The streams are fast flowing and the main stream is 3-4 m at its greatest width. In 1994-95 an adjacent stream, Holmes Brook, was included into the study area. This was necessary due to the exclusion of 2 study sites at Hayward Brook by the landowner, J.D.Irving, from scheduled harvest operations. Holmes Brook also drains into the Petitcodiac River just below the outlet of Hayward Brook (see Figure 1). The forests within the drainage basins of both brooks are predominantly 70-80 year old mixed growth. Spruce-bud worm killed much of the mature fir and those openings support regenerating stands of mixed species with young fir dominating. The area is mostly J.D.Irving free-hold lands.

Study Design:

The 5 year study is a cause-effect field experiment, with 2 years of resource calibration (1993-94 through 1994-95), 1 year of treatment (cutting - summer/autumn, 1995) and 2 years of response measurement (1996-97 and 1997-98). Originally proposed as an experiment to measure the effect of forested buffer strips on breeding bird populations, the potential of the study design was attractive to other researchers and additional elements of the study quickly developed. There are 8 study sites, each site located on a feeder stream of the Hayward or Holmes Brooks within a 30 km2 study area. There will be 2 replicates of 4 treatments. Those treatments will be: 1) clearcut with 30 metre buffer; 2) clearcut with 60 metre buffer; 3) best management practices ie. combination of clearcut and selection cut; and 4) control (no cutting). The study plots and proposed cutting plan by J.D. Irving is shown in Figure 2.

Each of the study components of the Hayward Brook project have distinct methodologies and as they are described within the relative project reports in this year end review I will not repeat them here.

Introduction:

It is worthwhile here to comment briefly on justification for the Hayward Brook Study and how this study addresses the goals and objectives of the Fundy Model Forest. This study, and several other "ecological" studies within the Fundy Model Forest research agenda, have been rolled into the Biological Diversity Technical Committee. Other related committees include the Wildlife Population

Committee and the Waters Committee, each with their own projects and funding allocations. It is quite apparant that the Hayward Brook Study includes elements of research with affiliation to several committees. Ecosystems research, such as that at Hayward Brook, must out of necessity, address a variety of ecological issues, both biotic and abiotic, all of which contribute to measuring and understanding how complicated ecosystems respond to manipulations. The Fundy Model Forest proposal included a number of specific objectives. Those objectives addressed the strategic goal of the FMF to derive the full economic potential from the forest resources through the implementation of a practical working sustainable management plan which encompasses multiple-use objectives. It was recognized that achieving that goal would require research to enhance knowledge of forest ecosystems, their dynamics, and cause/effect relationships impacting them.

The recognition by FMF of the tremendous uncertainty with respect to ecosystem function and response of ecosystems to management led to the priorization of research to address those information needs. Results from a coordinated environmental research program was seen as a need to contribute to development of a management strategy for the forest ecosystem built upon the principle of multiple use on a sustained basis. Compromises to the wood fibre single-use strategy of the past would be needed. New sustainable forestry practices needed to be developed and implemented. Although multiple-use would represent the thrust of, or theme for, this new management strategy within the forest system, it was the demand for wood fibre, and the need to enhance and sustain wood fibre production, that was the reason for developing the model forest. The practical application (utility) of results from research initiatives within the context of an environmentally sustainable management plan was to remain the focus (priority) of a meaningful research strategy. This is clear in the third goal of the FMF proposal.

"To enhance our knowledge of forest ecosystems in order to develop and adapt new management tools which will enable us to increase the benefits from, and more efficiently manage our forest ecosystem on a sustainable basis."

The prime objective of the FMF, then, is to improve knowledge of ecosystem function and to better understand the responses of that system to forest disturbance, and from that knowledge to improve our ability to develop a multiple resource management plan within the concept of sustained, or enhanced environmental quality. There is an initial need to expand and complete certain data bases for resources within the FMF. Activities should focus on this collection of resource inventory information relative to timber, wildlife, water, recreation and other values.

To integrate wildlife and timber management, the status of specific wildlife populations must be known along with the ability to project these into the future under alternate management strategies. The objectives for research and inventory activities will be to quantify species-habitat relationships for selected species in the FMF ecosystem so that they can be used in management decisions.

The 3 key elements on which research will focus are identified in the FMF proposal as:

1) development of appropriate inventory methodologies.
2) elucidation of ecosystem function, ecological processes and management responses.
3) advancement of technology available for management design and implementation.

The basic and absolute requirement to integrate wildlife habitat management into forest ecosystem management is a fundamental premise of the FMF management strategy. Once wildlife and habitat interrelationships are better defined, prediction of the impacts of activities on wildlife habitat and populations can be developed.

An important objective of habitat/population studies should be to establish cause/effect relationships between stand and forest structure and animal use. Predictions of how population characteristics change over time in response to management intervention are the means by which inventories are forecast into the future. Research should therefore concentrate on establishing cause/effect (treatment response) relationships with the prediction of these data over time and with the use of these data to design better strategies.

The FMF proposal identifies 4 areas under Population Studies where research can address the current state of timber and non-timber resources, and which will facilitate the development of methodologies capable of collecting the necessary information at the required resolution.

They are:

1) Remote censusing for timber inventory updating.
2) Wildlife habitat use.
3) Wildlife habitat/population relationships.
4) Biodiversity indices.

The proposal also identifies 5 areas under Treatment Response where research should be directed to predict how animal and plant population characteristics change over time in response to management interventions.

They are:

1) Forest growth and yield forecasting.
2) Tree improvement
3) Harvesting prescriptions.
4) Harvesting in buffer strips.
5) Environmental impacts and ecological integrity.

The FMF emphasizes that impacts [of certain forest management practices] on wildlife populations and biodiversity must be measured in order to design and implement sustainable management strategies. This Hayward Brook Watershed Study addresses 3 of the 4 research issues under Population Studies (2, 3 & 4) and 3 of the 5 research issues under Treatment Response (3, 4 and 5) as identified within the Fundy Model Forest Proposal.

Overall Summary:

The Hayward Brook Watershed Project is an interdisciplinary research study of riparian forested buffer strips of different widths and treatments and their comparative ability to protect the integrity of terrestrial and aquatic ecosystems following timber harvest. The 5 year study is a cause-effect field experiment, with 2 years of resource calibration (1993-94 through 1994-95), 1 year of treatment (cutting - summer/autumn, 1995) and 2 years of response measurement (1996-97 and 1997-98). Originally proposed as an experiment to measure the effect of forested buffer strips on breeding bird populations, the potential of the study design was attractive to other researchers and additional elements of the study quickly developed. There are 8 study sites, each site located on a feeder stream of the Hayward or Holmes Brooks within a 30 km2 study area. There will be 2 replicates of 4 treatments. Those treatments will be: 1) clearcut with 30 metre buffer; 2) clearcut with 60 metre buffer; 3) best management practices ie. combination of clearcut and selection cut; and 4) control (no cutting).

Activities during the first 2 years of resource calibration have included the following:

1) Breeding birds - Through the cooperative efforts of Canadian Wildlife Service and University of

Moncton, populations of breeding birds on the 8 study sites have been censused. Descriptive demographic measurements include species richness (number of breeding species), abundance (total number of bird territories) and diversity (distribution of terrirories among species). All territories are entered into the GIS at Fundy Model Forest office in Sussex. This provides a spatial dimension to the population data. Intensive sampling of the forested habitat at each site allows a multivariate analysis of species specific habitat selection. This is important when assessing the impact of forest change on individual bird species. These data are being used by the principal field investigator, Denis Haché, towards a M.Sc. degree in biology at University of Moncton. A completed thesis is expected in spring, 1995. A preliminary report on the 2 years of predisturbance measurements of breeding birds is attached (Appendix 1).

2) **Cavity nest ecology** - The second element to breeding bird studies is also a cooperative initiative between Canadian Wildlife Service and University of Moncton. Although cavity nesting birds were included in the general population analysis described above (and in greater detail elsewhere in this report by Denis Hache) this group of breeding birds was given particular attention because of their reliance on specific trees for excavating cavities used for nesting. Although the vulnerability of this group of breeding birds to timber operations has long been recognized, and certain provisions to address their unique nesting requirements have been incorporated into general forest management guidelines, there are few descriptive data on nest trees used by individual bird species, or on microhabitats around nest trees. These information needs formed the objective of the cavity nest study at Hayward Brook. Denis Doucette, a graduate student at University of Moncton, is the principal field investigator, and will use the resulting data towards a M.Sc. degree from that university. Denis will continue his research through the 1995 field season and complete his thèsis in the spring of 1996. A report by Denis detailing methodologies used and preliminary results from the first year of study is attached (Appendix 2).

3) **Small mammals** - Randomly selected one hectare small mammal survey plots were established in all 8 study sites. The streams bisect each plot. Each plot extends 50 metres from the centre of the stream and includes 98 sample stations (ł2.5 m equidistance). Each plot is sampled for small mammals for 8 consecutive nights in late July and August. Two snap traps are positioned at each sample station. Small mammals collected are labelled and frozen. The objective is to measure the responses of small mammal communities to timber harvest and subsequent forested stream buffers. Specimens from 1994 were necropsied by Andrew Boyne who used the data for an Honour's program in Biology at Mt. Allison University. That report was included with the 1993-94 Hayward Brook year end report. Specimens from 1995 are presently being necropsied at Acadia University. As results from those analyses are not yet available I have again included the report from 1993-94 by Andrew Boyne (Appendix 3). It will serve to acquaint the reviewer with methodologies and the types of analyses the small mammal data are subjected to. Results of analyses of the 1995 small mammal data will be submitted to FMF when available. I should say that the sampling in 1995 went as planned and, at last report, most specimens have been necropsied at Acadia.

4) **Aquatic invertebrates** - Aquatic invertebrates in the streams at each of the 8 study plots were sampled in 1993-94 and again in 1994-95. The sampling strategy follows that outlined by

Bevan Lock and included with the 1994 year end report. I have again included that summary of sampling methods. All samples (approximately 700) from each summer have been sorted during the intervening winter period and invertebrates stored in vials containing alcohol. The individual vials remain in storage awaiting identification of specimens. The appropiate (and affordable) means for specimen identification has not yet been decided but may include the services of a graduate student. The sampling in 1995 followed that conducted in 1994 and the series should provide an acceptable assessment of the invertebrate fauna at each study site prior to timber harvest.

4) **Fish populations** - Dr. Alyre Chaisson, University of Moncton, began sampling fish populations and their habitats in several of the major feeder streams in summer, 1994. Sampling will continue in spring and summer, 1995 prior to timber harvesting. Dr. Chaisson has submitted several progress reports to FMF in the past 12 months. The attached year end report summarizes his research to date at Hayward Brook (Appendix 4).

5) **Best management practices** - Dr. Helmut Krause, Faculty of Forestry, University of New Brunswick has been involved with research at Hayward Brook for the past 2 years. Dr. Krause is using 2 of the 8 study sites for his project. During the period of predisturbance, Dr. Krause has taken measurements at the 2 sites which will allow him to propose a "best management practice" for each. His proposed harvest regimes will include a combination of clearcut and selection cut, depending upon site characteristics. We have also included the 2 sites in our sampling scheme for aquatic invertebrates, small mammals and breeding birds. This will allow an assessment of the impact of prescribed timber harvests on certain wildlife populations. A year-end report is attached (Appendix 5).

6) **Water quality and quantity** - Environment Canada has been responsible for sampling all streams for water quality and quantity over the past 2 years. Sampling and monitoring has involved both scheduled bottle sampling and stream gauges and probes. A year end report by Environment Canada is attached (Appendix 6).

7) **Winter birds and mammals** - The need for assessing the use of study sites by birds and mammals during winter, and the use by birds and mammals of consequent forested stream buffer corridors following cutting, was recognized as an important component of the study. Although provincial forest management guidelines recognize the potential value of stream buffers as wildlife corridors, especially in winter, there are few data supporting that assumption. The Hayward Brook study provides the opportunity for verification, or reassessment and perhaps refinement of guidelines. The grids established for censusing breeding birds were also used for the winter inventories. Each grid was surveyed 6 times from January 1 through March 3, 1994. Those surveys are being repeated in 1995. The general method is to traverse the transect lines on each plot and record all birds seen and heard and all mammal tracks intersected. The 1994 surveys went as planned and the 1995 surveys are also on schedule(3 of the 6 surveys completed by mid-February). The results of the 2 winter surveys will be analysed by a graduate student at Acadia University (research course). The distributions of winter birds and mammals (tracks) will be assessed both spatially and temporally (among surveys within years and between years). The objective is to measure

how effective forested corridors of several widths are in maintaining populations of birds and mammals in winter, and if they serve as travel corridors for wildlife between adjacent uncut stands.

I refer the reader now to the individual reports which follow for greater details on specific components of the Hayward Brook Research Project.

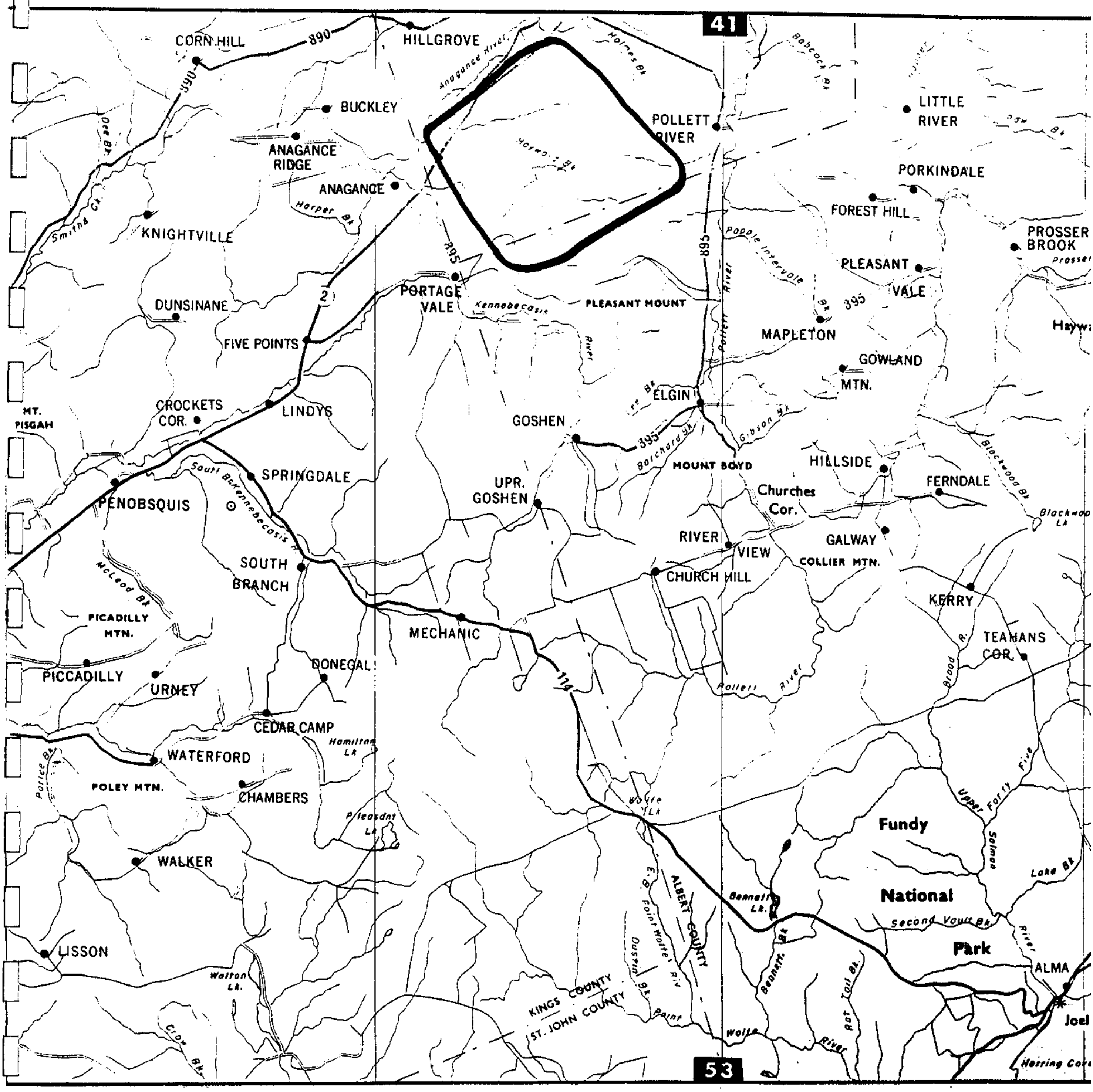

Figure 1: Hayward Brook Watershed Study Area

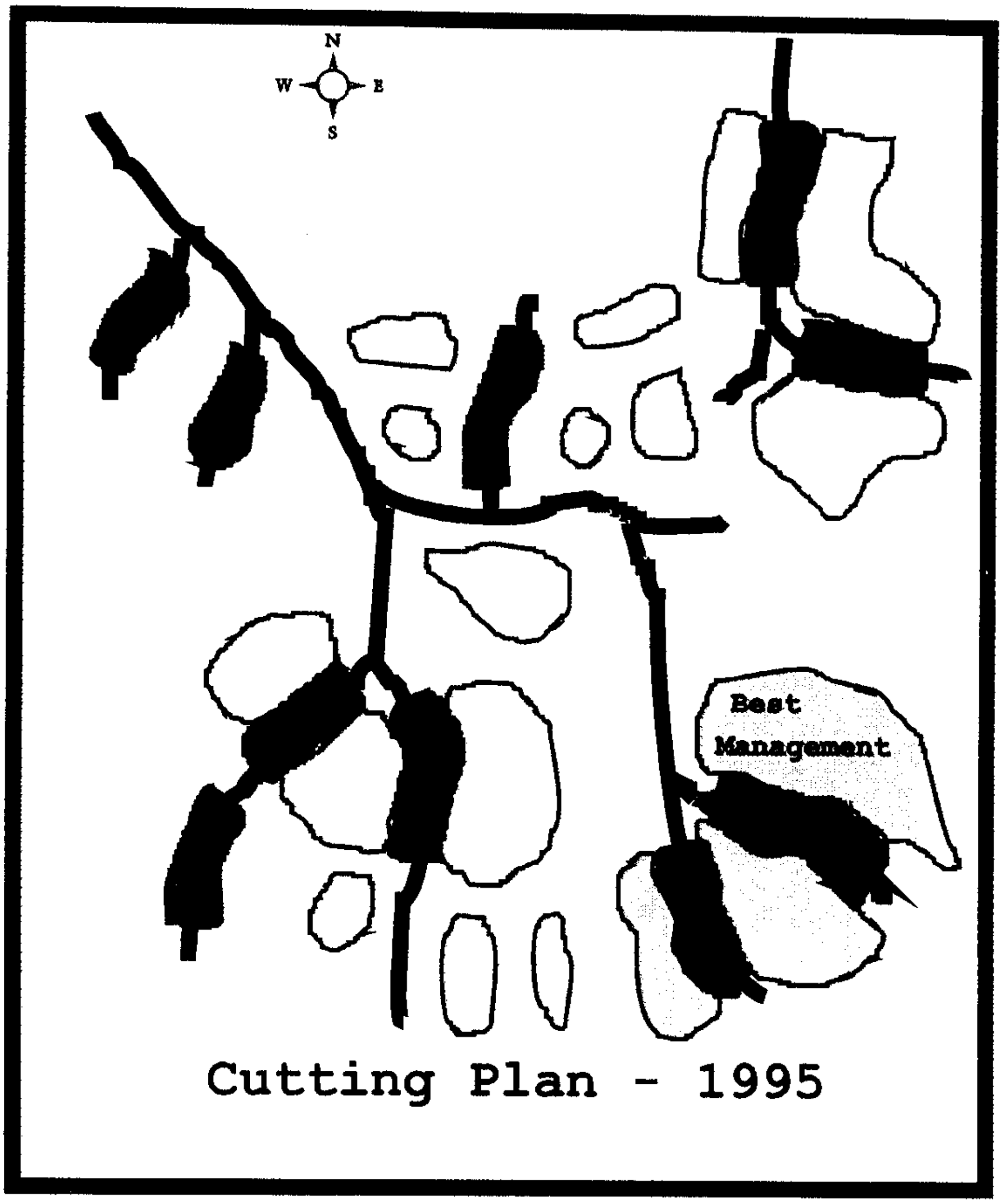

Figure 2: Study sites at Hayward Brook and proposed cutting plan for 1995

Appendix 1: Annual report (1994-95) on survey of breeding birds at Hayward Brook Watershed Study.

Habitat Selection in birds of a mature second growth Acadian Forest.

Progress report submitted to the Fundy Model Forest.

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October 31, 1994

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ABSTRACT

During the summers of 1993 and 1994, the territory mapping technique (International Bird Census Committee, 1970) was used to locate the territories of 42 breeding bird species in ten plots (20 to 30 ha ea.) which were centred on several first and second order streams of the Hayward and Holmes Brooks (Albert-Westmorland Co., N.B.). The habitat consisted of various stand types of mature Acadian Forest. This project, part of the Fundy Model Forest, represents a pre-disturbance study of the Riparian Zones Management project which will be examining the effect of buffer strip width on water quality and on usage by wildlife. Therefore, one of the goals was to identify and to determine relative abundances of breeding bird species in the undisturbed habitat of the riparian zones before application of the buffer strip treatment. The main objective of this paper was to develop a scheme for describing avian habitat selection using easily obtainable and comprehensive habitat variables. This paper is intended to give forest managers a quantitative description of vegetation and its relation to the distribution of the region's common breeding bird species.

A modification of an avian habitat sampling technique (Noon, 1981) was used to obtain data on vegetation. The 0.04 ha vegetation sampling plots were randomly positioned across the larger bird census plots. Measured variables consisted of counts of stumps, shrubs, trees and snags. Counts for trees and snags were separated by species and stage of decomposition respectively, as well as among different size classes. A series of twenty point observations of the vertical foliage profile was also taken. The foliage profile was determined by presence or absence of foliage in four forest layers. Birds were related to this vegetation sampling data by determining which vegetation plots were situated inside the mapped bird territories. Correspondence Analysis and Principal Component Analysis will be used to relate bird distribution to tree species basal area, stem densities of similar foliage types (coniferous, deciduous or snag) and measures of foliage profile. For comparison to these results, a Geographic Information System will also be employed to examine the relationship of forest stand classification to the distribution of bird territories.

INTRODUCTION

One of the principal goals of the Fundy Model Forest (FMF) is to integrate wildlife habitat management into forest ecosystem management. Therefore, wildlife and habitat interrelationships must be clearly defined in order to predict the response of wildlife populations to various alterations of the forest's structure, age and composition. This research project is designed to elucidate the relationships between species of the forest breeding bird community and the habitat that they use. The first goal was to identify and to determine the relative abundances of breeding species in the avian community of a mature contiguous forest representative of the FMF. The main objective is to test the hypotheses that the breeding species' distributions are related to habitat physiognomy and floristic variables, and to quantitatively describe the habitat selected by each species. Also, the current forest classification system used by the J. D. Irving company will be examined to determine its usefulness as a bird habitat descriptor. Upon comparison with the results of the analyses of our own habitat data, the effectiveness of the forest classification system for purposes of habitat management will be questioned.

The physical design of this study (location and configuration of study plots) is due in part to its dual role as a pre-disturbance study for the Riparian Buffer Zone Management project which will be examining the effect of buffer strip width on water quality and on usage by several wildlife populations. The first two years of this five year project will concentrate on the study of these populations and their habitat in an undisturbed forest. The subsequent years will be committed to studying the response of wildlife populations to different types of buffer strip treatments and to "develop recommendations/guidelines for forest management prescriptions within riparian buffer zones which would mitigate adverse impacts on certain species, and/or enhance responses by other species to habitat modification." (proposal, Parker and LaPierre, 1993).

The territory mapping technique as described by the International Bird Census Committee (I.B.C.C. , 1970) was used to sample the community. Statistically valid, randomly positioned vegetation sampling plots were taken within the larger bird census plots to represent habitat used by the birds. The vegetation plots were the 0.04 ha circular plots designed for bird habitat description by James and Shugart (1970). Habitat variables of both the structural and floristic components were measured.

The concept of relating bird distributions to structural components of the vegetation is not a new idea (Emlen, 1956; MacArthur *et al.*, 1962). Several studies have been conducted on bird-habitat associations along environmental gradients (James, 1971; Smith, 1977; Stauffer and Best, 1980), among successional stages (Conner and Adkisson, 1975; Morgan and Freedman, 1986; Thompson *et al.*, 1992), and in habitats varying in the amount or time of disturbance (Titterington *et al.*, 1979; Crawford *et al.*, 1981; Mannon and Meslow, 1984). Some studies have shown relationships between bird species and the floristic composition of habitats (Wiens and Rotenberry, 1981; Arnold, 1988; MacNally, 1990). Most studies of this type have demonstrated strong associations between bird distribution and certain habitat variables. This largely correlational approach, often found useful for describing or predicting bird habitat selection, is criticized by some authors. Cody (1981) discussed the importance of competitors and productivity in addition to vegetation structure as determinants of habitat selection. Sherry and Holmes (1985) have demonstrated that the dispersion patterns of some bird species were to some extent determined by the presence or absence of other species and on the species' social systems. Though we do not contest this last argument, our approach remains the "habitat-niche" approach of James (1971). This approach has dominated North American studies of habitat selection in small terrestrial birds, and we find it appropriate for describing habitat selection in birds in a first attempt to bridge the gap between forest management and wildlife habitat management in the Acadian Forest.

METHODS

Study site

Hayward and Holmes Brooks drainage basins were chosen as location of the study (FIG. 1). The study area is situated approximately 7 km south of the village of Petitcodiac, New Brunswick.

The area of land is freehold of J. D. Irving Ltd.

Preliminary analysis of our vegetation surveys (vegetation sampling methodologies explained further) revealed that Red Spruce, Red Maple, Balsam Fir, Trembling Aspen, White Pine and White Birch, in order of decreasing importance, were the dominant tree species found. TABLE 1 contains the estimated percentage of total basal area of the six dominant species in each of the ten study plots. Basal area is the sum of the cross sectional area of the boles at breast height (1.3 m). Plots one (1) and two (2) were characterized by dominance of White Pine and Red Spruce. The vegetation of plots one (1) and ten (10) was dominated by coniferous species while the other plots had more equitable proportions between deciduous and coniferous trees. Plot three (3) was typified by having White Birch as the most dominant species, while the dominant on plot four (4) was Trembling Aspen. Both plots three (3) and four (4) had Red Maple and Red Spruce as principle sub-dominants. Plots five (5), six (6), seven (7) and eight (8) were dominated by Red Spruce, Red Maple, Trembling Aspen and Balsam Fir. And lastly, plots nine (9) and ten (10) were differentiated from the others in that Black Spruce was among the dominating species.

The ten study plots were situated along eight streams (FIG. 2). The plots were 300 m in width and were centred on the streams. Plot sizes varied from 20 ha to 30 ha. Several plots (no. 1 to 7) were situated near where its small feeder stream joined with the main Hayward Brook stream. Plot eight (8) was situated further upstream due to proximity of a power-line corridor, and number three (3) was adjacent to another plot on the same stream. Plots nine (9) and ten (10), situated on Holmes Brook, were added during the second year of the study for purposes of being a set of replicates for a particular buffer strip treatment. They will replace plots seven (7) and eight (8) in this respect. Due to some uncontrolled harvesting, plot eight (8) was only censused during the first year of the study.

Bird Census

During the summers of 1993 and of 1994, the standard territory mapping method recommended by the International Bird Census Committee (1970) was used to census the avian community. The basis behind this technique is in mapping the location of stationary singing male birds during the breeding season. Non-passerine taxa, such as the Picidae family, also defend territories and can be counted by this method. The census is done by an observer walking slowly along transect lines, recording the exact position of all birds observed or heard on a map of the plot.

The I.B.C.C. (1970) recommends a minimum of ten visits to a plot in a closed habitat (forest) during one breeding season. Due to a limited number of field workers and to periods of inclement weather, we were able only to visit each plot six times. Visits were evenly distributed between the 26th of May and the 10th of July during the 1993 season, and between the 28th of May and the 4th of July during the 1994 season (see appendix A for schedule of field work).

Surveys were conducted between 06:00 AM and 10:30 AM (AST). On days when bird activity was particularly strong and persisted throughout the morning, some surveys lasted until 11:00 AM. Individuality of observers, routes taken by observers, time at starting and finishing locations, weather conditions and total effort are all possible sources of bias. All these factors were taken into consideration when planning the field work.

Upon completion of the census work, all observations for each bird species were summarized from the visit maps to the final species maps. These maps indicate where and when the birds were located and the behaviour noted during each observation. After analysis, the species maps show the spatial arrangement of territories as the example depicted in FIG. 3 for two species.

Vegetation Sampling

Vegetation was sampled using the 0.04 ha circular plot method described by James and Shugart (1970) and revised by Noon (1981). These 22.6 m diameter circles were randomly positioned across the larger bird census plot (Noon, 1981). The 300 m transects had points at each 50 m intercept where vegetation sampling plots could be located (FIG. 3). With a table of random numbers (Rohlf and Sokal, 1981), 25% of these points for each plot were chosen as centres for vegetation samples. Sample sizes for plots 1 to 10 were 36, 25, 27, 37, 37, 27, 30, 24, 25 and 25 respectively. This sampling scheme covers approximately five percent of the total bird census plot area. Over all plots, a total of 293 vegetation samples were taken . These samples were measured after the bird breeding season. The circular plots were delimited by setting out two 22.6 m ropes in the cardinal directions so that their centres crossed at the point designated on the transect (FIG. 4).

Within the circular plot all trees with stems larger than 3 cm in diameter at breast height (dbh) were counted by species and placed in one of nine dbh size classes (see appendix B for size classes). All snags were also counted and placed in the same dbh classes. Snags were not identified by species but rather by stages of decomposition: partially dead, dead, loose bark, clean, broken bole, decomposed (Thomas *et al.*, 1979). When more than one class applied to the state of the snag, the most advanced one was chosen (most towards the decomposed stage). Snags considered were those taller than 1.3 m with dbh > 3 cm.

Understorey vegetation was sampled in two ways. First, saplings with a dbh of 3 to 8 cm were counted along with the trees and placed in the first size class. Second, shrub stems of a dbh < 3 cm and higher than one meter were counted in two 2 m wide transects oriented along the cardinal directions within the circular plot (FIG. 4). Counted stems included main stems and those that branched out beneath the one meter level. Coniferous and deciduous stems were tallied separately. The number of stumps were also counted with coniferous and deciduous stumps recorded separately. Stumps considered were those > 10 cm in diameter and < 1.4 m in height.

Foliage profile was measured at a series of 20 points along two axes oriented in the cardinal directions within the circular plot (FIGS. 4 and 5). The foliage profile represents vegetation cover from different layers within the forest. The profiles are measured by sighting through an ocular tube, made from a piece of plastic tubing with cross hairs at one end (Noon, 1981). The observer sights directly above each of the twenty locations and notes the presence or absence of green vegetation at the intersection point of the cross hairs within each layer considered: A) 0 - 0.5 m, B) 0.5 m - 3 m, C) 3 m - 10 m and D) >10 m (modified from Noon, 1981). The major modification that was made to this method was the manner in which the data was recorded. Instead of simply noting the presence (+) or absence (-) of vegetation, we recorded presence of vegetation as either deciduous (D), coniferous (C) or as ground layer vegetation (H - represented any plant species that would not grow out of the ground cover and was used only in the 0 - 0.5 m layer). Absence of vegetation was noted as (0).

Statistical Analysis

Principal Component Analysis and other multivariate statistical methods will be used to relate the distribution of the different bird species to measures of habitat structure and of habitat species composition. The habitat measures will be summarized into different sets of data to represent the habitat's physiognomy and the habitat's floristic composition. The distribution of birds will be analyzed in relation to variables representing the amount of basal area per tree species for all trees larger than 3 cm dbh. Also, this analysis will be repeated using variables of stem densities of snags, coniferous and deciduous trees of the different size classes shown in appendix B. The foliage profile data will also be analyzed separately. Thus, we will be examining the ordination of bird habitat selection in relation to two data sets that describe the habitat in a structural fashion and one data set that gives a description of the habitat's species composition.

The Arc/Info Geographic Information System (GIS) will be used as an alternative tool to analyze our data. The study plots and bird territories will be digitized into the FMF GIS database as spatial data. In keeping with our goal to test whether breeding birds species' distributions are related to habitat physiognomy and composition, we will examine how bird territories of different species are distributed within the existing forest stand classification. This stand classification is what forestry companies base their harvest plans on and this information is available for all the forest under their management. If trends in bird use can be identified using this stand classification, then the GIS may be considered for future use as a tool for predicting impacts of forest management on bird populations. However, if the forest classification system is demonstrated to contain information that is of poor quality to describe the distribution of birds then its modification for purposes of habitat management will be discussed.

Results of statistical analyses were not yet available at the time of writing this report.

RESULTS

Bird Census

During the entire bird census over the breeding seasons of 1993 and 1994, a total of 66 bird species were observed (english and scientific names of these species found in appendix C). Among these, 42 were determined as being breeding birds, having at least one territory within the study plots during one of the seasons. The 24 other species were either visitors from other habitats (Common nighthawk, Tree swallow, Chimney Swift, American Crow, Cedar Waxwing, Chestnut-sided Warbler and Brown-headed Cowbird) or forest birds that were either not breeding, breeding outside of the study plot, or breeding but not conspicuous due to low density, nocturnal or discreet behaviour, or due to an extremely large home range (American Woodcock, Ruffed Grouse, Broad-winged Hawk, Barred Owl, Ruby-throated Hummingbird, Pileated Woodpecker, Least Flycatcher, Common Raven, Gray Jay, Boreal Chickadee, Northern Waterthrush, Red Crossbill and American Goldfinch). Many of these species are non-passerine species that do not sing and are therefore not targeted by the census technique employed.

TABLES 2 and 3 summarize the number of territories and the calculated densities found for all breeding species over each plot for 1993 and 1994 respectively. The number of territorial individuals counted was 727 in 1993 and 695 in 1994. The total number of territories however was only 684 and 621 due to the fact that edge territories were counted as halves (0.5). There was a decline in the overall bird population during the second year of the study. As seen in FIG. 6, there was an average decline of 15% of population density on plots numbers one (1) to seven (7) for which we have two years of data. Values of species richness also seem to decline slightly during the second field season with the exception of plots one (1) and four (4) (TABLE 4).

DISCUSSION

The territory mapping method that we used has received a fair amount of criticism and one must be aware of its limitations. Best (1975), during an intensive study of field sparrows using catching and marking techniques, was able to compare the actual territories with those identified by the mapping technique only. Five experienced analysts, who where not involved in the field work, interpreted the species maps and gave estimates of absolute population sizes ranging from 8 to 13 breeding pairs. The actual number of pairs determined by the very intensive study of marked birds was 15. Sources of interpretational error identified by Best were: 1) territories of a pair whose activity was much less conspicuous than its neighbours was partitioned among adjacent territories; 2) territories located on the boundary were generally overlooked or joined to other territories; 3) territorial shifts following territory abandonment are generally not detected by the mapping method; and 4) very large territories were split between others due to lower density of observations. Best concluded that the mapping method tended to underestimate the absolute number of breeding birds. The magnitude of variation in the census results of Best's study were partly inherent to his own design plan and are not expected of all studies using this technique. Individuals analyzing the species maps all felt that firsthand experience with the field work would have enhanced their interpretation. Also, unmated male Field Sparrows tend to sing more than mated males. Moreover, his study plot was only 2.25 ha in size, a small fraction of the 40 to 100 ha minimum recommended by the I.B.C.C. (1970) for open habitats, thus increasing the proportion of edge territories.

Oelke (1981) also discusses the "serious limitations of evaluating bird territories by means of the mapping method". Oelke concurs with Best in that the method must be considered at best to be a good approximation of bird density. However, a study in which four observers of differing census experience are compared, O'Connor (1981) found that though more experienced observers had higher estimates of bird density, there was a high amount of concordance between the observers' estimates of population change over time. Bibby *et al.* (1992) also state that despite the limitations of the method, if standards are clearly enunciated and strictly adhered to, comparison to other studies and the tracking of population changes can be done with confidence.

I therefore believe that the design of this study is valid. Even though some territories could have been erroneously divided, the method will still tend to identify the area used as habitat by a particular bird species. And for the post-treatment studies following this one, adherence to the present methodology should give accurate estimates of population changes.

Vickery *et al.* (1992) studied territories of three co-occurring emberizine sparrows using the spot-mapping method. With use of a simple reproductive index, they discovered that a significant difference existed in the habitat selected between territories of known high reproductive success and of territories of known low success. Therefore, it would seem that more investigation is warranted for a better estimation of a species "quality" habitat. Although we did not invest more time towards more observation of reproductive success in our work, we believe that it will be necessary during the post-treatment portion of this study. Since it is evident that higher nest parasitism and higher nest predation as well as increased competition from forest-edge and open field species will occur in a fragmented habitat (Whitcomb *et al.*, 1981), monitoring of reproductive success in the buffer strips will be needed to accurately describe whether bird species are merely present or are capable of prospering in the modified habitat.

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APPENDIX A

Schedule of field work:

summer of 1993:

1st of May to 25th of May:

- localisation of study plots, flagging of transects and study plots no. 1 to 8 on Hayward Brook
- 4 surveyors.

26th of May to 10th of July:

- breeding bird surveys; eight plots surveyed six times.
- preparation of summary maps.
- 3 surveyors.

11th of July to 17th of August:

- vegetation surveys; 244 plots (0.04 ha).
- 4 surveyors.

summer of 1994:

6th of May to 16th of May:

- localisation of study plots, flagging of transects and study plots 9 and 10 on Holmes Brook.
- 4 surveyors.

28th of May to 4th of July:

- breeding bird surveys; nine plots surveyed six times (no. 8 dropped).
- preparation of summary maps.
- 4 surveyors.

5th of July to 16th of July:

- vegetation surveys; 50 plots (0.04 ha ea.).
- 3 surveyors.

APPENDIX B

I. Tree size classes based on diameter at breast height (Noon, 1981).

Class label	dbh range (cm)
S	3 £ dbh £ 8
A	8 < dbh £ 15
B	15 < dbh £ 23
C	23 < dbh £ 38
D	38 < dbh £ 53
E	53 < dbh £ 69
F	69 < dbh £ 84
G	84 < dbh £ 102
H	102 < dbh

APPENDIX C

List of all birds observed during the census.

English name	Scientific name	code
1 Sharp-shinned Hawk	*Accipiter striatus*	SSH
2 American Woodcock	*Scolopax minor*	AW
3 Ruffed Grouse	*Bonasa umbellus*	RG
4 Broad-winged Hawk	*Buteo platypterus*	BWH
5 Barred Owl	*Strix varia*	BO
6 Common Nighthawk	*Chordeiles minor*	CN
7 Ruby-throated Hummingbird	*Archilochus colubris*	RTH
8 Pileated Woodpecker	*Dryocopus pileatus*	PWd
9 Northern Flicker	*Colaptes auratus*	NF
10 Yellow-bellied Sapsucker	*Sphyrapicus varius*	YBS
11 Downy Woodpecker	*Picoides pubescens*	DWd
12 Hairy Woodpecker	*Picoides villosus*	HWd
13 Black-backed Woodpecker	*Picoides arcticus*	BBWd
14 Eastern Wood-Pewee	*Contopus virens*	EWP
15 Yellow-bellied Flycatcher	*Empidonax flaviventris*	YBF
16 Least Flycatcher	*Empidonax minimus*	LF
17 Tree Swallow	*Tachycineta bicolor*	TSw
18 Chimney Swift	*Chaetura pelagica*	CS
19 American Crow	*Corvus brachyrhynchos*	AC
20 Common Raven	*Corvus corax*	Rvn
21 Blue Jay	*Cyanocitta cristata*	BJ
22 Gray Jay	*Perisoreus canadensis*	GJ
23 Black-capped Chickadee	*Parus atricapillus*	BCC
24 Boreal Chickadee	*Parus hudsonicus*	BC
25 Red-breasted Nuthatch	*Sitta candensis*	RBN
26 Brown Creeper	*Certhia americana*	BCr
27 Winter Wren	*Troglodytes troglodytes*	WW
28 Ruby-crowned Kinglet	*Regulus calendula*	RCK
29 Golden-crowned Kinglet	*Regulus satrapa*	GCK
30 American Robin	*Turdus migratorius*	Rob
31 Swainson's Thrush	*Catharus ustulatus*	ST
32 Hermit Thrush	*Catharus guttatus*	HT
33 Veery	*Catharus fuscescens*	V
34 Cedar Waxwing	*Bombycilla cedrorum*	CWx
35 Red-eyed Vireo	*Vireo olivaceus*	REV
36 Philadelphia Vireo	*Vireo philadelphicus*	PhV

Appendix C (cont.)

English name	Scientific name	code
37 Solitary Vireo	*Vireo solitarius*	SV
38 Northern Parula	*Parula americana*	NP
39 Black-throated Green Warbler	*Dendroica virens*	BTG
40 Black-and-white Warbler	*Mniotilta varia*	BWW
41 Black-throated Blue Warbler	*Dendroica caerulescens*	BTB
42 Magnolia Warbler	*Dendroica magnolia*	MW
43 Yellow-rumped Warbler	*Dendroica coronata*	YRW
44 Canada Warbler	*Wilsonia canadensis*	CW
45 Chestnut-sided Warbler	*Dendroica pensylvanica*	CSW
46 Bay-breasted Warbler	*Dendroica castanea*	BBW
47 Blackburnian Warbler	*Dendroica fusca*	Bbn
48 American Redstart	*Setophaga ruticilla*	ARS
49 Palm Warbler	*Dendroica palmarum*	PM
50 Tennessee Warbler	*Vermivora peregrina*	TW
51 Nashville Warbler	*Vermivora ruficapilla*	NW
52 Mourning Warbler	*Oporornis philadelphia*	MoW
53 Common Yellowthroat	*Geothlypis trichas*	CYT
54 Northern Waterthrush	*Seiurus noveboracensis*	NWT
55 Ovenbird	*Seiurus aurocapillus*	OV
56 Brown-headed Cowbird	*Molothrus ater*	BHC
57 Scarlet Tanager	*Piranga olivacea*	ScT
58 Dark-eyed Junco	*Junco hyemalis*	DEJ
59 Red Crossbill	*Loxia curvirostra*	RC
60 White-winged Crossbill	*Loxia leucoptera*	WWC
61 Purple Finch	*Carpodacus purpureus*	PF
62 Evening Grosbeak	*Coccothraustes vespertinus*	EG
63 American Goldfinch	*Carduelis tristis*	AGF
64 Pine Siskin	*Carduelis pinus*	PS
65 Rose-breasted Grosbeak	*Pheucticus ludovicianus*	RBG
66 White-throated Sparrow	*Zonotrichia albicollis*	WTS

List of TABLES.

List of FIGS.

TABLE 1. Estimated percentage of total basal area of the six dominant tree species on each study plot for all trees larger than 3 cm dbh. The six dominant species contain at least 85% of the total basal area estimated of each plot.

Plot	1	2	3	4	5	6	7	8	9	10
species										
White Pine	38	28	9				2			11
Red Pine	6	5								
Jack Pine	7									
White Spruce				5		5			5	
Red Spruce	23	23	15	17	19	35	14	23	20	33
Black Spruce									19	19
Balsam Fir			12	20	12	15	29	25	9	11
Trembling Aspen	6	8	10	24	15	13	21	10	12	5
Largetooth Aspen					10			5		
White Birch		16	29	5	13	10	4	4		
Red Maple	9	12	19	23	18	19	27	26	21	11

TABLE 2. Results of breeding bird survey, 1993 field season. Columns topped by N show the total number of territories found on each plot. Columns topped by (100ha) indicate the density of birds calculated for 100 hectares.

	PLOT 1 (30 ha)		PLOT 2 (19.8 ha)		PLOT 3 (21 ha)		PLOT 4 (30 ha)	
BIRD SPECIES	N	(100 ha)	N	(100 ha)	N	(100 ha)	N	(100 ha)
1. Northern Flicker					1	5	1	3
2. Yellow-bellied Sapsucker	1	3	1	5	2	10	4	13
3. Downy Woodpecker							1	3
4. Hairy Woodpecker					1	5	1	3
5. Eastern Wood-Pewee							0.5	2
6. Yellow-bellied Flycatcher	5	17	1.5	8	4	19	5	17
7. Blue Jay					1	5		
8. Black-capped Chickadee	2	7	1.5	8	3	14	4	13
9. Red-breasted Nuthatch	3.5	12	3	15	1	5	3.5	12
10. Brown Creeper	4	13	2	10			1	3
11. Winter Wren	0.5	2			1	5	2.5	8
12. Ruby-crowned Kinglet	1	3					2	7
13. Golden-crowned Kinglet	5.5	18	3	15	2	10	3	10
14. American Robin					1.5	7	5	17
15. Swainson's Thrush	2	7	1	5	4	19	3.5	12
16. Hermit Thrush	0.5	2	2	10	1	5		
17. Veery					1.5	7	3.5	12
18. Red-eyed Vireo	2	7	0.5	3	2	10	5	17
19. Philadelphia Vireo								
20. Solitary Vireo	3.5	12	6	30	1	5	5	17
21. Northern Parula	1.5	5	3.5	18	5	24	5	17
22. Black-throated Green Warbler	2	7	2	10	2	10		
23. Black-and-white Warbler					3	14	6	20
24. Black-throated Blue Warbler	9	30	5	25	6.5	31	6.5	22
25. Magnolia Warbler	5	17	1	5	6.5	31	12	40
26. Yellow-rumped Warbler	5.5	18	4	20	3	14	2	7
27. Canada Warbler	2	7			1.5	7	8.5	28
28. Bay-breasted Warbler			1	5			2.5	8
29. Blackburnian Warbler	10	33	6.5	33	3	14	2	7
30. American Redstart					4	19	6	20
31. Tennessee Warbler								
32. Nashville Warbler	1	3						
33. Mourning Warbler								
34. Common Yellowthroat								
35. Ovenbird	7.5	25	5.5	28	4.5	21	7.5	25
36. Scarlet Tanager								
37. Dark-eyed Junco			1	5				
38. Purple Finch			1	5	1	5	2	7
39. Evening Grosbeak	1	3						
40. Pine Siskin								
41. Rose-breasted Grosbeak							4	13
42. White-throated Sparrow							2.5	8
TOTALS	75	250	52	263	67	319	117	390

TABLE 2. (cont.)

Species Code	PLOT 5 (30.5 ha) N	PLOT 5 (30.5 ha) (100 ha)	PLOT 6 (21 ha) N	PLOT 6 (21 ha) (100 ha)	PLOT 7 (24 ha) N	PLOT 7 (24 ha) (100 ha)	PLOT 8 (20 ha) N	PLOT 8 (20 ha) (100 ha)	TOTALS
1. NF			1	5	1	4	1	5	5
2. YBS	4	13	3	14	4	17	2	10	21
3. DWd									1
4. HWd					1	4	1	5	4
5. EWP	1	3			1	4	1	5	3.5
6. YBF	3	10	4	19	2	8	3	15	27.5
7. BJ	1	3	1	5			1	5	4
8. BCC	3	10	3	14	4.5	19	2.5	13	23.5
9. RBN	2	7	4	19	5	21	1	5	23
10. BCr	4	13	2	10			2	10	15
11. WW	1	3	3	14	3	13	2.5	13	13.5
12. RCK	1.5	5	1	5			3	15	8.5
13. GCK	4	13	7	33	1	4	2	10	27.5
14. Rob			1.5	7	3	13	2.5	13	13.5
15. ST	3	10	3	14	5	21	4	20	25.5
16. HT	1	3							4.5
17. V			1.5	7	3	13	2	10	11.5
18. REV	4	13	2	10	2	8	2	10	19.5
19. PhV	0.5	2							0.5
20. SV	7	23	3	14	5	21	2.5	13	33
21. NP	6	20	5	24	3	13	5.5	28	34.5
22. BTG	6	20	2	10	4	17			18
23. BWW	2	7	0.5	2	3.5	15	3.5	18	18.5
24. BTB	10	33	4.5	21	7	29	2.5	13	51
25. MW	10.5	34	7.5	36	11.5	48	6.5	33	60.5
26. YRW	4	13	1	5	1.5	6	2	10	23
27. CW	4	13	2.5	12	6	25	7	35	31.5
28. BBW	5	16	4	19	6.5	27	5.5	28	24.5
29. Bbn	4.5	15	5	24	2.5	10	3	15	36.5
30. ARS	1.5	5			5	21	2	10	18.5
31. TW					1	4			1
32. NW					1	4	1	5	3
33. MoW			0.5	2					0.5
34. CYT							1	5	1
35. OV	11	36	2.5	12	8	33	4.5	23	51
36. ScT	1	3			1	4			2
37. DEJ	1	3	1	5					3
38. PF	2	7					1	5	7
39. EG									1
40. PS									0
41. RBG					1	4	1	5	6
42. WTS	1	3	1	5	1.5	6	1	5	7
TOTALS	109.5	359	77	367	104.5	435	82	410	684

TABLE 3. Results of breeding bird survey, 1994 field season. Columns topped by N show the total number of territories found on each plot. Columns topped by (100ha) indicate the density of birds calculated for 100 hectares.

	PLOT 1 (30 ha)		PLOT 2 (19 ha)		PLOT 3 (21 ha)		PLOT 4 (30 ha)		PLOT 5 (30 ha)	
BIRD SPECIES	N	(100 ha)	N	(100 ha)	N	(100 ha)	N	(100 ha)	N	(100 ha)
1. Northern Flicker							0.5	2	1	3
2. Yellow-bellied Sapsucker							4	13	4	13
3. Downy Woodpecker										
4. Hairy Woodpecker							1	3	1	3
5. Eastern Wood-Pewee			2	10			1	3	1	3
6. Yellow-bellied Flycatcher	3	10	1	5	3	14	3	10	3	10
7. Blue Jay										
8. Black-capped Chickadee	3.5	12			3	14	3	10	4	13
9. Red-breasted Nuthatch	1	3	1	5	2	10	2	7	1	3
10. Brown Creeper	3	10	1.5	8	1	5	3	10	1	3
11. Winter Wren	0.5	2			1	5	2	7		
12. Ruby-crowned Kinglet	2.5	8	0.5	3						
13. Golden-crowned Kinglet	6	20	3	15	2	10	2.5	8	3	10
14. American Robin					2	10	2	7	1	3
15. Swainson's Thrush	3	10	1	5	3	14	4	13	3	10
16. Hermit Thrush	1	3					1	3	1	3
17. Veery					1	5	2	7		
18. Red-eyed Vireo	1	3	0.5	3	2	10	3.5	12	1	3
19. Philadelphia Vireo										
20. Solitary Vireo	2	7	2	10	2.5	12	3	10	4.5	15
21. Northern Parula	3	10	2	10	7	33	5	17	7	23
22. Black-throated Green Warbler	0.5	2	1.5	8	2.5	12	1	3	4	13
23. Black-and-white Warbler					3	14	4	13		
24. Black-throated Blue Warbler	6	20	4	20	8	38	5.5	18	9	30
25. Magnolia Warbler	4.5	15	1	5	5.5	26	9	30	9	30
26. Yellow-rumped Warbler	2.5	8	1.5	8	1	5	1	3	2	7
27. Canada Warbler	2	7			1.5	7	6.5	22	2	7
28. Bay-breasted Warbler	4	13	1.5	8	2.5	12	8.5	28	5	16
29. Blackburnian Warbler	8	27	5	25	4	19	2	7	6	20
30. American Redstart	1	3	0.5	3	0.5	2	5.5	18	2	7
31. Tennessee Warbler					1	5	0.5	2		
32. Nashville Warbler	1	3					0.5	2	1	3
33. Mourning Warbler										
34. Common Yellowthroat										
35. Ovenbird	7.5	25	3.5	18	4	19	5	17	9.5	31
36. Scarlet Tanager										
37. Dark-eyed Junco	1	3								
38. Purple Finch	1	3								
39. Evening Grosbeak	2	7								
40. Pine Siskin	1	3								
41. Rose-breasted Grosbeak							2	7	1	3
42. White-throated Sparrow							3	10	1	3
TOTALS	71.5	238	33	167	63	300	96.5	322	88	289

TABLE 3. (cont.)

	PLOT 6 (21 ha)		PLOT 7 (24 ha)		PLOT 9 (19.5 ha)		PLOT 10 (19.5 ha)		
Species Code	N	(100 ha)	N	(100 ha)	N	(100 ha)	N	(100 ha)	TOTALS
1. NF									1.5
2. YBS	3	14	2.5	10	3	15	2	10	18.5
3. DWd							1	5	1
4. HWd									2
5. EWP			3	13					7
6. YBF	3	14	3	13	3	15	3.5	18	25.5
7. BJ									0
8. BCC	2	10	3	13	1.5	8			20
9. RBN	1	5	3	13	2	10	1	5	14
10. BCr	2	10	1.5	6	1.5	8	1.5	8	16
11. WW	3	14	0.5	2			1	5	8
12. RCK					1	5	1.5	8	5.5
13. GCK	4	19	4	17	2.5	13	3	15	30
14. Rob	2	10	3	13	1.5	8			11.5
15. ST	2.5	12	5	21	1	5	3	15	25.5
16. HT					1	5	1	5	5
17. V			4	17	1	5			8
18. REV			2	8					10
19. PhV									0
20. SV	3	14	3	13	1	5	2	10	23
21. NP	3.5	17	6	25	1.5	8	3	15	38
22. BTG	3	14	3	13					15.5
23. BWW	0.5	2	2.5	10	1	5	2	10	13
24. BTB	6.5	31	6.5	27	7.5	38	3.5	18	56.5
25. MW	7	33	10	42	7	36	6	31	59
26. YRW	1	5	1	4	2	10	1	5	13
27. CW	0.5	2	6.5	27	5	26	2	10	26
28. BBW	4	19	8.5	35	1.5	8	2	10	37.5
29. Bbn	7.5	36	2.5	10	4	21	3.5	18	42.5
30. ARS			2.5	10					12
31. TW					2	10			3.5
32. NW			1	4	2.5	13	1.5	8	7.5
33. MoW									0
34. CYT									0
35. OV	2	10	3	13	5.5	28	3	15	43
36. ScT									0
37. DEJ	1	5			0.5	3			2.5
38. PF	0.5	2	1	4					2.5
39. EG			1.5	6			1	5	4.5
40. PS	1	5							2
41. RBG									3
42. WTS	0.5	2	1.5	6			1.5	8	7.5
TOTALS	64	305	94.5	394	60	308	50.5	259	621

TABLE 4. Area of study plots with values for density of breeding territories and bird species richness and diversity (H'). Values for 1993 and 1994 are in first and second rows respectively. Years for which no data was obtained are indicated by "---".

Plot #	area (ha)	density/100 ha	richness	diversity
1	30	250	22	1.22
		238	26	1.30
2	19.75	263	20	1.20
		167	18	1.17
3	21	319	26	1.32
		300	23	1.27
4	30	390	30	1.38
		322	31	1.39
5	30.5	359	30	1.36
		289	27	1.30
6	21	367	28	1.36
		305	24	1.27
7	24	435	30	1.37
		394	28	1.36
8	20	410	32	1.43
		---	---	---
9	19.5	---	---	---
		308	24	1.27
10	19.5	---	---	---
		259	23	1.30

TABLE X. Chi-square analysis on frequency of occurrence of breeding territories within particular forest stand types for 1993 and 1994 (portions less than 5% of territory area were ignored). Assuming territories were distributed evenly among stand types, expected frequencies were based on total area of each stand type. Values of partial Chi-squares are represented by signs: "+", "++" and "+++" indicated partial Chi-squares greater than one seventh the critical value of Chi² (d.f. 6), greater than one half the cri. val. Chi² (d.f. 6) and greater than the cri. val. Chi² (d.f. 6). Other signs, "-", "--", "---" represent the same values and are used were observed frequencies are less than expected frequencies.

1993 Stand type(s)	IHTH/ THIH	INHW	IHSP	SPIH	SPTH/ THSP	SPBF	PINE		
area (ha)	31.6	19.3	39.9	23.6	30.6	23.2	24.7	no.	
Species								observ.	signific.
Yellow-bellied Sapsucker							-	63	
Yellow-bellied Flycatcher	--	-			+			55	*
Black-capped Chickadee	+				+		-	58	
Red-breasted Nuthatch								78	
Golden-crowned Kinglet	-						+	63	
Swainson's Thrush				-	+			64	
Solitary Vireo		+						70	
Northern Parula		+			+		-	77	near
Black-throated Blue Warbler	---	+	+		+	-		101	***
Magnolia Warbler	+				+		-	142	*
Canada Warbler	++	-					-	72	**
Bay-breasted Warbler	+			-			--	53	*
Blackburnian Warbler						--	++	78	**
Ovenbird		++		-		--		125	**

1994 Stand type(s)	IHTH/ THIH	INHW	IHSP	SPIH	SPTH/ THSP	SPBF	PINE		
area (ha)	29.1	21.4	45.1	21.5	40.3	24.2	27.2	no.	
Species								observ.	signific.
Yellow-bellied Sapsucker				-	+		-	53	*
Yellow-bellied Flycatcher		-						63	
Black-capped Chickadee	+							55	near
Golden-crowned Kinglet								72	
Swainson's Thrush								71	
Solitary Vireo	+			-			-	63	
Northern Parula		+		-	+			89	
Black-throated Blue Warbler	+	+	+		---			108	***
Magnolia Warbler	++	-		-	+		-	138	***
Canada Warbler	+++	-				-		68	***
Bay-breasted Warbler	++						-	91	**
Blackburnian Warbler	-						+	102	
Ovenbird		+						98	

significance levels "near", "*", "**" and "***" represent p-values: $0.05 < p < 0.10$, $0.01 < p < 0.05$, $0.001 < p < 0.01$, $p < 0.001$.

TABLE X. Chi-square analysis on frequency of occurrence of breeding territories within particular forest stand types for 1993 and 1994 combined (portions less than 5% of territory area were ignored). Assuming territories were distributed evenly among stand types, expected frequencies were based on total area of each stand type. Values of partial Chi-squares are represented by signs: "+", "++" and "+++" indicated partial Chi-squares greater than one seventh the critical value of Chi² (d.f. 6), greater than one half the cri. val. Chi² (d.f. 6) and greater than the cri. val. Chi² (d.f. 6). Other signs, "-", "--", "---" represent the same values and are used were observed frequencies are less than expected frequencies.

1993+1994	Stand type(s)	IHTH/ THIH	INHW	IHSP	SPIH	SPTH/ THSP	SPBF	PINE		
	area (ha)	60.7	40.7	85.1	45.1	70.9	47.4	51.9	no.	
Species									observ.	signific.
Yellow-bellied Sapsucker		+			-	+		--	116	**
Yellow-bellied Flycatcher			-			+			118	near
Black-capped Chickadee		++			-	+		-	113	**
Red-breasted Nuthatch									94	
Brown Creeper								++	82	near
Winter Wren			-				+	-	51	*
Golden-crowned Kinglet								+	135	
Swainson's Thrush					-				135	
Veery		+++	-		-	++	-	--	55	***
Red-eyed Vireo			+					-	48	near
Solitary Vireo		+	+		-			-	133	**
Northern Parula			+		-	+		-	166	**
Black-throated Green Warbler			+		-	+	-	-	83	**
Black-and-white Warbler		+			-			-	59	*
Black-throated Blue Warbler			++	+		-			209	**
Magnolia Warbler		+++	-		-	++		--	280	***
Yellow-rumped Warbler						-		+	68	
Canada Warbler		+++	-		-	+		-	140	***
Bay-breasted Warbler		+++			-			--	144	***
Blackburnian Warbler		-					-	++	180	**
American Redstart		+++			-		-	--	64	***
Ovenbird		+	++		-		--		223	***
all sp. 1993		++	+		--	++		---	1565	***
all sp. 1994		+++	-		---	+		--	1471.0	***
all sp. 1993 + 1994		+++			---	++		---	3036	***

significance levels "near", "*", "**" and "***" represent p-values: $0.05 < p < 0.10$, $0.01 < p < 0.05$, $0.001 < p < 0.01$, $p < 0.001$.

TABLE X. Classification of bird species with respect to association with stream, based on mean territory density (territories per 10 ha) in five zones at different distances from stream. Data from 10 plots, 1993 and 1994, combined (total of 17 plots). Zone 1 is a 60 m wide strip centred on the stream and zones 2 to 5 consist of the area on both sides of the stream within the following ranges: 30 m - 60 m; 60 m - 90 m; 90 m - 120 m; 120 m - 150 m.

Species	1	2	3	4	5	Total no. of territories	No. plots where species occurred
Associated with stream edge							
Yellow-bellied Sapsucker	1.22	1.18	1.09	0.98	0.71	36.2	14
Yellow-bellied Flycatcher	1.87	1.63	1.30	0.94	0.56	52.0	17
Brown Creeper	0.94	0.88	0.85	0.78	0.59	30.4	15
Winter Wren	1.10	0.91	0.68	0.44	0.28	20.9	13
Golden-crowned Kinglet	1.61	1.57	1.39	1.29	0.87	56.1	17
American Robin	1.32	1.14	0.96	0.65	0.38	23.6	11
Swainson's Thrush	1.47	1.44	1.33	1.11	0.82	51.2	17
Veery	0.97	0.96	0.83	0.66	0.46	19.0	10
Solitary Vireo	1.65	1.51	1.34	1.05	0.74	53.3	17
Canada Warbler	2.08	1.58	1.30	1.30	1.08	55.2	15
Bay-breasted Warbler	2.50	1.98	1.51	1.23	0.97	61.4	15
Blackburnian Warbler	2.06	2.05	2.01	1.86	1.40	77.6	17
Purple Finch	0.60	0.77	0.47	0.35	0.21	9.7	8
Rose-breasted Grosbeak	0.96	0.54	0.41	0.43	0.30	10.5	7
Associated with forest-interior							
Black-throated Blue Warbler	1.53	2.14	2.88	3.29	2.74	106.7	17
Ovenbird	0.65	1.51	2.49	3.23	3.14	96.8	17
Undetermined association							
Eastern Wood-Pewee	0.56	0.63	0.54	0.43	0.41	10.2	8
Black-capped Chickadee	1.08	1.29	1.30	1.13	0.78	42.2	15
Red-breasted Nuthatch	0.80	0.97	0.94	0.82	0.59	34.3	17
Ruby-crowned Kinglet	0.52	0.69	0.68	0.68	0.48	15.1	10
Hermit Thrush	0.24	0.36	0.62	0.64	0.38	9.9	9
Red-eyed Vireo	0.75	0.63	0.73	0.89	0.77	27.8	14
Northern Parula	1.84	1.92	1.90	1.70	1.18	70.8	17
Black-throated Green Warbler	1.04	1.20	1.15	0.99	0.83	33.9	13
Black-and-white Warbler	0.78	0.99	1.26	1.25	0.99	31.4	12
Magnolia Warbler	2.55	2.89	3.11	2.97	2.20	116.4	17
Yellow-rumped Warbler	0.57	0.73	0.97	1.21	0.85	36.8	17
American Redstart	0.82	1.00	1.07	1.05	0.94	31.2	12
Nashville Warbler	0.32	0.54	0.63	0.61	0.44	10.8	9
White-throated Sparrow	0.60	0.56	0.61	0.57	0.59	13.5	9

Appendix 2: Annual report (1994-95) on the study of cavity nesting birds at Hayward Brook Watershed Study.

Cavity-nest research at Hayward and Holmes Brooks Study Area - Fundy Model Forest

Thesis description and report (Fall 1994)

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INTRODUCTION

A major goal of the Fundy Model Forest (FMF) is to improve forest ecosystem management by incorporating many aspects of wildlife habitat management. Consequently, a series of research projects have been undertaken to learn more about the responses of wildlife to changes in forest structure, age and composition caused by harvesting. This research project identifies the requirements of cavity-nesting birds species in the FMF. Objectives of the project are to gain greater knowledge on the nesting habitat requirements of cavity-nesters and to apply these findings to the improvement of provincial forest management guidelines. Current commercial forest and snag management guidelines in New Brunswick are based on inadequate knowledge of the habitat requirements of cavity-nesters. The only guideline presently followed is an encouraged retention of 7 snags/ha of harvested forest. There are no specifications concerning species, sizes, conditions or emplacement of snags to be retained during commercial harvesting operations.

The choice of location for this study was determined by other research projects already underway in the Hayward and Holmes Brooks drainage basins. Cavity search and other field work was done on and around the breeding bird survey plots established by Haché (unpubl. data) in 1993 and 1994. The plots are part of the Riparian Zone Buffer Management project examining the effect of buffer strip width on water quality and wildlife use. Haché utilized these plots for his predisturbance study on the relative abundance of breeding bird species residing in riparian zones of a mature second growth Acadian forest.

Breeding birds making extensive use of tree cavities are divided into two groups: primary cavity-nesters and secondary cavity-nesters. Both groups use cavities in trees for nesting and roosting. Primary cavity-nesters, such as woodpeckers, excavate the cavities they utilize. Secondary cavity-nesters, such as nuthatches or chickadees, use naturally occurring cavities or abandoned cavities excavated by primary cavity-nesters. They will on occasion excavate cavities in very decayed wood. This two year research project will concentrate on the nesting microhabitats of the cavity-nesters found in the Hayward and Holmes Brooks drainage basins and will attempt to quantify primary and secondary cavity-nesting microhabitat. A second project, conducted in conjunction with this one and scheduled to begin in 1995, will measure the impact of timber harvest interventions on cavity-nesters. The data and ensuing results of these two projects and all other research projects of the FMF will contribute modifications to New Brunswick forest management guidelines. Modified guidelines might be used, for example, to ensure the retention and development of suitable forest habitat capable of maintaining healthy populations of cavity-nesting birds.

The study of cavity-nester habitat is not new although its importance has increased with the important role of snags in forest ecosystems. Many research projects have dealt with various aspects of cavity-nesting bird ecology. Nesting habitat requirements (Conner et al. 1975, Conner and Adkisson 1977, Li and Martin 1991), foraging habitat selection (Kilham 1970, Conner and Crawford 1974, Conner 1981), and effects of habitat modification (Galli et al. 1976, Zarnowitz and Manuwal 1985, Stribling et al. 1990) are but some of the aspects of cavity-nesters that have been and that are presently being studied. Most research in North America has been in the United States, although suprisingly little from the northeastern part of the continent. Very few studies of cavity-nesters have been conducted in the Atlantic provinces of Canada. Cavity-nesters have different nesting habitat search images depending on forest type and composition, as well as geographical location (Lundquist and Mariani 1991). Nesting habitat requirements for cavity-nesters in southern New Brunswick, for instance, may differ greatly from those of similar birds located elsewhere on the continent . It is thus of prime importance to quantify the nesting habitat utilization of cavity-nesters in New Brunswick to ensure the proper management of these birds in the Acadian forest.

METHODS

Study site

The study site is located in the Hayward and Holmes Brooks drainage basins, situated approximately 7 km south of the village of Petitcodiac, New Brunswick. The area of land encompassing the drainage basins is freehold of J.D. Irving Ltd. Elevations on the study sites vary between 200 and 500 m.

Preliminary analysis of vegetation surveys done by Haché show that the forest in the study area is composed of 6 dominant tree species: Red Spruce, Red Maple, Balsam Fir, Trembling Aspen, White Pine and White Birch. Each study plot had different combinations of these tree species. A more detailed description of the forest composition can be found in Haché's update report. The plots where cavity searches were focused are located along eight first order streams (Fig. 1). These plots, centered on the streams, are 300 m wide and vary in size from 20 ha to 30 ha. Plots 1 through 7 are situated near their stream junction with Hayward Brook. Plot 8 is located farther upstream due to the proximity of power lines to its stream junction with Hayward Brook. Plots 9 and 10 are situated on the upper main branch of Holmes Brook.

Cavity searches

A preliminary season of cavity searching was conducted during the 1993 field season. Active cavity nests (cavities nested in during that reproductive season) were located during breeding bird surveys. Active cavity-nests were identified with flagging tape and were mapped for future reference. No records on the cavity-nester breeding chronology were kept.

The first season of extensive cavity searching began in 1994. Cavity searches began on 11 May and were concluded on 4 July (most chicks were fledged at this time). Cavity searching was impeded from 28 May to 4 July field personnel were occupied with breeding bird censuses. Furthermore, cavity searches were mostly confined to the breeding bird survey plots during this period. Cavity searches were conducted from approximately 0600 until 1100. The forest habitat adjacent to the breeding bird survey plots was also searched for evidence of cavity-nester breeding behaviour (i.e. courtship rituals, drumming, conflicts, excavation,etc). Piles of wood chips or coarse sawdust at the bottom of some trees also helped locating fresh excavations. Cavity searches were not carried out during rainy or exceptionally windy days. Trees with active cavities were flagged and mapped as in 1993. Regular visits were conducted at 4 to 5 day intervals to determine general breeding chronology and presence of predation. 1993 cavity locations were also examined to determine degree of cavity and cavity-tree re-use.

Nest-tree and microhabitat sampling

The microhabitat around nest-trees was sampled with 11.3 m radius (0.04 ha) circular plots centred on the cavity-trees. The choice of plot size was influenced by other studies (Li and Martin 1991 and others). The circular plots are delimited by 4 22.6 m ropes, two in primary cardinal directions (North-South, East-West) and two in secondary cardinal directions (Northeast-Southwest, Northwest-Southeast). All trees and snags with stems larger than 8 cm diameter at breast height (dbh) were measured and mapped on sampling plot data sheets. This mapping gives a spatial distribution of trees and snags found within each microhabitat sample plot. Trees were identified by species, while snags were identified by type (coniferous or deciduous) and by decomposition stage (see Hunter 1990 for decomposition stage classification) .

Foliage profile was measured at a series of 22 points set along each of the four axes (ropes) for a total of 88 sample points per plot. Profiles were measured by looking through an ocular tube with cross hairs at one end (Noon 1981). Sighting directly above each point, the observer noted presence or absence of live vegetation at the cross hairs intersection for 4 different height strata: 1 - 2 m, 2 - 4 m, 4 - 8 m, 8 m and higher. Presence or absence of live vegetation by height strata was recorded as deciduous (D), coniferous (C) or absent (0) (Haché, unplub. data). As with trees and snags, foliage profile was mapped on data sheets. This was done to give an approximate view of spatial foliage distribution over each microhabitat sample plot. All nest-tree measurements and microhabitat sampling were preformed after fledging so not to interfere with reproductive activities.

An equal number of possible cavity-trees have been selected randomly on the study site. Descriptions and measurements of these randomly selected trees and their surrounding microhabitat will be conducted to search for differences between selected nest sites and apparently potential nest sites that were not selected. Random sites were chosen using a dot gridover a forest cover map (approx. scale 1 : 12 500). One tree on each of these random sites was randomly chosen to match an actual cavity-tree found during cavity searches. Random trees matched to live trees had to be of the same genus (for aspen) or species (for all other tree species) and of same dbh (± 5 cm when possible). Random trees matched to dead or further decayed trees (snags) had to be of the same decomposition stage and dbh (± 5 cm when possible). Some of the very large trees and snags used as cavity substrate were difficult to match because of their rarity, causing selection of smaller random trees and snags. Unfortunately, due to insufficient time allocation, random tree and corresponding microhabitat measurements could not be completed during the 1994 field season.

Statistical analysis

Principal component analysis will be used to quantify the nesting habitat of cavity-nesters found within the Hayward and Holmes Brooks drainage basins. Exact choice of statistical tests and database formats are still being resolved at the present time. The Arc/Info Geographic Information System (GIS) will also be utilized to analyze data. Nesting-cavity locations will be digitized into the FMF GIS and will be matched to the existing forest stand classification. Haché's digitized data for habitat use by breeding birds could also be of value in describing cavity-nester nesting habitat on a broader scale. Results of statistical analysis are not available at this time.

RESULTS

A total of 87 active cavities (30 from 1993 and 57 from 1994) from 7 cavity-nester species were found (Fig. 2). The Yellow-bellied Sapsucker was the most common species. The Black-capped Chickadee was removedfrom analyses because of low sample size. The Winter Wren, a facultative cavity-nester, and the Brown Creeper, a bark cavity-nester, were difficult to locate and will not be considered in the context of this study.

Trembling Aspen was the tree species most ferquently used by cavity-nesters (Fig. 3). All primary cavity-nesters used Trembling Aspen or Large-toothed Aspen as nest-trees. All other tree species (1 deciduous, 4 coniferous) chosen as nest-trees were solely used by secondary cavity-nesters. Secondary-cavity nesters also chose decaying Trembling Aspen as nest-trees. Primary cavity-nesters appeared to choose nest-trees in better condition than trees chosen by secondary cavity-nesters (Fig. 4). Primary cavity-nesters that chose dead or further decomposed nest-trees were Downy Woodpeckers and Northern Flickers. Secondary cavity-nesters appeared to choose nest-trees in more advanced stages of decomposition. Partially dead trees used by secondary cavity-nesters had dead tops where the cavities were located.

Results on microhabitat characteristics are not yet available.

DISCUSSION

Yellow-bellied Sapsucker

All Yellow-bellied Sapsucker cavities were found to be in Trembling Aspen. Since much of the study area contains rather large trees (25 to 45 cm dbh) of this species, it appears to be excellent habitat for this species of woodpecker. Yellow-bellied Sapsuckers to often nest in Trembling Aspen in the northeastern United States (Kilham 1971). Yellow-bellied Sapsucker breeding behaviour was conspicuous through most of the field season compared with other cavity-nesters. Sapsuckers frequently responded to imitations of its drumming pattern. Cavity searches may have begun too late to detect cavities of some species of cavity-nesters. Kilham (1968) has shown that Hairy Woodpeckers in New Hampshire start incubating in early May and fledge young by early June. Some species might be rarer than others because of large territory size (i.e. Pileated Woodpecker) or because of lack of suitable nesting habitat.

Importance of Trembling Aspen

The importance of Aspen as cavity-nest substrate is apparent. Forest management plans should encourage retention of Aspen trees of various sizes and in various stages of decomposition to ensure sufficient numbers of potential cavity-trees. Other trees were also used as cavity excavating substrate, but no trends are apparent at the present time. No data has yet been gathered on the behaviour and habitat preferences linked to foraging activities. This could be the object of further research.

Grouping cavity-nesters for analysis

Because of low sample size for most cavity-nesters, it may be advisable to group them into two categories: hard substrate nesters (Yellow-bellied Sapsuckers, Hairy Woodpeckers and Pileated Woodpeckers), and soft substrate nesters (Red-breasted Nuthatches, Downy Woodpeckers, and Northern Flickers). This would increase sample size and may simplify certain statistical analyses. Species by species analysis could also be carried out if deemed necessary. As stated in the results, Black-capped chickadees will be eliminated from analysis because of small sample size and because this species does not fall into one of the two prementionned categories (it would be considered a decayed substrate nester).

CONCLUSION

With limite breeding bird censuses planned for 1995 (year of intervention), more time will be allocated to cavity searches and to other field work associated with this project. This should increase the location of more cavities and allow the completion of microhabitat sampling before the end of the 1995 field season.

Preliminary data analysis will be continued through the winter along with the required course work. Feeding behaviour of the Hairy Woodpecker and Downy Woodpecker will be compared from literary sources as requirement for fall coursework supervised by Dr. Louis Lapierre. Part of the data gathered during the 1994 season will be analyzed, presently orally and written up as a mock scientific article as coursework supervised by Dr. Stépahn Reebs. Random tree locations are almost completed and are ready to be GPSed in November and to be sampled early next summer.

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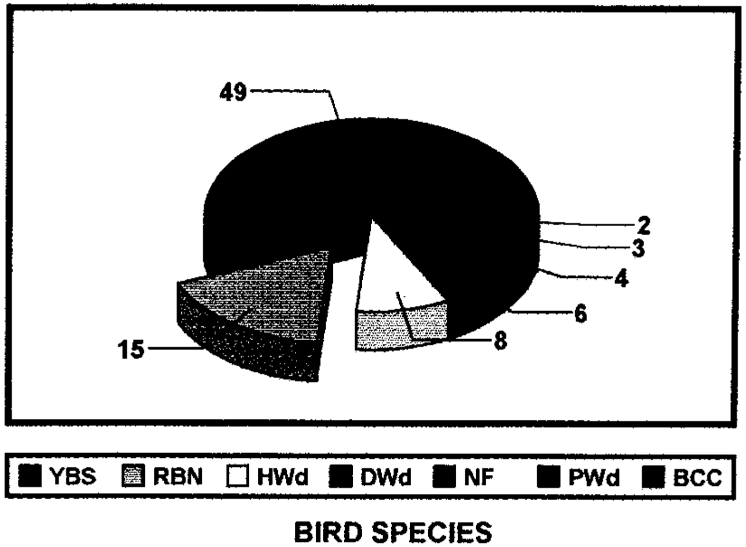
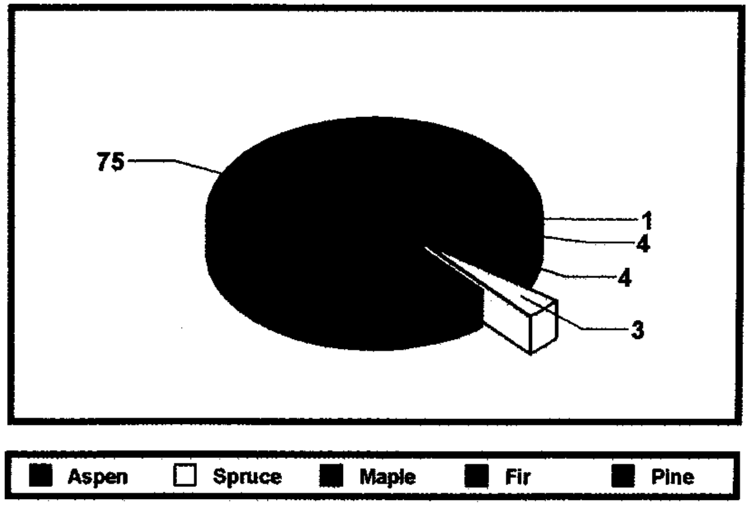
DISTRIBUTION OF CAVITIES BY SPECIES
(n= 87; 1993 & 1994)



TREES USED FOR CAVITIES
(1993 and 1994; n= 87)



CAVITY TREE SPECIES

study area. The universe will include information from numerous sources and will be aimed at providing links to the landscape and water resources. The project will be taken on by Ms. Michelle Poirer, a geography student at Université de Moncton. The product will be credited towards Michelle's degre and will provide a required on site database to establish linkages with other ongoing research.

Appendix 3: Annual report (1994-95) on the study of small mammals at Hayward Brook Watershed Study (this report includes results from 1993-94; 1994-95 specimen material being analysed at Acadia University; methods similar to 1994; on schedule).

THE INFLUENCE OF RIPARIAN CORRIDORS ON THE SPATIAL DISTRIBUTION OF SMALL MAMMALS IN HAYWARD BROOK

By

Andrew Boyne

A thesis submitted to the Biology Department,
Mount Allison University,
in partial fulfillment of the requirements for the
Bachelor of Science degree with Honours in Biology
May, 1994.

Abstract

Small mammals were trapped from August 20 to September 21, 1993, in plots encompassing the riparian corridors of seven small feeder streams of the Hayward Brook, New Brunswick. It was expected that riparian corridors would influence the distribution of small mammals because of the increased habitat patchiness caused by streams in forest ecosystems. Eight species of small mammals were caught; *Clethrionomys gapperi*, *Peromyscus maniculatus*, *Sorex cinereus*, *Napaeozapus insignis*, *Sorex fumeus*, *Blarina brevicauda*, *Zapus hudsonius* and *Sorex palustrus*. *C. gapperi* was the most abundant species in all eight plots and the number trapped increased with distance away from the stream in three of the eight plots. Forty percent of the *N. insignis* were trapped in one plot (#3) and they were concentrated along the stream. This plot was dominated by a relatively young stand of balsam fir (*Abies balsamea*). *C. gapperi* was associated with trap sites with fewer logs and ground cover with less deciduous leaves and bare ground

and more grasses. There were no trends away from the stream for any of these habitat features so they could not account for the trends. Competition also could not account for the spatial distribution of *C. gapperi*, but *N. insignis* was negatively correlated with high numbers of *C. gapperi*. Most of the habitat features and small mammals in the riparian corridors of Hayward Brook appeared to be distributed randomly, possibly because the riparian corridors in this study were narrow, thus their influence was minimal.

Acknowledgements

I would like to recognize Dr. Jim Gallivan to whom I owe thanks for providing me with the opportunity to complete my honours thesis. When I arrived in September it was only through luck and Dr. Gallivan's graciousness that I was able to acquire both a supervisor and a topic. His knowledge and experience were invaluable as my knowledge and experience alone could never have carried me through the year. I would also like to thank Gerry Parker and the Canadian Wildlife Service who trapped the small mammals and who trusted me to work on the study. Without the help of these two individuals this project would not have occurred. I would also like to thank my committee, Dr. J.-G. Godin and Gay Hanson for their patience in waiting for my draft and for their helpful comments.

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Introduction

A habitat is defined as a region in which a combination of unique biotic and abiotic features, such as forest type and soil composition, separate it from surrounding areas (Morris, 1987; Danielson, 1991). There have been many studies documenting habitat preference and habitat segregation in small mammals (Miller and Getz, 1977; Dueser and Shugart, 1978; Morris, 1979; Vickery, 1980; Vickery *et al.*, 1989; Drickamer, 1990). These studies indicate that different species of small mammals have specific habitat preferences, which result in microhabitat segregation between species. Due to species-specific habitat preferences, superior habitats will maintain higher densities of a given species (Morris, 1987).

There have been two opposing theories presented that attempt to explain species differences in habitat preference (Borcard *et al.*, 1992). The first is the environmental control model which proposes that environmental or abiotic factors are responsible for the variation in spatial distribution of species between and within habitats. The second model is the biotic control model which proposes that variations in the spatial distribution of species are caused by biotic factors such as competition (Dueser and Hallett, 1980) and predation.

Environmental patterning is the non-uniform distribution of environmental factors (Addicott *et al.*, 1987), and the reaction of species to environmental patterning has become an important topic of ecological research. Small mammals are influenced by the patchiness of their environment (DeGraff *et al.*, 1991). A patch is a region that contains only one type of habitat (Danielson, 1991). Patches and environmental patterning are species defined, because it is the species who perceive patches, not the investigator. Smaller species with shorter life spans will respond to environmental and patch variations on a smaller spatial scale than larger species because large species are buffered from smaller changes by their size (Wiens, 1976).

Riparian corridors, which occupy the region from the high water mark of streambeds up to the point where the vegetation no longer is affected by the stream (Naiman *et al.*, 1993), increase the patchiness of forest ecosystems. The size, structure and vegetation of the riparian corridor are determined by many factors, including the gradient, altitude, size, topography, soil, type of stream bottom and water source of the stream (Thomas, 1979). Smaller rivers, like those embedded in forests, have narrow riparian zones, while larger rivers have wider riparian zones (Naiman *et al.*, 1993). Riparian corridors are one of the most diverse, dynamic and complex terrestrial environments (Thomas, 1979; Croonquist and Brooks, 1991; Naiman *et al.*, 1993). Unique patches of flora, microclimate fluctuations, increases in the availability of water and nutrients, and small scale fluctuations in stream flow all result in an increase in habitat patchiness and environmental patterning. Plants which are limited by the availability of water and nutrients in adjacent forests may flourish in the riparian corridor, and it has been suggested that wildlife use riparian corridors significantly more than other surrounding areas. Of the 378 species of terrestrial vertebrates and invertebrates inhabiting the Blue Mountains of Oregon, 285 are either dependent on the riparian corridors or use them more than other habitats (Thomas, 1979) and Naiman *et al.* (1993) suggested that more than 70% of vertebrates in any given region make significant use of riparian zones during their life.

Doyle (1990), in the only paper specifically on small mammals in riparian habitats, suggested that the diversity of small mammal species is greater in riparian habitats than in upland habitats. Possible reasons for the increased use of riparian zones included: higher densities of invertebrates and deciduous shrubs, fruits and herbs which are the food sources for insectivores and herbivores, cooler and more consistent temperatures which would decrease the energetic cost of thermoregulation, and moister soils which facilitates burrowing. However, the spatial distribution of small mammals may not be due to the riparian corridor per se, but to other features associated with the latter. Small mammals are often associated with decaying logs, exposed roots, old stumps, woody and non-woody debris and ground cover (Morris, 1955; Getz, 1961; Brower and Cade, 1966; Whitaker and Wrigley, 1972; Banfield, 1974; Hayes and Cross, 1987; Drickamer, 1990; DeGraff *et al*., 1991; Tallmon and Mills, 1994). These provide possible nest sites, refuges from predators and cooler microclimates for small mammals. Decaying logs and other woody debris have an abundance of invertebrates and mycorrhizal fungi, which are common food sources of small mammals (Getz, 1966; Merritt, 1981; Tallmon and Mills, 1994).

The objectives of this study were to describe the spatial distribution of small mammals within the riparian corridors of an undisturbed section of the Acadian Forest Region, and to relate the presence and abundance of small mammal species to structural components of the riparian and forested ecosystem. Since riparian corridors increase the patchiness of the environment which in turn influences small mammal distribution, it was hypothesized that the river and its accompanying riparian corridors would affect the spatial distribution of the small mammal population. Ground cover, litter, the abundance of shrubs, logs and stumps, and low vegetation cover are habitat characteristics that were examined in an attempt to associate the presence and abundance of small mammals with the structural and physical components of their habitats.

Materials and Methods

Study site

The data for this study were collected as part of a cooperative study with the Canadian Wildlife Service on the impact of different logging practices on riparian habitats. The study was conducted in the Hayward Brook drainage basin located in the Fundy Model Forest between Sussex and Petitcodiac, New Brunswick (45°53'N and 65°12'W). Hayward Brook is a tributary of the Anagance River which flows into the Petitcodiac River. The Hayward Brook drainage basin is approximately 9 km by 4 km, encompassing an area of roughly 3600 ha.

The Fundy Model Forest is located within the Acadian Forest Region which covers Nova Scotia, Prince Edward Island and much of New Brunswick (Hosie, 1979). The Acadian Forest is a mixed coniferous-deciduous forest with red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), yellow birch (*Betula alleghaniensis*), white birch (*B. papyrifera*), red maple (*Acer rubrum*)and sugar maple (*A. saccharum*) as the dominant species. Other common trees are striped maple (*A. pensylvanicum*), speckled alder (*Alnus rugosa*), white spruce (*Picea glauca*), black spruce (*P. mariana*)and white pine

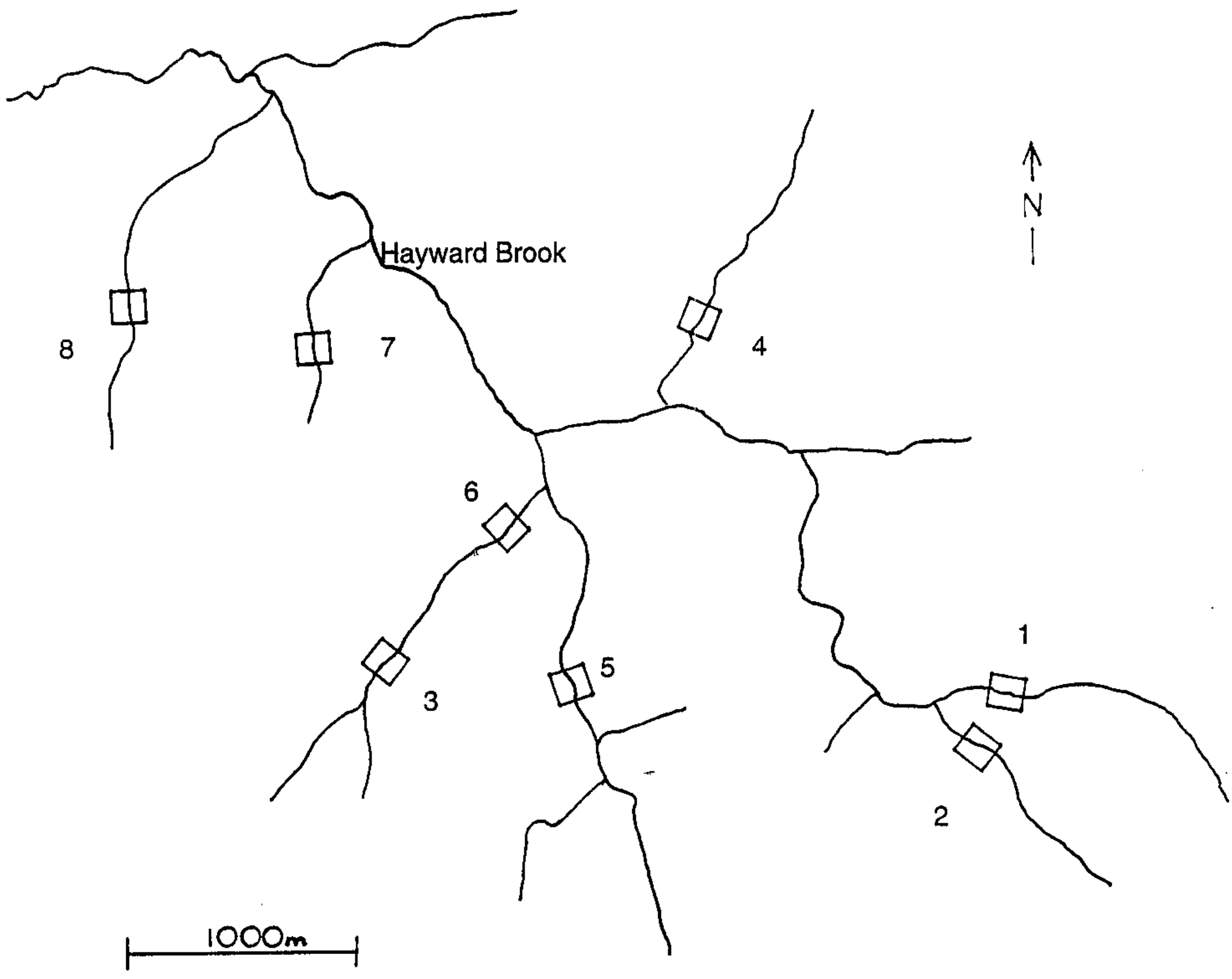

Figure 1. The distribution of riparian plots in the Hayward Brook Watershed.

(*Pinus strobus*) (Burzynski and Haworth, 1988).

Small mammals were trapped at eight riparian plots along feeder streams flowing into Hayward Brook (Figure 1). Each plot was 100 m by 100 m (1 ha) and was bisected by the stream. The feeder streams had a maximum width of 40 cm. Six of the plots were positioned where the small feeder streams connected to Hayward Brook. One was positioned upstream to avoid a powerline and the other was positioned upstream from another plot. The dominant tree species within the eight riparian plots were balsam fir, red maple, red spruce, and white birch. The plots had very little bare ground, and the litter was dominated by deciduous leaves.

Small Mammal Sampling

Each riparian plot was divided into a uniform 9 x 9 grid with lines 12.5 m apart running parallel and perpendicular to the stream. A trap site was placed at each point where the lines intersected, yielding 81 trap sites (figure 2). The trap sites in each grid were numbered systematically from 1 to 81. Each trap site was marked with a flag and the traps were placed in the "most likely location" within 2-3 m of the flag. The traps could be placed on either bank when the trap sites were located along the

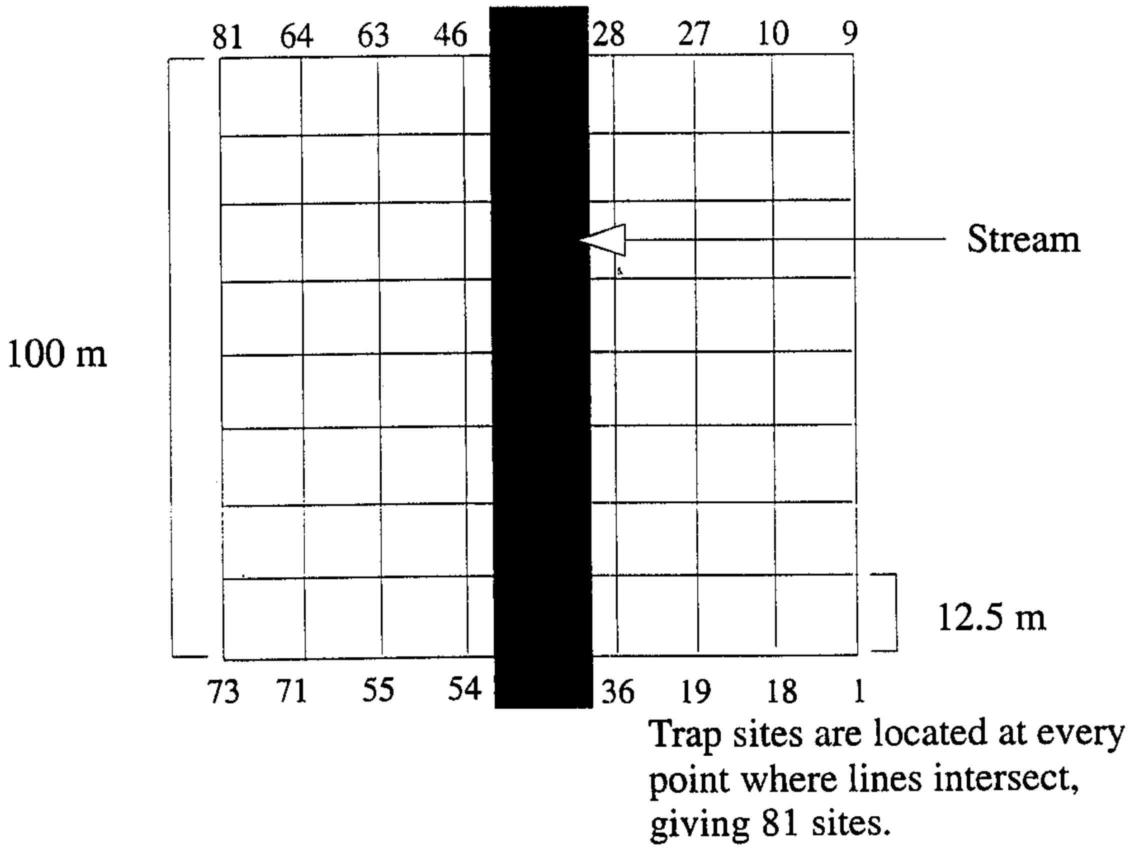

Figure 2. Riparian plot showing trap sites.

stream. Two snap traps, one museum special and one Victor, were placed at each trap site and baited with rolled oats and peanut butter.

Each plot was trapped for eight consecutive nights at the end of August or in September, 1993. Plots 1, 2, 3, and 5 were trapped from August 20 to August 27, plots 7 and 8 from September 3 to September 10, and plots 4 and 6 from September 14 to September 21. The traps were checked each morning and rebaited when necessary.

Each trapped mammal was placed in a bag with a card containing the date, trap site and riparian plot number. The specimens were frozen as soon as possible, and later thawed for examination. Each specimen was identified to species, and its weight and total length (from the tip of the nose to the base of the tail) were measured. Each specimen was dissected for the determination of sex and age. The lengths of the testes were measured, as adult and juvenile males can be separated by comparing testes size. Uterine scars were counted in the females, as each offspring produces a scar. If scars were present, the female had bred and was considered adult. Any female that had given birth and any male that had sufficiently large testes to produce sperm was considered adult.

Habitat Sampling

Habitat was sampled at thirteen trap sites in each plot (Figure 3). The habitat sampling criteria are summarized in Table 1. A circle with a radius of 3 m was delineated around the trap site. Within this circle, every shrub and tree with a stem diameter greater than 3 cm was recorded by species and stem diameter class. Each snag (dead tree still rooted in the ground) greater than 1.3 m in height was recorded according to decomposition class and stem diameter. Logs longer than 1.5 m and greater than 8 cm in diameter and stumps less than 1.3 m high and greater than 10 cm in diameter were recorded according to decomposition class. The percent canopy cover, the percentage of the canopy cover that was coniferous and the maximum, minimum and mean canopy heights were estimated from the center of each site.

Belt transects 2 m wide were made across the middle of each circle, both parallel and perpendicular to the stream. Each conifer and deciduous shrub with a stem diameter less than 3 cm within the belt transect was recorded. The foliage profile was taken at 1 m intervals along each arm of the belt transect using an ocular tube. The profile was taken at heights of 0-0.5 m, 0.5-3.0 m, 3.0-10.0 m and at greater than 10 m. At each height, the

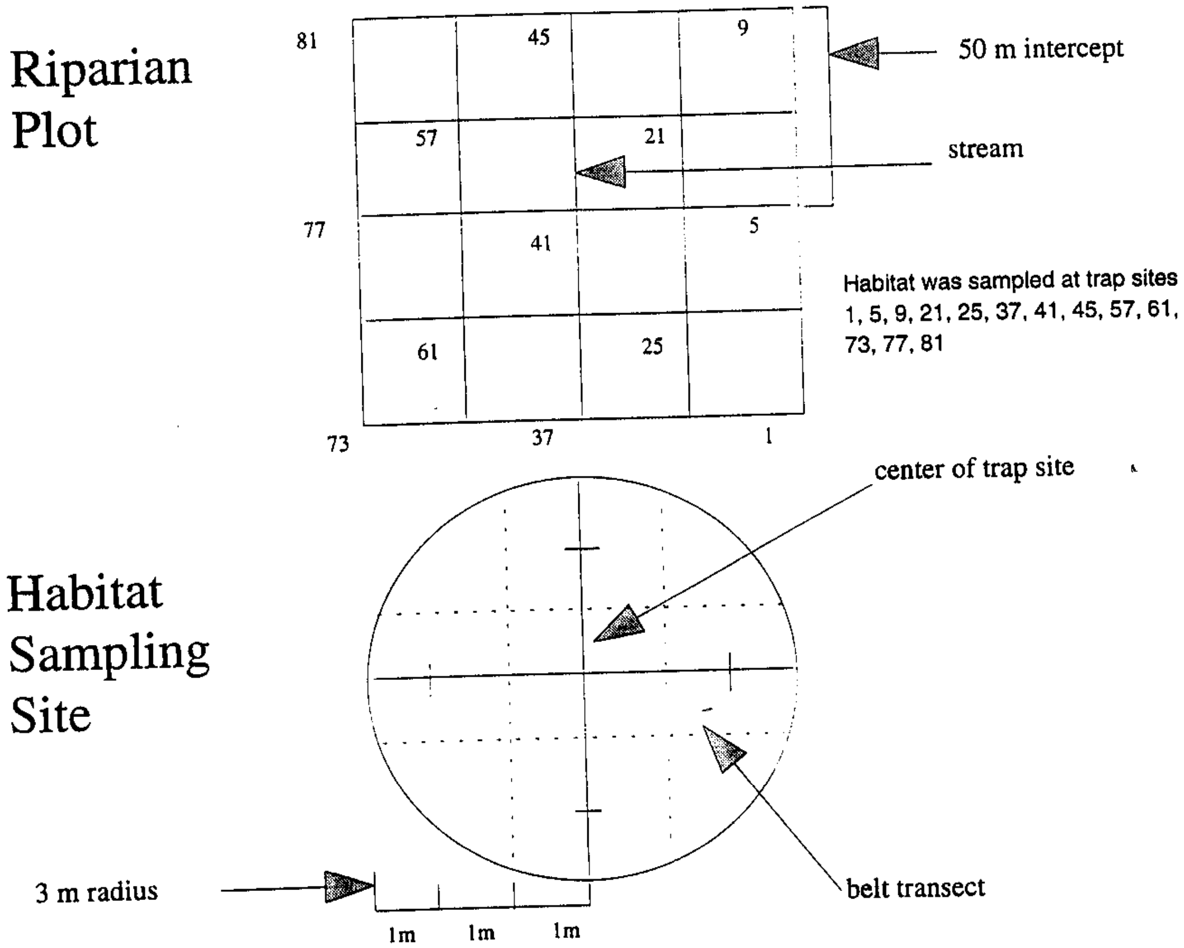

Figure 3. Riparian plot showing habitat sampling sites and diagram of habitat sampling site showing belt transects.

Table 1: Criteria for Habitat Sampling

Habitat feature	Criteria
Trees	Species; diameter ≥ 3; diameter classes: 3-8 cm, 8-15 cm, 15-23 cm, 23-38 cm, 38-53 cm, 53-69 cm
Shrubs	Diameter less than 3 cm
Snags	Height ≥ 1.3 m; decomposition classes: partially dead, dead, loose bark, clean, broken, decomposed
Logs	Length ≥ 1.5 m; diameter ≥ 8 cm; decomposition classes: recent (≥ 50% bark), recent (<50% bark), recent (no bark), med (early signs of rot), old (soft; punky)
Stumps	Height < 1.3 m; diameter > 10 cm; decomposition classes: recent (≥ 50% bark), recent (<50% bark), recent (no bark), med (early signs of rot), old (soft; punky)
Ground Cover	Bare ground, conifer needles, deciduous leaves, non-woody debris, woody debris, grasses / sedges, forbs, deciduous shrubs and conifer shrubs; cover classes: 0 (0% cover), 1 (1-10% cover), 2 (10-25% cover), 3 (25-50% cover),4 (50-75% cover), 5 (>75% cover)
Foliage profile	Foliage profile: conifer (C), deciduous (D), absent (A)

* see figure 3 for diagram of sampling site

foliage was recorded as either conifer, deciduous or absent.

Ground cover was estimated at five points, the center of each site and at 1 m out from the center, along each arm of the belt transects. An ocular tube was used to estimate the percent coverage of bare ground, conifer needles, deciduous leaves, other non-woody debris, woody debris, grasses and sedges, forbs, and both conifer and deciduous shrubs at each point.

Statistical Analysis

A chi-square test was used to compare the number of individuals trapped at each site to the expected Poisson distribution, which assumes a random distribution within the plot (Zar, 1974). The Kolmogorov-Smirnov test was used to test for distribution trends with respect to the river. Regression analysis was used to determine the relation between specific habitat characteristics within each riparian plot and the total number of species and total number of individuals of each species trapped in each plot. For ground cover, the average score for the five points at each site where ground cover was recorded was used. Regression analysis was also used to determine the relation between specific microhabitat characteristics at habitat sampling sites and the total number of species that were trapped at each site where habitat was sampled. Regression analysis at the habitat sampling site level was only conducted with *C. gapperi* and *P. maniculatus* because only fourteen *S. cinereus* and one *N. insignis* were trapped at sites where habitat was sampled. A two-way analysis of variance (ANOVA) using distribution trend and distance from the stream as the main factors, was used to test whether the habitat features differed between those plots with a random species distribution and those with a trend.

Results

Small Mammal Analysis

Eight species of small mammals were captured in the 8 riparian plots during the study period (Table 2). Red-backed voles (*Clethrionomys gapperi*), deer mice (*Peromyscus maniculatus*), masked shrew (*Sorex cinereus*) and woodland jumping mice (*Napaeozapus insignis*) accounted for 97% of the total number trapped. The other four species, smoky shrew (*Sorex fumeus*), short-tailed shrew (*Blarina brevicauda*), meadow jumping mouse (*Zapus hudsonius*) and northern water shrew (*Sorex palustrus*), were only caught in small numbers and therefore are disregarded in the remainder of the analysis. *C. gapperi* was the dominant species in all eight plots, and was most abundant in plots 4, 6, 7 and 8. *P. maniculatus* and *S. cinereus* were trapped in all eight plots while *N. insignis* was trapped in five plots, but was most abundant in plot 3 (Table 2).

The frequency distribution of testes size for *C. gapperi* and *P. maniculatus* males are shown in Figures 4 and 5. There were too few male *N. insignis* to produce a reliable plot of testes size. Sexing and aging were not attempted for *S. cinereus* because their testes

Table 2: Small Mammal Species Trapped in Each Riparian Plot

Riparian Plot	*Clethrionomys gapperi*	*Peromyscus maniculatus*	*Sorex cinereus*	*Napaeozapus insignis*	*Sorex fumeus*	*Blarina brevicauda*	*Zapus hudsonius*	*Sorex palustrus*	Total
1	17	12	5	3	1	0	1	0	39
2	27	14	8	5	4	0	0	0	58
3	21	6	7	12	0	0	1	1	48
4	49	27	10	0	0	2	0	0	88
5	30	10	14	7	0	0	0	0	61
6	44	7	2	5	2	4	0	0	64
7	37	15	7	0	0	0	0	0	59
8	43	12	3	0	0	0	0	0	58
Total	268	103	56	32	7	6	2	1	475

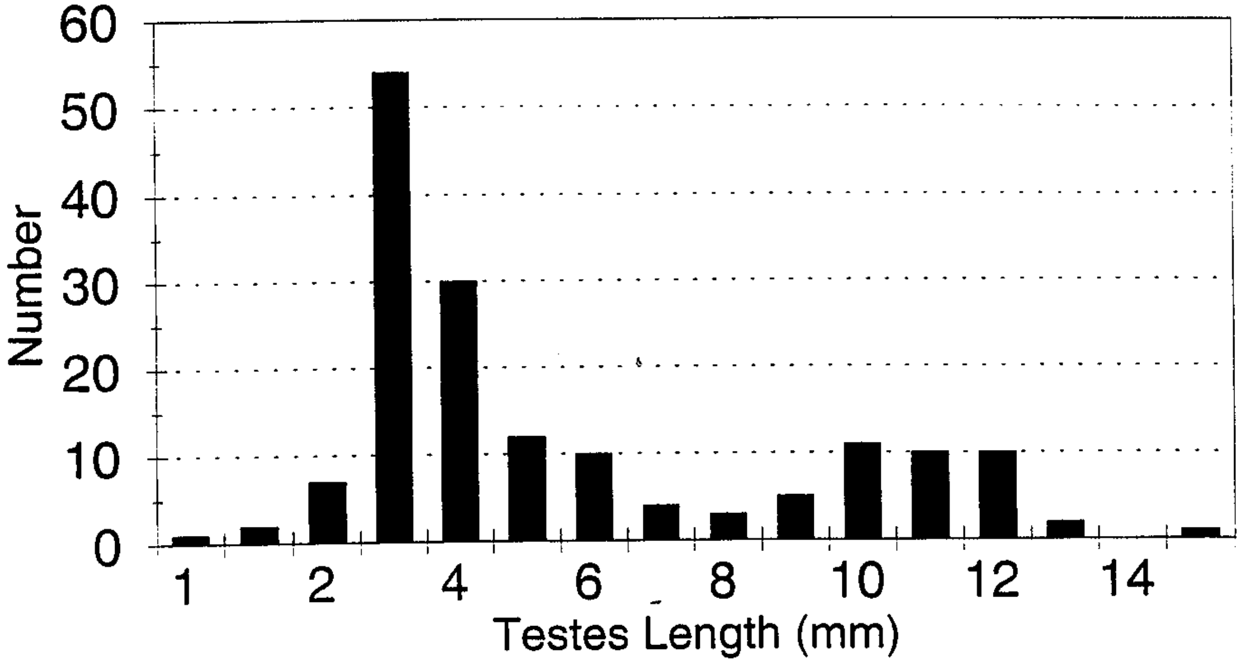

Figure 4. Frequency distribution of testes length for *Clethrionomys gapperi*. Males with testes greater than 8 mm in length are considered adult and those with testes less than 8 mm are considered juveniles.

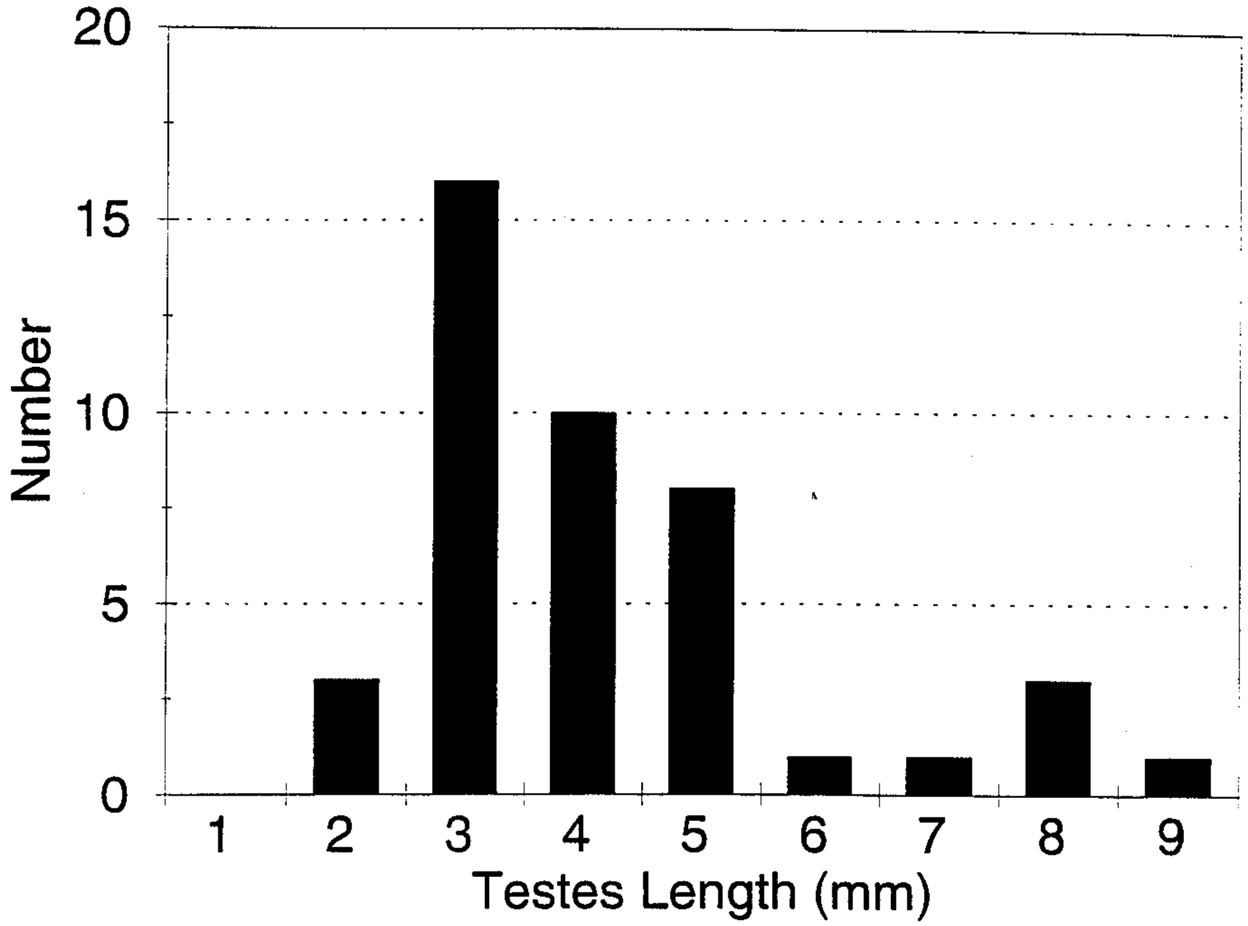

Figure 5. Frequency distribution of testes length for *Peromyscus maniculatus*. Males with testes greater than 6.5 mm in length are considered adults and those with testes less than 6.5 mm are considered juveniles.

Table 3: Population Structure of Four Major Species

Species	Adult		Juvenile				Sex Ratio	Age Ratio
	Male	Female	Male	Female	Unknown	Total	(M/F)	(A/J)
Clethrionomys gapperi	41	41	118	66	2***	268	1.49	0.45
Peromyscus maniculatus	5	14	48	36	-	103	1.06	0.23
Napaeozapus insignis	17*	7	-	8	-	32	3.00	1.13
Sorex cinereus **	-	-	-	-	-	56	-	-

*Not enough males were trapped to get a good enough testes plot to distinguish between adult and juvenile males.

** The sex data was not very accurate because in many cases no genitals could be found because they were so small and the specimens decomposed quickly when thawed.

*** Both specimens were badly mangled in the trap.

and uteri are extremely small and the specimens decomposed quickly when they were thawed. Male *C. gapperi* were considered adult if they had testes larger than 8 mm while male *P. maniculatus* were considered adult if they had testes larger than 6.5 mm. The age and sex ratios of the four major species are presented in Table 3.

Spatial Distribution

There was a significant non-random distribution of *C. gapperi* in plots 4, 6 and 8, both within the plot and with respect to distance from the stream (Table 4; Figures 6 and 7). Tests for the random distribution within plots were only performed for *C. gapperi* as it was the only species found in sufficient numbers in all eight plots. For *P. maniculatus, S. cinereus* and *N. insignis* the numbers trapped in all eight plots were pooled and their distribution from the stream was tested for trends. There were weak trends for increasing *S. cinereus* captures away from the stream and towards the stream for *N. insignis* (Figure 8). In plot 3, where 40% of the *N. insignis* were trapped, there was a distinct trend of increasing *N. insignis* captures towards the stream (Figure 9). *P. maniculatus* was trapped evenly throughout the plots (Figure 8).

Habitat Analysis

Table 4: Results for chi-square tests for randomness (Poisson distribution) with respect to the entire plot and for Kolmogorov-Smirnov tests for trend from the stream for Clethrionomys gapperi

Riparian Plot	Random distribution with respect to entire plot	Trend with respect to distance from stream
1	0.5687; $p > 0.100$	3.686; $p > 0.100$
2	3.7916; $p > 0.100$	3.5; $p > 0.100$
3	5.676; $p > 0.100$	4.929; $p > 0.100$
4	9.296; $p < 0.050$	29.812; $p < 0.005$
5	1.3629; $p > 0.100$	6.3; $p < 0.100$
6	11.081; $p < 0.025$	7.955; $p < 0.050$
7	1.7035; $p > .100$	7.636; $p < 0.100$
8	6.9375; $p < 0.100$	16.025; $p < 0.005$

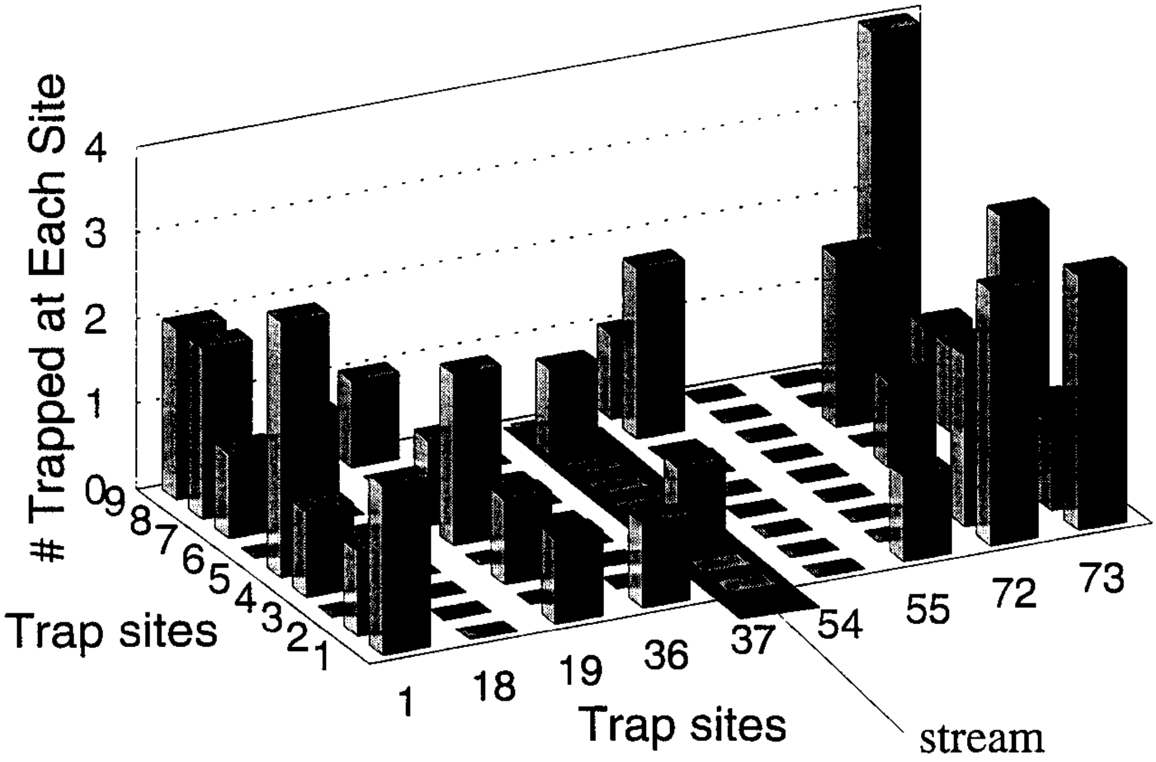

Figure 6. Frequency distribution of *Clethrionomys gapperi* in riparian plot 4.

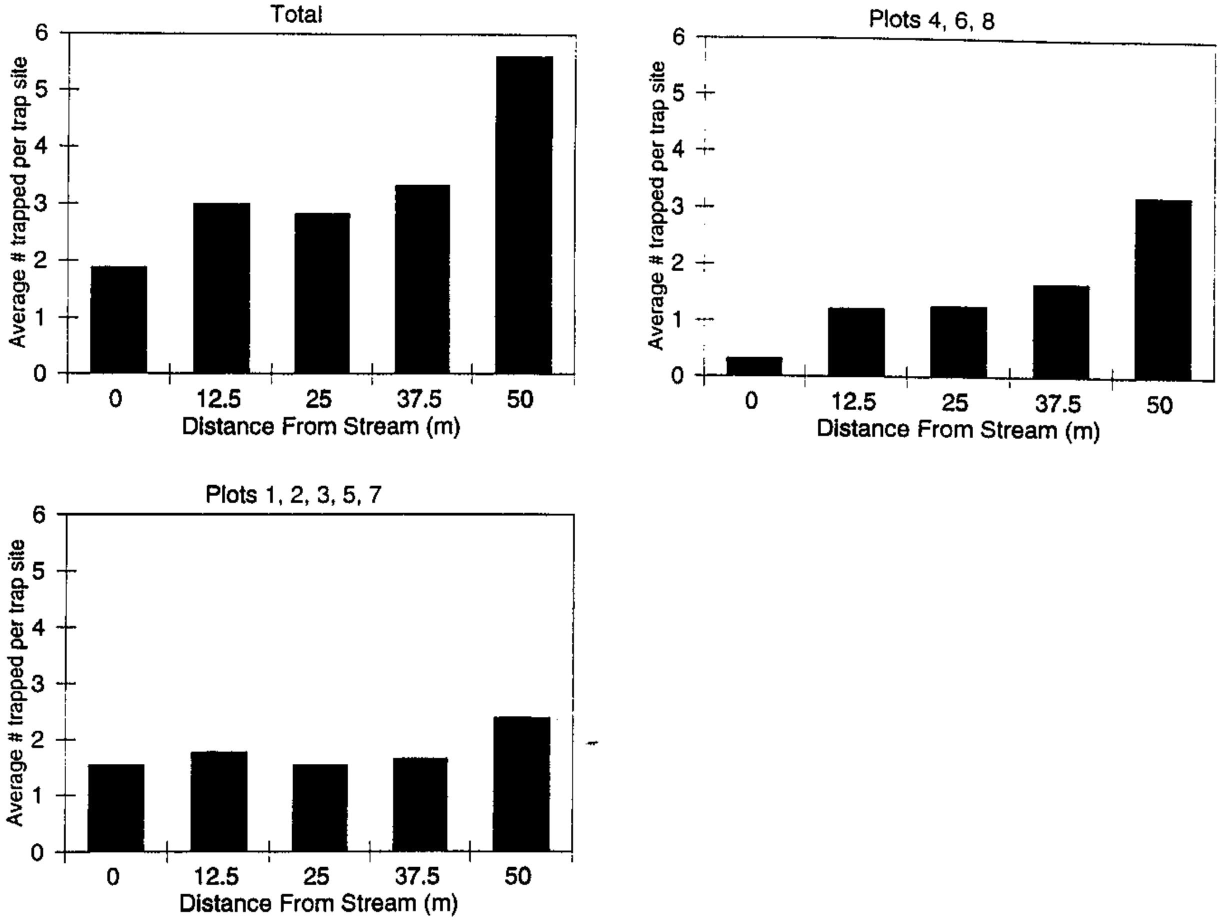

Figure 7. Average number of *Clethrionomys gapperi* trapped per trap site with respect to distance from the stream. The distribution of *C. gapperi* in riparian plots 4, 6 and 8 was proven to be non-random using a Poisson distribution test (Table 4).

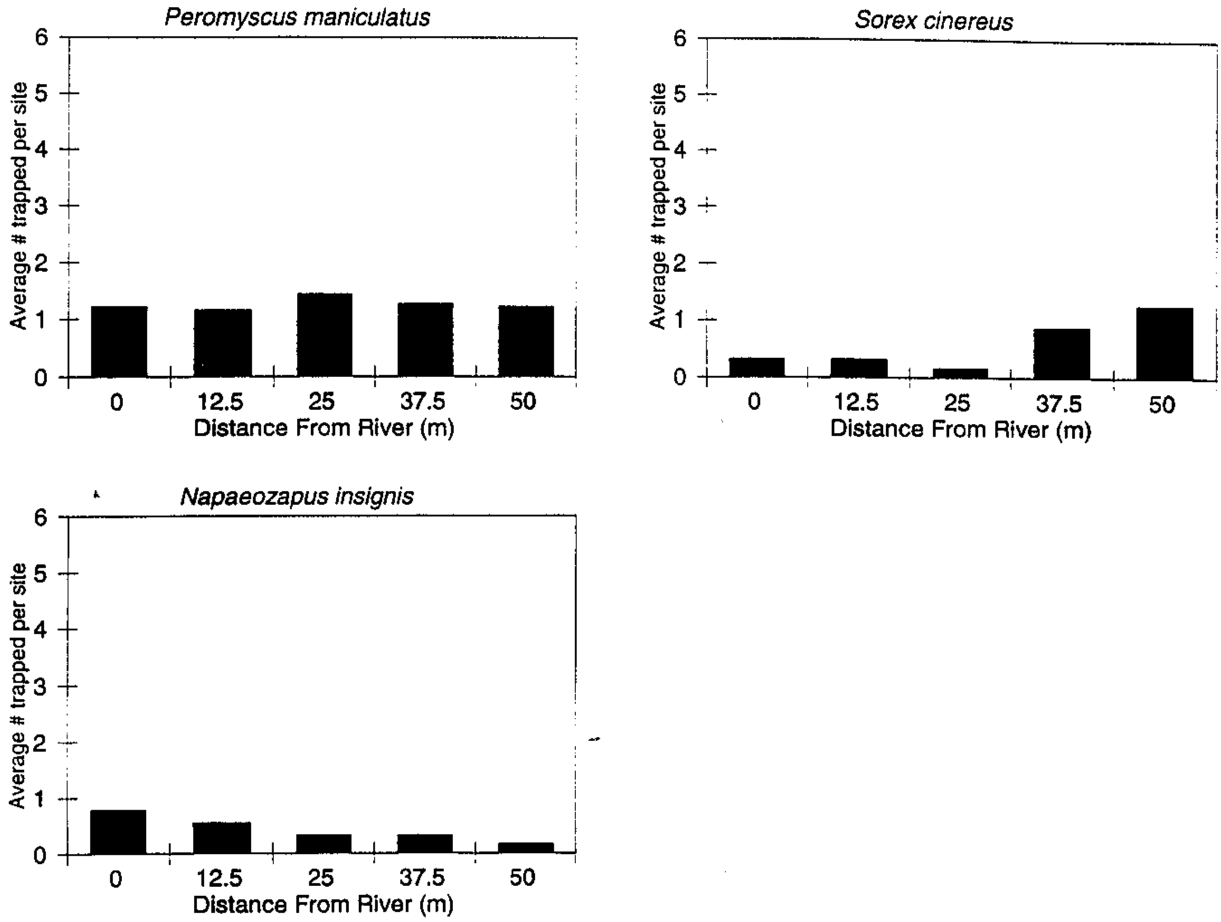

Figure 8. Average number of *Peromyscus maniculatus*, *Sorex cinereus* and *Napaeozapus insignis* trapped per trap site with respect to distance from the stream. All eight plots are summed together.

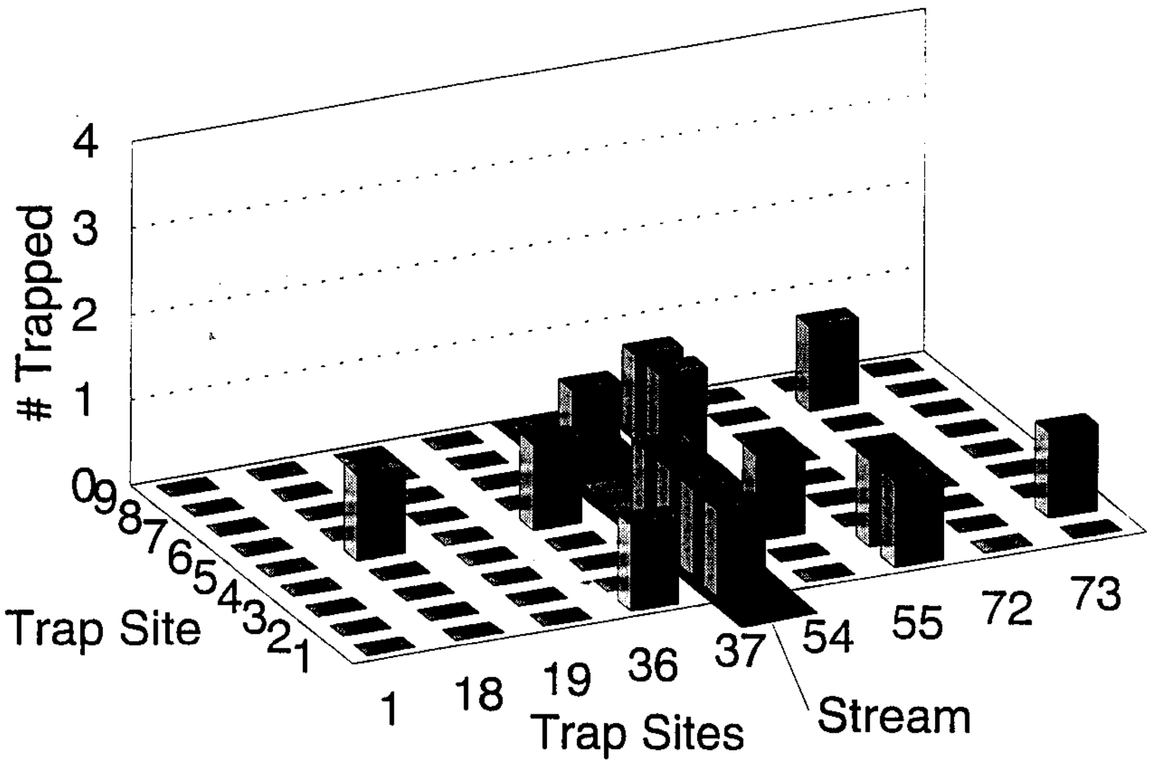

Figure 9. Frequency distribution of *Napaeozapus insignis* in riparian plot 3.

Table 5: Tree Diameter Classes and Species in the Riparian Plots

Riparian	Diameter Classes (cm)						Tree Species							
Site	3-8	8-15	15-23	23-38	38-53	53-69	balsam fir	red spruce	red maple	white birch	striped maple	white pine	other	Total
1	105	65	43	22	5	2	55	19		22	53	14	79	242
2	92	88	49	33	2		35	90	44	46	13	15	21	264
3	351	105	63	9			207	37	102	52	3	45	82	528
4	83	59	22	23	6		67	31	68	1			26	193
5	132	87	48	24	2	1	111	46	56	18	3		60	294
6	93	37	44	21	1		88	37	33	8	1	1	114	196
7	169	68	30	13	2		212	4	37	1		1	27	282
8	111	59	22	17			83	23	43	2			58	209

Table 6: Habitat Factors and Ground Cover Class Averages in the Riparian Plots

Riparian Plot	Habitat factor					Ground Cover Class						
	% Canopy Cover	Deciduous Shrubs*	Conifer Shrubs*	Logs*	Stumps*	Bare Ground	Conifer Needles	Deciduous Leaves	Non-Woody Debris	Woody Debris	Grasses/ Sedges	Forbs
1	71.7	11.3	43.0	7.6	1.9	0.4	2.0	3.5	0.6	1.3	0.2	2.1
2	75.3	9.3	36.0	7.0	3.8	0.3	1.6	3.6	0.6	1.2	0.2	1.4
3	74.3	6.1	21.2	5.8	1.3	0.0	1.1	4.1	0.1	1.0	0.1	0.9
4	63.7	6.3	26.7	1.1	0.9	0.0	1.0	2.9	0.5	1.1	0.7	1.1
5	79.8	5.0	22.5	11.2	2.3	0.2	0.6	3.4	0.2	1.2	0.3	1.4
6	51.9	7.7	40.7	1.3	2.2	0.0	0.9	2.3	0.5	0.8	1.0	1.7
7	47.3	5.5	21.0	5.9	3.2	0.0	1.3	2.5	0.2	1.3	0.8	2.0
8	61.5	6.8	28.7	2.7	0.7	0.0	1.1	1.7	0.5	1.1	0.7	1.0

* The average number of shrubs, logs and stumps at the 13 sampling sites in each plot

Plot 3, the plot in which almost 40% of the *N. insignis* were trapped, was the youngest stand and along with plot 7 had the greatest density of balsam fir; 207 of 528 trees and 212 of 282 trees, respectively (Table 5).

Habitat data for each plot is summarized in Table 6. There were negative correlations between the number of *C. gapperi* trapped in the plots and the number of logs and percentage of bare ground and deciduous leaves, and a positive correlation between ground cover of grasses and sedges and the number of *C. gapperi* (Table 7).

The plots that had non-random distributions of *C. gapperi* (4, 6 and 8) had fewer stumps and logs and the ground cover had a greater percentage of grasses and sedges and less deciduous leaves than the plots which had random distributions of *C. gapperi*. However, these habitat characteristics did not show any trends with respect to distance from the river. The remainder of the habitat features were distributed randomly in plots with and without animal distributional trends, and there were no significant correlations between the number of small mammals or each species caught at a trap site and any of the habitat factors (Table 7 and 8).

Table 7: R Values For Correlations Between Habitat Factors and Number Of Small Mammals Trapped in Each Plot

Habitat Factor	**R Values**				
	Total Number	*Clethrionomys gapperi*	*Peromyscus maniculatus*	*Sorex cinereus*	*Napaeozapus insignis*
Total Canopy cover	-0.2775	-0.6345	-0.1460	0.5601	0.5816
Deciduous Shrubs	-0.4844	-0.4652	-0.0714	-0.4380	-0.0705
Conifer Shrubs	-0.2587	-0.1407	-0.1242	-0.5472	-0.1338
Total Logs	-0.5322	-0.7346*	-0.3394	0.5984	0.4135
Stumps	-0.1929	-0.2938	-0.1392	0.1876	0.0802
Ground Cover					
Bare Ground	-0.5556	-0.7323*	-0.1270	0.1018	0.1525
Conifer Needles	-0.5813	-0.5708	0.0243	-0.3654	-0.1589
Deciduous Leaves	-0.3458	-0.7845*	-0.1433	0.4976	0.7108
Non-Woody Debris	0.0723	0.1841	0.3493	-0.4447	-0.5904
Woody Debris	-0.2446	-0.4068	0.3203	0.4894	-0.3057
Grasses and Sedges	0.5592	0.8873**	0.2105	-0.4589	-0.5708
Forbs	-0.3600	-0.2558	-0.0993	-0.1821	-0.2661

*$p < 0.05$
**$p < 0.01$

Table 8: R Values For Correlations Between Habitat Factors and Number Of Small Mammals Trapped at Each Site

Habitat Factor	**R Values**		
	Total Number	*Clethrionomys gapperi*	*Peromyscus maniculatus*
Total Canopy cover	0.0040	-0.0125	0.0719
Deciduous Shrubs	-0.0686	-0.1433	0.0299
Conifer Shrubs	0.1315	0.2274*	-0.1139
Old Logs	0.1894	-0.0065	0.0119
Total Logs	-0.0728	-0.1428	0.0233
Stumps	-0.0184	-0.0894	0.1377
Ground Cover			
Bare Ground	-0.0643	-0.1727	0.0867
Conifer Needles	-0.1749	-0.1698	-0.0751
Deciduous Leaves	-0.0417	0.0208	-0.0997
Non-Woody Debris	0.0467	-0.0695	0.1024
Woody Debris	-0.0680	-0.0225	-0.1155
Grasses and Sedges	-0.0217	-0.0053	0.0633
Forbs	-0.0018	-0.1177	0.0711
Conifer Shrubs	-0.0477	-0.0039	-0.1214
Deciduous Shrubs	0.0471	-0.0914	0.0937

* $p < 0.05$

Table 9: Small Mammal Habitat Preference

Species	Habitat Preference	Reference
Clethrionomys gapperi	Associated with mainly mesic habitats in all forest types with an abundance of litter and woody debris; especially decaying logs.	Morris, 1955; Merritt 1981; Tallmon and Mills, 1984
Peromyscus maniculatus	Found in a wide range of habitats, from grasslands to woodlands. Associated frequently with bases of large diameter trees and associated with litter and woody debris.	Morris, 1955; Bowers and Smith, 1979; Drickamer, 1990
Napaeozapus insignis	Associated with spruce-fir and hemlock-hardwood forests and herbaceous or low woody vegetation; There are conflicting results concerning their association with water.	Whitaker and Wrigley, 1972; Preble, 1956; Whitaker, 1963; Brower and Cade, 1966
Sorex cinereus	Associated with logs, stumps and ground cover that helps maintain a humid climate.	Getz, 1961
Sorex fumeus	More common in mature hardwood stands; requires deep leaf litter like that characteristic of northern hardwood forests.	Morris, 1955
Blarina brevicauda	More common in mature hardwood stands where increased amounts of leaf mould facilitates burrowing.	Morris, 1955
Sorex palustrus	Confined to cold, small streams with cover along the banks and in bogs.	Burt and Grossenheider, 1976
Zapus hudsonius	Most common in low meadows but not restricted to them.	Burt and Grossenheider, 1976

Discussion

The red-backed vole, *Clethrionomys gapperi ochraceous* (Miller), is the most abundant small mammal species in New Brunswick, especially in hardwood stands, and the deer mouse, *Peromyscus maniculatus abietorum* (Bangs) is the second most abundant (Morris, 1955). These two species, along with the meadow vole, *Microtus pennsylvanicus*, tend to dominate non-arid temperate habitats (Galindo and Krebs, 1985). Other common species in New Brunswick are the masked shrew, *Sorex cinereus acadicus* (Gilpin), and the short tailed shrew, *Blarina brevicauda pallida* (Smith). The woodland jumping mouse, *Napaeozapus insignis insignis* (Miller), is present but uncommon in New Brunswick (Morris, 1955). The ranges of *Z. hudsonius*, *S. fumeus* and *S. palustrus* extend throughout the Maritimes, but they are only common in certain localities (Burt and Grossenheider, 1976).

The environmental control model (May, 1984 as cited in Borcard *et al.*, 1992) hypothesizes that it is environmental differences that result in microhabitat preference and separation. Small mammal distribution is influenced by ground cover types and woody debris, such as logs and stumps (Table 9). However, there were few correlations between the habitat features and the numbers of small mammals trapped in the current study. The negative correlation between the number of logs and the numbers of *C. gapperi* is contrary to previous findings (Table 9). The correlation between deciduous leaves, grasses and sedges, and bare ground are not independent factors as there was an inverse relationship between grasses and the abundance of leaf litter or bare ground. Therefore, if one of these factors is significant then others will also be significant. It would appear that environmental variations within and between plots cannot provide an explanation for the observed trends of *C. gapperi*.

N. insignis is strongly associated with balsam fir and eastern hemlock (*Tsuga canadensis*) stands (Whitaker and Wrigley, 1972). In plot 3, where the density of *N. insignis* was the greatest and concentrated along the stream, balsam fir is the most dominant species. This appears to be relevant except that in plot 7, in which no *N. insignis* were trapped, balsam fir is even more dominant. The difference in *N. insignis* densities may be because plot 3 is a younger stand. There were no associations between any of the other species and any habitat feature within the plots or at trap sites.

The biotic control model (May, 1984 as cited in Borcard *et al.*, 1992) hypothesizes that distribution patterns are affected by competition (Dueser and Hallett, 1980). The numbers of *P. maniculatus* and *C. gapperi* in plots were positively correlated suggesting that competition between the two species was not a factor (Galindo and Krebs, 1985). The absence of *N. insignis* from plots 4, 7 and 8, may be due to the presence of the more aggressive *C. gapperi*. Plots 4, 7 and 8 along with plot 6 have the highest densities of *C. gapperi,* and it has been noted that often *N. insignis* will avoid areas with high densities of *C. gapperi* (Lovejoy, 1973; Merritt, 1981). It has been suggested that *N. insignis* competes with *P. maniculatus* (Whitaker and Wrigley, 1972), but there is no evidence in this study or in the literature to support this hypothesis. The distribution of *S. cinereus* will not be affected by interspecific competition with mice because a shrew's characteristic diet of insects results in different habitat requirements (Morris, 1979). The other four species were trapped in such small numbers that they would not affect the distribution of the four most common species. Also, while competition may influence small mammal distribution, it cannot account for the trends in the distribution of *C. gapperi* in plots 4, 6 and 8. Although, the biotic control and the environmental control models are often considered to be mutually exclusive, it is probable that all of the elements in the environment affect the distribution and structure of biological communities.

As the distribution pattern of *C. gapperi* in this study cannot be explained by environmental heterogeneity or by interspecific competition, the spatial scale at which this study was analyzed must be considered. The difficulty with studying spatial distribution is one of scale. Addicott *et al.* (1987) suggest that if the scale of a study is chosen arbitrarily, then it may not be accurate to compare the same species in different habitats or different species in the same habitat. The home ranges of the four major small mammals in this study are 0.1-0.5 ha for *C. gapperi* (Merritt, 1981), 0.3-0.7 ha for *P. maniculatus* (Morris, 1955), 0.4-3.6 ha for *N. insignis* (Whitaker and Wrigley, 1972) and about 0.3 ha for *S. cinereus* (Vaughan, 1986). Therefore, in a 1 ha plot, their home ranges could cover half of the trap sites, and in the case of *N. insignis* may extend beyond the plot.

There are also limitations to what trapping alone can show with respect to spatial distribution and habitat use. With snap trapping, only one point within an individual's entire home range is being sampled. It is not realistic or practical to assume that the habitat characteristics at one trap site are representative of an individual's entire home range. When an animal is trapped at a specific location, all that is really known is that the animal visited that area. It is not possible to know the intensity of use of that area during the trapping period (Desy *et al.*, 1989). Alternatively, Tallmon and Mills (1994) used radio tracking to accurately determine the habitat use and distribution of *Clethrionomys californicus*. Tallmon and Mills showed that *C. californicus* did not use its home range uniformly. They showed that *C. californicus* spent 98% of their time associated with logs, even though logs made up only 7% by area coverage of their home ranges. Therefore, snap trapping at only one point in a home range could nonetheless give an indication of habitat preferences because those characteristics that attract an individual to a certain habitat will be exploited more than the remainder of its home range. When baited traps are used, it is assumed that the bait will not draw animals away from areas of normal use but it is an assumption (Tallmon and Mills, 1994).

The lack of significant findings in this study could also be due to the homogeneity of the plots. Habitats within the riparian plots were similar. Thus, habitat selection may not have been as pronounced as in more patchy heterogeneous environments. Because of the small size of the streams, the riparian corridors are very narrow on the Hayward Brook. Therefore, the disruption that they cause appears to be minimal.

#31 - SH. animals bufferstrips 95-96.

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Appendix 4: Annual report (1994-95) on results of fisheries research at Hayward Brook Watershed Study.

Effect of riparian zone management on fish community structure

Hayward and Holmes Brook Study

Year end report for 1994
Submitted to the Fundy Model Forest
February 15, 1995

by

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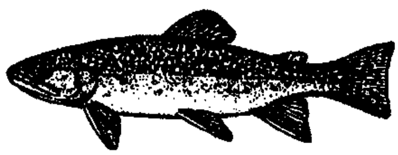

Brief statement of goals

The major objective this year was to assess habitat and fish community structure in the Hayward and Holmes Brook watersheds. This baseline will provide a comparison for experimental treatments within the riparian zones to commence in 1995. (See research proposal for more details). This project continues to make a unique contribution to the understanding of fish habitat in small stream ecosystems and is one of the functional units of the Hayward and Homes Brooks Studies. No other project in the Fundy Model Forest examines the micro and macro links between fish habitat and different forestry practices in riparian zones. In addition, the project has to date contributed successfully to a better understanding of small forest streams and their dynamics. In conjunction with the other projects occurring in these watersheds the fish habitat study is contributing to a total ecosystem overview of the effects of different forestry pratices in the Fundy Model Forest.

As proposed in 1994, a graduate student was to have undertaken the project at the Master's level in the spring of 1994. Unfortunately, the prospective candidate was forced to withdraw from the program due to family and financial problems. However, as of January 1995, I have accepted Terrance Melanson as a Masters graduate student who is currently working on last year's data and will continue with the project in the next 2 years. The fish habitat project is therefore contributing to the higher education of a graduate student.

STUDY SITE

The study area is situated on the Hayward and Holmes Brooks (45°52'N, 65°09'W), near Petitcodiac, New Brunswick (Figure. 1). Four plots (sections of 700 to 1000 m) on the Hayward Brook (plots 3, 4, 5, and 6) and two plots (sections of 650 m) on the Holmes Brook (plots 9, and 10) were chosen for study.

EVALUATION OF FISH POPULATIONS, ABUNDANCE AND STRUCTURE

Fish populations were studied in each plot by trapping, electrofishing, and marking. Six minnow traps were placed in each of the downstream (100 m), middle (100 m), and upstream (100 m) sections of the plot. In each of these sections, two traps were in riffles, two in runs, and two in pools. These habitats were marked with colour coded flagging tape (riffle - yellow, run - red, pool - blue) on the nearest tree as a reference point. Between June 28 and July 13, 1994, traps were fished for a 24 hour period on two consecutive days. Fish were identified, counted, measured and released (see Table 1 for study schedule).

Electrofishing was performed with a Smith Root Electro-seiner Model 12 POW (setting at J-7, 400-500 volts) from July 19 to 22, 1994, on all plots except plot 10 which was difficult to access with heavy equipment. A closed-off section of the stream was swept 4 times between the downstream and middle sections of the plots. A fifth sweep was conducted when fish were caught in the fourth sweep. Fish were identified, counted, and measured. Brook trout (*Salvelinus fontinalis*) were adipose clipped, and marked on the peduncle with a panjet (Alcian blue dye) (see Table 2 for marking method).

From August 3 to August 17, 1994, minnow traps were deployed a second time in the same manner as described previously (Table 1). However, this time brook trout were marked (Table 2) and fin clipped. Changes in original trap sites had to be made in plot 4 due to low water levels. The upstream section was completely dry, therefore traps were placed in the last 100 m above the water monitoring station. All but two of the traps were placed in pools. Traps 6, 7, 9 and 11 were not relocated.

Length frequency plot of fish captured in each tributary are found in Appendix 1. We are currently performing statistical test to determine differences: within each tributary, among tributaries and within season. Length frequency plots are useful in determining age structures.

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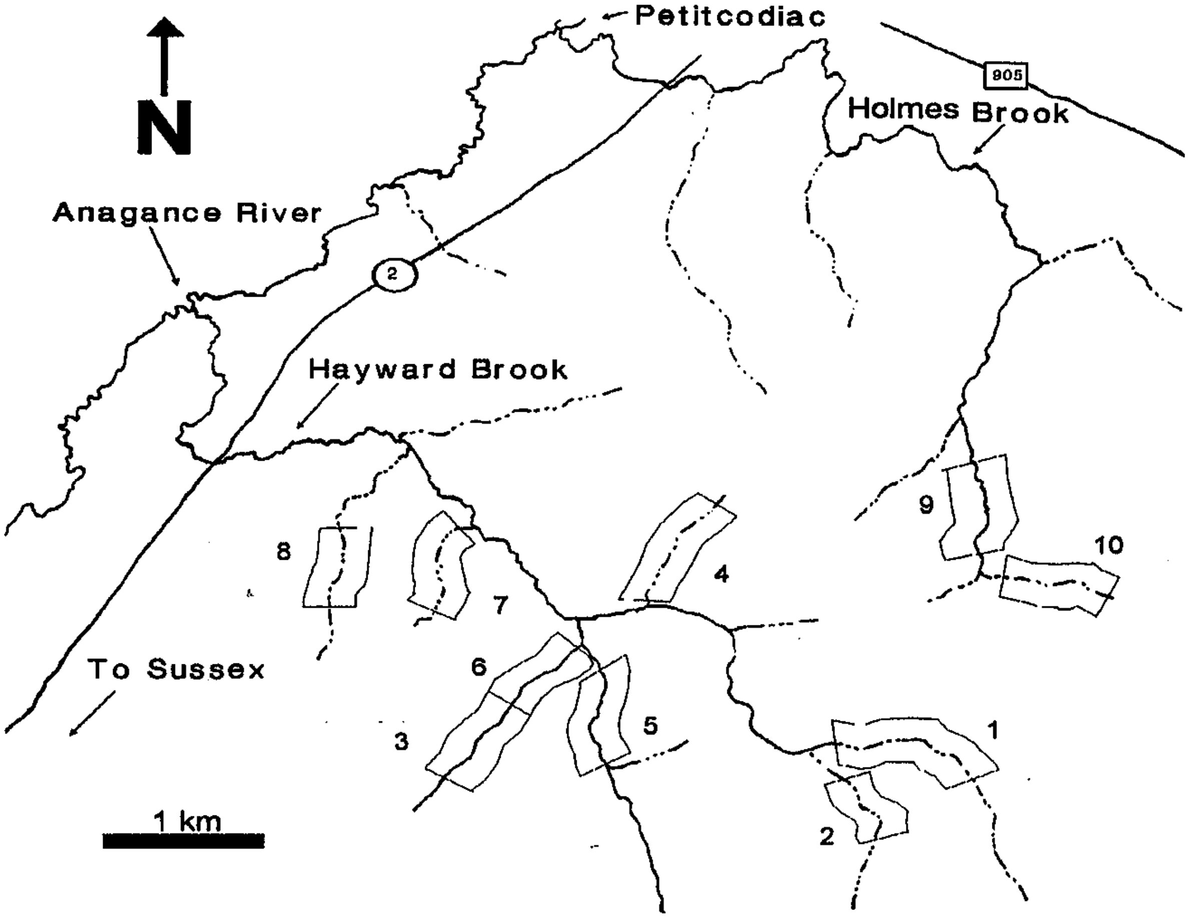
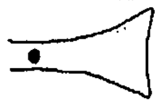
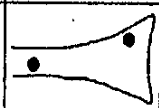
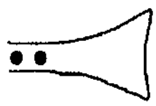
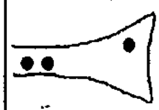
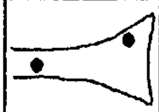
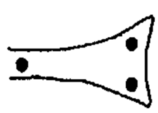
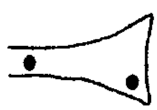
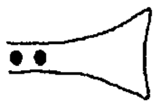
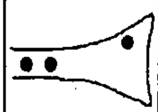
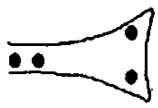
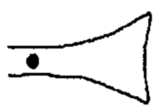
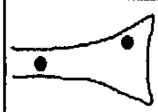
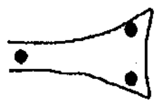
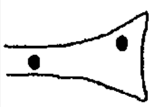
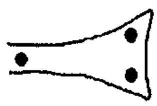


Figure 1. Map of study sites.

Table 1. Schedule of fishing and marking of fish in the Hayward Brook (Plot 3, 4, 5, and 6) and the Holmes Brook (Plot 9 and 10) in the summer of 1994.

PLOT	DATE FISHED	DATE ELECTROFISHED AND MARKED	DATE FISHED AND MARKED
3	June 30 and July 5	July 19	August 9 and 10
4	July 7 and 8	July 21	August 9 and 10
5	June 28 and 30	July 18	August 3 and 4
6	July 5 and 6	July 20	
9	July 7 and 8	July 22	August 16 and 17
10	July 12 and 13	not electrofished	August 16 and 17

Table 2. Marking codes used to distinguish between brook trout from different plots (LEFT or RIGHT peduncle) and sections of plots (caudal fin).

	Marking for electrofished and trapped fish		Marking for trapped fish		
Plot	PEDUNCLE		CAUDAL FIN		
			Downstream	Middle	Upstream
3	LEFT				
4	RIGHT				
5	RIGHT				
6	LEFT				
9	LEFT				
10	RIGHT				

A total of 30 brook trout were retained from fall sampling to explore the possibility of using scale sample for aging to confirm conclusion based on length frequency distributions.

Information regarding population abundance can be derived from two sources of data collected in 1994. The first source is a series of estimates derived from electrofishing surveys using the Zippan method to calculate abundance. The second consists of tag and release data collected during the summer.

HABITAT ANALYSIS

Habitat analysis was carried out after the fish population study to avoid influencing fish behaviour by some unavoidable walking in the stream. Habitat at all trap sites were physically described and photographed. The length, width and maximum depth of each site were recorded.

Woody debris is now recognized a key factor in fish habitat as well as being subject to alteration due to forestry practices. There ia a strong link between forest cover and structure and woody debris. The woody debris present in the stream was sketched for downstream, middle and upstream in sites 5 and 3. Also, measurements were taken to obtain digger log length and distance between digger logs. The sketches of sites 5 and 3 are found in appendix 2. We are currently working on a method to quantify this information to compare difference among sites and years.

Pools are essential to productive brook trout habitat. They provide both a refuge and feeding area. Spawning also occurs in the head and tail sections. Bottom substrate type of the first ten pools in all sites were recorded. A wooden frame ($1 m^2$) was ruled in $25 cm^2$ squares with string. This frame was placed over pools. Each $25\ cm^2$ was attributed a dominant substrate type (cobble 5cm; coarse gravel 5cm, 2cm; fine gravel 2cm; sand; vegetation; woody debris). Habitat types were plotted out using a color code. We are currently in the process of quantifying this information and provide a black and white representation. Photocopies of the pool information are found in Appendix 3 as an index as to the type of data collected. The ratio of pools, runs and riffles was estimated for each site for the first 500 m or until a minimum count of 20 were reached for each habitat type.

Both habitat and population information will be evaluated in conjunction with the water quality data collected by Environment Canada. Since brook trout are good indicators of water quality a link between these two sources of information is expected. The effects of turbidity are also expected to evident in the composition of pool substrate measured in this study.

FALL SURVEY

A minimum of 50 m was electrofished on all sites between the October 14 and 21, 1994. Fish were identified for the presence or absence of marks(Table 2), measured, evaluated for reproductive status and released. A sample of 30 fish were retained form site 5 for further study.

MAJOR FINDINGS OF IMPORTANCE FOR THE STUDY

Fish were captured from all sites located within both watersheds(Table 3). Surprisingly, site 4(control) which was viewed as ephemeral in nature prior to the study, contained fish in the upper part of the site in early summer. The 1995 season will determine if fish recolonize this type of habitat each spring.

Recaptures to within the very same pool between and within months indicated restricted fish movement. Hence, the effects of disturbance on this distribution will be easy to evaluate compared to a widely dispersed and variable pattern. Electrofishing using the Zippan method, and mark recaptures from the minnow traps will establish population abundance.

Brook trout were the only species captured in all study sites with the exception of only 4 slimy sculpin and 2 threespine stickleback.

Measurement of woody debris could only be conducted on sites 5 and 3 due to costs. However, the information is detailed and complete and will be extremely useful. All sites will have water quality data through the parallel study by Environment Canada as well as descriptions of substrates within pools.

Table 3. Total number of fish captured in minnow traps in July and August, 1994.

SITE	NUMBER OF FISH
3	62
4	32
5	51
6	53
9	56
10	127
TOTAL	381

The fall survey was limited but successful. Fish had or were in the progress of spawning as early as October 14, 1994. Despite the small size of the tributaries these sites are used for spawning. Fish in site 5, the only one in which samples were retained, showed that fish were cannibalizing their own eggs. Overall, indications are that habitat is marginal and populations are stress. They should therefore be susceptible to any further disturbance making them an excellent study population to examine the effects of different riparian zone practices.

Overall we are in an excellent position to monitor changes that will occur once cutting commences. We have met our initial goals and in some cases exceeded them. Data collected in 1994 will be present the the Canadian Association of Hydrologists to be held in Fredericton on June 20, 1995. The abstract has already been accepted.

Alyre Chiasson

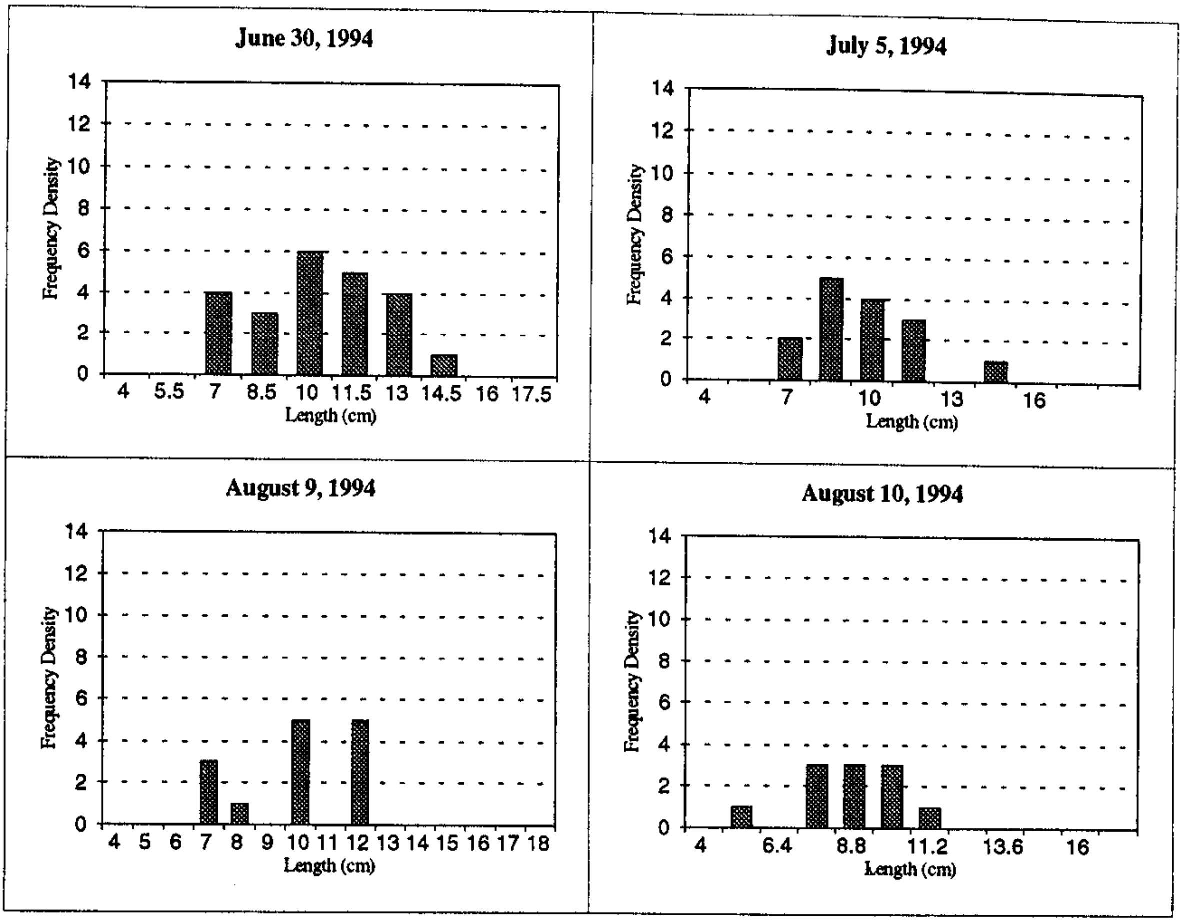
Alyre Chiasson

Date: February 15, 1995

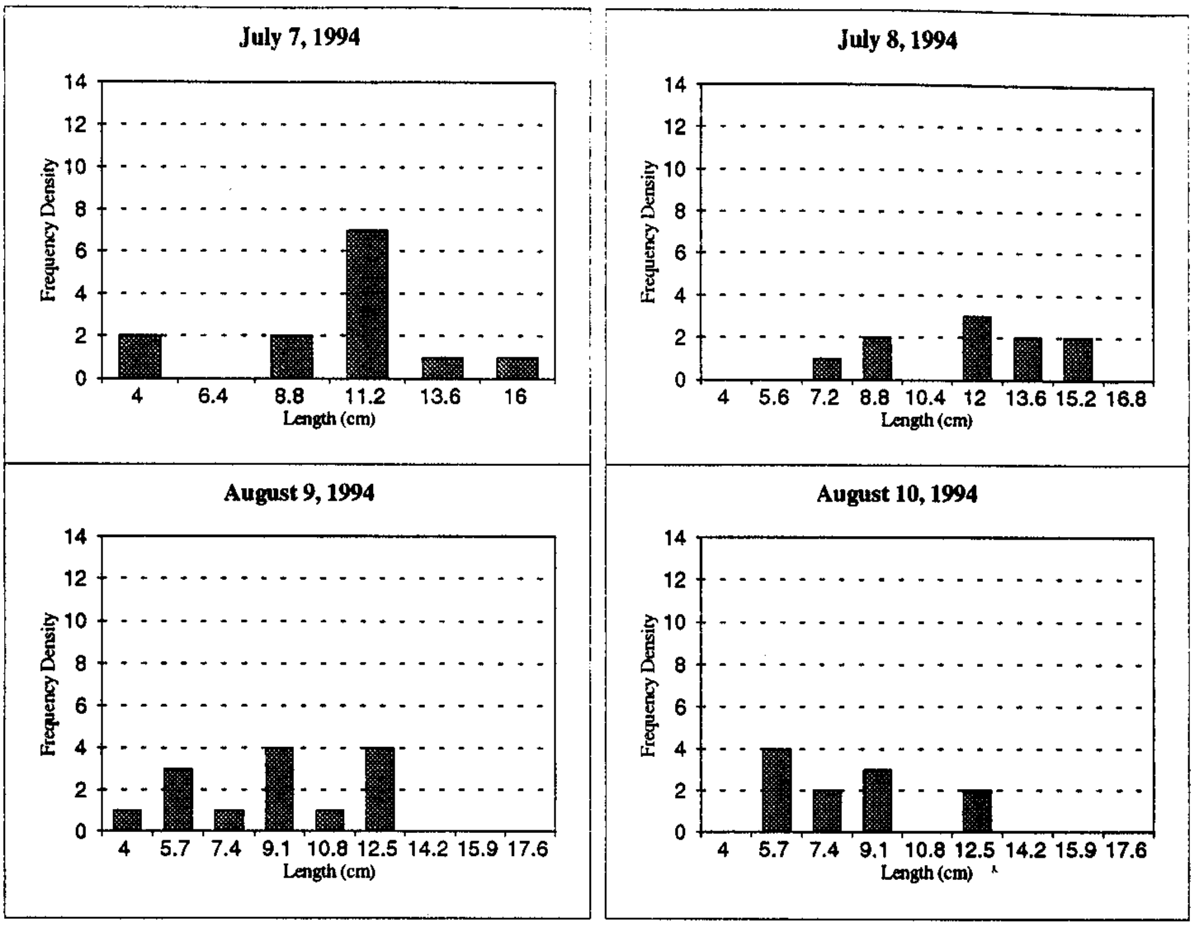
Appendix 1

Length frequency distributions for brook trout.
Plot numbers refer to sites identified in Figure 1.

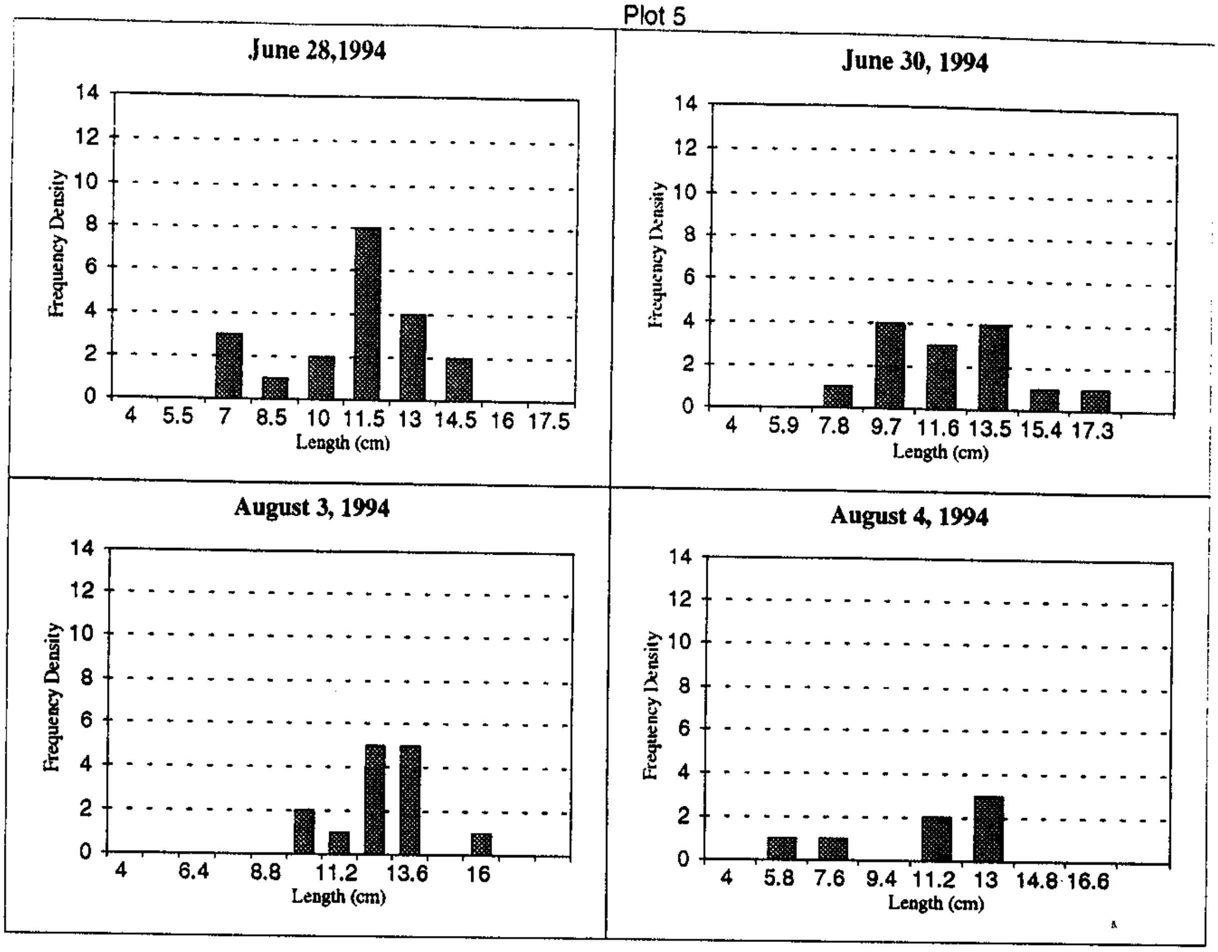
Plot 3


June 30, 1994
Frequency Density
Length (cm)
0 2 4 6 8 10 12 14
4 5.5 7 8.5 10 11.5 13 14.5 16 17.5
July 5, 1994
Frequency Density
Length (cm)
0 2 4 6 8 10 12 14
4 7 10 13 16
August 9, 1994
Frequency Density
Length (cm)
0 2 4 6 8 10 12 14
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
August 10, 1994
Frequency Density
Length (cm)
0 2 4 6 8 10 12 14
4 6.4 8.8 11.2 13.6 16

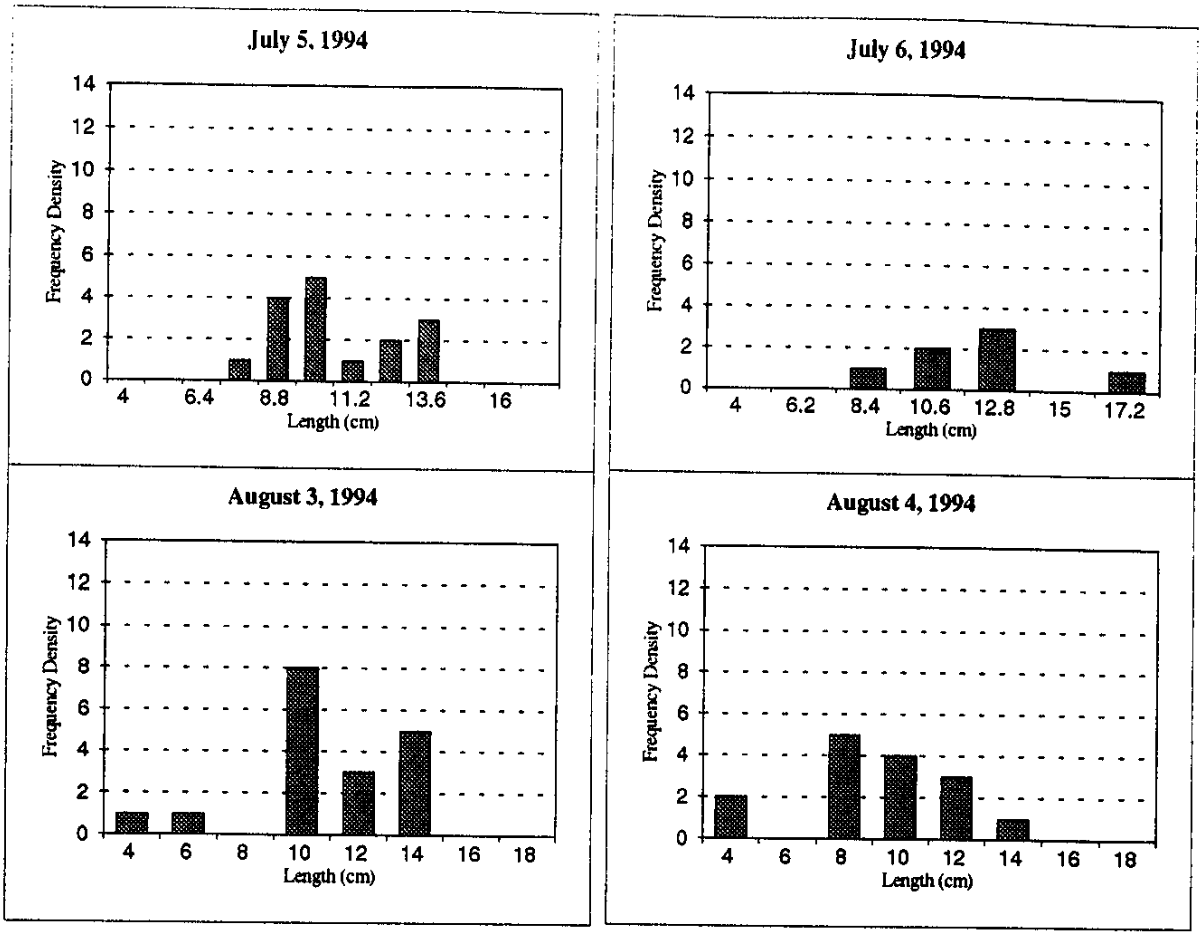
Plot 4


July 7, 1994
Frequency Density
0 2 4 6 8 10 12 14
4 6.4 8.8 11.2 13.6 16
Length (cm)
July 8, 1994
Frequency Density
0 2 4 6 8 10 12 14
4 5.6 7.2 8.8 10.4 12 13.6 15.2 16.8
Length (cm)
August 9, 1994
Frequency Density
0 2 4 6 8 10 12 14
4 5.7 7.4 9.1 10.8 12.5 14.2 15.9 17.6
Length (cm)
August 10, 1994
Frequency Density
0 2 4 6 8 10 12 14
4 5.7 7.4 9.1 10.8 12.5 14.2 15.9 17.6
Length (cm)

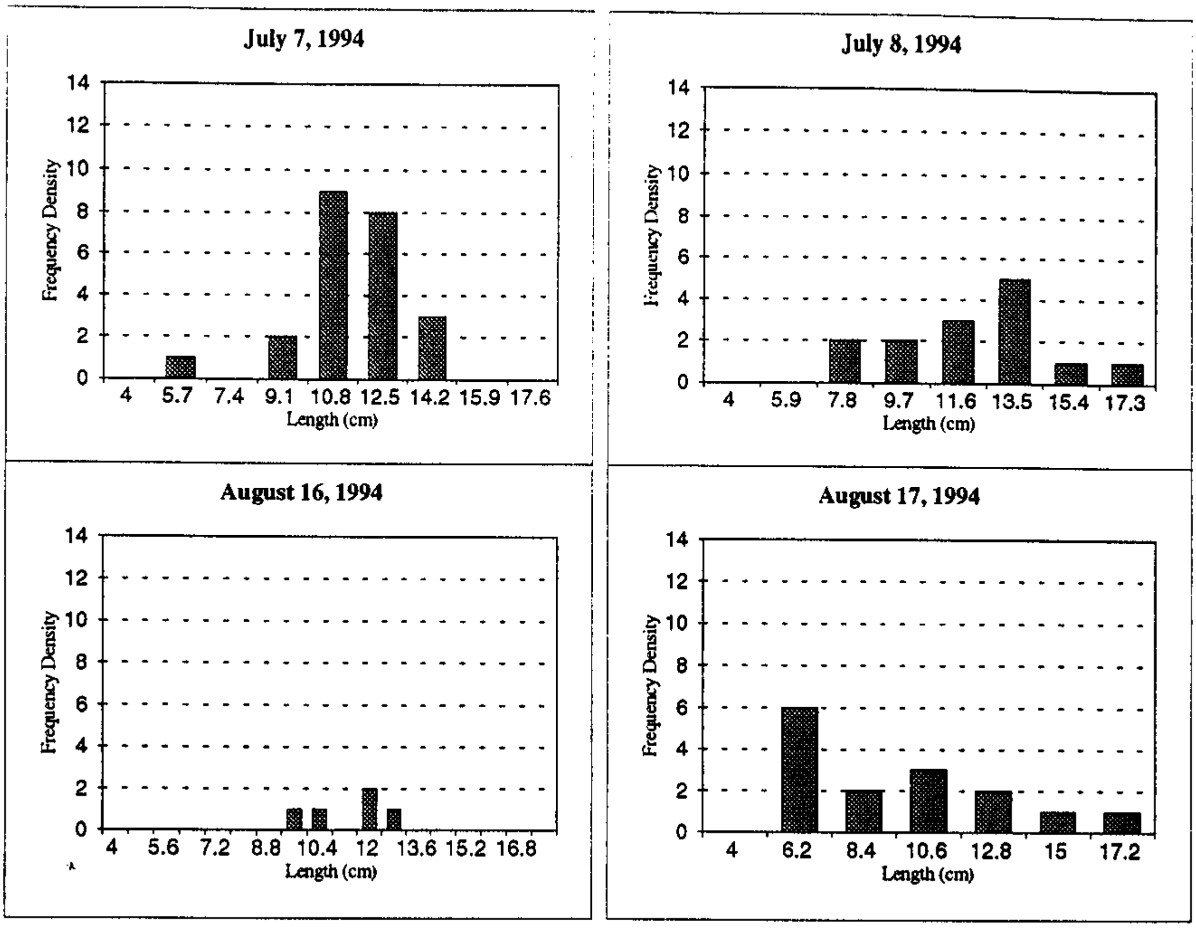
Plot 5



June 28,1994
Frequency Density
Length (cm)
4 5.5 7 8.5 10 11.5 13 14.5 16 17.5
June 30, 1994
Frequency Density
Length (cm)
4 5.9 7.8 9.7 11.6 13.5 15.4 17.3
August 3, 1994
Frequency Density
Length (cm)
4 6.4 8.8 11.2 13.6 16
August 4, 1994
Frequency Density
Length (cm)
4 5.8 7.6 9.4 11.2 13 14.8 16.6

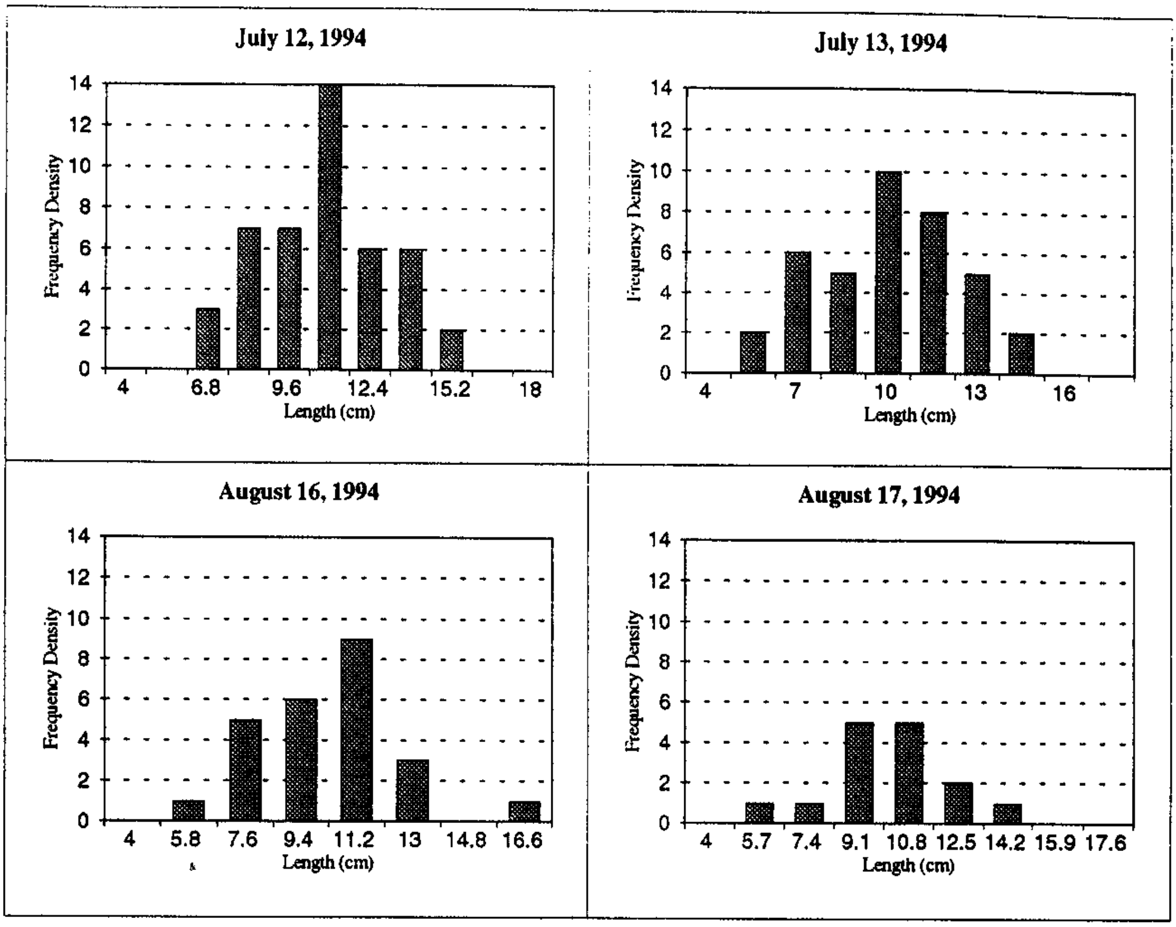

July 5, 1994
Frequency Density
0
2
4
6
8
10
12
14
4
6.4
8.8
11.2
13.6
16
Length (cm)
July 6, 1994
Frequency Density
0
2
4
6
8
10
12
14
4
6.2
8.4
10.6
12.8
15
17.2
Length (cm)
August 3, 1994
Frequency Density
0
2
4
6
8
10
12
14
4
6
8
10
12
14
16
18
Length (cm)
August 4, 1994
Frequency Density
0
2
4
6
8
10
12
14
4
6
8
10
12
14
16
18
Length (cm)

Plot 9



July 7, 1994
Frequency Density
14
12
10
8
6
4
2
0
4 5.7 7.4 9.1 10.8 12.5 14.2 15.9 17.6
Length (cm)
July 8, 1994
Frequency Density
14
12
10
8
6
4
2
0
4 5.9 7.8 9.7 11.6 13.5 15.4 17.3
Length (cm)
August 16, 1994
Frequency Density
14
12
10
8
6
4
2
0
4 5.6 7.2 8.8 10.4 12 13.6 15.2 16.8
Length (cm)
August 17, 1994
Frequency Density
14
12
10
8
6
4
2
0
4 6.2 8.4 10.6 12.8 15 17.2
Length (cm)

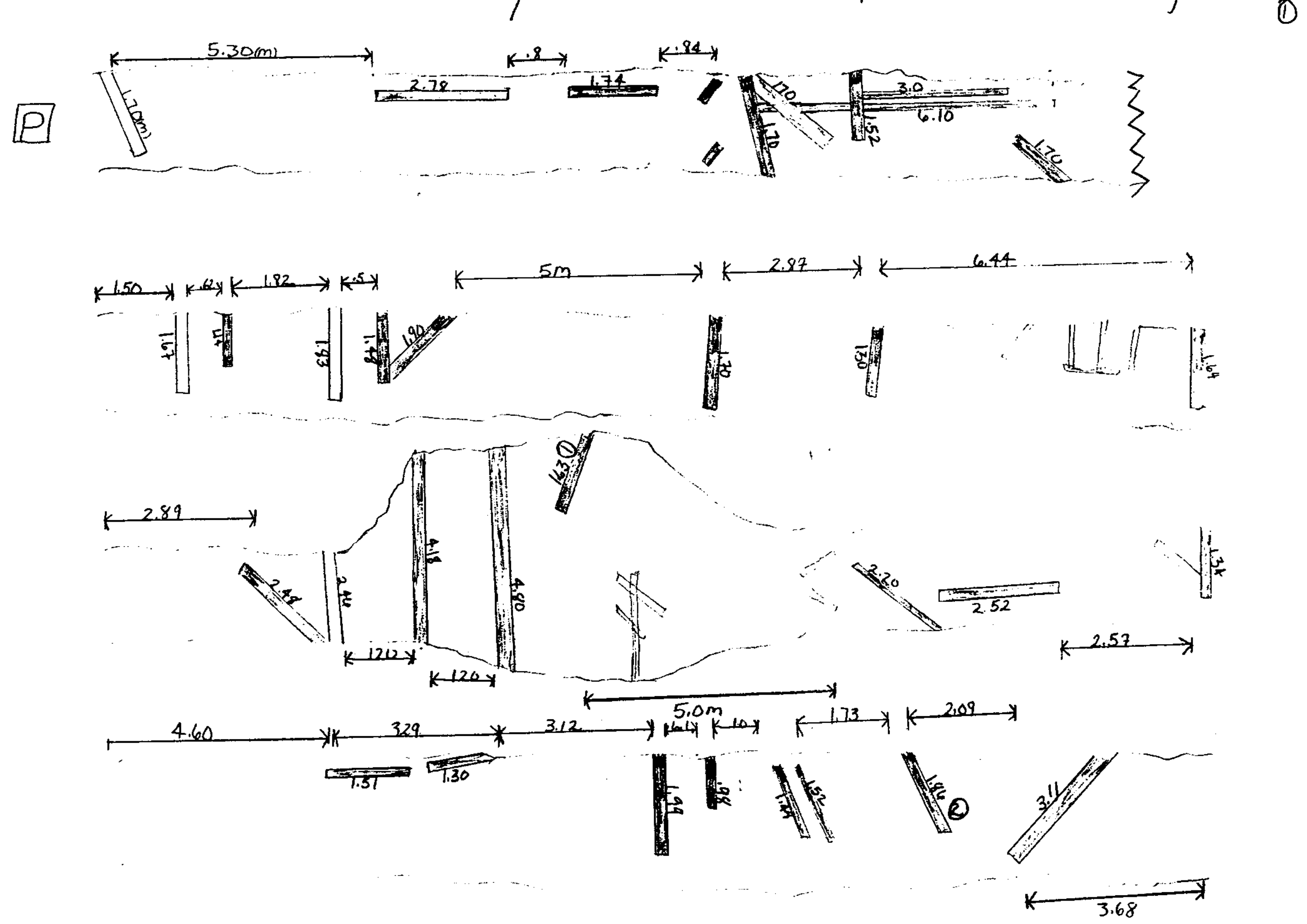
Plot 10

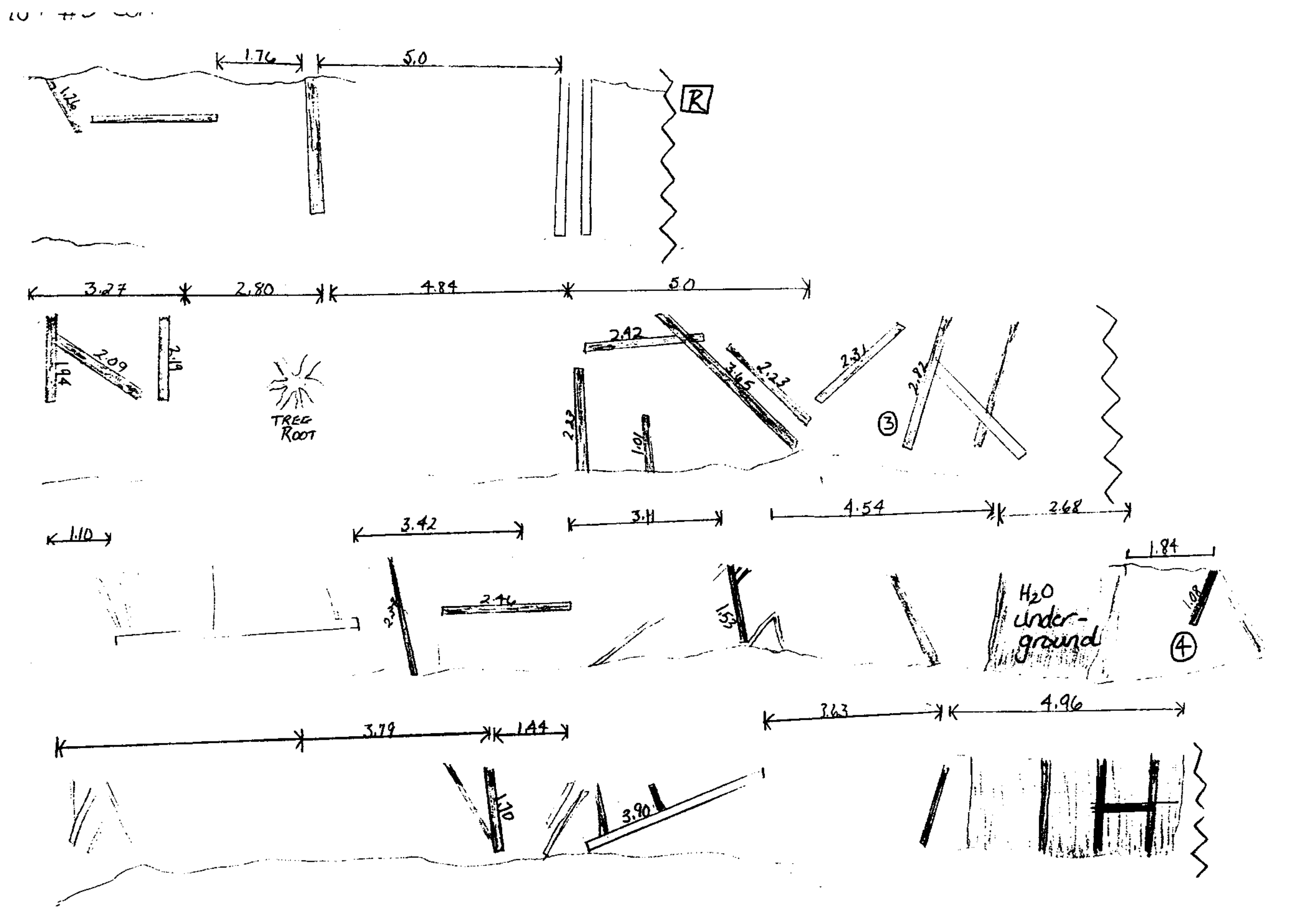


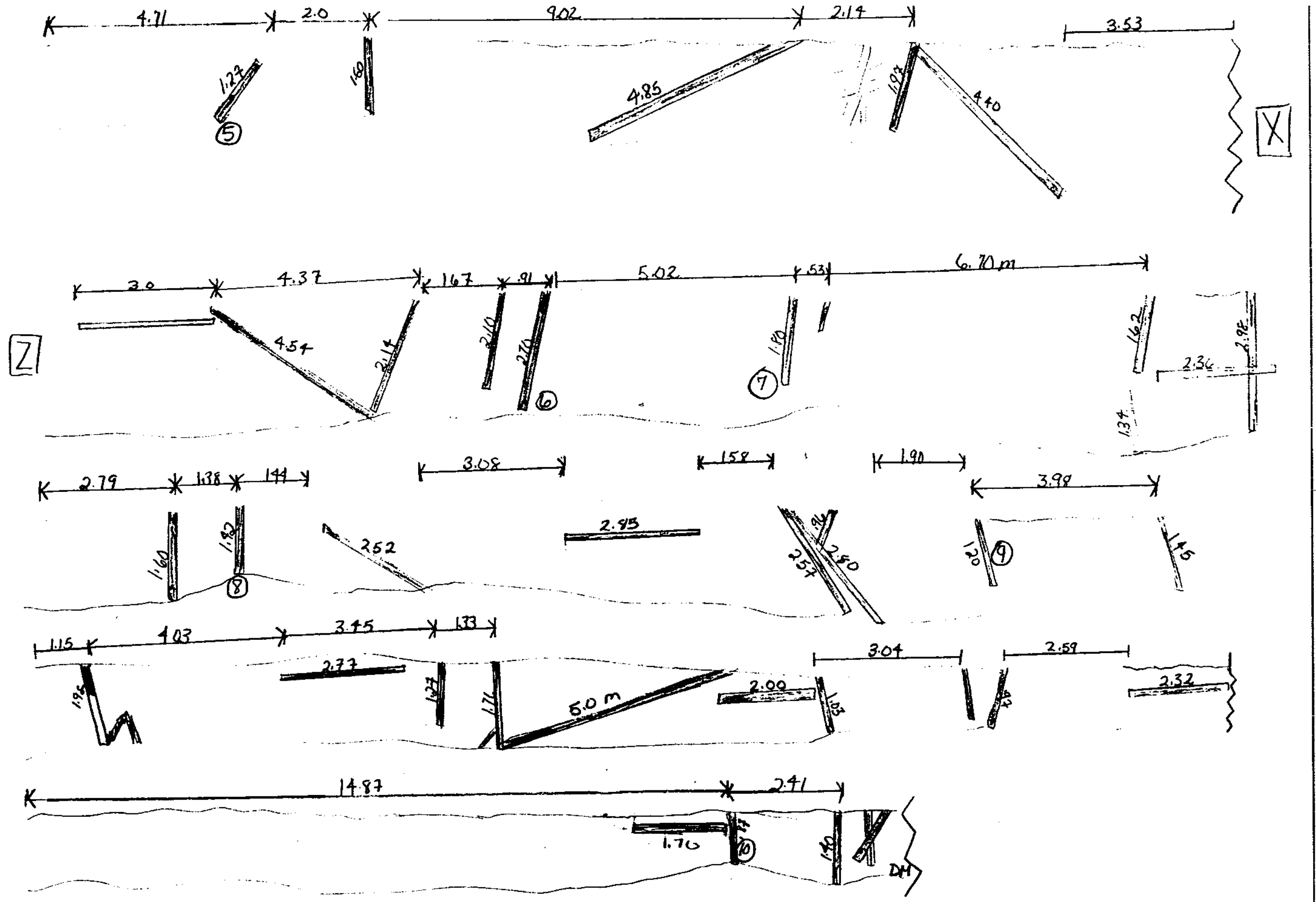
July 12, 1994
Frequency Density
Length (cm)
July 13, 1994
Frequency Density
Length (cm)
August 16, 1994
Frequency Density
Length (cm)
August 17, 1994
Frequency Density
Length (cm)

Appendix 2

Plot of wood debris.
Plot numbers refer to sites identified in Figure 1.


P
5.30(m)
1.70(m)
2.78
.8
1.74
.84
1.70
1.70
3.0
6.10
1.52
1.70
1.50
1.67
.62
.47
1.82
1.93
.5
1.48
1.90
5m
1.70
2.87
1.30
6.44
1.64
2.89
2.48
2.44
4.18
4.90
1.63
1.34
2.20
2.52
2.57
1.22
1.20
5.0m
4.60
3.29
3.12
1.73
2.09
1.51
1.30
1.99
.98
1.52
3.11
3.68


R
1.26
1.76
5.0
3.27
2.80
4.84
5.0
1.94
2.09
2.19
TREE ROOT
2.42
3.45
2.23
2.31
2.82
2.22
1.01
③
1.10
3.42
3.11
4.54
2.68
1.84
2.46
1.53
H2O under-ground
1.08
④
3.79
1.44
3.63
4.96
1.70
3.90



X
Z
4.71
2.0
9.02
2.14
3.53
1.27
5
1.60
4.85
1.97
4.40
3.0
4.37
1.67
.91
5.02
.53
6.70 m
4.54
2.14
2.10
2.70
6
1.80
7
1.62
2.36
2.98
1.34
2.79
1.38
1.44
3.08
1.58
1.90
3.98
1.60
1.82
8
2.52
2.85
2.57
2.80
1.20
9
1.45
1.15
4.03
3.45
1.33
2.77
1.27
1.71
5.0 m
2.00
1.03
3.04
2.59
2.32
1.96
14.87
2.41
1.70
10
1.40
DH

Maximum depth above and below digger logs (m)

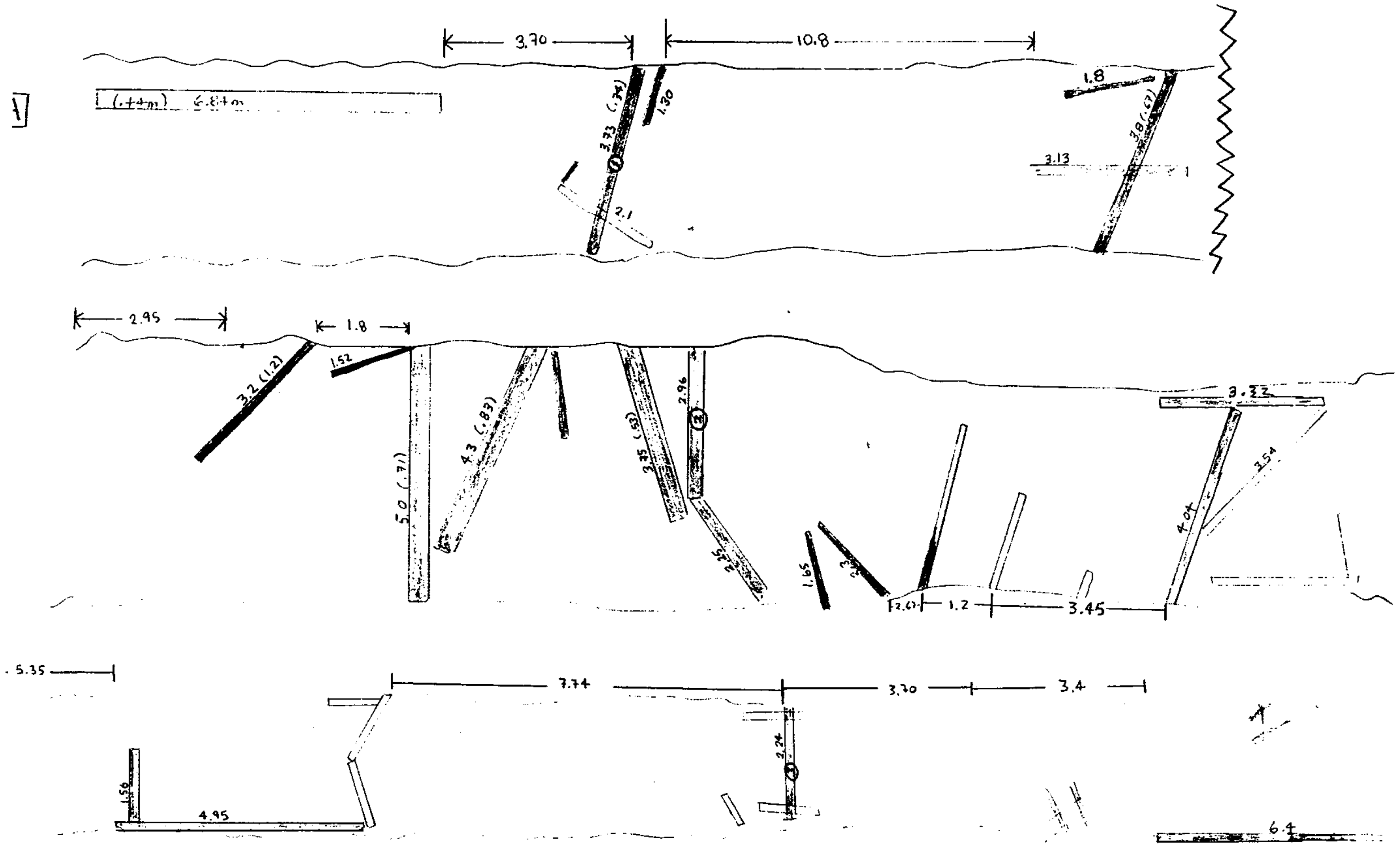
digger log	upstream	downstream
1	10	1
2	25	18
3	19	11
4	10	17
5	9	9
6	9 grass	13
7	10	13
8	9	11
9	11	8
10	grass	8

Legend:
log
log covered with vegetation
1 meter = 1 centimeter

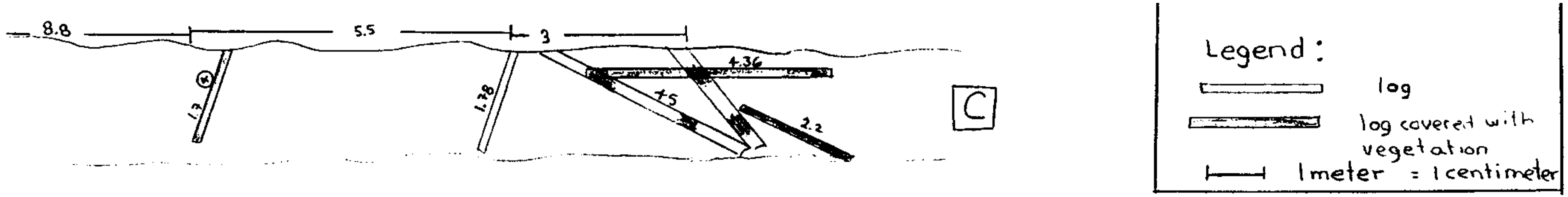
Average width of fist 100m = 1.37 m

Average width of middle 100 m = 1.49 m

Average width of upstream 100m = 1.31 m



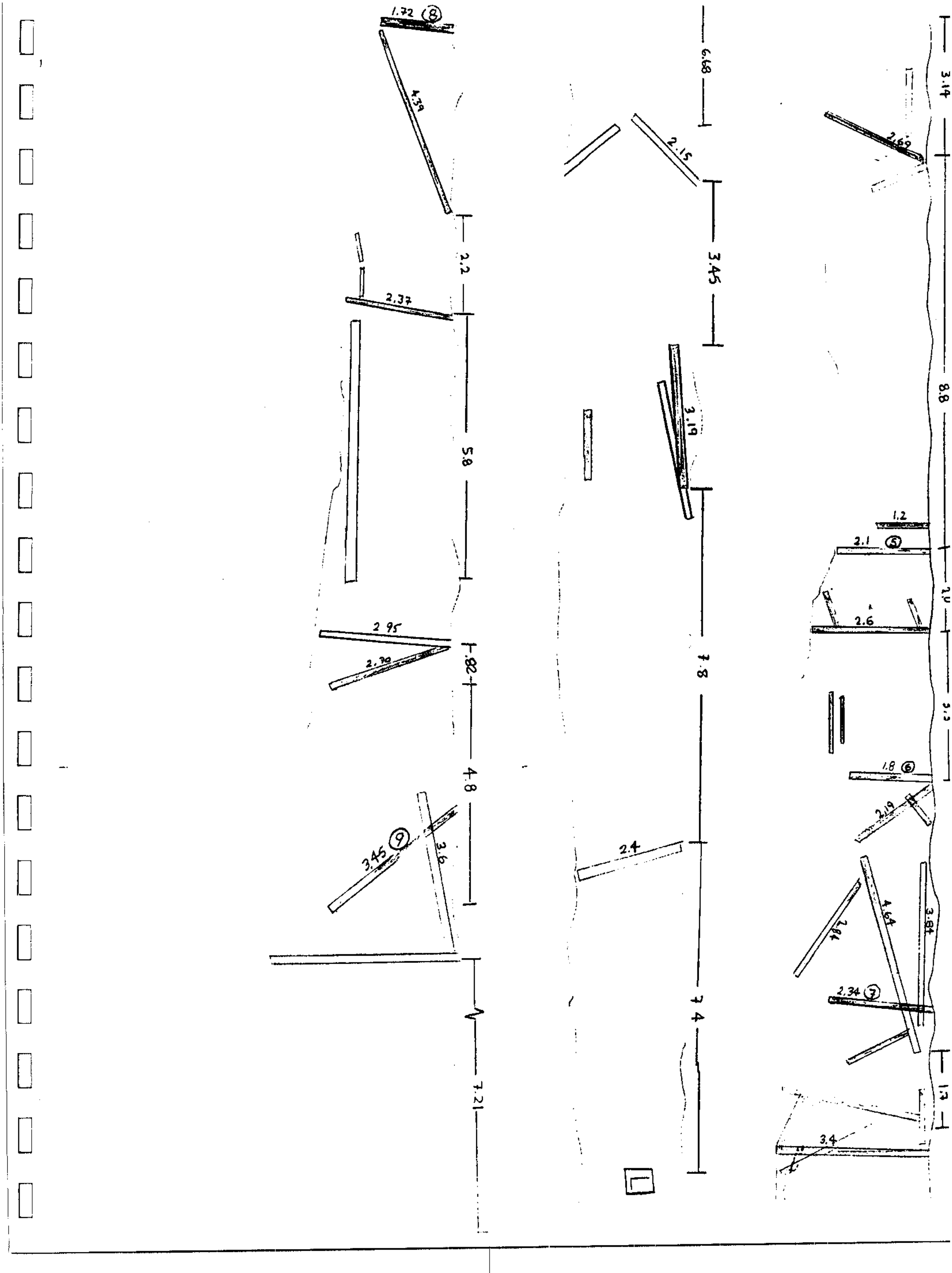
(.+4m) 6.84m
3.70
10.8
3.73 (.74)
1.30
2.1
1.8
3.8 (.67)
3.13
2.95
1.8
3.2 (1.2)
1.52
5.0 (.71)
4.3 (.83)
3.75 (.53)
2.96
2.25
1.65
3.33
3.54
4.04
1.2
3.45
5.35
7.74
3.70
3.4
1.56
4.95
2.24
6.4



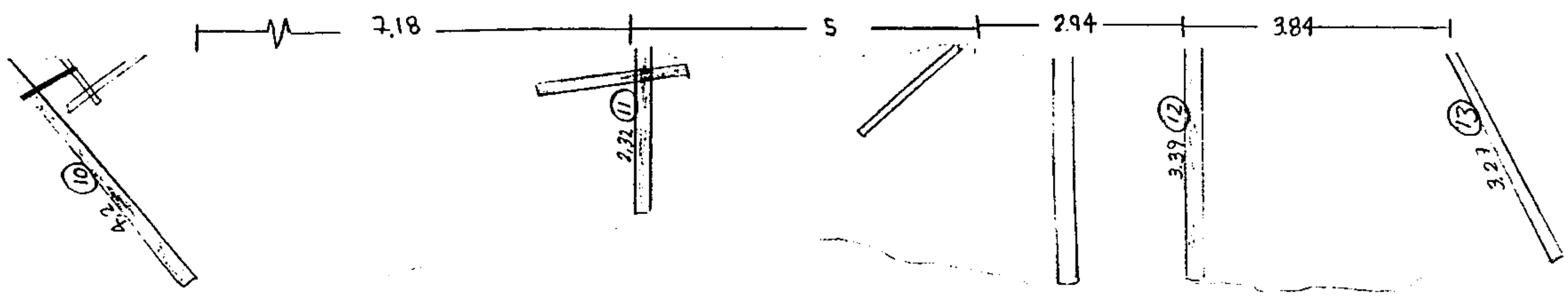
average width of first 100 m = 2.65 m

maximum depth above and below digger logs (m)

digger log	upstream	downstream
①	.07	.11
②	.13	.22
③	.17	.28
④	.11	.27



1.72
8
4.39
2.2
2.37
5.8
2.95
2.70
.82
4.8
3.45
9
3.6
7.21
6.68
2.15
3.45
3.19
7.8
2.4
7.4
3.14
2.69
8.8
1.2
2.1
5
2.6
2.0
1.8
6
2.19
4.64
2.84
3.84
2.34
7
1.7
3.4

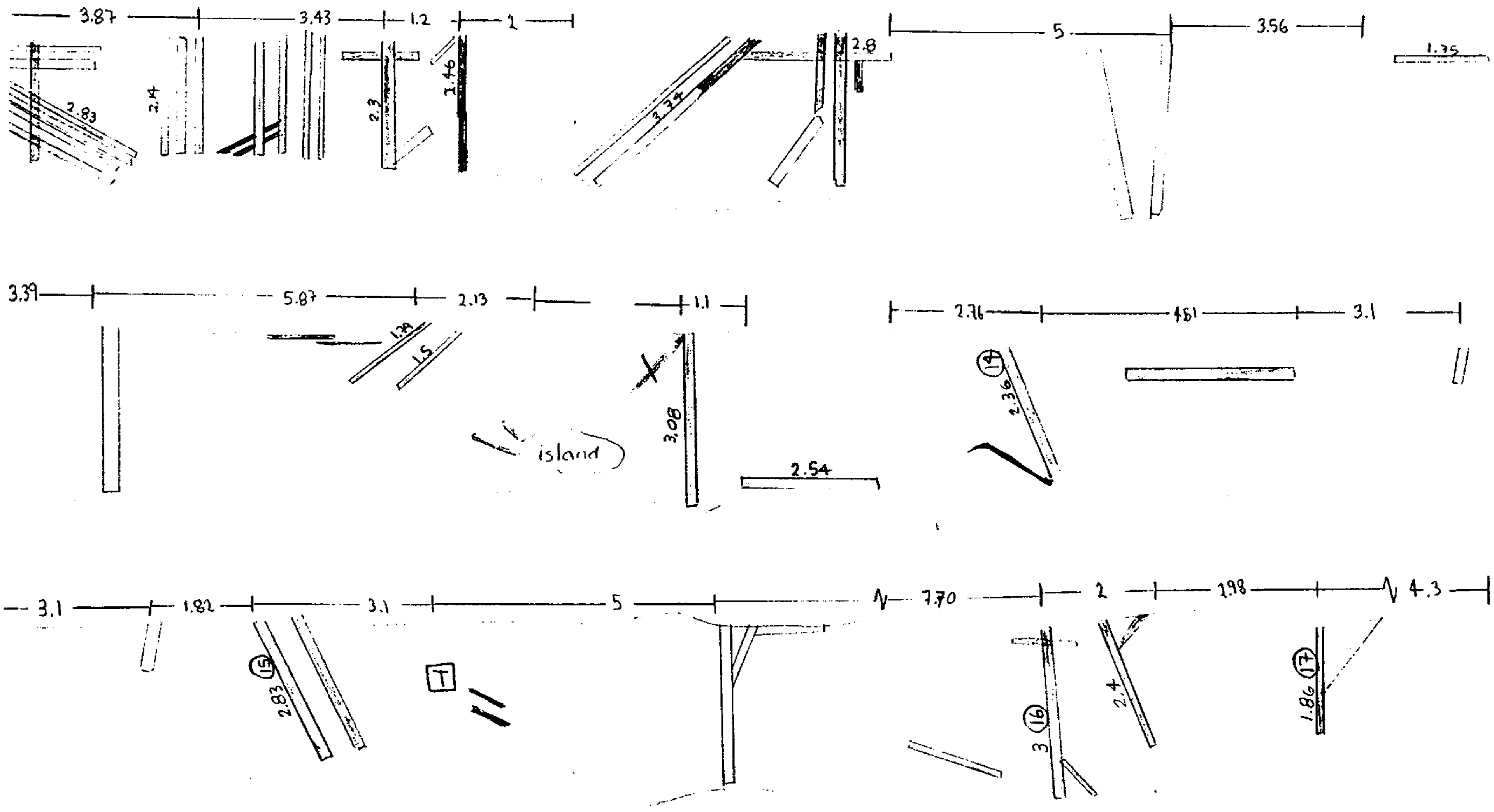


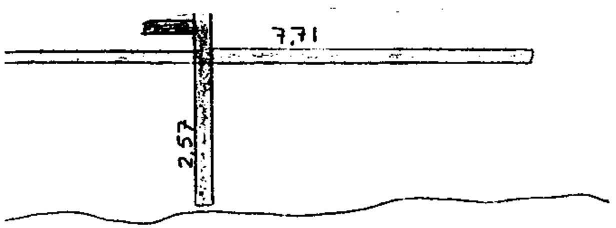
M

average width of middle 100 m = 3.07 m

maximum depth above and below digger logs (m)

digger log	upstream	downstream
5	16	18
6	21	18
7	41	17
8	14	23
9	20	28
10	16	17
11	33	24
12	19	20
13	17	16





average stream width of last 100 m = 1.91 m

max. depth above and below digger logs (m)

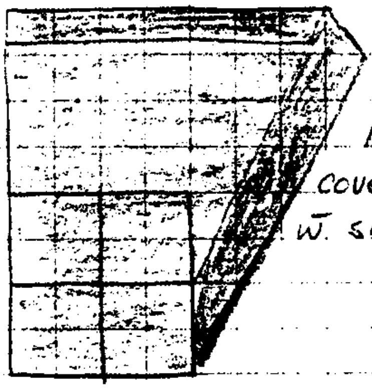
digger log	upstream	downstream
14	18	13
15	16	12
16	15	13
17	9	2

Appendix 3

Pool substrate composition.
Plot numbers refer to sites identified in Figure 1.
Originals are in colour.

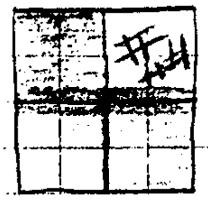
Plot #3 DETAILED POOLS ⊔ = .25m x .25

1.

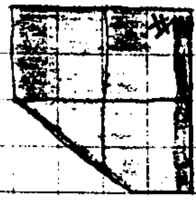


100% covered w. silt

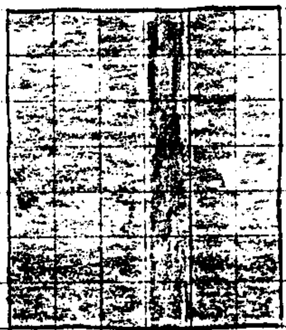
2.



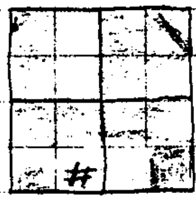
3.



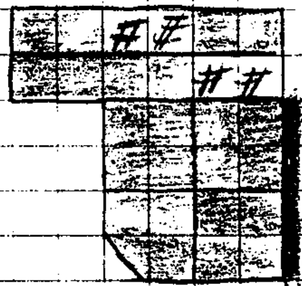
4.



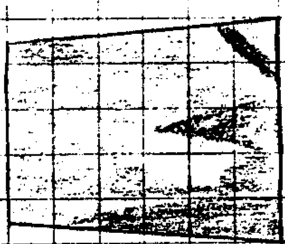
5.



6.

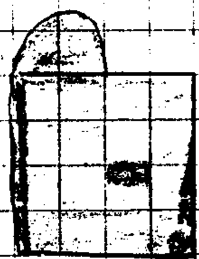


7.



100% covered w̄ silt

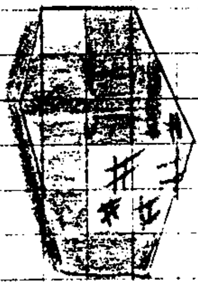
8.



100% covered w̄ silt

9.

10.

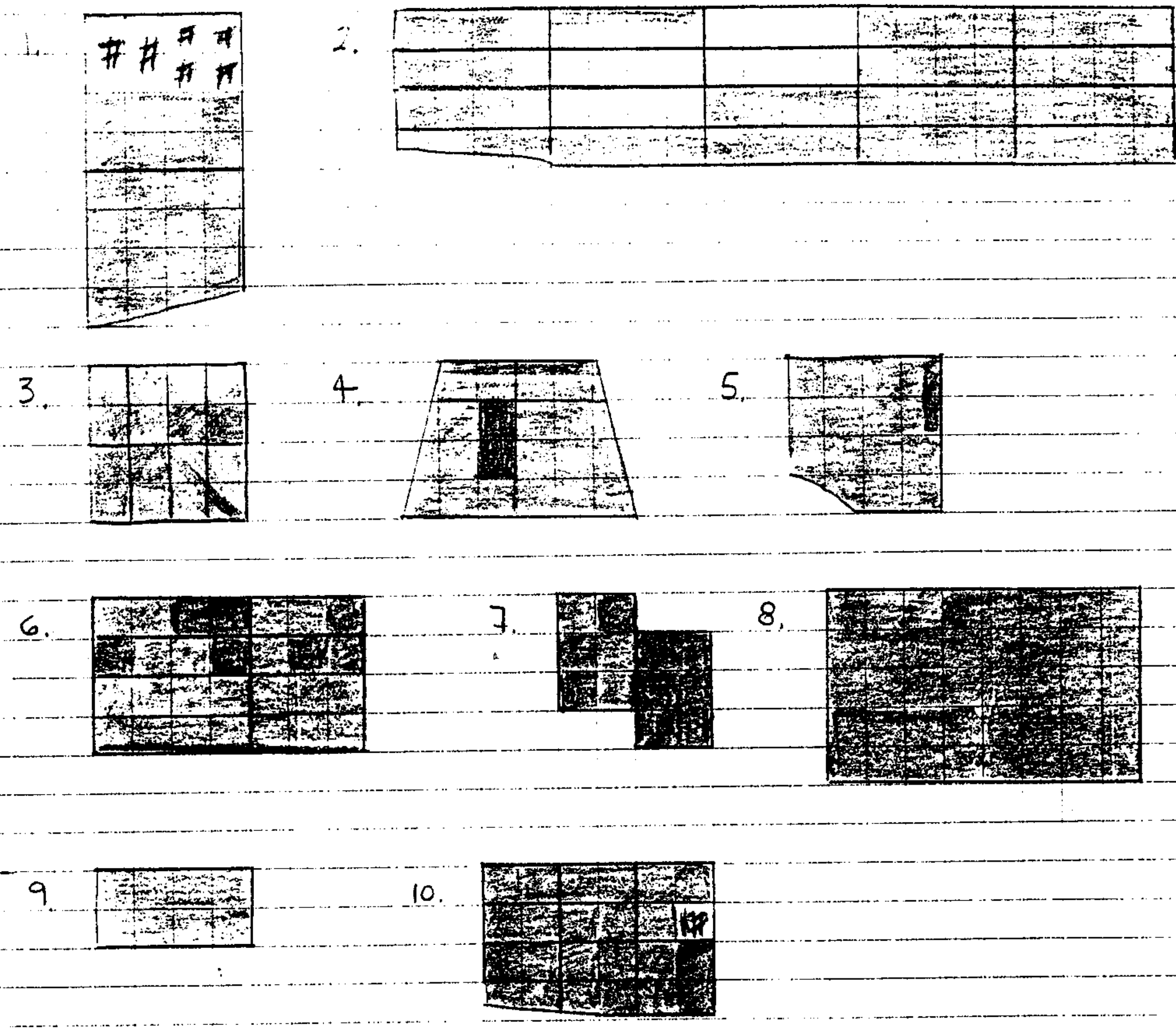


100% covered c̄ silt

cobble >5cm		sand	
cobble <5 >2cm		vegetation (+ logs)	
gravel <2cm		# woody debris	

Plot # 4 DETAILED POOLS July 28, 1994

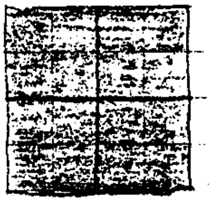
□ .25 × .25 cm



- cobble >5cm
- cobble <5cm >2cm
- gravel <2cm
- sand
- vegetation (+ log)

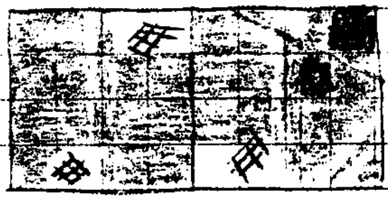
woody debris

Plot #5 — DETAILED POOLS — □ .25m x .25m — July 25,

1. 

2. 

3. 

4. 

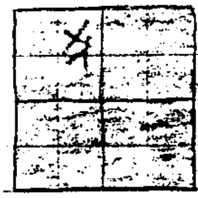
5. 

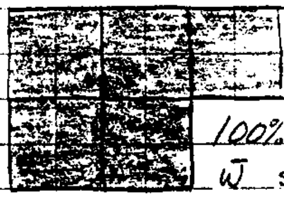
100% covered w̄ silt

6. 

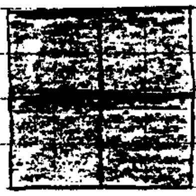
100% covered w̄ silt

7. 

8. 

9. 

100% covered w̄ silt

[illegible] 

cobble

gravel <2cm

sand

vegetation (+log covered w̄ vegetation)

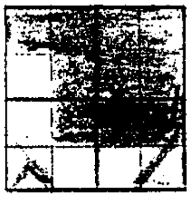
woody debris

Plot # 6 DETAILED POOLS July 26, 1994

1.

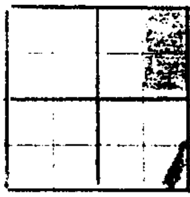
50% covered ū silt.

2.



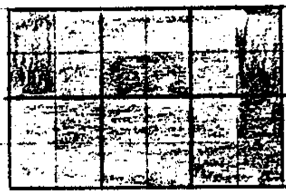
100% covered ū silt

3.



100% covered ū si

4.



100% covered ū silt

5.

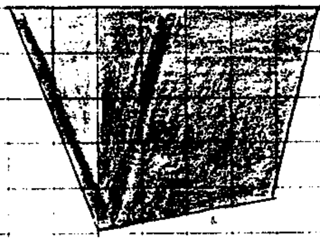
100% covered ū silt

6.

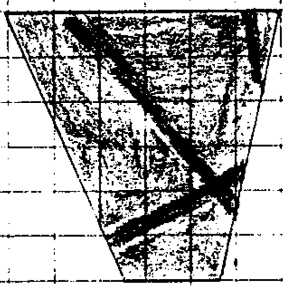
7.

20% covered ū silt

8.



9



10.

cobble >5cm

cobble <5cm >2cm

gravel <2cm

sand

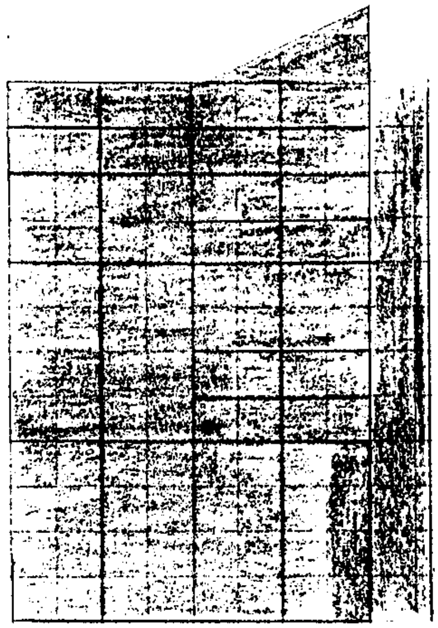
vegetation (+ logs)

woody debris

□ .25 x .25 cm

Plot #9 DETAILED POOLS Aug. 28, 199[illegible]

1.



100% covered w silt

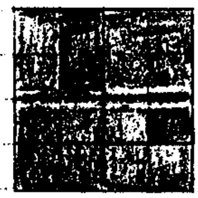
2.

3.

sand + gravel

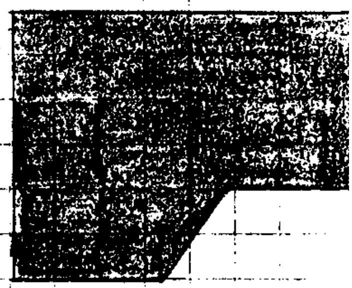
4.

5.

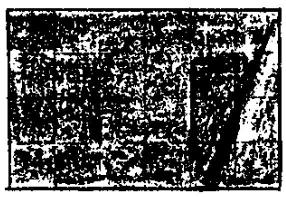


100% covered w silt

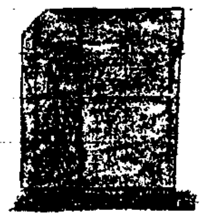
6.



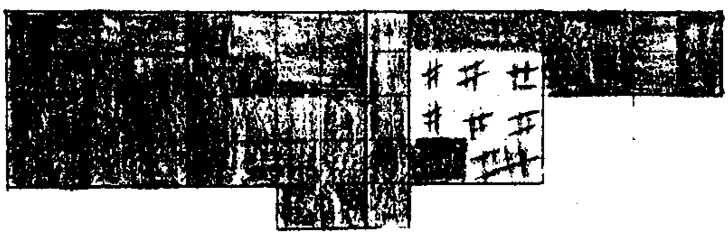
7.



8.

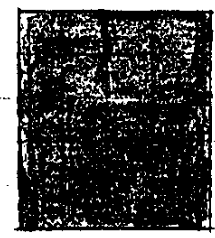


9.



100% covered w silt

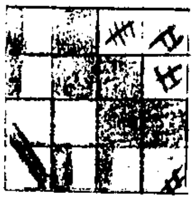
10.



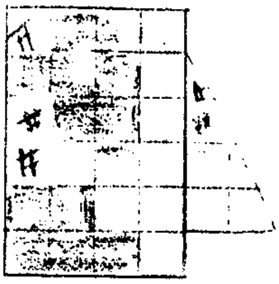
.25 X .25 cm	cobble >2cm < 5cm	sand
cobble >5cm	gravel <2cm	vegetation (+ logs and debris

Plot # 10 DETAILED POOLS August 11, 1994

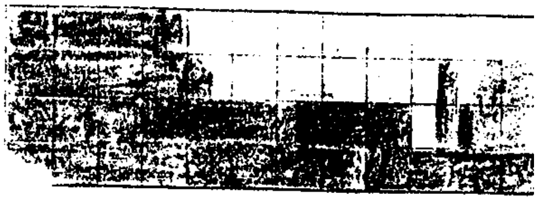
1.



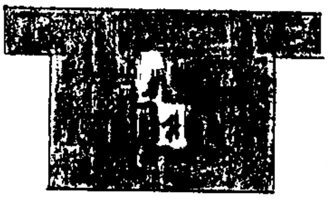
2.



3.

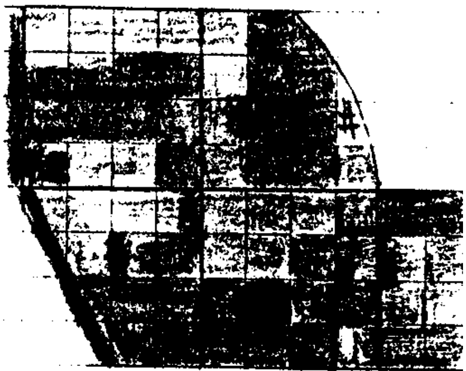


4.

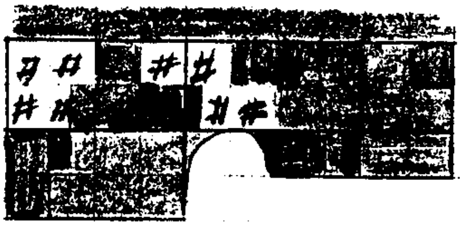


5.

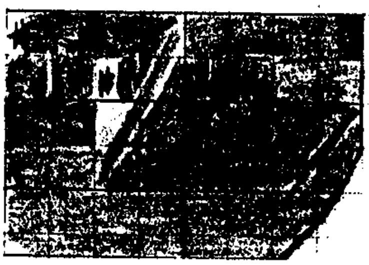
6.



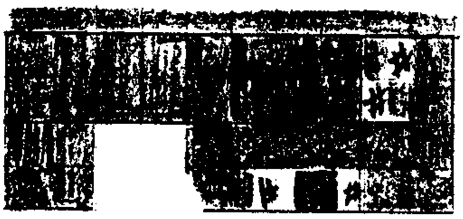
7.



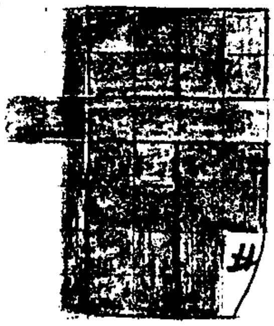
8.



9.



10.



	.25 x .25 m
	cobble >5cm
	cobble <5cm >2cm
	gravel <2cm
	sand
	vegetation (+ log)
#	woody debris

Appendix 5: Annual report (1994-95) on "best management practices" research at the Hayward Brook Watershed Study.

Appendix 6: Annual report (1994-95) on the results of water monitoring at the Hayward Brook Watershed Study.

ENVIRONMENT CANADA / ENVIRONNEMNT CANADA

HAYWARD/ HOLMES BROOKS WATER MONITORING PROJECT

FUNDY MODEL FOREST

ANNUAL PROGRESS REPORT

1994-95

J. Pomeroy (ECB) P. DeLong (AEB) J-G Deveau (ECB)

Dr. T. Pollock (ECB)

MARCH 01, 1995

TABLE OF CONTENT

1. OBJECTIVES AND DESCRIPTION

The Hayward /Holmes Brooks Water Monitoring Project is part of an integrated applied research effort being conducted under the umbrella of the Fundy Model Forest (FMF). The water monitoring project is included within the Water Resources sub-group of the FMF, but affinities exist with other sub-groups, particular Biological Diversity, Soils, and Landscape Dynamics.

The general objectives of the overall research work being done in the study area is to provide information required to develop best management practices for a forest in a variegated landscape. In this context, managemen includes the animate and inanimate constituents of the ecosystem, not just maximizing fibre production. In such an ecosystem, water is the main medium by which the landscape is sculpted and nutrients are carried to, or away from the animated component. This justifies and even imposes the looking at water quality and quantity in concert with the effect of forestry practices (ripari strips) on the biosystem. The water monitoring project's objective is to determine the stream hydrogeochemical interactions to different forestry practices.

The FMF is located in southern New Brunswick and covers an area of some 4200 km2. The area was selected as representative of the coniferous/deciduous mix of the Acadian Forest. Both Hayward and Holmes Brooks watersheds are a tributary of the Anagance/Petitcodiac River system which drains a sizeable portion of the model forest area.

2. EXPANDING PROJECT TO HOLMES BROOK

Initially the water monitoring project was located in the Hayward basin only. The network consisted of eight stations of which 4 contained automate water monitoring stations which collect hourly data on stage height, equipmen condition and water quality. In 1994 all parties conducting research in the known as sites 7,8 agreed that these two sites were not suitable because of historic anthropogenic impacts. To replace these, two new sites were established in the adjacent Holmes Brook.

In mid summer two staff gauges were surveyed in at site 3 on Hayward Brook and at site 9 in Holmes Brook. The placement of these will provide sta height which will be used in calculations with discharge to determine loading

In the fall of 1994 JDI Ltd. began construction of the haul roads. Originally the main road was to pass above the water monitoring sites 5 and 6 but due to a change in the company's plans the road was placed below the sites. This decision meant the the impact of the road could not be assessed with repect to the water component. Because of the potential impact associat with haul roads Environement Canada has provided funding to purchase an additional water monitoring system to be placed in Holmes Brook at site 9.

3.0 ACCOMPLISHMENTS IN 1994

In 1993-94 the four water monitoring stations supplied by the EC Projec 2000 (Modernization) Initiative were installed. Water quality mutiprobes at sites were installed in March of 1994 and the other two in June. Since thos dates the probes have been operational.

In the summer of 1994, site 3 in Hayward Brook and site 9 in Holmes Brook were surveyed in by P. Delong (AEB) for the positioning of staff gauges for stage height. This project was not included in last years goals, but aft considering the importance of these sites and the calculation of loadings AEB gave the approval for installation. As part of the commitment for the instal of the staff gauges AEB will also provide additional time to do discharge measurements and calculate rating curves.

Another major accomplishment for the water project was the approval by ECB to purchase equipment for an additional water monitoring station for placement in Holmes Brook, site 9. This station will be the same as the othe automated station with the exception that it will have a low ionic strenght p probe. The establishment of this station is very important to the final res the project because this will be the only station below the haul road. AEB a ECB will provide in 1995 the time for the installation and the ongoing operat for this additional site .

In 1994 two hundred surface water grab samples and numerous suspended sediment samples were collected as part of the water quality study. Along with the maintenance of the stations AEB completed 44 stream discharge measurements.

In the fall of this year Dave Wilson a geographer from EC Dartmounth spent two days at Hayward / Holmes Brook categorizing and photgraphing the landscape along the streams being sampled. He also reviewed available air photos of the study area to determine which are best suited for our study. T information will be used in a GIS universe being created in the coming year. His observations will be incorporated into a GIS layover.

The past year has been challenging for those operating the automatic stations on a continuous basis, but overall the problems were solved and 1995 is expected to be another successful year.

To maintain the project, technical and scientific staff from various EC sections were:.

- Joe Pomeroy - Moncton: project scientist for water quality, suspended sediment and inverterate sampling

- Tom Pollock - Moncton: FMF contact and scientific expertise
- Jean-Guy Deveau - Moncton: project co-ordinator and hydrometric expertise
- Roy Lane - Fredericton: Field reconnaissance and project design
- Peter Delong - Fredericton: field co-ordination and operations
- Tom Springer - Moncton: water quality instrumentation and electronic expertise
- Dick Bingham - Moncton: Project data management
- Guy Brun - Moncton: Laboratory analyses
- Gerry Parker - Sackville: University student sampling and co-ordination with Biodiversity sub-group
- Dave Wilson - Darthmouth: Forest stand and landscape expertise

4.0 INTERACTION WITH OTHER PLAYERS

Canadian Wildlife Service:

The Canadian Wildlife Service component of Environment Canada is a key proponent and collaborator in the Hayward brook Project. During the wint of 1995 field workers contracted by G.Parker to do large mammal surveys collected additional surface water samples during each plot survey. CWS also provided equipment, such as an ATV to the water group.

University of New Brunswick:

Dr. Krause of UNB is studying best management practices (variable riparian buffer strips) in sites 1 and 2 of the Hayward Brook Project. Autom continuous water monitoring in site 1 and surface water grab sample data from both sites will be made available to Dr. Krause for evaluating the temporal variability of key water parameters.

Université de Moncton:

Dr. Alyre Chiasson is studying aquatic species in the plots . The study plots have been surveyed for fish counts, river bed characteristics, etc. His studies will use the flow and water quality data collected at the EC stations.

JD Irving Ltd.

JD Irving Ltd have received input from the water group on the placement of haul roads and consultation in relation to tree stand treatment. During t harvest phase of the program information will be exchanged to correlate water events with harvest events.

5.0 IMPLEMENTATION OF PROJECT

Problems met/overcome:

- Access to stations was by ATV loaned by G. Parker of CWS and in the winter a Ski-doo was on loan from R. Lane, AEB Fredericton. AEB also purchased an ATV in 1994 which was also used at these sites. A trailer was rented from Atlantic Cycles in Moncton to transport vehicles to the site.

- Power source for stations -> At two sites with telemetry, the gel bat size had to be increased from 26 AMP/Hour to 100 AMP/Hour. In the spring the foliage was shading the the solar panels at telemetry sites and caused the batteries to discharge below 10 v. This problem was overcome by replacing th 18 watt solar panel with a 30 watt panel and installing a different voltage regulator which allowed more amperage to flow from the panel to the battery. A problem with battery voltage reoccurred at the telemetry sites and to preve the loss of data, the satellite transmitting unit at site 1 was disconnected September and replaced with a basic Vedas logger. At site 5 the real time d variables were reduced so that only water level data is now transmitted. Wit the reduction in variables power supply has been maintained to an acceptable level.

- Data logger programing - When power voltage decreased to the minimum level required to operate the logger, a design flaw in the VEDAS woul cause the programing to be lost. Because reentering the progam can be time consuming, the VEDAS utility program was purchased to enable the program to be stored in a notebook computer and uploaded to the logger when required.

- Nitrogen gas loss- Because of inaccurate nitrogen gas tank regul the line feed on the transducers cause the bubble rate to increase which resu in the use of large amounts of nitrogen gas. To deal with this problem the l feed pressure is positioned to full (15psi compared to 5psi). When the regul is fully opened the treads are tighlty sealed and gas is less likely to escap inline pressure relief value was installed to protect the transducer from hig pressure should the line freeze.

- Multi probe removal - Because of the unusually dry summer and fall, water levels at sites 1 and 4 were extremely low. This condition resulted in removal of the probes at these sites between the first freeze up in December a high precipitation period in late January 1995. The precipitation in Janua was significant enough to increase the discharge so that the probes were . submerged in running water at a level in which freeze-up should not occur.

6.0 RESULTS OBTAINED - EVALUATION OF OUTPUT

Water data has been collected throughout 1994 at the eight sites in Holmes and Hayward Brooks. Hydrometric data collection began at the automatic stations in December 1993, and water quality data collection from t multiprobes began in January- March,1994. Surface water grab samples were collected throughout the project with 300 samples analyzed to date (200 in 1994). Suspended solid samples were collected at each station during the summer and fall of 1994. The number of suspended solid samples are lower than expected as a result of the extremely dry fall.

The automatic data collection went well with only 12 percent data loss i 1994. The loss of data was associated with the power problems at all station and low water levels at sites 1 and 4 on Hayward Brook (See Section 5.0). Discharge measurements were taken throughout the year in an effort to measure different discharge volumes. Measurements at various stages in the hydrologic cycle are required to calculate a stage discharge curve. The low water levels this year introduced various sources of error in the discharge measurements. P. Delong (AEB) expects that on a few occasions the water levels may have been too low for the metre to accurrately detect the currents Another source of error created by the low flow was backwater as a result of build up of leaves in the fall and the build up of ice early this winter. B Delong rated the quality of the discharge measurements as good with smooth stream bottoms and even velocities at the metering sections. Rating cuvres a now being processed. Shift corrections based on actual discharge measurements will be applied when and where required.

The surface water grab samples have been collected since July 1993. The data has provided a good baseline although low water conditions in 1994 were unusally low and are expected to be an atypical year for this basin. Th data from the mutiprobes has been collated and will be analyzed after a coupl of transformations have been programed into the database transfer. As of January 1995 site 5 monitoring station had logged 8500 values for water temperature, dissolved oxygen, specific conductance, pH, and turbidity. Simi databases are present for the other 3 stations. The data appears to be supported by the grab sample analyses and discreptancies are usually present in the early stages of the data. The discreptancies are usually associated w a problem in design which was corrected with minor alterations. An example i the sand which settled in the protective jacket and filled the turbidity metr problem was corrected by drilling holes in the casing and allowing the water current to wash the sand out. Other discreptancies occurred with long calibration periods. Experience has shown that a four week calibration perio provides best data. These discrepancies will be corrected by calulating a calibration correction factor into the final value.

The final data from the mutliprobes will be used to supply real time measurements of the 5 variables mentioned above, and to produce inferences about other variables. The specific conductance in the basins is mainly the result of calcium and sulphate. The Mutliprobe data will provide an insight the movement of these ions in groundwater and through the surficial soil duri precipitation events and during soil disturbances. Turbidity will be used to determine the erosin in these basins, but will also be considered in its use estimate the concentrations of nutrients moving through the system. The multiprobe data will be ready for initial interpretation shortly. The grab s have provided an overview of the baseline conditions in the two basins. For this report the data from the eight stations have been grouped together and sorted by month. The graphs will provide a indication of the baseline condit which have existed with minor anthropogenic impacts. The minor impacts include old roads which are used by ATVs and hunter vehicles.

The data in figure 1 indicates that the basins receive minor quantities nutrients from the surrounding forest land. The increase in the lowest concentrations on the graph from 0.01 to 0.02 mg/L was a result of a change in the detection limit of the methology for nitrate-nitrogen. The peaks in t nitrate-nitrogen graph show that of the 300 samples collected the concentrati are all below the 0.1 mg/l. The peaks on the graph are usually samples from smaller sized brooks.

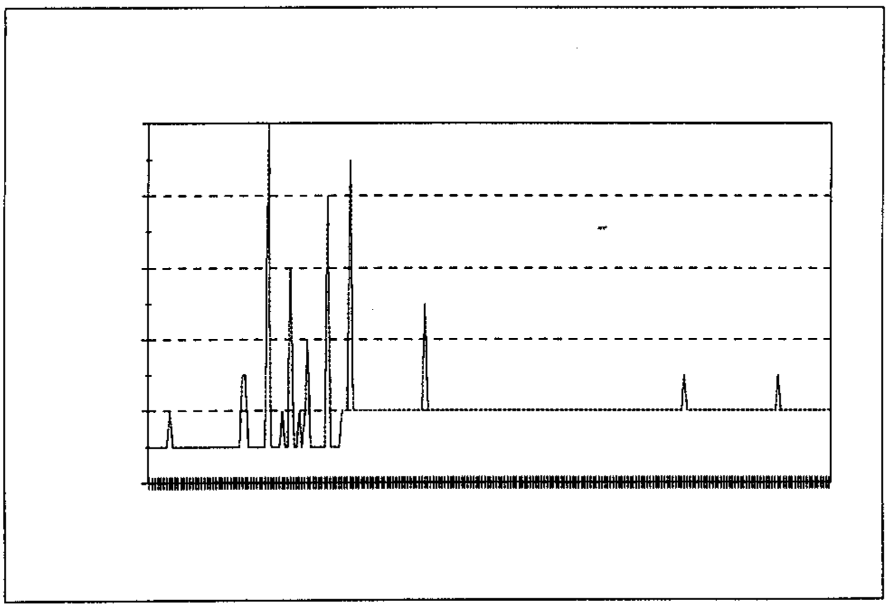


Figure 1

Turbidity in JT units also indicate that in these two watersheds the quantity of suspended material is minor (see figure 2). The peak in March of 1994 was at site 4, a control site on Hayward Brook. This brook is one of the smalles size and so has a tendency to flush quickly during spring floods.

Figure 2

The specific conductance at the eight sites shows a typical range expected fo brooks with a low discharge (see figure 3). In this area the major ions are calcium, sodium, and sulphate. Because of the geological origin of these ion high concentrations are present in the summer when groundwater supplies much of the brooks' flow. In the high discharge times the dilution factor ca concentrations to range between 20 to 40 µsie/cm. The graph also indicates t difference in geology of the streams.

Generally sites 1,2,3 of Hayward have low conductivity whereas the other sit produce higher values.

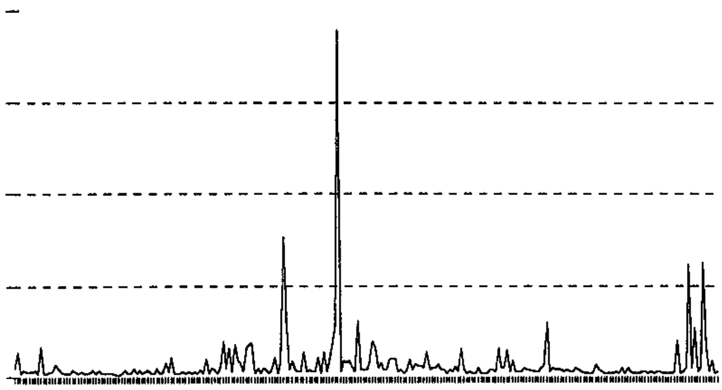


Figure 3

Alkalinity is almost the mirror image of the conductance because both are basically driven by three major ions which include calcium (see figure 4). T graph represents the concentrations found in all eight sites and again shows variability present in the two basins. The concentrations drop in the high discharge periods but again this is a result of the dilution factor. In summ concentrations are the highest and in the summer of 1994 concentrations reached up to 50 mg/l as a result of lack of rain.

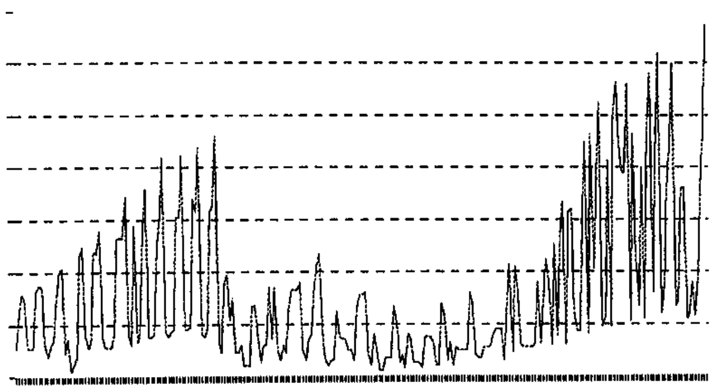


Figure 4

The pH in the eight streams usually ranges between 7.0 and 7.5 pH units (see figure 5). At two occasions the pH dropped to below 6.5 units, and both readings were at site 4, the control site. These two samples were collected triplicate and the pH range is within 0.4 units. An interesting aspect in th pHs is that alkalinity also reached its lowest concentrations at those times. major difference in the features of this plot is that the upper portion of th watershed is located in a historical clearcut. The significance of this is n known. Generally at the eight sites the higher pH occurs in the summer mont when alkalinity is high as a result of groundwater and the lower pH occurs in winter during thaws.

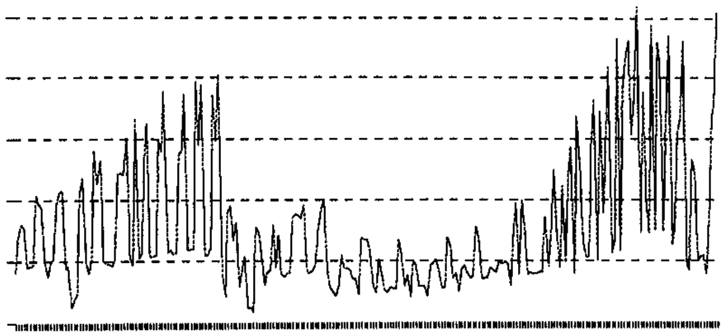


Figure 5

In the next few months the water data collected at the eight sites will be interpreted to a greater degree. At that time water quality and quantity wil considered and loadings will be calculated for this preharvest period.

PROPOSED PROJECT GOALS FOR 95/96

Goals for the comimng year include:

- the installation of the water monitoring station at site 9, Holmes Brook
- the operation and maintenance of 5 automated water monitoring stations

- the collection of surface water and suspended sediment samples at the 8 sites
- collection of stage height and discharge measurements at the staff gauge in place at site 3
- obtain discharge measurements at the six gauged sites to establish stage-discharge rating curves and discharge measurements in the ungauged sites to correlate with the gauged sites
- a request has been proposed to purchase a software package "CompuMod", for the analysis of water quality data. This system is presently in use in Fredricton by AEB in the analysis of hydrometric da

An additional task set up for this year is the creation of a GIS universe for