THE COPPER LAKE BUFFER ZONE STUDY: PROJECT SITE DESCRIPTION AND GENERAL STUDY DESIGN

D.A. Scruton, K.D. Clarke, J.H. McCarthy, S. Forsey, D.M. Whitaker, G.I. McT. Cowan, E. Baggs, W.A. Montevecchi, J.M. Green, I. Bell and L.J. Moores

Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland
A1C 5X1

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by

D.A. Scruton, K.D. Clarke, J.H. McCarthy[1], S. Forsey[1], D.M. Whitaker[2], G.I. McT. Cowan[1], E. Baggs[1] W.A. Montevecchi[2], J.M. Green[1], I. Bell[3] and L.J. Moores[4]

Department of Fisheries and Oceans
Science Branch
P.O. Box 5667 St. John's, NF
A1C 5X1

[1] Department of Biology, Memorial University of Newfoundland
[2] Biopsychology Program Department of Psychology, Memorial University of Newfoundland
[3] Newfoundland Department of Environment - Water Resources Management Division
[4] Newfoundland Department of Natural Resources - Newfoundland Forestry Service

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABSTRACT/RESUME

Scruton, D.A., K.D. Clarke, J.H. McCarthy, S. Forsey, D.M. Whitaker, G.I. McT. Cowan, E. Baggs, W.A. Montevecchi, J.M. Green, I. Bell, and L.J. Moores. 1995. The Copper Lake Buffer Zone Study: Project Site Description and General Study Design. Can. Tech. Rep. Fish. Aquat. Sci. No. 2043: vi + 47 p.

Currently, recommended buffer strip sizes for environmental protection related to forest management practices in Newfoundland have been based on 'best available information' from research conducted in other jurisdictions. Region-specific considerations are essential to fully understand forestry and fish/wildlife interactions and to establish the need for and benefits of mandatory protective buffer zones, including appropriate size (width). The Copper Lake Buffer Zone Study is a multi-agency and multi-disciplinary research study that was conceived to conduct region-specific research on the benefit of providing buffer strips in riparian zones to protect fish and wildlife resources, and water quality. The study is designed to quantify environmental perturbations arising from forest harvesting operations and investigate the ability to ameliorate these perturbations through the provision of an unharvested leave strip of varying widths along riparian zones. This initial report from this research project is intended to document background information on the study. The report includes a general description of the study site, identifies the roles and objectives of the various study participants, outlines the general study design, and provides some detail on the various study components and methods to be employed.

Jusqu'à présent, la largeur des bandes tampon ménagées à des fins de protection de l'environnement dans le cadre des pratiques de foresterie à Terre-Neuve est calculée à partir des "meilleures informations existantes" tirées de recherches menées dans d'autres juridictions. Or, il est essentiel d'avoir des données spécifiques à la région pour comprendre les interactions entre l'exploitation forestière et les poissons/la faune et évaluer le besoin et les avantages de rendre obligatoire l'aménagement de bandes tampon, ainsi que de réglementer la largeur de ces bandes. La Copper Lake Buffer Zone Study (Étude sur la zone tampon du lac Copper) a pour objet de faire évaluer par des intervenants de diverses agences et disciplines la pertinence d'établir des bandes tampon dans les zones riveraines pour protéger le poisson, la faune et la qualité de l'eau dans la province. L'étude doit permettre de quantifier les incidences des activités d'exploitation forestière sur l'environnement et d'évaluer dans quelle mesure ces incidences peuvent être atténuées par le maintien de rideaux d'arbres de diverses largeurs le long des berges des cours d'eau. Le présent rapport initial présente des renseignements généraux sur cette étude. Il esquisse une description du site étudié, détermine les rôles et objectifs des participants, énonce le plan général de l'étude et présente certains détails sur ses diverses composantes et sur les méthodes qui seront appliquées.

1.0 PREFACE

Many areas of life involve conflict this is particularly evident in the management of renewable natural resources. These conflicts are of foremost importance in the management of riparian zones, which represent an ecotone between aquatic and forest ecosystems and thus support a large diversity of plant and animal life. The complexity of these areas make them both favoured areas for recreation and highly susceptible to external disturbances. An interference in one component of these ecosystems can result in serious impacts to other components of the ecosystem.

Little research has been conducted on the fishery/wildlife-forestry interactions within the riparian zone of boreal forests and much of our existing knowledge is based on research carried out on the west coast of North America. The fish/wildlife fauna, climate, forest and bio-physiography conditions are radically different in Atlantic Canada, therefore these results cannot be readily applied to boreal forest riparian zones in eastern Canada. There is also limited information on the effects of historical forestry practices on fish and wildlife populations and habitats in Newfoundland from which to base sound management decisions.

The Copper Lake Buffer Zone Study was conceived to conduct region specific research on the benefit of providing buffer strips in riparian zones to protect fish and wildlife resources, and water quality. The study is designed to quantify environmental perturbations to fish and wildlife habitats arising from forest harvesting operations and investigate the ability to ameliorate these perturbations through the provision of an unharvested leave strip along riparian zones. This study has been initiated under the auspices of the Western Newfoundland Model Forest Program which has provided a major component of the funding for this study and, as well, has served as the forum for coordination of the various agencies and groups involved. This study is multi-agency and multi-disciplinary in nature such that the interests and mandates of various resource management agencies can be addressed in a common framework. This approach will also facilitate integration of study results to evaluate the relative tradeoffs and benefits for resource protection associated with forest harvesting activities and provision of riparian buffer zones.

This is the initial report developed from this research project and is intended to document background information on the study. This report includes a general description of the study site, identifies the roles and objectives of the various study participants, outlines the general study design, and provides some detail on the various study components and methods to be employed. Further publications arising from this research study will be disseminated in the primary, technical, and popular literature, as appropriate and as results become available.

2.0 INTRODUCTION

Intensive forest harvesting activities have been ongoing since the early 1900's in Newfoundland. Much of the merchantable timber in the province is associated with riparian zones, consequently potential interaction between fish and wildlife resources and forestry practices is high. Current environmental protection guidelines for timber resource management in Newfoundland and Labrador require the maintenance of a no harvest 20 m buffer zone along all water bodies that appear on a 1:50,000 scale topographic map. In special cases (e.g. protected water supply areas; pesticide application areas; areas of significance for known concentration of wildlife) wider no harvest buffer zones are established.

The current recommended buffer strip sizes for environmental protection related to forest management practices in Newfoundland are based on 'best available information' and lack region-specific considerations. Before a general policy related to buffer zones can be widely applied, it is essential to evaluate whether acceptable levels of wildlife habitat protection are being afforded by different sized buffer zones. Region-specific considerations such as forest structure and diversity, topography, soil type, hydrologic regime, water quality, climate, aquatic and terrestrial wildlife species and their habitat use are essential to fully understand forestry and fish/wildlife interactions. The Copper Lake Buffer Zone Study will collect vital information to help establish the need for and benefits of mandatory protective buffer zones, as well as their appropriate sizes (widths), which will assist in reaching a reasonable compromise between environmental protection and a sustainable forest industry.

3.0 SITE DESCRIPTION

3.1 Site Selection

After extensive discussion with various study participants and an initial survey of candidate sites, including the Corner Brook Stream watershed, the Copper Lake system at the southeast end of Corner Brook Lake (Figure 1) was selected as the preferred site for this study. The Copper Lake watershed (13.5 km^2) is a small tributary of Corner Brook Lake, which has a total drainage area of approximately 127 km^2. This area has not been previously harvested and contains a diversity of terrestrial and aquatic habitats. The watershed was scheduled for harvest by Corner Brook Pulp and Paper Ltd. in either 1994 or 1995 and therefore fit the scheduling and general study design for this project.

A variety of other factors contributed to selection of the Copper Lake watershed as the preferred study site. The city of Corner Brook and Corner Brook Stream Development Association are active in the management and conservation of the Corner Brook Stream watershed and encouraged the selection of a study basin within this watershed area. In addition, a gauging station has been established on the Copper Lake stream which will provide essential hydrological data for the study. The study watershed is located close to Corner Brook and road and helicopter access to the site is good and will improve as access road construction is completed. The study area is also located within the Western Newfoundland Model Forest and this study was well suited to the research agenda of the Model Forest Program.

The Copper Lake watershed is typical of a small headwater drainage basin in the forest landscape of western Newfoundland and, as such, is considered representative of forested areas subject to harvesting in the western part of the province. The watershed is located at altitudes from 350 to 650 m, and the gradient of the streams and riparian slopes in the watershed range from moderate to high. Within the Copper Lake drainage basin, there are five primary (or headwater) tributaries (labelled T1-1 through T1-5, by convention; Scruton et al. 1992) (Figure 1). The outlet of Copper Lake (T1) draining into Corner Brook Lake is a second order (2^0) stream. Initial survey results identified three primary tributaries (T1-1, T1-2, and T1-3) and the second order stream (T1) as containing suitable fish and wildlife habitats and these streams have been selected for detailed study.

3.2 Geology and Soils

The geology of the Corner Brook Lake Area has been described in detail by Kennedy (1981) and is summarized below. This area is part of the metaclastic terrane which consists of a varied assemblage of intensely deformed and highly metamorphosed rocks. The Copper Lake watershed lies on the boundary of two formations within the metaclastic terrane . The Caribou Lake formation borders the northwest of the watershed and is comprised of a varied sequence of dominantly feldspathic metasediments. The Mount Musgrave formation borders the southeast of the Copper Lake watershed and is comprised of a quartz rich, metasedimentary sequence.

The surface soils of the Corner Brook Lake area are dominated by glacial till having a moderate to coarse texture (i.e. sand and coarse loam) with gleysols and gleyed podzols being dominant, comprising 41% of the watershed (van Kesteren 1992). Other areas of the watershed are covered with glacial till with a variable texture where orthic podzols are dominant (23%), moderately course to fine mineral soils overlaid with fibric and mescic peat soils (17%) or exposed bedrock with some organic and mineral soils (16%). There is also a small amount of fine glacial till (i.e. silt and loam) which is generally composed of orthic podzols (4%).

3.3 Meteorological Conditions

Information on the atmospheric and weather conditions of the study watershed is inferred from available data (1933 to 1990) collected at a MET (meteorological station) in Corner Brook, approximately 17 km from the study watershed. The region is characterized as having a relatively cool, average annual temperature of 5.2° C, and wet climate, average annual precipitation of 1186 mm (Table 1). Temperature shows a very distinct seasonal pattern with the coldest months of the year in January and February, average monthly temperatures of -5.4 and -6.8° C, respectively, and the warmest months in July and August, 17.4 and 16.8° C, respectively (Table 1). Total precipitation amounts have a more uniform pattern throughout the year with a slight peak from October to January (Table 1). The total precipitation from November to March is dominated by snow and the area has an average snow cover of 30 cm by the end of December (Environment Canada 1991). This snow cover represents a large storage of water resources which will be an important factor in the hydrological budget of the Copper Lake watershed.

3.4 Vegetation and Forest Characteristics

The Copper Lake watershed is located in the Western Newfoundland Ecoregion which is considered the most favourable part of the island for plant growth due to its extended growing season and fertile soils (Damman 1983). Specifically, the Copper Lake watershed is located in the Corner Brook sub-region of the Western Newfoundland Ecoregion (Damman 1983). The Corner Brook sub-region is characterized by heavily forested areas with a rugged topography and nutrient rich\productive soils (Damman 1983). Forest fire is rare in this region and natural secession appears to be insect driven, therefore forest stands originating from fire compose very little area in this region and balsam fir (*Abies balsamea*) is the predominate tree species.

The forest in the Copper Lake watershed is largely composed of mature and overmature balsam fir (*A. balsamea*) with some intermixing of black spruce (*Picea mariana*) (Figure 2). The black spruce (*P. mariana*) are generally restricted to poorly drained sites and bedrock outcrops due to the lack of forest fire in this region (Damman 1983). There are also areas of balsam fir-white birch (*Betula lutea*) mixes along with some softwood and hardwood scrub, bog and treed bog which are generally located at the fringes of the forested area (Figure 2). There are larger areas of scrub species and rock barrens on the steeper slopes of upland areas outside of the study area which correspond to the unproductive areas in figure 2. A checklist of the understorey plants has been developed for the mammalian study transects (Table 2) and these plants are typical for the watershed.

3.5 Hydrology and Water Quality

Water quality monitoring has been ongoing in the Copper Lake watershed tributaries on a monthly basis since November 1993. The streams being monitored in the Copper Lake watershed are similar in water quality characteristics (Table 3). These streams are acidic (average pH ranging from 5.73 - 6.34), soft (average $CaCO_3$ concentrations ranging from 2.5 - 4.4 mg/L), and oligotrophic (average NO_3 and PO_4 concentrations 0.01 - 0.045 mg/L and 0.01 mg/L, respectively). An important water quality parameter in this study will be turbidity as an indicator of suspended sediment load. Average turbidity measurements for the period from November 24, 1993 to October 19, 1994 indicate a low level of natural sedimentation in the study streams with average turbidity ranging from 0.32 - 1.42 NTU and Total Suspended Solids (TSS) averaging 2 mg/L in all streams (Table 3). Total Dissolved Solids (TDS) were similar in the study streams (15 -18 mg/L) with chloride, sulfate and carbonate constituting the major anions and sodium, calcium, magnesium, and potassium constituting the major cations (Table 3). Metal concentrations are generally low to below detection in the study streams with iron, manganese, aluminum having the highest concentrations and, occasionally, copper and zinc in detectable quantities (Table 3).

There is no available historical hydrological data for the Copper Lake watershed and data available for the Corner Brook Stream is not relevant as the watershed is regulated. Based on the mean annual runoff of Harry's River, the closest gauged and unregulated system, of $0.041 m^3s^{-1}km^{-2}$ (Newfoundland and Labrador Department of Environment and Lands - Water Resources Division 1991), a watershed the size of Copper Lake (13.5 km^2) would have a mean annual flow (MAF) in the order of 0.554 m^3s^{-1}. Similarly, the tributaries T1-1, T1-2, and T1-3 with drainage basins of 2.022, 1.926, and 3.593 km^2, respectively would have MAFs of 0.083, 0.079, and 0.147 m^3s^{-1}, respectively. The hydrograph for Harry's River can be used to provide some indication of the expected seasonal distribution of runoff for the Copper Lake watershed. The flow pattern is typical of a west coast river displaying two peak flow periods. The greatest period of runoff is observed in spring (May and June) and is associated with snow melt. The second peak in runoff is associated with rainfall in the fall and has generally half the magnitude of the spring runoff (Newfoundland and Labrador Department of Environment and Lands - Water Resources Division 1992). Low flow periods are in the summer months, July through early September, associated with low rainfall and winter, January through March, when precipitation is accumulated as snow. The Copper Lake watershed would also be expected to react quickly and extremely to rainfall events being a headwater system with no upstream standing water storage.

3.6 Site Sensitivity

Specific site selection within the watershed will consider the site sensitivity to forest harvesting assessment conducted by Forestry Canada (van Kesteren 1992) (Figure 3). This approach essentially combines soil erodibility, slope/topography, and soil moisture from ecosite classifications into an index of potential sensitivity to forest harvesting, ranging from none (L_0)

to extreme (L_6). Ecosites were delineated as homogenous pedologic, geomorphologic and hydrologic land units using conventional air photo interpretations. This sensitivity classification will be incorporated into the experimental design and interpretation of data.

The Copper Lake watershed is nestled in a valley characterized by the various tributary streams having high gradients in their upper reaches. This characteristic, in addition to the high precipitation and erodibility of surficial soils in the region, translates into a rating of high to extreme sensitivity to forest harvesting for most of the watershed (Figure 3). Specifically; T1, T1-1, T1-2 and T1-3 (upper) all have large proportions of their drainage area in high to extreme sensitivity areas. T1-3 (lower) is the only stream being monitored in the present study with a lower than high sensitivity rating.

3.7 Fish and Fish Habitat

Historical information and field surveys determined that the basins selected for study are used by one resident species only, brook trout (*Salvelinus fontinalis*). This component of the study therefore will focus on habitat effects associated with forest harvesting and buffer zones as it relates to resident brook trout. This species is considered to have a lower thermal tolerance and tends to be more closely associated with riparian habitat in their ecological requirements than Atlantic salmon (*Salmo salar*), another salmonid species of recreational and economic importance in the province. Results of this study therefore, should be conservative and potentially be applicable to anadromous salmon habitat.

Fluvial habitats associated with the proposed treatment reaches have been surveyed in detail. The section of streams surveyed are identified in Figure 4. In total, 49 sections were surveyed in detail on tributaries T1 (14 sections), T1-1 (6 sections), T1-2 (10 sections - lower, 3 sections - upper), and T1-3 (4 sections - lower, 13 sections -upper).

Tributary T1, the main outlet of Copper Lake flowing downstream to Corner Brook Lake, was surveyed along the entire 1399 m of length. A total of 14 sections were surveyed totalling 117.3 habitat units (1 habitat unit = 100 m^2). The habitat in this stretch of river was characterized as 66% riffle and 31% rapids. Mean wetted widths, channel widths, and depth are 8.85 m, 11.1 m, and 13.0 cm, respectively. Mean substrate composition for the reach, as percentages, includes bedrock (2), large boulder (20), small boulder (36), rubble (21), cobble (12), pebble (5), gravels (3), and fines (1). It is noteworthy that there is no pool habitat in this reach. Twelve of the sections include canopy cover for a total of 28% of the reach. Obstructions noted in this reach included a falls at section 3, 1.5 m in height (considered passable to adult brook trout).

Tributary T1-1 was surveyed for a total length of 527 m to an impassable falls at the end of section 5. Over this length, a total of 5 sections were surveyed totalling 17.8 habitat units. This stretch of river was characterized as having 90% riffle with 10% steady habitat. Mean wetted widths, channel widths, and depth are 3.4 m, 6.3 m, and 6.0 cm, respectively, reflecting the relatively small drainage basin of this tributary. Mean substrate composition for the reach, as percentages, included bedrock (5), large boulder (4), small boulder (17), rubble (26), cobble (32), pebble (14), gravels (3), and fines (0); reflecting the smaller nature of substrate material relative to T1 indicative of the differences in hydrologic and geomorphological control. Again, pool habitat was completely absent in this stretch. All five (5) sections included canopy cover for a total of 45% for the reach. The survey was terminated at the major falls at 527 m (end of section 5) as this was classified as impassable to adult brook trout.

Tributary T1-2 was surveyed for a total length of 1295 m to an extremely steep stretch above section 13 and this was divided into lower (sections 1 - 10) and upper (sections 11 to 13) reaches. Over this length, the 13 sections totalled 45.1 habitat units (34.0 units - lower, 11.1 units - upper). The lower stream was characterized as having 68% riffle with 30% other habitat while the upper reach was 98% riffle habitat. Mean wetted widths, channel widths, and depth are 3.5 m, 6.1 m, and 9.0 cm, respectively, similar in character to T1-1. Mean substrate composition for the reach, as percentages, included bedrock (25), large boulder (6), small boulder (26), rubble (25), cobble (14), pebble (2), gravels (1), and fines (0). Pool habitat was completely absent on this tributary as well. Nine (9) sections included canopy cover for a total of 54% for the entire stream reach. The survey identified a total of 6 obstructions over this stretch including a 1.0 m debris/log jam (section 1), a 7.0 m falls (section 6), a chute (section 7), a 9.0 m falls (section 8), and two falls (10 and 1.5 m) at the end of section 9. Three of the four falls identified are likely impassable to adult brook trout.

Tributary T1-3 was surveyed for a total length of 1595 m, divided into lower (sections 1 - 4) and upper (sections 5 to 17) reaches. Over this length, the 17 sections totalled 76.7 habitat units (39.1 units - lower, 37.6 units - upper). The lower reach was characterized as having 75% riffle with 25% steady habitat while the upper reach was 70% riffle with 17% run, 8% steady, and 3% rapid habitats. Mean wetted widths, channel widths, and depth are 4.0 m, 5.8 m, and 9.0 cm, respectively. Mean substrate composition for the reach, as percentages, included bedrock (3), large boulder (7), small boulder (21), rubble (24), cobble (15), pebble (15), gravels (13), and fines (3). Generally, the upper reach was characterized as contained higher proportions of the finer substrates (pebbles, gravels, fines). Pool habitat was completely absent on this tributary as well. Eleven sections included canopy cover for a total of 26% for the entire stream reach, with a higher percentage of canopy cover in the lower section (72%). The survey identified a total of three obstructions over this stretch including two debris/log jams (section 4 and 6) and a 5.0 m falls (section 8).

There are a number of standing water bodies in the study area including Copper Lake, which is the largest water body in the area, having a total area of 82,4 ha. Tributary T1-1 had a total of four lakes totalling 15.2 ha with all lakes located above the fluvial habitat surveyed. Tributary T1-2 contained six small lakes totalling 6.5 ha, 4 of these above the fluvial habitat to be studied. Tributary T1-3 contained seven lakes totalling 30.0 ha, including one large lake (hereafter called Jim's Lake totalling 17.5 ha) located between the upper and lower reaches.

3.8 Mammals and Mammalian Habitat

The island of Newfoundland, as a result of the Wisconsinian glaciation, was denuded of productive topsoils and was left with shallow glacial till. As a consequence, the natural flora and fauna were relegated to isolated refugia and the resultant recovery of biodiversity stemmed from a pauperized source. Much of the present biodiversity is a result of accidental, natural and deliberate exotic introductions. Those species with low nutrient, denning and germination requirements have predominated while those requiring specific resources remain in isolated pockets and/or have become indicator species of specific ecotypes (Dodds 1983). Generally, the low productivity and biodiversity of the forest systems has resulted in associated fauna composed of generalists which utilize a broad range of ecotypes. The numerous lakes, rivers and streams in Newfoundland have produced a multitude of riparian areas which are the most biologically productive/active areas in the forest ecosystem and thus have the highest biodiversity and population numbers of any ecological zone in the insular portion of the province.

The riparian areas of the Copper Lake watershed are utilized by large mammals (i.e. moose, caribou, black bear), furbearers (i.e. beaver, otter, marten, weasel, etc.), small mammals (i.e. voles, squirrels, rabbits, etc.) (Table 4) and a variety of passerine and ground nesting birds (see section 3.9 below).

The degree of utilization by the various fauna will depend upon the biophysical characteristics of the individual waterways, such as slope, water content of soils, plant diversity and plant density/visibility for nesting/resting. The importance of these riparian zones is also subject to seasonal changes whereby leaf loss and snow depth can greatly alter the habitat characteristics. These changes may require increased buffer zone widths to ensure survivorship of sensitive species (e.g. pine marten).

3.9 Birds and Avian Habitat

Birds are the most diverse vertebrate group inhabiting the forests of Newfoundland, with various species occupying a broad range of niches and feeding at several trophic levels (e.g. insectivores, gramnivores, piscivores, carnivores). They are the most highly detectable animal components of woodland ecosystems, and are easily studied and censused. The distributional patterns of species occupying different niches are often distinct (Montevecchi 1993). Anthropogenic and natural habitat perturbations have measurable effects on avian communities, making them useful as indicators of habitat change and biodiversity.

To date, 34 species of birds have been identified in the study area (Table 5). Twelve study plots have been established in the Western Newfoundland Model Forest (WNMF), six of which are in the Copper Lake watershed (Figure 5). The forest types in these plots are typical of the area (see description above). All plots combined represent a total of 3050 m of edge length, and an area of about 45 ha. Of this, 1550 m of edge is in uncut areas, 800 m in clearcut areas having 50-100 m buffer zones, 350 m in clearcut areas having 20 m buffer zones and 350 m in an area which has been cut to the waters edge.

Plots were selected alongside ponds and lakes as well as streams in order to provide information regarding the similarities and differences between these two types of water edge habitat. A plot bordering a woods road was established to provide insight into the bird communities associated with a non-riparian forest edge. This will help to distinguish between forest edge and riparian effects on bird communities. A breakdown of each habitat type covered is as follows: 1550 m of edge habitat lie along streams, 900 m border on lakes or ponds, 200 m on a combination of stream and pond and 400 m on a woods road.

4.0 PARTICIPATING AGENCIES AND ROLES

There are a variety of federal and provincial government agencies and other organizations involved as partners, participants, or as contributors to this multi-agency, multi-disciplinary project and the roles and mandates of these groups, relative to this study, are outlined in the following section. The research will be conducted collaboratively with the Canadian Department of Fisheries and Oceans; the Newfoundland Department of Natural Resources, Newfoundland Forest Service; the Newfoundland Department of Natural Resources, Wildlife Division; the Newfoundland Department of Environment, Water Resources Management Division, and Memorial University of Newfoundland. Presently most of the active research is either being conducted by staff of the various agencies or by faculty and graduate students of Memorial University of Newfoundland, financially supported by the study partners or the Western Newfoundland Model Forest Inc. Cooperation and in-kind support will also be provided by the Corner Brook Pulp and Paper Ltd.

4.1 The Department of Fisheries and Oceans (DFO)

The DFO has the mandate for conservation and protection of aquatic fisheries resources and the habitats supporting these resources. Thus, DFO will lead and coordinate the aquatic component of the Copper Lake study. Specifically, it will be responsible for monitoring water temperature, sediment movement, benthic invertebrate and fish populations during the study. DFO, in conjugation with Dr. J.M. Green and J.H. McCarthy (M. Sc. candidate) of Memorial University of Newfoundland, will also evaluate the effect of forest harvesting on trout movements within the watershed (see below). DFO will also work in close consultation with the Newfoundland Department of Environment - Water Resources Management Division in monitoring hydrology and water quality as key components of aquatic habitat quality (see below).

4.2 Newfoundland Department of Natural Resources, Newfoundland Forest Service (NDNR-NFS)

The NDNR-NFS has the mandate for the management of the province's forest resources. NDNR-NFS will provide technical aid for studies involving habitat typing including aid in identification of understorey and overstorey plants and habitat typing as outlined in Meades and Moores (1994). The NDNR-NFS will also be responsible for overseeing the forest harvesting practices in the Copper Lake watershed, in conjunction with Corner Brook Pulp and Paper Ltd. and their contractors, to ensure that these practices adhere to the general study design as close as possible.

4.3 Newfoundland Department of Natural Resources, Wildlife Division (NDNR-WD)

The NDNR-WD has the mandate to manage the wildlife resources of the Province and will coordinate studies on habitat utilization of the riparian zone and the effects of timber harvesting on terrestrial wildlife species (i.e. mammals and birds). These studies will focus on a high intensity habitat inventory and evaluation, along with measured indices of species diversity, abundance and distribution. Several of these studies will be carried out in conjunction with faculty and graduate students from Memorial University of Newfoundland (see below).

4.4 Newfoundland Department of Environment, Water Resources Management Division (NDE-WRMD)

The NDE-WRMD has the mandate for management of the province's freshwater resources and will coordinate the hydrological and water quality monitoring of effects from forest harvesting. Water Resources Management Division will be conducting two monitoring programs: i) a hydrological monitoring program and ii) a water quality monitoring program. The study will address impacts of forest management on the entire Copper Lake watershed in general and will focus in detail on the impacts on three smaller tributary watersheds within the Copper Lake system. A fourth tributary watershed will act as a control (no forest management activities).

4.5 Memorial University of Newfoundland (MUN)

Several of the projects undertaken in the Copper Lake Buffer Zone Study will be in conjugation with faculty and graduate students at Memorial University of Newfoundland.

<u>Fish Movements and Migrations</u> (J.H. McCarthy, student; Dr. J.M. Green, supervisor)

Mr. McCarthy will be conducting studies on habitat utilization and movements of resident brook trout through the monitoring of counting fences, established at T1-1, and T1-3 (upper) (Figure 6), fish tagging, tracking and habitat characterization. The data will be analyzed in consultation with DFO staff and will contribute to the overall aquatic study plan.

<u>Use of the Riparian Zone by Mammals</u> (S. Forsey, student; Dr. G.I. McT. Cowan and Mr. E. Baggs, supervisors)

Ms. Forsey will be studying the use of the riparian zone by mammalian species through pellet counts, browse surveys, winter track surveys and live/snap trapping of small mammals along permanent transects. Population estimates of large mammals will be conducted through aerial surveys. In addition, information on habitat utilization, site specific plant identification and wind fall evaluation will be collected and analyzed in consultation with NDNR-WD.

<u>Use of Riparian Habitat by Birds</u> (D. Whitaker, student; Dr. W. Montevecchi, supervisor)

Mr. Whitaker will be studying riparian habitat use by avian species through censusing birds along transects in the Copper Lake watershed as well as others established in the Corner Brook Lake Area (Figure 5). In addition, information on habitat characteristics will be collected and analyzed in consultation with NDNR-WD and NDNR-NFS.

4.6 Western Newfoundland Model Forest (WNMF)

The Copper Lake Buffer Zone Study is being undertaken within the boundaries of the Western Newfoundland Model Forest (WNMF) and as such the WNMF will be the coordinating agency for the project, and is providing a portion of the funding for various study components. The WNMF will monitor the progress of individual projects and will provide financial, technical and administrative support though the course of the project. The WNMF will also serve as the focus for broader collaboration, coordination, and communication with other similar national and international projects through the Model Forest Network.

This study is also designed to meet the overall objectives of the WNMF, specifically to develop an integrated resource planning (IRP) process for the forestry industry in the province. Study results and output will be developed and integrated such that they will contribute to the overall development of an IRP process.

4.7 Corner Brook Pulp and Paper Ltd. (CBPP)

Corner Brook Pulp and Paper Ltd. leases the timber in the Copper Lake watershed from the Crown and as such will be coordinating the harvesting of the watershed according to the experimental design developed for this project (details to follow). CBPP will be responsible for developing the detailed cutting plan and coordinating all forest harvesting operations within the Copper Lake watershed which will be conducted by contractors hired through CBPP.

5.0 OBJECTIVES, STUDY COMPONENTS, and METHODS

5.1 Study Objectives

The following goals and objectives for Copper Lake Buffer Zone Study reflect the intention to define what is needed in terms of buffer zones for adequate protection of fish, mammalian and avian habitats and the maintenance of water quality under Newfoundland conditions. The project will bring the major players in resource management together so that an acceptable formula can be found and then applied to similar conditions elsewhere. The multi-partner approach to this project has resulted in a large number of objectives as follows:

Fisheries Component:

1) Determine benefits for habitat protection associated with maintaining an unharvested strip of timber along the riparian zones of fluvial salmonid habitats.

2) Develop a set of criteria and/or indices (possibly involving habitat models and suitability indices) to permit an evaluation of sensitivity of fish habitats to the effects of forest harvesting under a variety of conditions and in consideration of prevailing guidelines and practices.

3) To describe brook trout movements and habitat utilization in the Copper Lake watershed before harvesting, to correlate these movements to environmental and/or physiological factors and to determine if forest harvesting activities effect regular movements of brook trout.

Mammalian Component:

4) Examine mammalian habitat use relative to a small lake and its tributaries and compare habitat within and outside of riparian zones.

5) Investigate the effects of different size buffer widths on mammalian activities.

6) Obtain baseline and post-harvest data for mammalian wildlife utilization of various buffer zone widths over several years to determine forest harvesting impacts within the riparian zone on mammalian populations.

7) To evaluate possible buffer loss from wind fall through historical and present situations in the immediate area.

Avian Component:

8) Increase understanding of avian utilization and ecological relationships in riparian habitats in the boreal forests of western Newfoundland.

9) Evaluate the influence of different buffer zone widths and configurations on patterns of avian utilization of habitat adjacent to waterways.

Hydrology and Water Quality Component:

10) Assess the effectiveness of various buffer widths for mitigating the impacts of forest management practices on the hydrology and water quality of small watersheds.

5.2 General Study Design

Tributaries T1 and T1-1 will be harvested with no buffer strip (0 m) and will be considered representative of 'maximum potential impact' (Figure 8). In this treatment, it will be possible to contrast effects between a primary (T1-1) and a second order (T1) stream. The lower reaches of T1-2 and T1-3 will be harvested with a 20 m buffer strip, which is considered a practical strip width for protection of fish habitats and is currently under consideration by the NDNR - NFS for wide scale application. The upper reaches of T1-3 will not be harvested essentially leaving a buffer strip of at least 100 m, which is a treatment that the NDNR-WD, would like to evaluate for protection of wildlife species. This treatment will serve as a control for the fish and fish habitat components.

The experimental design was compromised by the duration of the Model Forest Program (4 years) and was modified to attain realistic deliverables and milestones based on the available budget. The experimental design was coordinated with Corner Brook Pulp and Paper Ltd., and their contractors, to ensure adequate collection of baseline data and to accommodate changes in the cutting plan. Harvesting was kept to a minimum in the study catchments throughout the first and second field seasons of the study (1993 and 1994), with only the disturbance necessary to build an access road to the area. This allowed the collection of baseline data, habitat mapping of the watersheds, and permitted the refinement of experimental protocols and techniques. The third year of study (1995) ideally will be the period of harvesting (harvesting was initiated in November, 1994) and, if possible, all anthropogenic activity within the experimental catchments should be concluded within this year (or in a constrained time frame. Year 4 and subsequent years would allow for post-harvesting assessment of the catchments to determine the effects of cutting and the relative benefits of the buffer strip widths. Additional follow-up research will be conducted should the Model Forest program continue past 1997 or if replacement funding can be secured.

5.3 Water Quality and Quantity

Hydrological Monitoring

The hydrological monitoring program will include a hydrometric monitoring station on the stream flowing out of Copper Lake (T1) which will be operated by Inland Waters Branch, Environment Canada (Figure 8). This station will provide continuous stage height data which will be used to calculate continuous discharge. Less rigorous methods will be employed on T1-1 (lower) and T1-3 (upper). After sufficient measurements have been taken, a stage-discharge relationship will be developed for each tributary, a staff gauge installed, and discharge will then be calculated from the stage height reading. Stage height (discharge) will be measured opportunistically, during movement studies and when water quality samples are collected.

Discharges will also be recorded manually on a hourly basis during storm events as opportunities permit. Storm events are characterized as an environmental perturbation which caused a large increase in stream discharge over a relatively short period of time. Discharges will be measured at the beginning of storm events, then every few hours until the stream discharge subsides. These event measurements should provide an indication of the duration and maximum discharge levels during a storm event of a known size or duration. These measurements will be conducted on the control stream (T1-3) and T1-1 (no buffer treatment) so that differences between pre- and post- harvesting can be evaluated.

Water Quality Monitoring

The baseline water quality network will include six sites which will be sampled monthly (Figure 8). The parameters to be analyzed include turbidity, hardness, total dissolved solids (TDS), total suspended solids (TSS), specific conductance, colour, pH, dissolved organic carbon (DOC), calcium, magnesium, sodium, potassium, chloride, sulphate, phosphorus, nitrogen (NO_2, NO_3, NH_3), aluminum, iron, manganese, cadmium, copper, lead and zinc (see Table 3). In general, analytical methods for these parameters are as follows: metal concentrations will be determined by atomic absorption, nutrient and ion concentrations will be determined by a Technicon Autoanalyzer and a variety of benchtop equipment will be used for descriptive parameters. A more complete description of the methods that will be used for each parameter can be found in Franson et al. (1985). In addition to this baseline network, there will be event sampling and, if possible, more frequent sampling during times when harvesting takes place (the extent of event sampling, as well as more intensive sampling, will depend on available resources).

5.4 Fish and Fish Habitat

The experimental design proposes to contrast changes in stream and lake fish populations, habitat usage and movements, stream temperature, sediment loading, and a variety of key habitat attributes for stream reaches under the differing proposed buffer strip width treatments.

Habitat Characterization and Mapping

Habitat characterization and mapping has been completed and includes depth, width, velocity transects, longitudinal gradient profiles, substrate characterization, habitat classification, measurements of cover, evaluation of riparian vegetation and stream bank characteristics, identification of obstructions, etc., in the fluvial habitat associated with the various buffer zone treatments (see description above). Detailed habitat mapping, within a GIS, will determine habitat stability, changes in quantity and quality of habitats, effects of blowdown and logging debris, and the channel dynamics resulting from harvesting activities under the various treatment regimes.

Bathymetric surveys of standing waters in the watershed will also be completed in order to determine lacustrine habitat quantity and quality and to assist in interpretation of hydrological, thermal, and sedimentary dynamics within the watershed.

Sedimentation

Sedimentation effects will be evaluated through bedload and suspended sediment collectors at selected stations in each of the treatment reaches. Whitlock-Viebert boxes (three boxes per location spread across the stream) (Figure 9) will evaluate suspended sediment transport (Wesche et al. 1989) while modified pit-type samplers (variation of a methodology described in Macdonald et al. 1992) will be used to evaluate bed load movement (Figure 9). These samplers will be harvested (and returned) twice annually or more frequently if required. In addition, a 1 L water sample will be collected on T1-1 and T1-3 at regular intervals to assist in the evaluation of suspended sediment. All sediment collected will be dried, analyzed by the dry sieve technique, and reported as a percentage of the total dry weight of the various size fractions (Lotspeich and Everest 1981).

Large Organic Debris Dynamics

Changes in habitat quality will be addressed through large organic debris (LOD) dynamics and resulting effects on stability of the stream. Techniques developed for the Carnation Creek study (Hartman and Scrivener 1990) will be used to map and quantify (diameter, length, orientation, amount of submergence, etc.) natural and anthropogenic debris in the various treatment reaches. This will be coupled with detailed stream reach mapping to determine the role of the LOD in the scouring and deposition processes, habitat productivity, and possible creation of log jams, etc. that would pose migration barriers. Post-harvesting surveys will be contrasted with pre-harvesting baseline data.

Stream Temperatures

Stream water temperatures can be altered by forestry practices (Brown and Krygier 1971, Swift and Messer 1971, Lynch et al. 1977, Brownlee et al. 1988) and the primary study species, brook trout, has been shown to have a relatively low thermal tolerance (Brett 1956, McCormick et al. 1972, Grande and Andersen 1991). Therefore, stream water temperatures will constitute one of the most important elements to be evaluated in this study. Data will be collected at key locations (Figure 10) in various treatment reaches using Hugrun recording thermographs (Type A, -2^0C to $+38^0$C range, 0.1^0C accuracy). Thermographs are set to record temperature hourly from which daily and monthly minimums, maximums, fluctuations and means will be calculated. This descriptive data will assist in determining the effects of harvesting on stream temperatures and the resulting effects on suitability of habitat for fish and possible movements/migrations in response to thermal stress. Results will be interpreted in a habitat suitability context.

In addition to data collection by thermograph, temperatures will also be measured manually at set transects of study streams T1-1 (lower) and T1-3 (upper) on alternate days with a YSI oxygen meter (model 51A). These measurements will be taken between 1100 and 1500 hrs each day.

Dissolved oxygen

Hall and Lantz (1968) found dissolved oxygen decreased due to increased stream temperature after clear cutting as a result of the increased oxygen demand of decomposing debris. Dissolved oxygen will be monitored in each stream macro habitat (T1-1 [lower] and T1-3 [upper]) with a YSI dissolved oxygen meter (model 51A) at the set transect lines. The lakes (Copper Lake and Jim's Lake) will also be measured for temperature/dissolved oxygen profiles at set points to determine possible stratification.

Water Velocity and Depth

Brook trout select micro-habitats characterized by low water velocity, greater depth, and more cover than other salmonids (Cunjak 1982). Water velocity will be measured with an Ott velocity meter (model KEMPTEN Z210) at the set stream study transects on alternate days for the study streams T1-1 (lower) and T1-3 (upper). Velocities will be measured by recording the blade revolutions over a 40 sec time interval which are later converted to ms^{-1}. Measurements will be taken at 0.6 depth to estimate average velocity. Depth at points in each transect will be measured (to the nearest 0.5 cm) using a meter stick.

Fish Population Studies

This study component will include detailed evaluation of juvenile and adult fish in study reaches within each of the treatments, partitioned by habitat type. Quantitative electrofishing, using the fixed effort (successive) removal method, will be used to determine population size (numbers/density, biomass), age class structure, growth, survival, condition, etc.. Three contiguous electrofishing stations will be located in each of the stream stretches (Figure 11). Abundance estimates (both numbers and biomass) will be calculated using the Microfish 3.0 software program (Van Deventer and Platts 1989), employing a maximum likelihood (ML) estimator. Population estimates and other biological parameters will be partitioned by age class and compared between the different treatments, seasons, and years. Macro-habitat investigation, using observation techniques or other sampling strategies, will be used to evaluate habitat use and effects of harvesting on habitat selection and this will be important in developing the results of studies for use in an integrated resource management context.

Population estimates will also be determined for selected lakes in the watershed using fyke trap nets (Figure 11) and employing a multiple mark-recapture (Schnaebel) technique (Ricker 1975). This will assist in evaluating the population dynamics and movements/migrations of fish within the watershed as related to effects of forest harvesting.

Scale samples will be collected during studies and will be used to evaluate age and growth characteristics. The number of annuli (total age estimates) and measurement of the radius of each annuli will be determined for back calculation of fish growth (Nickerson et al. 1980).

Fish Migration/Movements (J.H. McCarthy and J.M. Green)

The movements of brook trout may be related to a variety of habitat and environmental parameters and this study will focus on factors most likely to be affected by harvesting in the riparian zone. Factors to be considered are water temperature, dissolved oxygen, food availability, stream discharge, water velocity, water depth, and total suspended sediment (TSS). These parameters will be measured in two different macro-habitats (sections) in study streams T1-1 and T1-3 (Figure 6) at fixed transects across each macro habitat. Study sites at the lower end of both T1-1 (lower) and T1-3 (upper), T1-1-S1 and T1-3-S1 respectively, have less tree cover and lower stream gradient than T1-1-S2 and T1-3-S2, the upper study reaches.

Six transects per stream section, with three locations per transect, will be used for measurement of temperature, dissolved oxygen, water velocity, and depth for a total of 18 measurements per stream section. Stream discharge and TSS will be measured at the lowest (downstream) transect in each stream only. All measurements are taken between 1100 and 1500 hrs so that average daily measurements can be obtained. All measurements will be taken twice each week on each stream, alternating between study streams so that impacts on the fish and streams are minimized.

Counting fences and tagging:

Counting fences will be used to monitor fish movement into and out of selected macro habitats. Two streams, T1-1 (lower), the treatment stream, and T1-3 (upper), the control stream, will be monitored with each stream having two fences located between different macro-habitats types (Figure 6). Fish passing through the counting fences will be tagged with fingerling Floy tags (model # FTF-69), measured for fork-length (cm), weighed (g), and a scale sample collected for age determination. Recaptures will be weighed and measured to calculate length-weight relationships and growth rates. Floy tags will make it possible to maintain records on individual fish as they move between macro-habitats so that growth estimates may be obtained. Fences will be checked each morning, except when exceptional conditions (e.g. high water) requires more frequent checking.

Sub-samples of fish will be collected from the streams and lakes to examine stomach content so that comparisons can be made between diet and available food. The maturational stages of gonads as the season progresses will also be examined for each age group sampled. Gutted condition factors will also be calculated for these fish. RNA-DNA ratios may also be determined as an indication of instantaneous growth.

In addition to tagging at fences, tagging will be conducted within the macro-habitats by angling and electrofishing (length, weight, and scales are also collected). This will ensure that fish not actively migrating between habitats are also tagged, thus reducing the bias of only tagging moving fish. The techniques outlined above will permit evaluation of brook trout movements and habitat utilization in the Copper Lake watershed. Brook trout movement patterns will be correlated with environmental and/or physical factors so that impacts of forestry practices and buffer zone widths can be evaluated.

Night-time movement:

Diel fluctuations in small forested streams, similar to those in the Copper Lake watershed, can be very dramatic (Brownlee et al. 1988). Published research documenting whether brook trout re-enter streams during the night when the stream temperatures cool is lacking. Night-time movements will be monitored during warmer periods in the summer to determine if there is any diurnal movement of brook trout in response to diel fluctuations in lake and stream temperatures.

Homing fidelity of brook trout to spawning streams:

O'Conner and Power (1973) studied the fidelity of brook trout to the same spawning stream both in-season and from year to year in Matamek Lake, Quebec and found 31.1% of brook trout tagged in 1971 returned to the same spawning stream in 1972. Studies on the fidelity of brook trout to 'home' spawning streams has largely been overshadowed by studies on *Salmo* and *Oncorhynchus*. However, tagging conducted in this project will supply valuable information on this behavior and may also assist in evaluation of other aspects of migrations and habitat selection.

Invertebrates

Benthic macroinvertebrates have been shown to be good indicators of habitat health (Reice and Wohlenberg 1993) and they are important dietary items for brook trout (Scott and Crossman 1973, Baggs 1988). Changes in the community composition and/or abundance of key species may help predict and explain patterns observed in the fish components of this study. The abundance and community composition of benthic macroinvertebrates will be monitored throughout the study by the use of artificial substrates which were deployed in five locations on T1, T1-1, T1-3 (lower) and T1-3 (upper) in May 1993 (Figure 9). The artificial substrates consist of a holed plastic dish pan with cobble substrate similar in diameter to the substrate of the stream (Ryan et al. 1985). These substrates will be harvested in October of each year and specimens sorted, counted and identified to genus.

Food availability (i.e. aquatic invertebrates) will be evaluated in the stream study sections T1-1 (lower) and T1-3 (upper) (Figure 6) using a Surber sampler. Fifteen to twenty random replicate benthic samples per stream section will be collected as per Thonney et al. (1987). The samples will be collected from mid-stream to reduce the variability of sample habitat types and thus reduce invertebrate population variability.

The stream velocity inside the Surber sampler will be recorded as well as substrate characterization (Scruton et al. 1992) and in-stream plant cover (% coverage of vascular and non-vascular). Total biomass and mean frequency of occurrence both by number and weight will be calculated for the invertebrate families identified so that changes can be analyzed and documented. Lake benthos will be sampled in subsequent years if funding and time constraints permit.

5.5 Mammals and Mammalian Habitat (Dr. G.I. McT. Cowan, E. Baggs and S. Forsey)

The mammalian component of the Copper Lake riparian buffer zone study will evaluate the effect buffers of different widths (no buffer, 20 meters, and 100 meters, Figure 7) have on the occupancy and usage of riparian areas by mammals.

Preliminary evaluations of mammals started in February 1994 with the establishment of a series of transect lines parallel to and starting from the stream (at each side) at 20 m and then 50 m intervals (0 up to 250 m) (Figure 12, winter tracking). These were then utilized to evaluate winter usage (based on tracks) and their proximity to streams. Visual observations indicate that there was a reliance of several predatory fur bearers (fox, pine marten etc.) on prey species (rabbits, voles etc.) within riparian buffer zones. These indications (winter tracking) show maximum usage at a position approximately 50 m from stream and lake edges inferring a wider buffer zone requirement in winter than the proposed 20 m buffer. Subnivial usage can be inferred from such activity by fox, marten etc., however, dedicated year round field studies are required to evaluate whether predator tracks are indicative of migratory/search activity or prey centred activity.

An aerial survey was undertaken in February 1994 to determine the number and location of moose and caribou populations. This initial trip demonstrated scattered occurrences of caribou primarily on the mountain range adjacent to Grand Lake and the scrub and bog areas on the northeast corner of the watershed in close proximity to the Valley of Lakes. Most of the moose observed occurred in two yards located towards the top of the northern hills just inside the shrub boundaries (ecotonal area).

Active field research on the wildlife and botanical aspects of the study commenced in June 1994, and was dedicated to the evaluation of the forest canopy and abundance and usages by animals of selected riparian areas (T1-1, T1-2, and T1-3 upper) which flow into Copper Lake. The forest canopy (living) was established using standard Quarter-Point methodology (Figure 12) and a plant checklist for the study area (Table 2) was compiled prior to subsequent evaluations of the understorey which will utilize Braun-Blanquet techniques in each of the six sites. Evaluation of the coarse woody debris within each designated buffer will also be undertaken.

Wildlife evaluations for the non-winter time periods will be conducted by fecal pellet counts and casual observations of animals, dens/nests, tracks/trails and browse indicators within each transect. In addition, an attempt to evaluate small mammal (i.e. vole, shrew) populations was carried out using live and snap trapping techniques utilizing a 100 square grid comprised of 15 m^2 blocks (Figure 12). In the first event, 100 baited Sherman live traps were utilized to establish a mark and recapture population dynamics study. This approach failed to yield results even after bait and trap sensitivity manipulations were carried out, therefore an exponential snap trapping effort was utilized to establish whether or not small mammal populations existed in the study areas. The extremely low numbers of vole and shrew entrapments concurred with the results of other investigators in adjacent areas and indicate, when compared to recent data, that the small mammal populations are in the low density stage of their respective cycles. Similar trapping attempts in two other biotypes (fen and cutover) in the immediate vicinity yielded the same results. This would indicate that disturbance was not the mitigating circumstance which controlled the small mammal populations.

Animal presence based on pellet type/count and browse indicators will be carried out using thirteen 4 m^2 blocks equally spaced within 150 m^2 grid (Figure 12) on each of T1-1, T1-2 and T1-3 (upper). Preliminary surveys indicate that the mammalian species use the peripheral area surrounding the study blocks suggesting the usage of a riparian buffer zone in excess of 150 m.

Preliminary observations from the ground and aerial reconnaissance/photography indicate potential buffer zone loss due to windfalls which may result in blockage of waterways and wildlife corridors. An attempt will be made to evaluate the potential loss of habitat from this form of perturbation.

5.6 Birds and Avian Habitat (Dr. W.A. Montevecchi and D. Whitaker)

Study Sites

Study sites will be selected through an analysis of airphotos, topographical maps and ground truthing including consultation with individuals knowledgeable about the local forest. Once suitable sites are located, plots will be established and survey transects marked with coloured survey tape. On all plots, transects will run parallel to the waters edge at distances of 0, 20, 50, 100 and 150 m (Figure 13).

Bird Surveys

The survey method to be used is based on the strip transect method outlined by Bibby et al. (1992). Breeding birds are generally most vocal during early hours of daylight, becoming more likely to remain quiet as the morning progresses (Skirvin 1981). Therefore, surveys will be started as close as possible to sunrise, normally soon after 0500 h and will be completed by 0900 h. Transects will be walked at a slow pace, while listening and looking for birds. Each bird located will be classified according to species, sex, type of contact and its location and movements recorded on a transect map.

Birds are usually more vocal and thus more detectable during the breeding season therefore, the study period designated in 1994 was from 7 June to 7 July. This period is the accepted standard for censusing breeding birds in the region (e.g. Robbins et al. 1986). Surveys will be cancelled during rain and when winds exceed 20 km/h, as poor weather reduces the activity and detectability of birds (Robbins 1981). Each study plot will be surveyed twice.

Study Plot Position

Study plot locations will be determined using a Global Positioning System (GPS), collecting 30 positions at each of the four corners of a study plot. These positions will be corrected using reference data from the base station located at the Fisher Institute in Corner Brook. The 30 corrected positions for each corner will be averaged to give mean latitude and longitude coordinates. Final positions should have an error of less than 5 m (G. Payne, Fisher Inst., pers comm).

Habitat Analysis

Habitat information will be collected at 50 m intervals along the 20, 50, 100 and 150 m transects. In large areas of homogenous habitat data will be collected at 100 m intervals. Stand surveys will not be carried out in clear-cuts. Data on stand basal area and tree species composition will be collected using an optical prism and calipers. Trees falling within plots will be classified by species and Diameter at Breast Height (DBH; 1 cm class increments). Additionally, at each point three trees considered to be representative of the dominant size class and species composition will be sampled for Age at Breast Height (ABH), DBH, and height. Tree height will be measured using a Suunto clinometer and ABH with an increment borer. Stands will be classified to Damman site types using keys provided in Meades and Moores (1994) on the basis of soil type, moisture regime, stand succession, slope position and tree, forb moss and lichen species composition.

Plot Mapping

Study plots will be mapped using the most recent airphotos available and groundwork carried out to accurately identify the positions of transect, habitat boundaries, roads and other noteworthy features. Maps will be digitized for spatial analysis of avian distribution patterns using Geographic Information System (GIS) software.

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Table 1: Average weather characterises for the Corner Brook region from 1933 to 1990 (Source Environment Canada - Canadian Climate Normals 1961-1990)

Month	Temperature (°C)	Rainfall (mm)	Snowfall (cm)	Total Precipitation (mm)
Jan	-5.4	28.0	111.6	139.6
Feb	-6.8	17.1	74.9	92.0
Mar	-2.8	27.5	55.0	82.5
Apr	2.6	39.5	23.6	83.1
May	7.5	58.6	5.3	83.9
Jun	12.9	83.5	0.2	83.7
Jul	17.4	82.7	0.0	82.7
Aug	16.8	97.4	0.0	97.4
Sept	12.4	95.5	0.07	95.5
Oct	7.2	109.0	6.4	116.0
Nov	2.8	86.0	40.4	126.4
Dec	-2.5	46.0	97.0	143.1
Year	5.2	771.0	414.4	1186.0

Table 2: Checklist of understorey plants in study area.

Specific Name	**Common Name**
Alnus rugosa	Hazel Alder
Aster puniceus	Purple stem aster
Athyrium filix-femina	Lady fern
Carex spp.	Sedges
Cinna latifolia	Sweet reed grass
Circaea alpina	Smaller enchanter's nightshade
Clintonia borealis	Yellow clintonia
Coptis groenlandica	Goldtread
Cornus stolonifera	Red-Osier Dogwood
Cornus candensis	Crackerberry
Cypripedium acaule	Pink lady slipper
Deschampsia flexuosa	Wavy hair grass
Drosera sp.	Sundew
Dryopteris phegopteris	Long beech-fern
Dryopteris spinulosa	Spinulose shield fern
Epigaea repens	Trailing arbtetes
Equisetum sylvaticum	Wood horsetail
Fragaria sp.	Wild strawberry
Gaultheria hispidula	Wintergreen
Heracleum lanatum	Cow-parsnip
Hylocomium splendens	Stair-step Moss
Kalmia angustifolia	Sheep-laurel
Ledum groenlandicum	Labrador tea
Linnaea borealis	Twinflower
Lycopodium spp.	Club-moss
Moneses uniflora	One flowered wintergreen
Monotropa uniflora	Indian pipe
Myrica gale	Sweet gale
Onoclea sensibilis	Sensitive fern
Osmunda cinnamomea	Cinnamon fern
Pleurozium sp.	
Ptilium crista-castrensis	
Rhododendron canadense	Rhodora
Rhytidiadelphis spp.	Shaggy Moss
Rubus chamaemorus	Bake-apple
Rubus pubescens	Raspberry
Sanguisorba canadensis	Canadian burnet
Solidago rugosa	Golden rod
Sorbus sp.	Dogberry
Sphagnum spp.	Sphagnum moss
Streptopus sp.	Twisted stalk

Table 2 continued

Taxus canadensis	Ground hemlock
Thalictrum polygamum.	Tall meadow rue
Vaccinium angustifolium	Dwarf blueberry
Vaccinium ovalifolium	Oval-leaved blueberry
Viola cucllata	Marsh blue violet

Table 3: Average water quality parameters for the study streams in the Copper Lake Watershed (24 November, 1993 - 19 October, 1994)

Parameter	T1	T1-1	T1-2	T1-3(L)	T1-3(U)
Color (TCU)	37 (4.79)	62 (12.7)	42 (17.17)	42 (7.22)	47 (12.95)
Hardness (mg/L $CaCO_3$)	2.5 (0.34)	2.7 (0.5)	4.4 (1.22)	2.6 (0.4)	3.1 (0.94)
Nitrate (mg/L)	0.038 (0.009)	0.015 (0.012)	0.045 (0.035)	0.013 (0.012)	0.01 (0.006)
pH	6.0 (0.154)	5.73 (0.372)	6.34 (0.391)	5.96 (0.379)	6.03 (0.48)
Phosphorus (mg/L PO_4)	0.01 (0.012)	0.01 (0.008)	0.01 (0.003)	0.01 (0)	0.01 (0.006)
Chloride (mg/L)	2.8 (0.573)	2.7 (0.874)	2.7 (0.535)	2.6 (0.773)	3.0 (0.661)
Aluminum (mg/L)	0.11 (0.02)	0.16 (0.122)	0.13 (0.067)	0.14 (0.039)	0.14 (0.059)
Sulfate (mg/L)	2.7 (0.377)	3.4 (0.52)	3.2 (0.648)	3 (0.609)	3.5 (0.771)
TOC (mg/L)	3.3 (0.856)	4.3 (1.465)	4.1 (1.26)	4.0 (0.948)	4.2 (0.554)
Specific Conductance (u semens)	19.4 (1.513)	19.7 (2.929)	23.1 (3.688)	20.1 (2.110)	23.7 (3.991)
Calciium (mg/L)	0.46 (0.155)	0.6 (0.14)	1.15 (0.397)	0.48 (0.126)	0.59 (0.192)
Turbidity (NTU)	0.39 (0.273)	1.42 (2.98)	0.38 (0.316)	0.32 (0.158)	0.53 (0.244)
Magnesium (mg/L)	0.31 (0.047)	0.30 (0.056)	0.36 (0.07)	0.33 (0.056)	0.39 (0.058)
Manganese (mg/L)	0.0025 (0.0007)	0.0052 (0.0053)	0.004 (0.003)	0.0065 (0.0075)	0.007 (0.0081)
Sodium (mg/L)	2.01 (0.639)	1.79 (0.333)	1.9 (0.318)	1.98 (0.459)	2.26 (0.5)
Ammonia (mg/L)	0.01 (0.003)	0.01 (0.003)	0.01 (0.003)	0.01 (0)	0.01 (0.0006)
TDS (mg/L)	15 (1.477)	15 (2.019)	18 (5.728)	16 (1.605)	18 (2.981)

Parameter	T1	T1-1	T1-2	T1-3(L)	T1-3(U)
TDS (mg/L)	15 (1.477)	15 (2.019)	18 (5.728)	16 (1.605)	18 (2.981)
Iron (mg/L)	0.034 (0.025)	0.215 (0.085)	0.08 (0.04)	0.104 (0.059)	0.17 (0.056)
Copper (mg/L)	0.0032 (0.0022)	0.004 (0.0048)	0.0025 (0)	0.0025 (0)	0.0025 (0)
Zinc (mg/L)	0.0025 (0)	0.0046 (0.0051)	0.0025 (0)	0.0025 (0)	0.0025 (0.0008)
Cadmium (mg/L)	0.00025 (0)	0.00025 (0)	0.00025 (0)	0.00025 (0)	0.00025 (0)
Lead (mg/L)	0.0005 (0)	0.0005 (0)	0.0005 (0)	0.0005 (0)	0.0005 (0)
Potassium (mg/L)	0.2482 (0.049)	0.25 (0.0638)	0.2264 (0.0976)	0.2608 (0.0459)	0.3122 (0.0452)
Nitrite (mg/L)	0.0025 (0.0053)	0.0011 (0.0008)	0.0008 (0.0009)	0.001 (0.0006)	0.0015 (0.0014)
TSS (mg/L)	2 (0)	2 (0)	2 (0)	2 (0)	2 (0)

Table 4: Checklist of mammals in study area.

Specific Name	**Common Name**
Alces alces	Moose
Rangifer tarandus	Caribou
Ursus americanus	Black Bear
Vulpes vulpes	Red Fox
Castor canadensis	Beaver
Lutra canadaensis	River Otter
Martes americanus	Pine Marten
Mustela erminea	Short-tailed weasel
Lepus americanus	Snowshoe Hare
Tamiasciurus hudsonicus	Red Squirrel
Microtus pennsylvanicus	Meadow Vole
Sorex cineurus	Masked Shrew

Table 5: Bird species identified on avian study plots during 1994

Specific Name	**Common Name**
Actitis macularia	Spotted Sandpiper
Anas rubripes	American Black Duck
Aythya callaris	Ring-necked Duck
Carduelis pinus	Pine Siskin
Catharus guttatus	Hermit Thrush
Catharus ustulatus	Swainson's Thrush
Contopus borealis	Olive-sided Flycatcher
Ceryle alcyon	Belted Kingfisher
Corvus corax	Common Raven
Dendroica coronata	Yellow-rumped Warbler
Dendroica magnolia	Magnolia Warbler
Dendroica petechia	Yellow Warbler
Dendroica striata	Blackpoll Warbler
Dendroica virens	Black-throated Green Warbler
Empidonax flaviventris	Yellow-bellied Flycatcher
Falco columbarius	Merlin
Falco sparverius	American Kestrel
Gallinago gallinago	Common Snipe
Gavia immer	Common Loon
Junco hyemalis	Dark-eyed Junco
Melospiza lincolnii	Lincoln's Sparrow
Mniotilta varia	Black-and-white Warbler
Oporornis philadelphia	Mourning Warbler
Parus hudsonicus	Boreal Chickadee
Passerella iliaca	Fox Sparrow
Perisoreus canadensis	Gray Jay
Picoides arcticus	Black-backed Woodpecker
Picoides villosus	Hairy Woodpecker
Regulus calendula	Ruby-crowned Kinglet
Seiurus noveboracensis	Northern Waterthrush
Tachycineta bicolor	Tree Swallow
Turdus migratorius	American Robin
Wilsonia pusilla	Wilson's Warbler
Zonotrichia albicollis	White-throated Sparrow

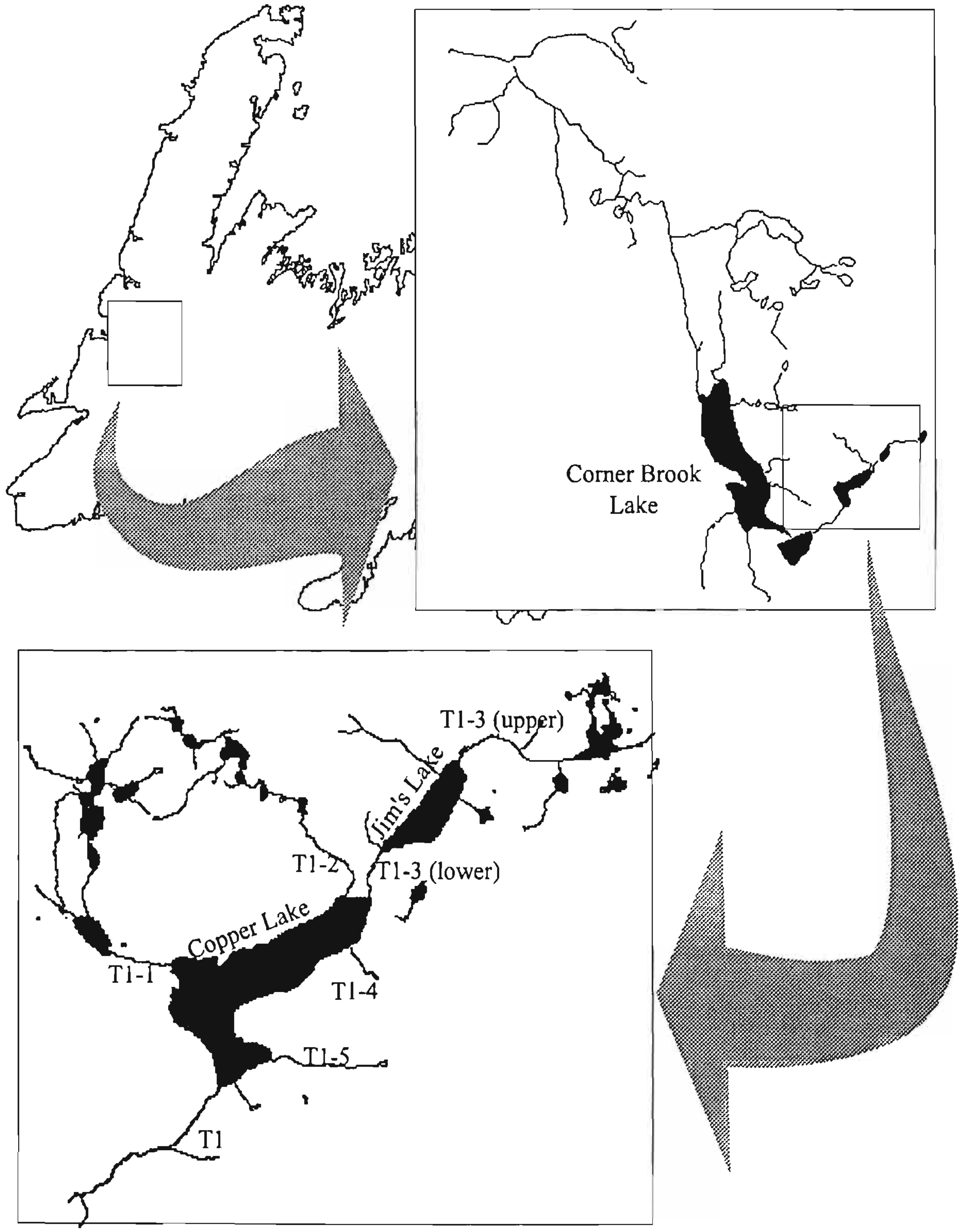

Figure 1: The Copper Lake buffer zone study area.

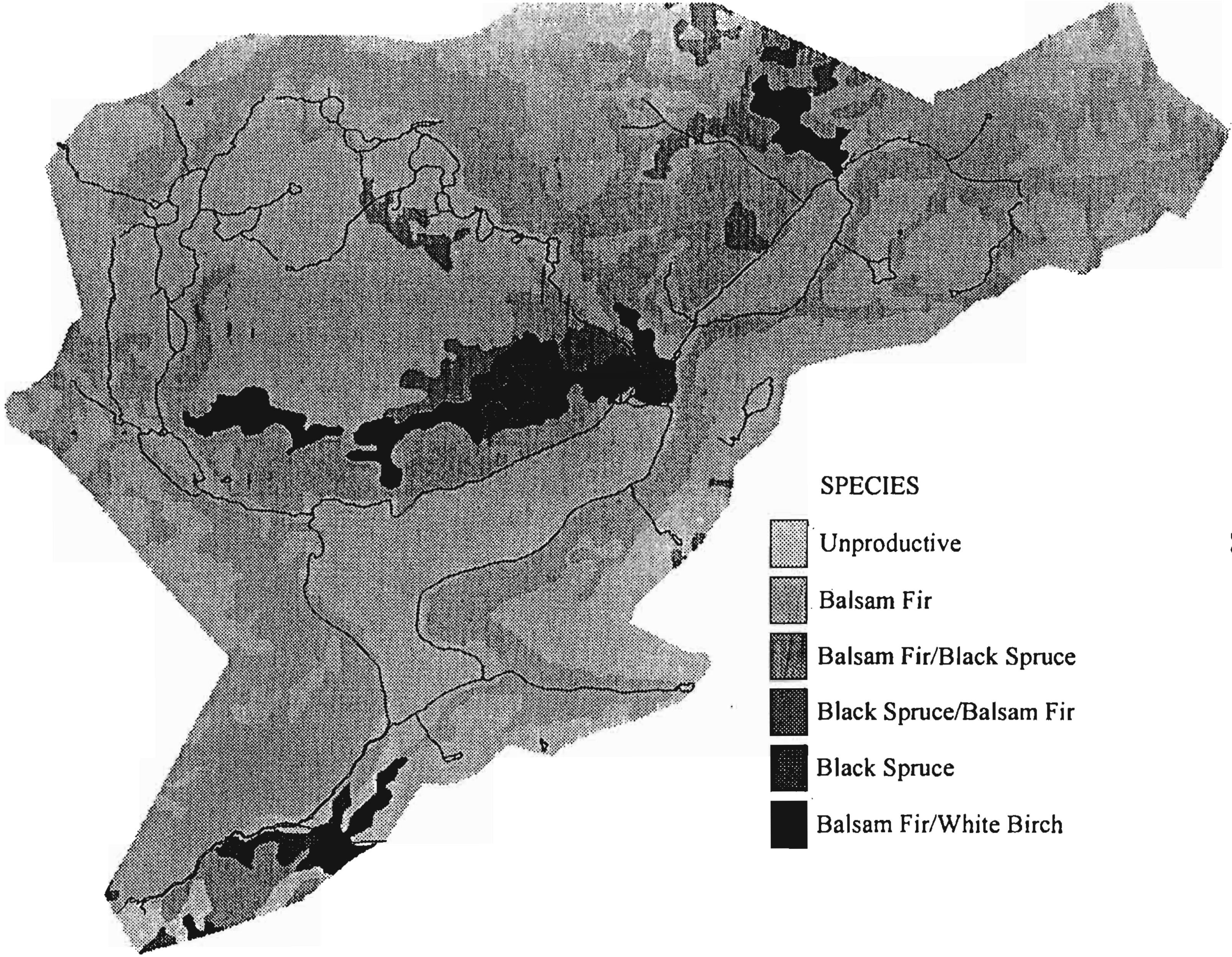

Figure 2: Forest type map for the Copper lake watershed.

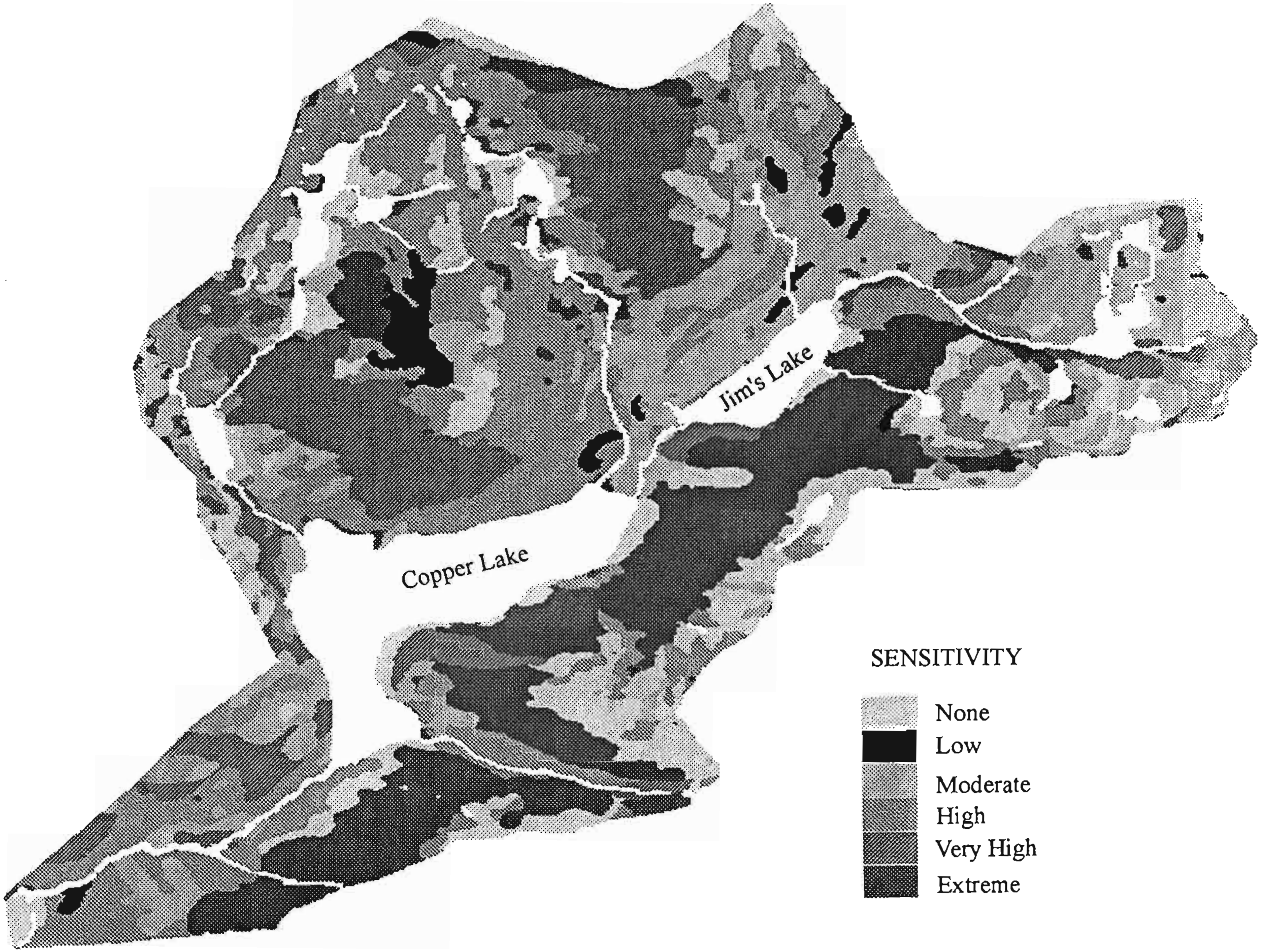

Figure 3: Sensitivity to forest harvesting in the Copper Lake Watershed (After van Kesteren 1992).

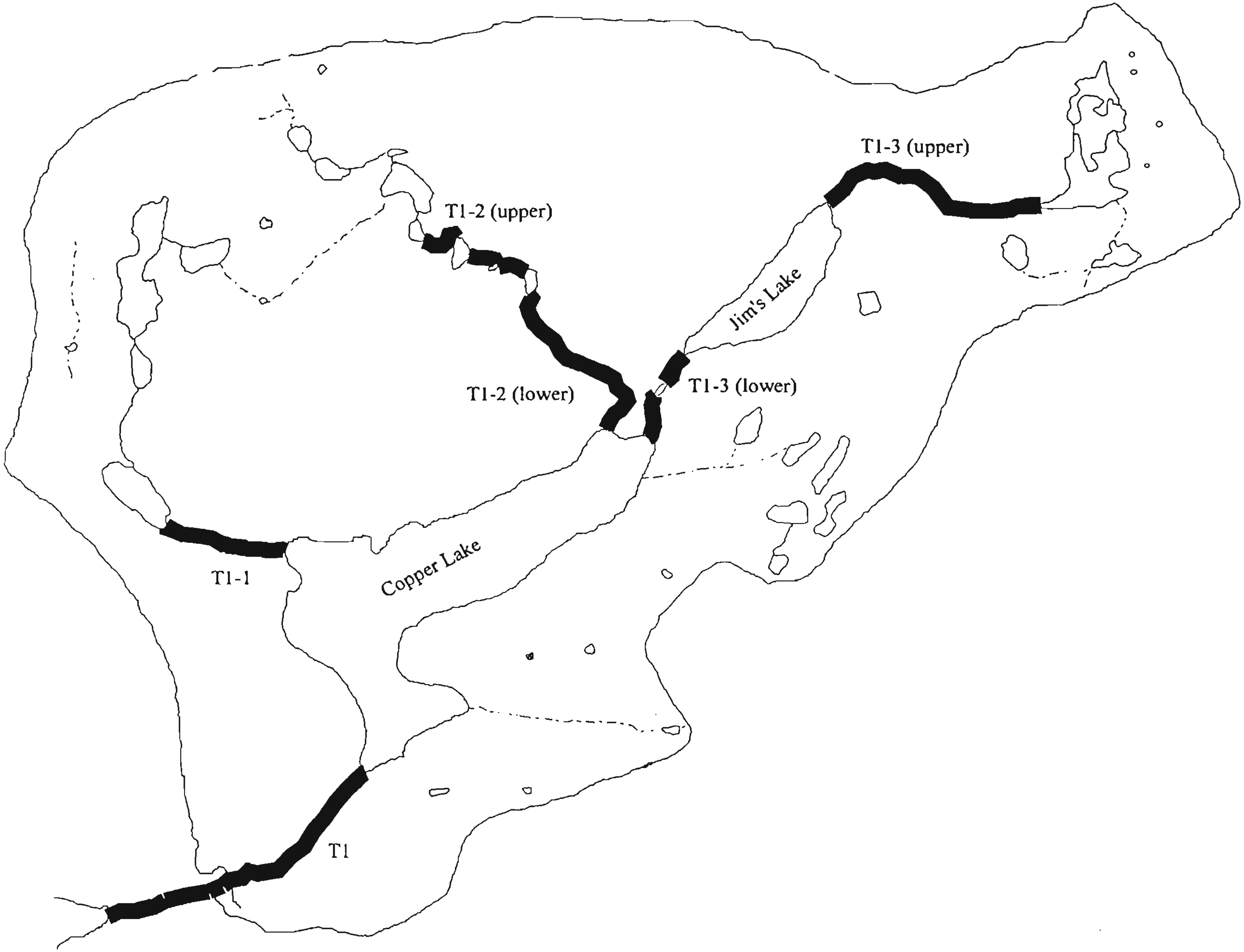

Figure 4: Stream sections used in habitat surveys of the Copper Lake watershed.

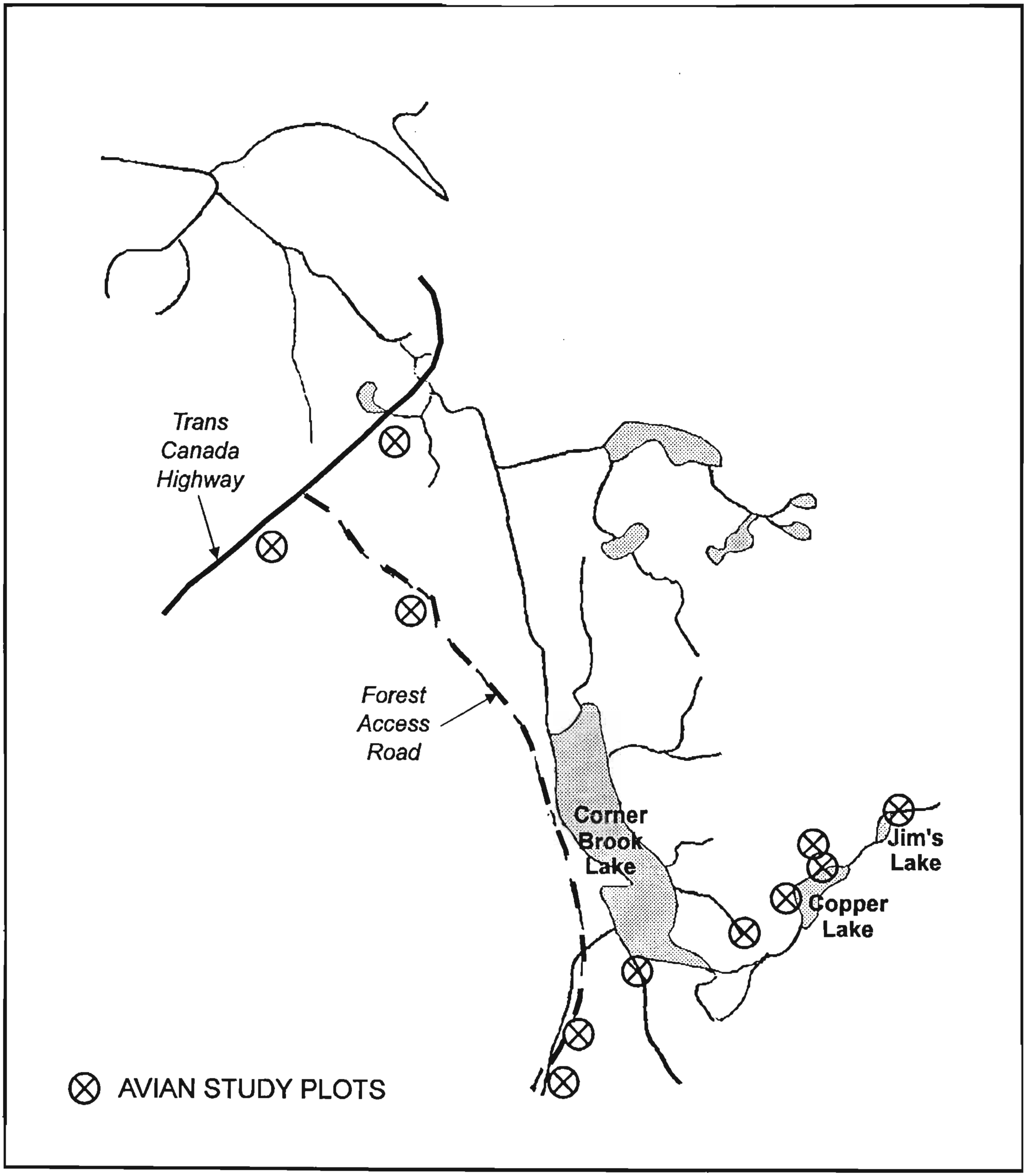

Figure 5: Avian study plot locations in the Corner Brook Straem watershed.

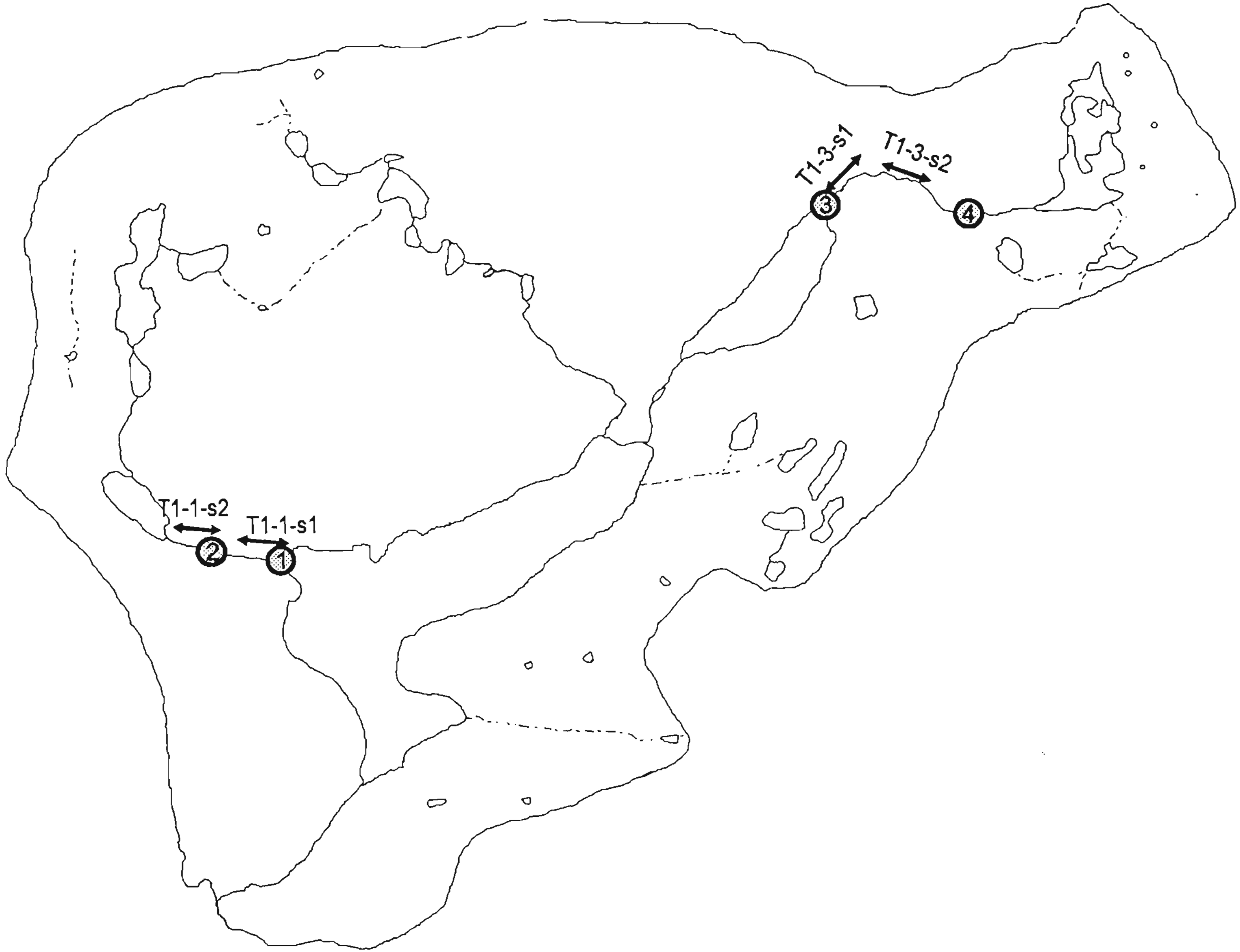

Figure 6: Macrohabitat study sections with counting fence locations highlighted.

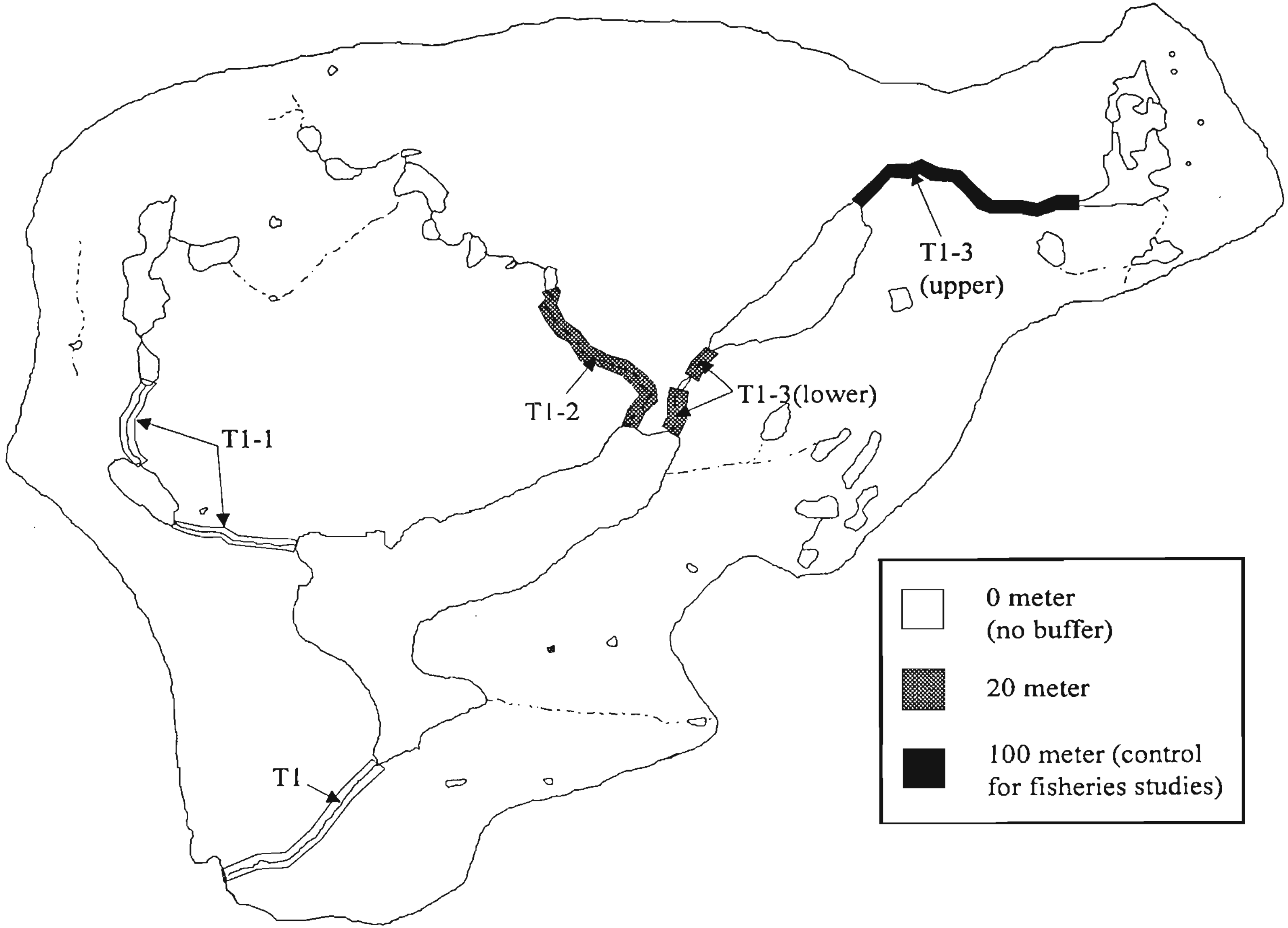

Figure 7: Proposed buffer zone widths for the Copper Lake study.

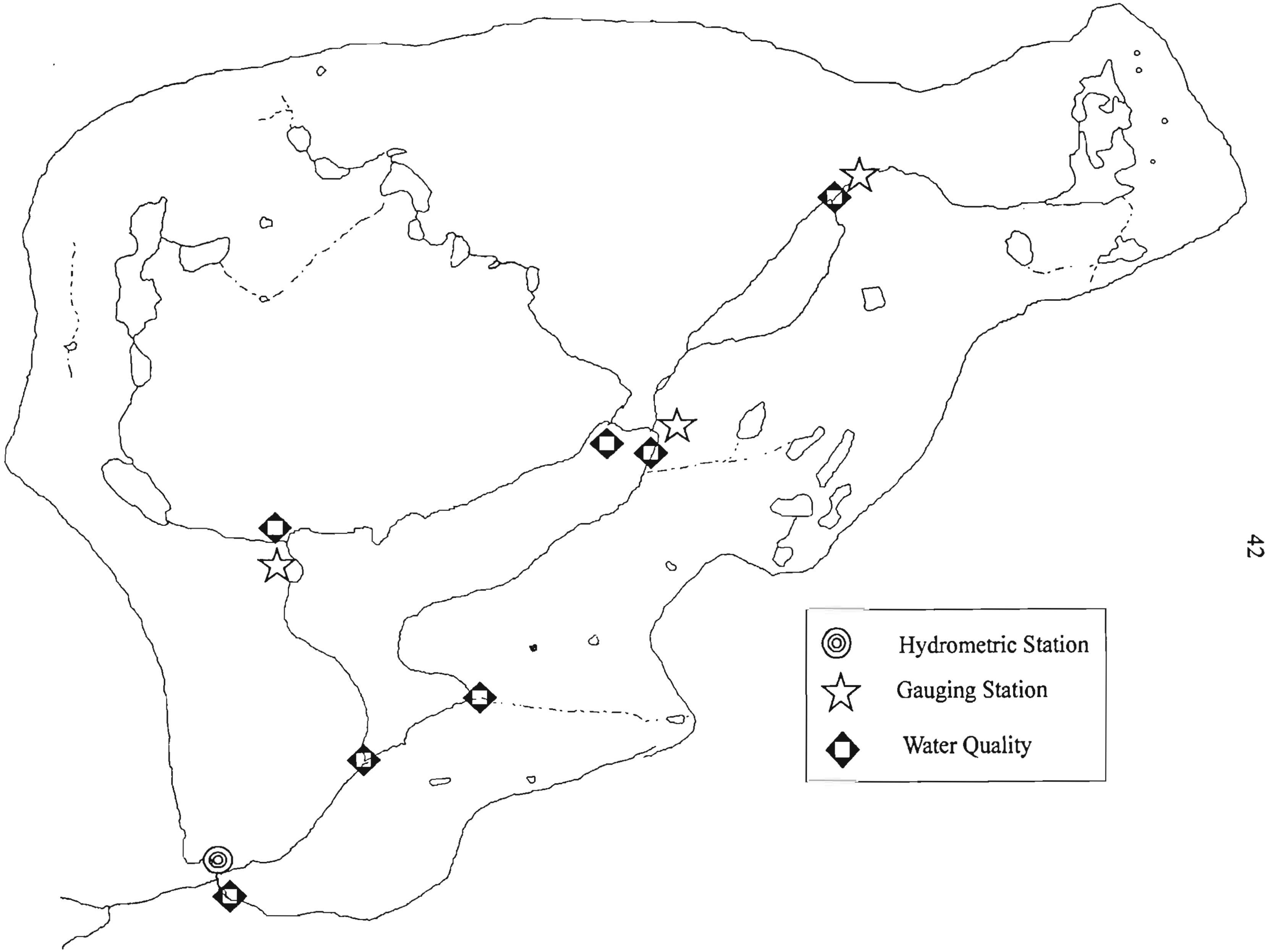

Figure 8: Water quality and quantity collection sites within the Copper Lake watershed.

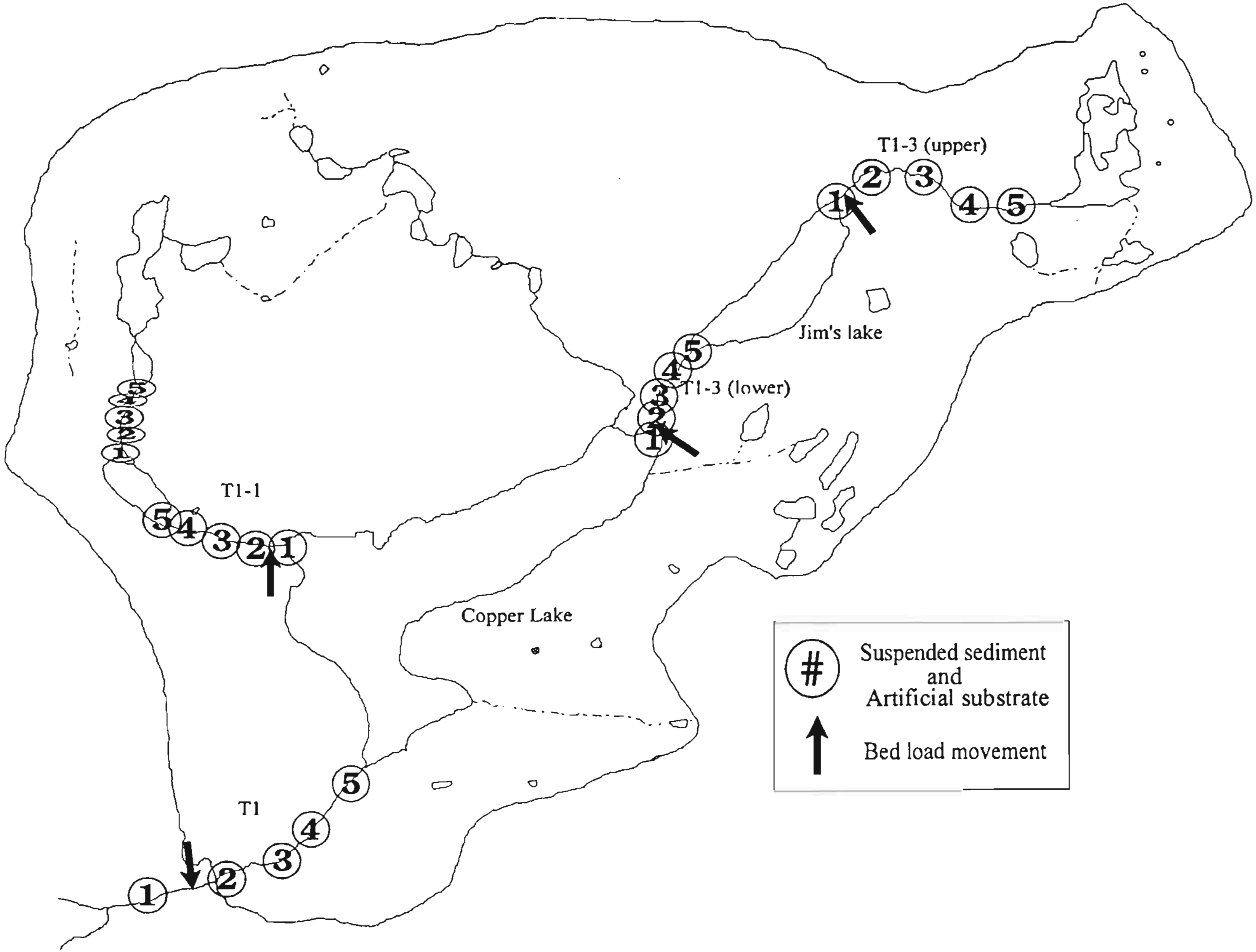

Figure 9: Sediment and artificial substrate sampling locations in the Copper Lake watershed.

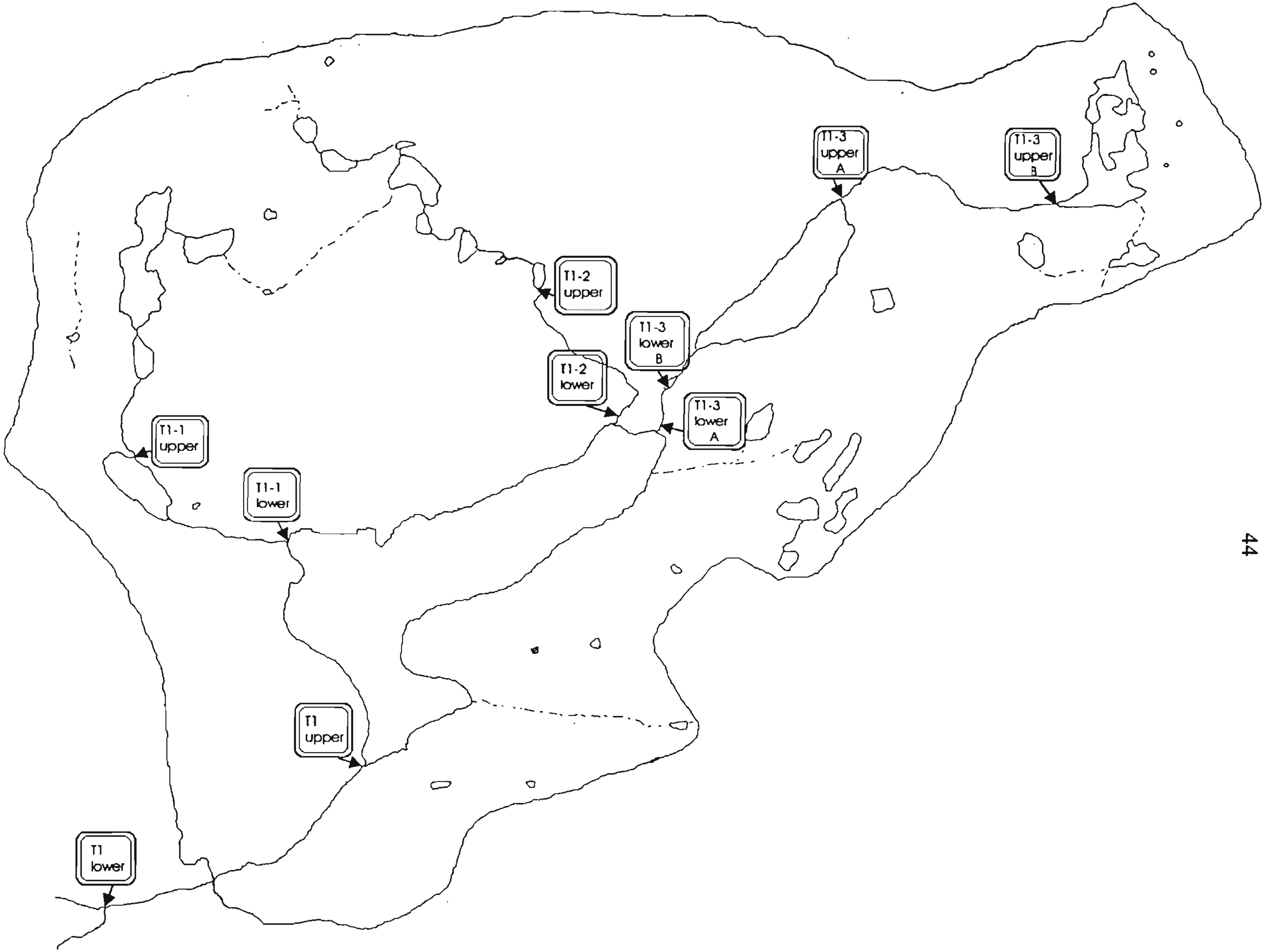

Figure 10: Thermograph locations in the Copper Lake watershed.

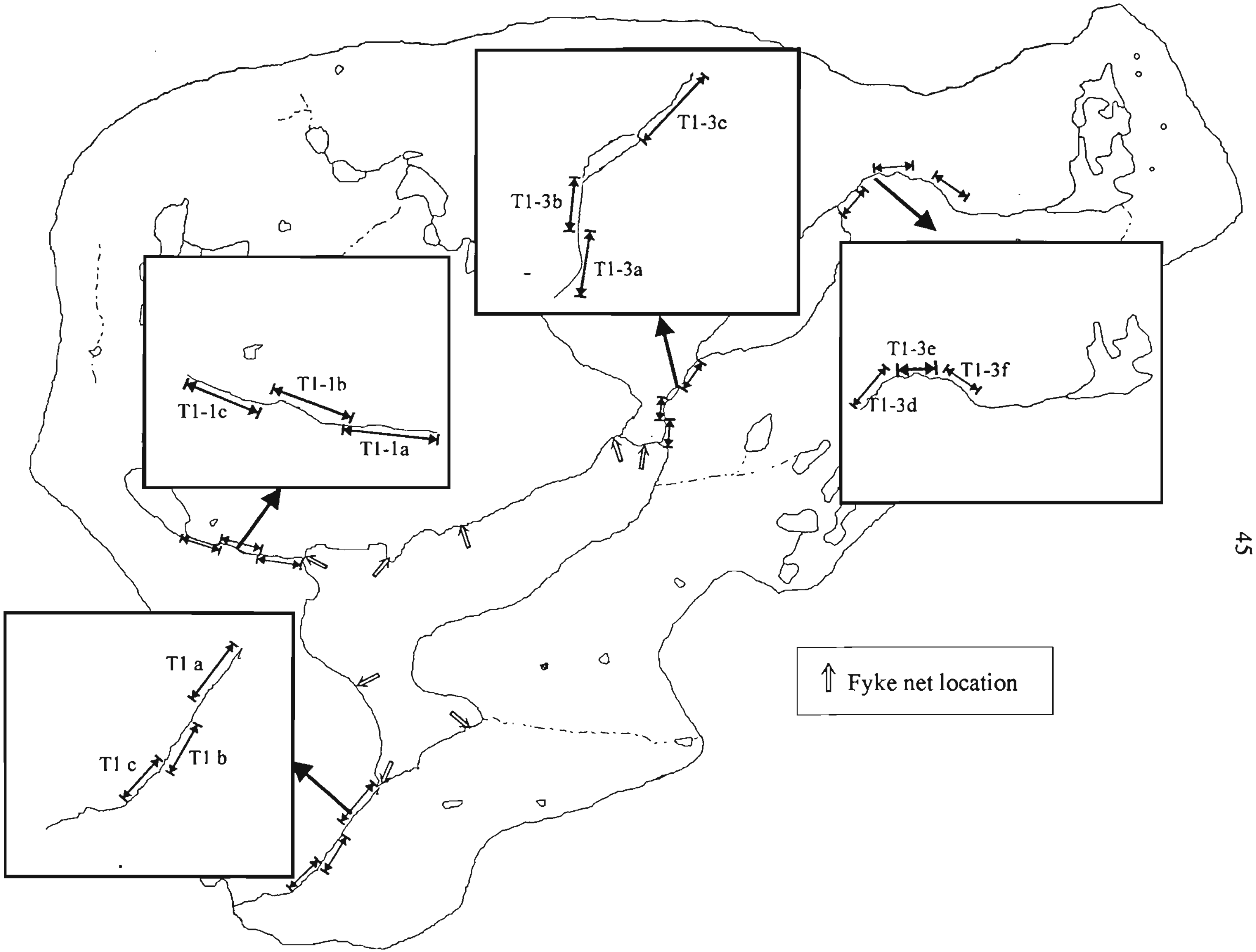

Figure 11: Electrofishing sites and fyke net locations in the Copper Lake watershed.

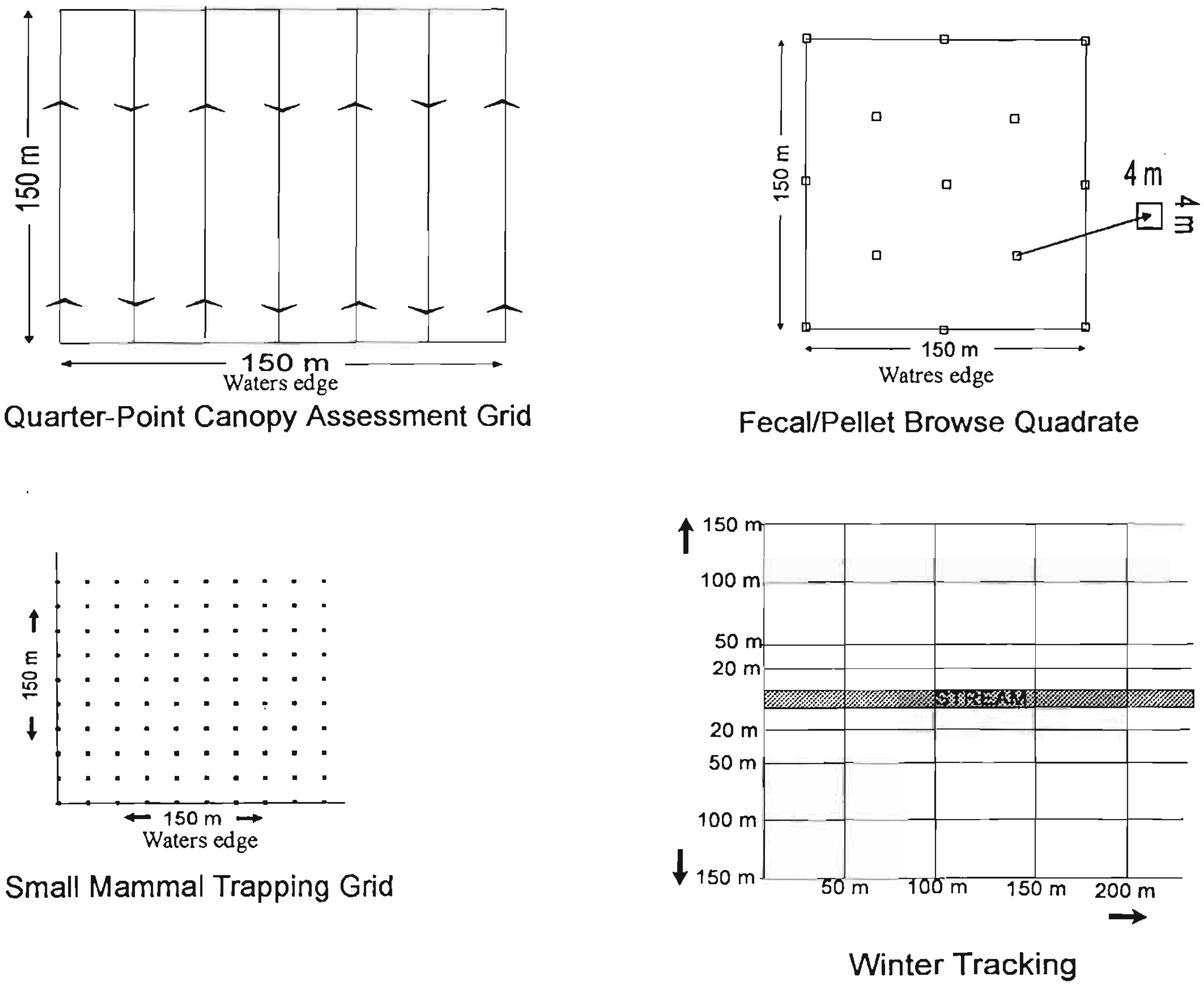

Figure 12: Survey grids used in the mammalian survey.

46

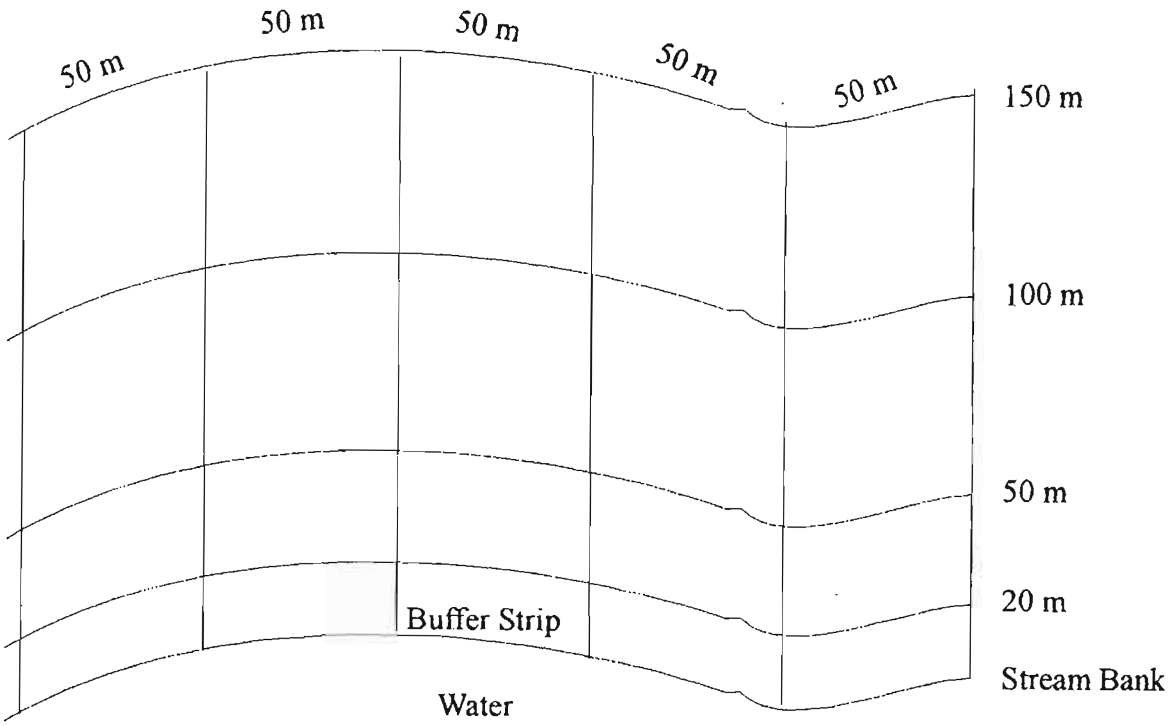

Figure 13: Study plot design for avian study: Including 5 survey transects, each of which is divided into 50 m interval. A 20 m buffer strip is indicated.