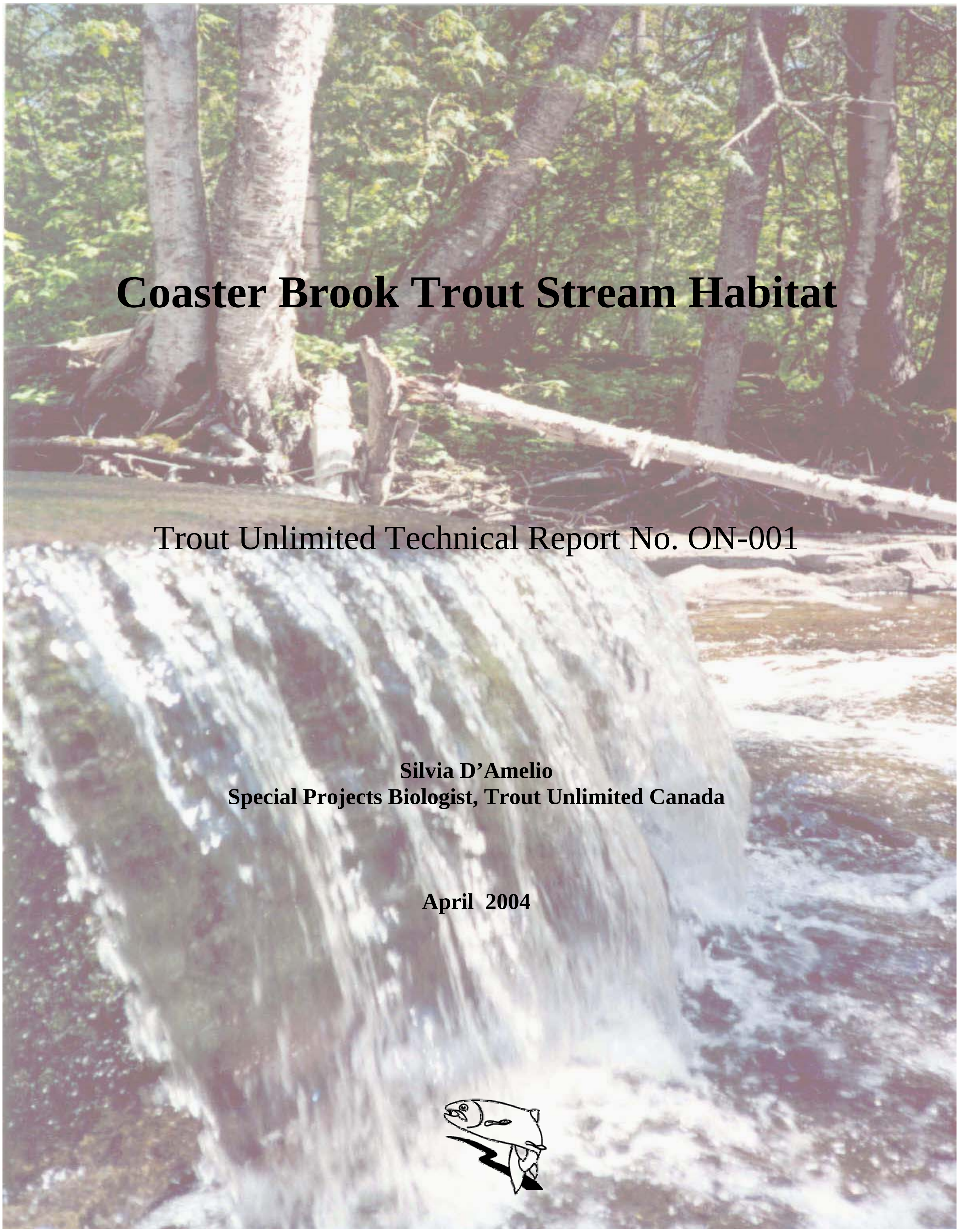

Coaster Brook Trout Stream Habitat

Trout Unlimited Technical Report No. ON-001

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Coaster Brook Trout Stream Habitat Evaluation

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A report of research in progress to Living Legacy Trust
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Introduction

The coaster brook trout is an ecotype of brook trout endemic to Lake Superior. Listed in many reports and rehabilitation strategies as a heritage fish in great need of protection and rehabilitation (OMNR 1985, Newman et al. 1999, Wisconsin Department of Natural Resources 2000), the coaster is one of only two native salmonid species in Lake Superior.

These unique fish are world renowned for their large size, unique colouration and migratory behaviour. This combined with the identification of the world record brook trout caught in the Nipigon district as a coaster brook trout makes Lake Superior a sought after destination for many sport and trophy anglers. The drastic decline in coaster brook trout numbers in Lake Superior and the complete loss of most populations around the lake have prompted a myriad of conservation and rehabilitation plans and programs. This study addresses the need for biological information key to the rehabilitation of coaster brook trout.

This report documents the results of the first year of a two year research program aimed at identifying key features associated with coaster brook trout production and movement. These variables will form the foundation to identify predictive features which will aid in identifying 'best bets' for conservation and rehabilitation while also focusing rehabilitation efforts by describing habitat features critical for the production of coaster brook trout in streams flowing into Lake Superior.

Background and Status

Coaster brook trout are a potadromous form of brook trout which migrate into Lake Superior where they spend a portion of their life span before returning to spawn (Becker 1983). Within the lake, coaster brook trout grow significantly larger than their river resident counterparts and adopt a silvery colouration for a portion of their time there. It is speculated that this change in habitat use and therefore prey base likely results in differential growth rates in comparison with typical stream resident brook trout. During the spawning period in late fall, coaster brook trout regain their typical brook trout colouration and stage at the mouth of tributaries before migrating upstream to spawn. The factors which trigger spawning migration are as of yet unknown but preliminary observations link this behaviour to temperature and flow rates (pers. obs.). In addition, unlike their salmon counterparts coasters do not home to their natal streams (D'Amelio, 2002), however the factors effecting choice of tributary for spawning are unknown. Spawning typically occurs in the fall at the same time and in the same locations as the typical river resident brook trout within Lake Superior tributaries. Lake spawning is well documented in other parts of their range (Blanchfield and Ridgeway 1997), but brook trout spawning in Lake Superior has not yet been documented.

Historically coaster brook trout were found to utilize virtually every tributary of Lake Superior during the spawning run (Figure 1). The combination of large numbers of a large popular sport fish combined with the remote beautiful scenery attracted the general public and nobility from around the world. Prior to 1870 it was noted that angling provided phenomenal harvest opportunities, with angler records reporting that "barrels of trout averaging four pounds have been taken in one day", but within twenty years declines in abundance's were already evident on the Nipigon River, where catches of coaster brook trout had dropped significantly (Kelso and Demers 1993). Within the lake historical misidentification of silver coasters as salmon lead to a lack of understanding of population sizes.

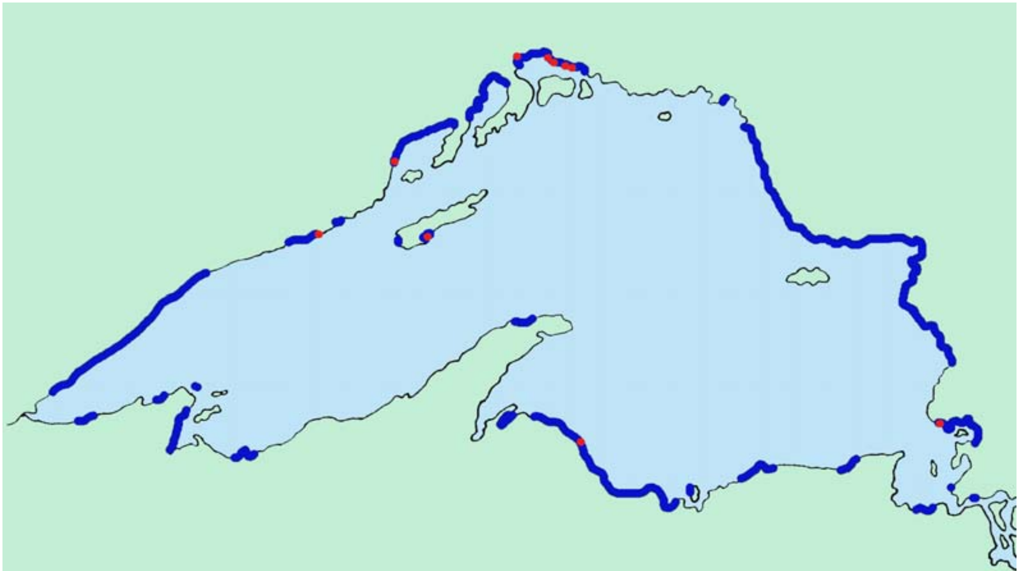

Figure 1 Historical (blue) and current (red dots) distribution of tributaries utilized by coaster brook trout during the spawning season in Lake Superior (from D'Amelio, 2002)

The decline of coaster brook trout, first noted in the mid 1800s was attributed to a variety of causes including habitat loss/alteration through development and damming, competition with introduced species, invasive species like sea lamprey and most notably over-harvesting. Prior to mitigation in recent years, the negative effects created from steep water flow ramping rates for power generation were most severe during the fall spawning period for brook trout. During this time low flow conditions frequently caused brook trout redds to be left dry (R. Swainson pers. com.) frequently and for extended periods of time. As improvements are made to water and effluent management, recreational and commercial fishing regulations and development practices and as rehabilitation and conservation efforts increase it is hoped that the north shore will once again hold world-renowned status for its coaster brook trout.

Currently, coaster brook trout utilize a mere handful of tributaries within Lake Superior during the spawning run (Figure 1). The majority of these tributaries are located within Nipigon Bay, the northern most point of the lake. Nipigon Bay is also home to the Nipigon River which is the largest tributary of Lake Superior and speculated as being the single largest source of coaster brook trout. This river population could potentially act as a source for smaller populations and metapopulations and may in part explain the reason for the persistence of the remaining coaster populations on the Canadian side of Lake Superior.

Despite the persistence of coaster brook trout in Nipigon bay, today, numbers are so low that population estimates are not reliable resulting in coaster brook trout being listed in many management plans, status reports and rehabilitation plans as a population of concern (OMNR 1985, Newman et al. 1999, Wisconsin Department of Natural Resources 2002). Recent changes in harvest regulations in the Nipigon district and water level agreements on the Nipigon River have resulted in population stability. Though this population no longer seems to be in decline, its lasting fragility is seen in the high number of recaptures in a tagging program along the north shore (R. Swainson, pers. comm.).

The coaster brook trout committee formed in 2003 is proposing more stringent regulations for the lake and river systems for all of the north shore, to take effect in 2005. It is hoped that this drastic reduction in harvest (potential possession reduction of five fish to one) will allow for population growth and therefore the rehabilitation of coaster brook trout along the north shore of Lake Superior. In 2003 all those involved in coaster rehabilitation research and management gathered to focus and prioritize efforts on both sides of the boarder. This diverse group including managers, academics and representatives from Trout Unlimited and Trout Unlimited Canada focused on the rehabilitation of coaster brook trout through the identification of information gaps. In addition, future collaborations of individuals on both sides of the border will increase the success of rehabilitation efforts. Some of these efforts are illustrated in Appendix 3.

River-resident brook trout persist in virtually all Lake Superior tributaries along the north shore. Ironically, the population dynamics within these tributaries has not been of great interest to date as the production of river-resident brook trout has remained relatively stable in this area of the lake. With the identification of coaster brook trout as a life history variant of river-resident brook trout and the knowledge that it is these populations that produce coaster brook trout, understanding these populations is key to the management of coasters (D'Amelio, 2002).

To date, rehabilitative efforts have focused on the stocking of Ontario provincial hatchery brook trout (Lake Nipigon strain) in tributaries on both the north and south shore of the lake as well as habitat restoration. There have been multiple brook trout stocking events within most of the tributaries of Lake Superior, and in Lake Superior itself. This tactic has had little success, but the reason for the failure is unknown. In recent years, the U.S. Fish and Wildlife Service has initiated a rehabilitative plan which involves the creation of a coaster brook trout brood stock from remnant populations. Unfortunately, the trigger for the development of the coaster variant is unknown, therefore this production stock will not guarantee coaster brook trout without the right conditions. Presently the rehabilitation of stream habitat has focused on rebuilding "typical" brook trout habitat. Unfortunately, the habitat characteristics necessary for the development of coaster brook trout are unknown and some have even theorized that coaster producing habitat is atypical of traditional productive stream resident brook trout habitat.

The lack of basic biological data such as age of smolting, reproductive rates, life history and population demographics is greatly hampering current rehabilitation efforts. Identification of source rivers and the characteristics that make them conducive to coaster brook trout production is necessary information for recovery plans.

Current Knowledge

We know very little about the basic biology of coaster brook trout and what is known is extrapolated from the biology of river resident brook trout. Though many management and conservation efforts are underway we still do not understand when coaster brook trout smolt or what triggers their movement out and into the tributaries. In addition, age at smolting, age at spawning, number of spawning events and habitat preferences are still unknown. Of key interest currently are those pieces of information which may significantly influence the effectiveness of management, conservation and rehabilitation efforts.

A tagging program initiated by the Nipigon District Ontario Ministry of Natural Resources and carried out by anglers shed light on catch-ability and recapture rates of these fish. The data illustrated high catch-ability by informed anglers and surprisingly high recapture rates. Although these data are not yet published they are beginning to indicate the vulnerability of coaster brook trout and just how low their numbers are.

In 1999 a telemetry study was undertaken in Nipigon Bay. Forty coaster brook trout caught in the bay were tagged and tracked for two seasons. Twelve of these fish were tracked into tributaries the first season identifying coaster migratory tributaries. In addition, tracking data allowed for the quantification of early and late season lake habitat use and distances traveled by individual fish over time (J. Mucha, pers. com.).

The genetic study that developed the genetic database this study will be utilizing also began in 1999 (D'Amelio, 2002). The goal of this research was to identify coaster brook trout as a life history variant, subspecies or unique population. The genetic data indicated that coaster brook trout are produced by river resident brook trout and are therefore a life history variant and do not compose a cohesive group (population, stock or ESU) unto themselves. In addition, some riverine populations of brook trout were shown to be closely related, indicating significant movement by coasters between river systems. Based on the number of coasters associated with river populations and the degree of relatedness among tributaries, coaster production varies considerably among Nipigon Bay tributaries. Lastly, comparison of hatchery brook trout stock with assessed river populations in these sites indicated that past stocking initiatives did not contribute to brook trout production in the study sites.

Coaster Habitat Study

The genetic study mentioned above identified tributaries which produce coaster brook trout and contribute significantly to the coaster density within the lake, and another tributary which does not seem to contribute significantly. Preliminary field observations indicated that differential coaster production in tributaries may be correlated with stream type, differing in some basic habitat features. These observations also indicated that populations of brook trout showed great seasonal variability, whereas those tributaries which did not produce coasters showed a more stable temporal distribution of brook trout. In addition, the populations which show high seasonal variability seem to inhabit typical brook trout habitat (D'Amelio pers. obs.) Brook trout are a highly adaptable, plastic species (Levin and Schiewe, 2001, Hutchings 1996) which are known to display migratory behaviour in the eastern part of their range (Scott and

Crossman 1973, Power 1980). It has been speculated that coaster brook trout may be adopting a migratory life history to escape fragmented tributary habitats and therefore increasing trout densities in optimal tributary habitats. These fragmented habitats and conditions can vary in space and time. New conditions in the lake like temperature regime, prey base and available habitat could cause a phenotypically plastic species such as the brook to alter features of its life history such as growth rates and colouration. We hypothesize that population which display significant seasonal variability occur in less optimal habitats and these habitats drive or condition the movement of fish and therefore the production of coaster brook trout.

The primary purpose of this research was to identify those habitat features associated with coaster brook trout producing tributaries. Identification of such features may also indicate the differences between stream resident brook trout habitat and coaster brook trout habitat. This report summarizes and outlines the first year of a two year research program in which basic habitat data were collected on six tributaries. These data were assessed to identify which features could be used as predictors for coaster brook trout producing habitats. The second year will fine tune these predictive variables for the development of a predictive model which will be tested against a growing genetic database. Comparison of these data with the genetic identification of coaster producing tributaries will validate the model and increase its predictive power.

Study Sites

This study utilized tributaries of Nipigon Bay, along the north shore of Lake Superior as it has been identified as the last stronghold for coaster brook trout and coaster producing tributaries have been identified within the bay. The genetic study (D'Amelio, 2002) identified four tributaries which displayed reliable production of coaster brook trout and one which has the capability, but does not seem to contribute to coaster production within the bay.

All the tributaries assessed are located within an approximate 50km stretch of Lake Superior shore line. Development in these tributaries is minimal, but each is crossed by both the Trans-Canada Highway and a rail line. Each tributary has an impassible barrier waterfall limited the amount of habitat available to fish within the lower section. In some cases, improperly designed culverts along the Highway or rail line have created artificial barriers to movement. Multiple resident and migratory species utilize these habitats including bait fish such as suckers, dace, and salmonids. While each of these tributaries is open to the lake not all are utilized by migratory salmonids. Each of these tributaries received some level of angling pressure which tends to increase in the spring and fall due to the migratory salmonids including steelhead, salmon and coaster brook trout.

Tributaries Assessed

Jackpine River
The Jackpine River is a large river with highly variable flow rates. It holds resident populations of brook trout and rainbow trout and supports migratory spawning runs of Chinook, coho, steelhead and coaster brook trout. This tributary receives relatively high angling pressure (in comparison with the rest of the bay). It is a large fast flowing river found in the largest watershed in this study. There has been some alteration of this tributary between the highway and rail line, likely to stabilize banks and avoid damage to bridges.

Figure 2 Jackpine River

Dublin Creek
Dublin Creek is a medium sized tributary dominated by bedrock below the highway and bedrock driven above. It is mainly a step-pool system from its barrier fall to Lake Superior. Species present in this tributary include brook trout, rainbow trout, stickleback, long nose dace, spoonhead sculpin and mottled sculpin. Development is minimal but includes a camp at the river mouth and a dump almost 2km from the river mouth (300m from the creek).

Figure 3 Dublin Creek

MacInnis Creek
This is a small tributary with relatively low flow rates. This tributary is bedrock driven and highly structured. Brook trout are found in this tributary throughout the season along with sculpin and long nose dace. Seasonally, steelhead have been seen in this tributary.

Figure 4 MacInnes Creek

Cypress River

The Cypress River is a medium sized tributary home to brook and rainbow trout and houses runs of coaster brook trout, steelhead, chinook and coho salmon. Some bank alteration was utilized to stabilize the bridge supporting the Trans-Canada highway. The only development on this tributary exists on the mouth which is flanked on either side by private camps, these properties are protected from erosion by bank stabilization.

Figure 5 Cypress River

Little Gravel River

The Little Gravel River is a medium to small tributary of Nipigon Bay. It is crossed by the Trans-Canada Highway and the rail line within 100m of the mouth (within lake effect). This tributary is known to house brook trout, rainbow trout, slimy sculpin, longnose dace and sea lamprey.

Figure 6 Little Gravel River

Nishin Creek

Nishin Creek is the smallest of the tributaries assessed in this study. It is crossed only by the rail line before the impassable falls and is home to brook trout, shiners and sea lamprey. There are no records of coaster migration in this tributary but this is likely due to the lack of knowledge of this tiny tributary. The have been few reports however reports of coaster brook trout within the area of the bay that this tributary is located.

Figure 7 Nishin Creek

Methods

Study Design

The physical habitats of tributaries streams were assessed to test the hypothesis that tributary habitat characteristics can predict (and potentially drive or condition) coaster brook trout production. Assessment was carried out at three scales: the watershed (using GIS/provincial data), segment and site levels (transects). Variables assessed include those which typically effect brook trout growth and production such as temperature, channel and riparian structure and habitat volume. Six tributary streams were selected based on general structure and production of coaster brook trout in addition to the degree of seasonal variability in brook trout populations.

Three of the tributaries are known to produce coaster brook trout, one is known to not produce, and the other two display characteristics similar to that which does not produce. Production of coaster brook trout was identified by genetic assessment (D'Amelio, 2002) and their ability to house resident brook trout populations throughout the season. It is hypothesized that tributaries which can hold large numbers of resident brook trout will produce fewer coaster brook trout due to potential pressures from population density. These six tributaries were assessed to identify characteristics (if any) that would separate the two types and therefore be tested as a predictor of coaster brook trout production.

Variables Investigated

Variables assessed are separated into three categories: temperature; habitat variables; and point data. First is temperature which is known to greatly effect brook trout growth, production, competitive ability and survival (REFS). Temperature may be regulated by groundwater inflow. These groundwater inflows would create a more stable habitat in the summer months and ideal spawning habitat in the fall. Temperature was recorded at multiple sites in most tributaries to identify potential temperature differences among tributaries over time and potential effects of habitat type and distance from mouth.

Second, habitat data was collected at each sampling transect and included variables like bank full width, wetted width, number and surface area of boulders, number and surface area of woody debris, … (Table 1). Variables used and measured followed a modified methodology prepared by MNR scientists (e.g. OSAP and Reach Level Habitat Assessment).

Table 1: Habitat variables assessed and justification

Variable	Justification
Bank full and Wetted width	• bankfull controls low flow channel structure • low flow channel c/s effects maintenance of water temperature in summer • preferred habitat • measure of relative channel complexity
Woody Debris	• provides rearing habitat • provides feeding habitat • provides cover from predation • provides habitat complexity
Boulders	• provides habitat complexity • cover from predation • provides feeding habitat
Entrenchment	• indicative of stream stability • helps determine stream type
Canopy Cover	• effects temperature • effects predation rates • is influenced by stream width • influences prey base in the tributary
Undercuts in bank	• utilized as habitat
Rooting depth	• linked to bank stability • linked to stability of undercuts
Particle at Toe	• linked to type and stability of banks • linked to flow rates
Bank Angle	• indicative of stream stability •
Bank Vegetation	• effected by bank stability • influences prey base • influences temperature • cover from predation

Lastly, point data was collected at multiple stations along each transect and included bank full depth, water depth and substrate size. These data provide information of channel structure.

Site Preparation

All channel measurements were calibrated to Bank Full, also called the channel forming flow. The length of channel measured was also calibrated to bank full. Bank full was calibrated and measured using a 50m surveyors tape across a riffle at three locations within the tributary.

Reach length for measurement was calculated by averaging the three bank full riffle measurements and multiplying by 20 (Stanfield et al 2002, White 1998) to determine a reach of river that encompassed two full meander wavelengths of river. Rivers are composed of repeating sequences of riffles and pools or step:pools that are calibrated to Bankfull width. Typically, one riffle:pool sequence occurs every 5 bankfull channel widths. Four sequences of 5 bankfull channel widths make up two meander wavelengths. Twelve transects were evenly spaced within the reach beginning with transect one in the middle of a riffle at the cross in a meander sequence. Work done to determine the number of transects necessary to characterize a reach of river and to capture most of the natural variability of the river determined that 12 transects were ideal (Prent 2002).

Data Collection

<u>Temperature</u>

Temperatures were measured using temperature data loggers (Tidbits) located approximately 150 to 175m from the mouth (after lake effect), depending on the location of the closest riffle. Tidbits were also placed in adjacent pools in four tributaries to investigate the differences in rate of change and average temperature between these habitat types. To investigate the distance effects, tidbits were also placed above in the first riffle above the highway in two tributaries. Each tidbit was leashed to a large rock or boulder within the tributary using 12 gauge wire, ensuring that the size of rock chosen was significantly larger than the average size of substrate . The rock was then placed within the center of the selected riffle or pool with the tidbit hidden to avoid potential temperature fluctuations from direct sunlight. Each rock with tidbit was stabilized in its location using surrounding substrate ensuring that current could flow freely by the tidbit. GPS co-ordinates and detailed physical descriptions were recorded for each site and photographs were taken to facilitate retrieval. All tidbits were launched to record temperature every 15minutes. Tidbits were retrieved every two weeks or as weather conditions and water levels allowed. Data was downloaded on site using a notebook computer and stored as excel spreadsheets and text files for later analysis.

<u>Bank full width</u>

Bank full width was measured at each of the twelve transects. A 50m surveyor’s tape was staked to the point on the bank marking the frequent flood levels. This point was identified based on the angles of the banks (usually the point at which the slope of the bank changes a second time from the water’s edge – Figure 8), differences in vegetation growth and presence of mosses. This width was recorded in meters at each transect.

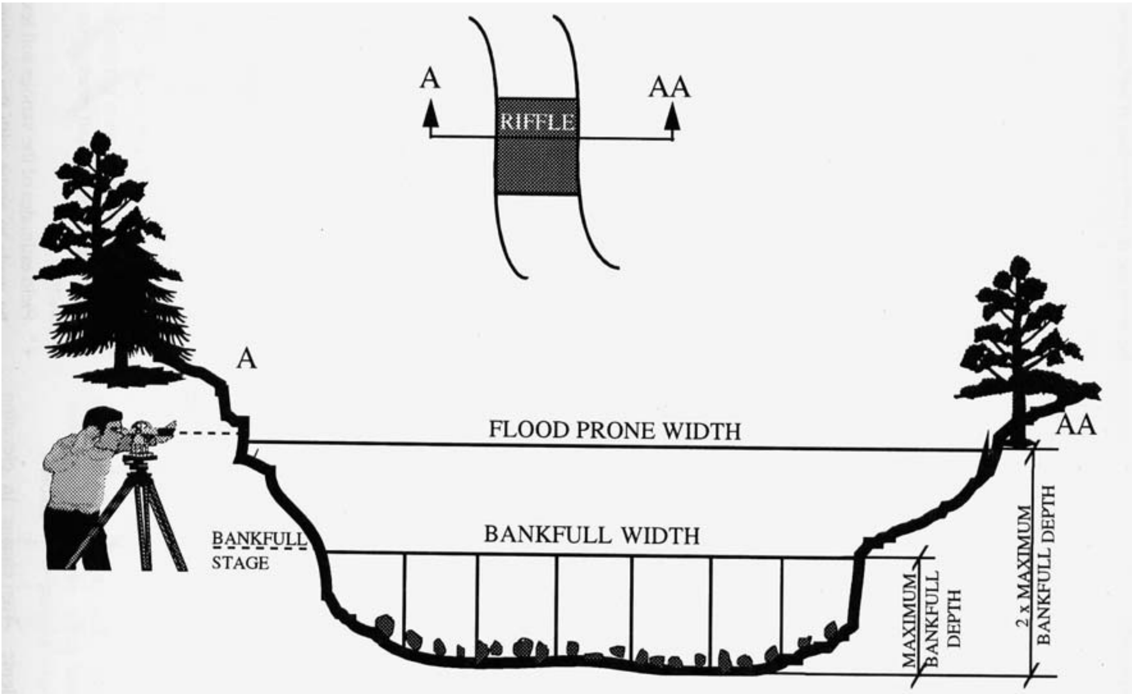

Figure 8 Bank full and entrenchment measurement methods (from Annabel 1996)

Wetted width

Measured as the total width of the channel currently covered by water (in meters) at each transect.

Woody Debris

Each piece of woody debris crossing the transect was measured. Woody debris was categorized as fine or large dependant on diameter (<5cm and >5cm respectively. In each case length and diameter was measured to the nearest centimeter, and length and width of debris jams crossing the transect were also recorded. These data were used to calculate the total surface area of woody debris within each transect. Each piece was only measured once regardless of the number of transects it crossed.

Boulders

The largest boulder in both the active channel and bank full channel were measured on three axes to calculate surface area of the largest boulder. In addition, the total number of particles larger than 30cm on any one axis was recorded.

Canopy Cover

The amount of canopy cover directly over the tributary was estimated using a densitometer at three transects (2,7,9) within each reach. Four measurements were taken at each transect facing upstream, right bank (when facing upstream), downstream and lastly left bank. These values were averaged and presented as percent cover for each transect.

<u>Entrenchment</u>

Entrenchment is the ratio of the width of the Bankfull channel to the width of its active riparian zone or floodplain. Entrenchment is measured at a riffle by determining the deepest point in the Bankfull cross-section and doubling the height. A horizontal distance from this elevation to the valley wall is drawn and the width of this zone is measured (Figure 8). Rivers with a low entrenchment ratio are considered confined and do not have a floodplain or active riparian zone.

<u>Bank Angle</u>

Bank angle was measured indirectly by placing a level 1.5m rod parallel from water's edge to bank. Height from ground to rod was measured at 0m, 0.5m, 0.75m and 1m from the waters edge. These data were used to calculate slope (rise/run) which was averaged over the four measurements at each bank

<u>Bank Vegetation</u>

Bank vegetation was estimated independently for each bank by two observers and averaged. This estimate was recorded as a percent for each bank at each transect.

<u>Particle at toe</u>

Particle at toe was measured on each bank at each transect. In each case a random piece of substrate was removed from the creek bed at the point where the water met the bank. A transverse measure of this particle was recorded for each bank.

<u>Point Data</u>

Point data was collected at each of ten equidistant points along each transect. These data include bank full depth, water depth and particle size. Bank full depth was measured as the distance from the transect line (surveyors tape stretched across the bank at bank full height) and water depth as the distance from the substrate to the water surface. A piece of substrate was randomly picked up at each point and the transverse measured taken.

Data Analysis

Temperature data was downloaded from temperature loggers on site and stored as text and Microsoft Excel files. These files were then merged and edited to remove erroneous readings (before launch and after retrieval) to create continuous data files for analysis. All habitat and point data was entered into a spreadsheet upon completion of the field season and data files were checked twice for errors. Tributary names were coded for ease of analysis (table 2).

Temperature data was summarized for each sampling day to display average temperature, maximum, minimum, temperature range and rate of change using Microsoft Excel. These values were plotted for all sites. In addition, comparisons of sites were plotted for each tributary to investigate site effect.

Habitat variables (excluding bank data) were summarized using averages and ranges by reach and where reaches showed little variance, these data are presented by tributary.

Factor analysis (using Statistica, StatSoft) was employed to identify key features that describe the variability observed among the sites. Prior to analysis all variables were transformed to meet the assumption of normal distribution of values. Bank vegetation, canopy cover and all measures of substrate were arcsine transformed while all others were log-transformed (Sokal and Rohlf 1995). Factor analysis was run using a PC removal method identifying a maximum of three factors or axes. Analysis was run primarily on the entire data set to identify potential tributary groupings and secondarily by tributary to identify potential factors unique to each tributary. Habitat variables related to derived factors were identified by factor loadings with a cut-off level of 0.70. In each case the two primary axes were plotted to identify patterns in habitat data.

Results

Habitat variables were assessed for six tributaries of Nipigon Bay in Lake Superior, the Jackpine River, Dublin Creek, MacInnis Creek, Cypress River, Little Gravel River and Nishin Creek. Due to remoteness and unpredictable weather (windstorms, thunderstorms, floods, hail, etc), time restrictions limited the number of reaches assessed per tributary. In some cases (Dublin and Nishin Creeks) the number of reaches assessed was limited by the length of stream below an impassible falls (Table 2).

Table 2: Tributary codes, number of reaches, reach length and watershed size

Tributary	Code	# of Reaches	Avg. Reach Length	Avg. bank full width	Watershed Size	Proposed coaster producing tributary
Jackpine River	JP	3	430.29m	19.32m		√
Dublin Creek	DB	4	230.38m	11.19m	21.98km^2	√
MacInnes Creek	MI	5	132.92m	6.65m	10.1 km^2	
Cypress River	CY	5	302.57m	15.3m	160.0 km^2	
Little Gravel River	LG	5	222.97m	9.61m	16.93 km^2	√
Nishin Creek	NC	2	105.97m	3.38m	1.17 km^2	

Temperature

Temperature was obtained from all tributaries with the exception of the Jackpine River where high flow rates hampered launch and retrieval of tidbits. Overall, the data illustrates a general increasing temperature trend between July 31st and August 6th followed by a decreasing temperature trend between August 20th and 30th (Figure 9). The Cypress River displays the highest temperatures at all three of its sites followed by Dublin Creek, Little Gravel River, MacInnis Creek and lastly Nishin Creek with the coldest temperatures. The trends observed however span a very tight range, especially Dublin, Little Cypress, and MacInnis Creek which display a range of less than two degrees among them. Sites vary in temperature within a tributary where riffle sites tend to be warmer than their corresponding pool sites. In addition, temperature ranges appear to be on average slightly greater for riffle versus pool sites (Figure 10). Temperature ranges are generally similar among all sites and all tributaries with the exception of the Dublin Creek riffle site (Figure 10). Daily maximum and minimum temperatures show the same trends as the average daily temperatures where the Cypress River shows the highest maximum and minimum followed by Dublin Ck., Little Gravel River, MacInnis Creek and lastly Nishin Cr. displaying the lowest values in both cases (Figure 11 and 12). The one exception to this is the Dublin Riffle site which shows the highest daily maximum temperature (Figure 11 and 12).

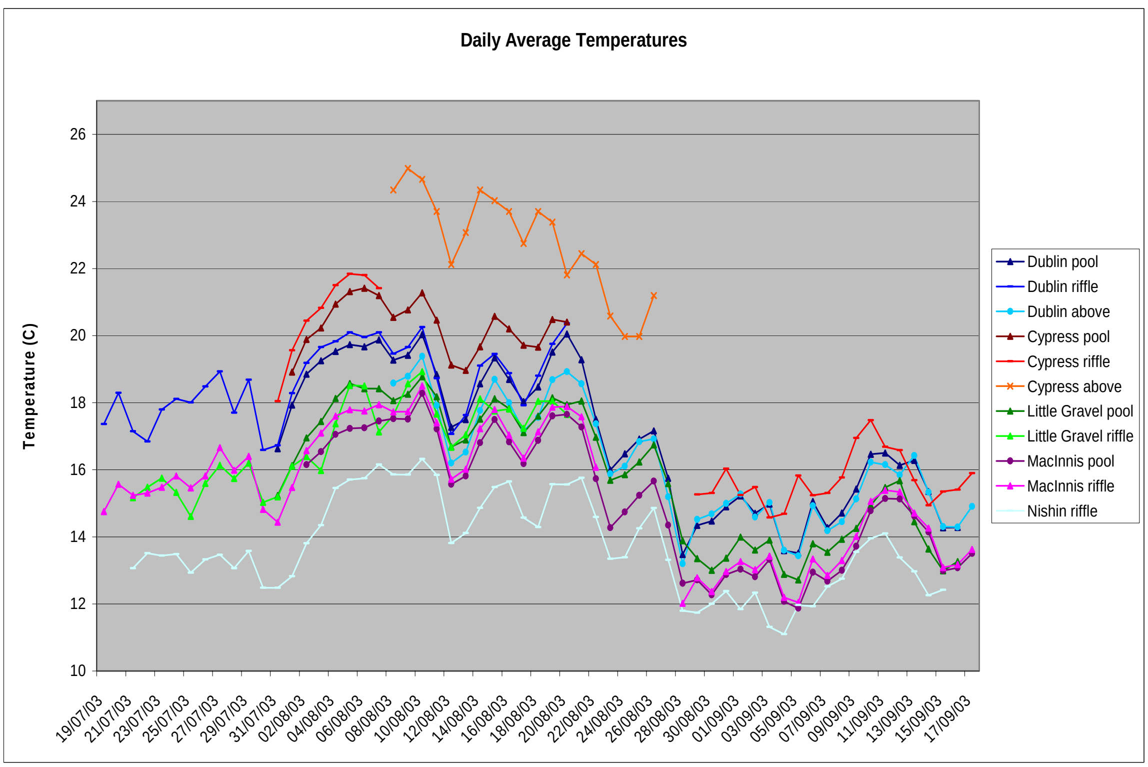

Figure 9 Daily average temperatures for all sample sites

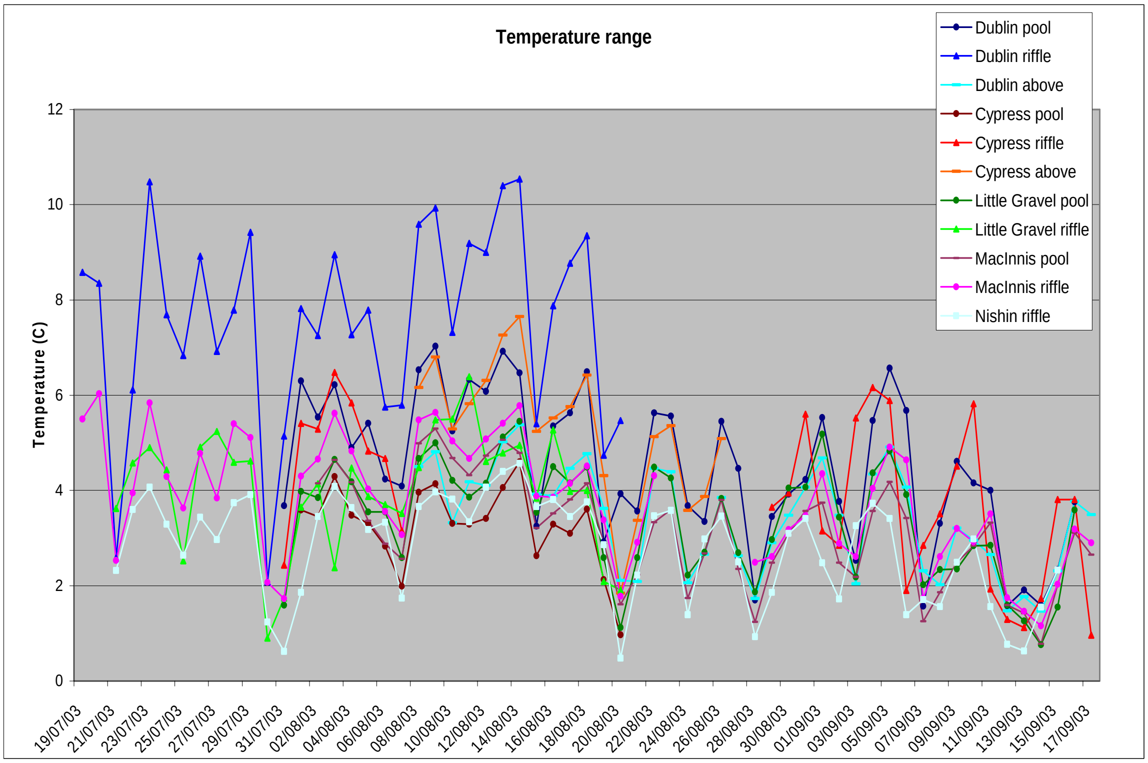

Figure 10 Daily average temperature range for all sample sites

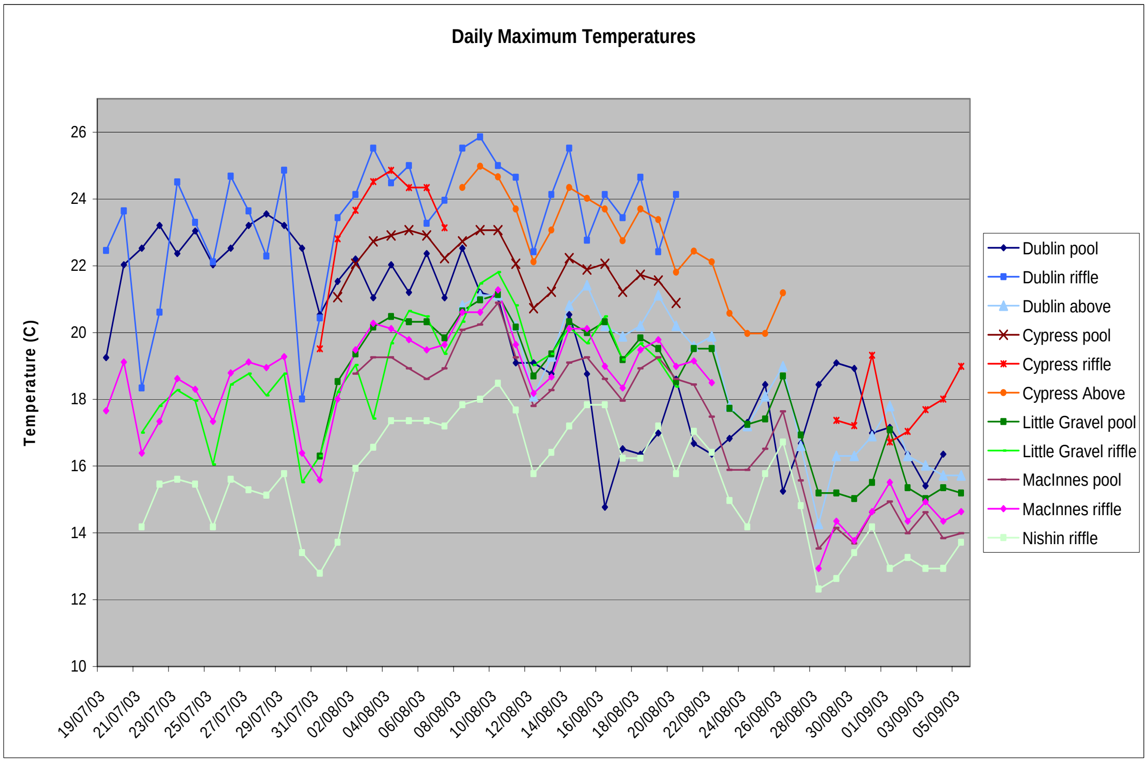

Figure 11 Daily maximum temperatures for all sample sites

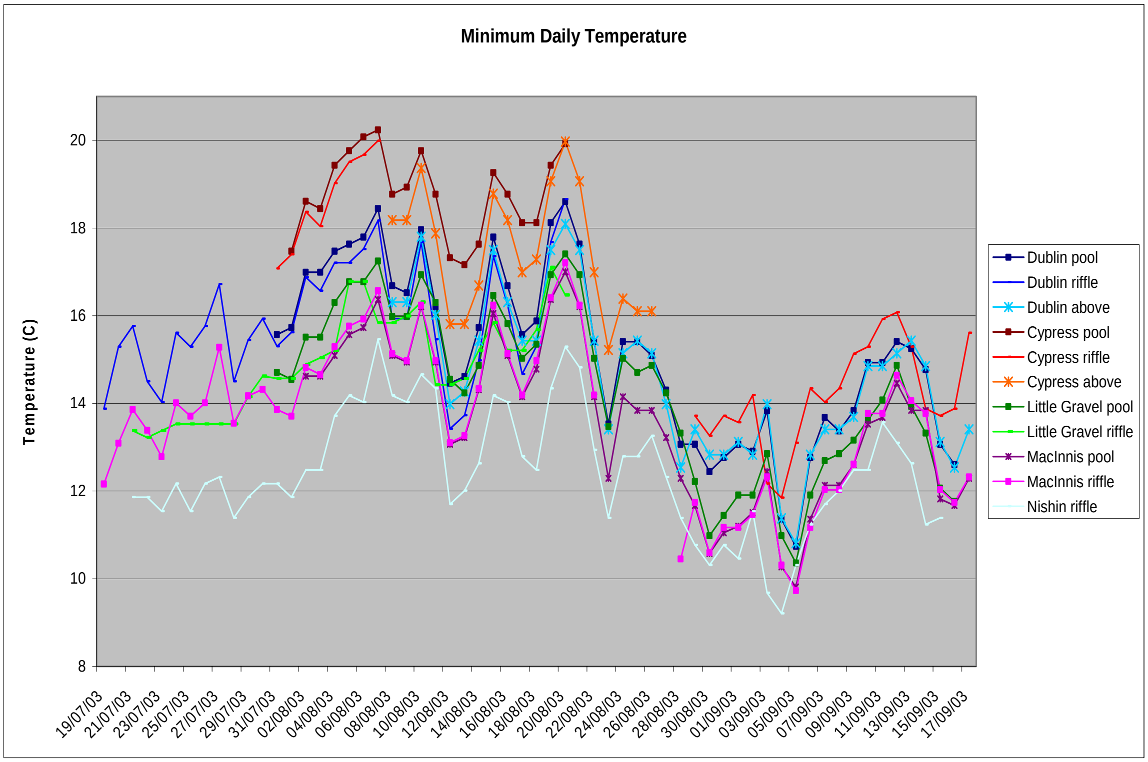

Figure 12 Daily minimum temperatures for all sample sites

<u>Bank Full Width and Width to Depth Ratio</u>

The Jackpine River displays the highest bank full width, depth and therefore width to depth ratio, followed by Cypress River, Dublin Creek, Little Gravel River, MacInnis Creek and lastly Nishin Creek (Table 3). All these channels appear to fall within either a "C" form or "B" form channel as relates to the Rosgen Classification.

Table 3: Average Bank Full Widths, Depths and Width to Depth Ratios

	Avg. BFW	Max. BFW	Avg. BFD	Avg. W/D
Jackpine River	19.32m	34.0m	0.60m	36.19
Dublin Creek	11.19m	18.0m	0.49m	24.98
MacInnis Creek	6.65m	15.4m	0.47m	15.55
Cypress River	15.3m	25m	0.56m	32.29
Little Gravel River	9.61m	17.6m	0.47m	23.01
Nishin Creek	3.38m	5.32m	0.25m	14.97

<u>Canopy Cover</u>

Tributaries displayed great variability in canopy cover, but seemed to fall into two distinct groups. The Cypress, Jackpine and Little Gravel Rivers all displayed canopy cover values <45% (21.69, 33.44, and 41.33 respectively). Dublin, MacInnis and Nishin Creeks all displayed canopy cover values greater than 65% (67.67, 69.83 and 90.63 respectively). In addition, these creeks showed less variability among their scores (data not shown). Width of the tributary was shown to be negatively correlated with canopy cover (-0.64).

Entrenchment

Average entrenchment ratios indicated that only one of the six tributaries assessed was highly entrenched (Nishin Creek) with a ratio of 0.88. Cypress River and MacInnis Creek were shown to be only slightly entrenched with ratios of 2.69 and 3.44 respectively. The Jackpine river, Dublin Creek and Little Gravel River displayed ratios consistent with moderate entrenchment (1.73, 1.72 and 1.93 respectively) (Table 4).

Table 4: Entrenchment Ratios and Ranges

	Entrenchment Ratio	Minimum Ratio	Maximum Ratio	Range
Jackpine River	1.73	1.17	3.14	1.97
Dublin Creek	1.72	1.22	3.28	2.06
MacInnis Creek	3.44	1.28	8.18	6.90
Cypress River	2.69	0.84	6.88	6.04
Little Gravel River	1.93	1.21	3.82	2.61
Nishin Creek	0.88	0.54	1.20	0.66

Substrate/Pebble Count

Substrate type did not display any trends among tributary types, though all tributaries show a high average percent of small gravel consistent with spawning habitat (Figure 13). When plotted by reach for each tributary (data not shown), little variability among reaches is observed indicating the overall average percentage is representative of each tributary.

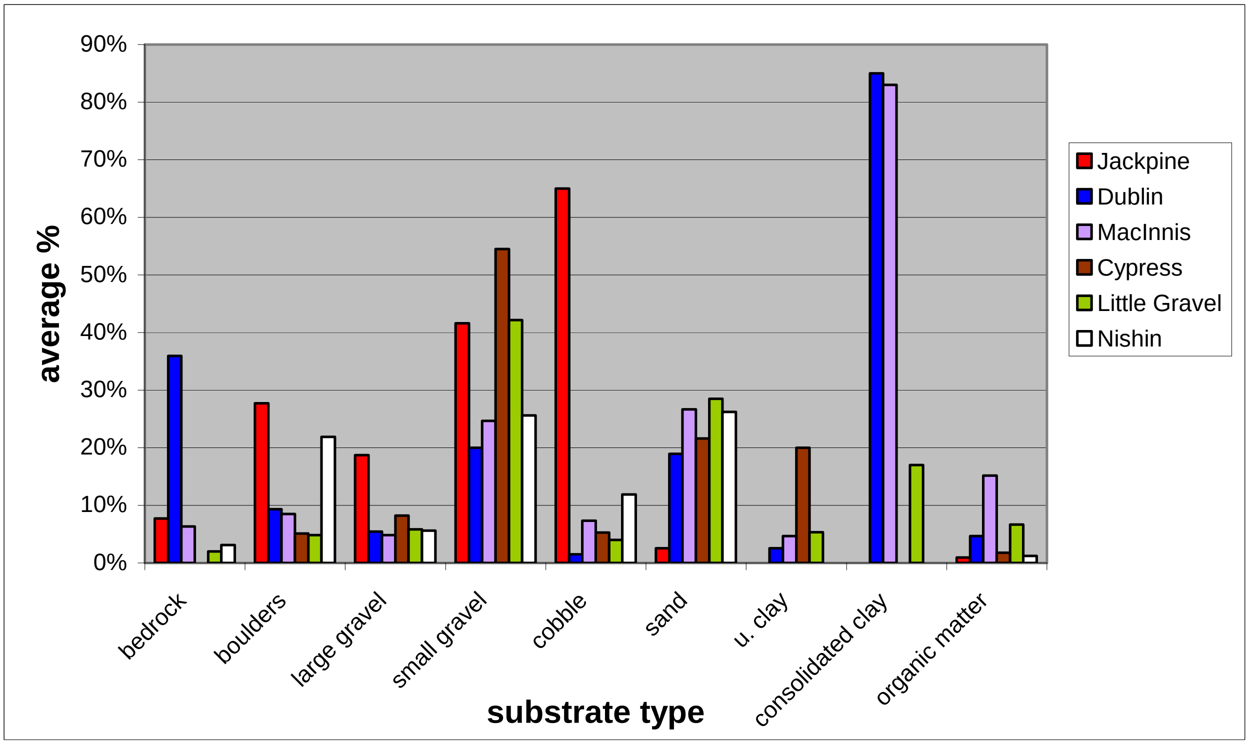

Figure 13 Average particle size at transects among tributaries

Watershed Area and Temperature

Preliminary analyses of watershed area versus maximum temperature did suggest a possible relationship. Given that the large scale spatial data was not made available until very late in this study year, it is not reported.

Multivariate Statistics

Factor analysis of all variables for all tributaries identified two factors (axes) that accounted for only 30% of the variance observed in the data. None of the variables displayed significant factor loadings nor were any remotely correlated to the axes identified. The analysis was rerun were rerun for the subset of data including entrenchment and canopy cover, with the same results. Lastly, factor analysis by tributary produced two axes which accounted for 41% of the variability observed in the data. Though there were no significant loadings associated with these results, correlated variables were identified along one axis. The primary axes in each case were driven by width/depth ratio and bank full depth or large woody debris identifying the differences between riffles and pools (i.e. Figure 14). These analyses were rerun grouping sites by habitat type (riffle or pool) again with no significant results.

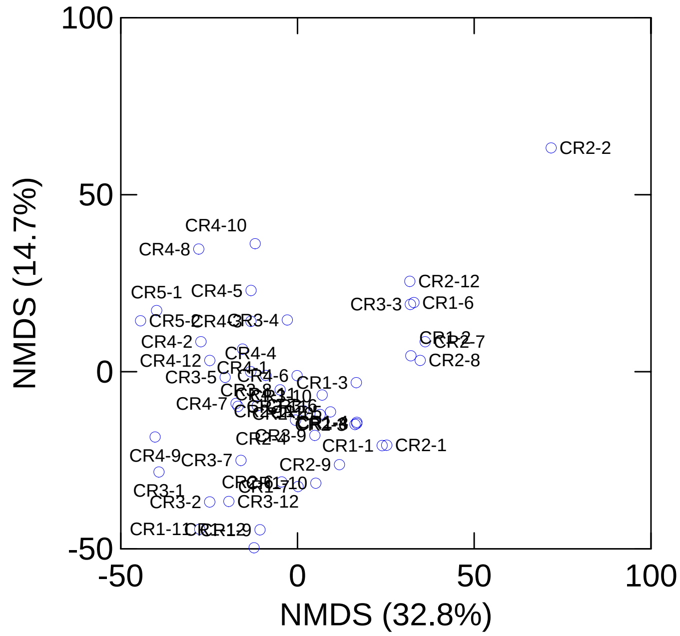

Figure 14: Factor Analysis for Cypress River demonstrating no significant factor loadings at this time.

Discussion

The data analyzed to date has not allowed us to clearly differentiate the major variables explaining the difference between resident brook trout systems and anadromous or coaster producing tributaries. However, several variables appear to be promising and do suggest that there may be a small number of variables that act as a trigger to migratory behaviour of brook trout in these streams.

All the streams that flow off into Nipigon Bay along this reach of Lake Superior fall over an escarpment, except for the Jackpine River. The Jackpine flows through a steep alluvial valley with highly readable banks and therefore exhibits the highest W/D ratio of all 6 streams.

All the streams in this study appear to fall into two major stream forms based on the classification (Rosgen 1996). The two stream forms are the riffle:pool, “C” forms and the step:pool “B” forms. The dominant stream form for the Jackpine is a “C” form, while the other streams in the study are a combination of “C” and “B” forms depending upon their proximity to the edge of the escarpment. All the streams in this study are influenced either directly or indirectly by bedrock which is either exposed (e.g. Dublin Creek) or is near the surface but only occasionally exposed (e.g. Nishin, MacInnis).

The Jackpine River is a suspected coaster producing tributary as are the Cypress and Little Gravel Rivers. All three display high width to depth ratios consistent with large tributaries flowing through loose alluvial material and with bedrock outcroppings. It is easier for a stream during high flow to widen itself under this combination of conditions rather than deepen itself.

In addition to the channel cross-section, observations of the response of the three potential Coaster brook trout streams (Jackpine, Cypress and Little Gravel), to heavy rainfall events suggested that these three streams had greater flow variability than Dublin, MacInnis, and Nishin. The flow characteristics of these three Coaster streams would be classified as "flashy" by stream hydrologists. Flow variability appears to be an important variable that will need to be assessed in Year 2 of the project.

Canopy cover was significantly lower on the Jackpine, Cypress and Little Gravel than the other sites. This is not surprising given the negative correlation of canopy cover and stream width. It is also important to note that temperature is greatly affected by canopy cover and therefore correlated. Therefore, as streams become wider in cross-section, the shading affect of canopy is reduced and the streams are more affected by solar radiation. These streams heat up more quickly and have a greater diurnal fluctuation in temperatures. These variables when analyzed with the watershed level data may begin to elucidate relationships between coaster brook trout production and temperature, channel form and canopy variables.

The Cypress River (the only tributary with temperature data that is known to produce coaster brook trout) displayed the highest temperatures. Between August 1st and August 28th, each site displayed temperatures which are consistent with the upper limit of brook trout's temperature range of 5-20C (Figure 10 and 11), and in some cases above and reaching the upper lethal limit for this species (Fry et al 1946, Power 1980).

Because of the exceptionally high flows in the Jackpine River during the summer of 2003, tidbits that were installed in the river were washed away by high flows. This is unfortunate because spot temperatures on the Jackpine River indicated that it experiences high water temperatures, perhaps even higher than those experienced on the Cypress. With the limited information on the Jackpine, it would appear that the highest temperatures recorded last year would have been on the Jackpine, Cypress, Dublin, Little Gravel, MacInnis and Nishin, in that order. Although temperatures in the lower Dublin did reach critical temperatures for brook trout, the upper reach on Dublin only reached this high temperature briefly and pools in the same reach were cooler and provided refugia for the brook trout. With the exception of the high temperatures on the lower Dublin, the three warmest streams with the greatest variability in temperature range appear to be Coaster streams.

The temperature ranges experienced on the Cypress are consistent with those in which rainbow trout are known to thrive at 21°C (Scott and Crossman 1973). As mentioned above, the riffle and pool sites on the upper portion of Dublin Creek also displayed critically high temperatures for a portion of the season (Figure 12). Field observations indicated that brook trout were identified at these sites, but were replaced by schools of white sucker by August 22nd,2003 which are known to utilize a significantly higher temperature range of up to 27-34°C www.wfs.sdstate.edu).

Over the last century exotic salmonids have been introduced to Lake Superior including four species of Pacific salmon, brown trout, and both resident rainbow trout and anadromous steelhead (MacCallum and Selgeby 1987, Peck et al 1994, Crawford 2001). All of these introduced species are now naturally reproducing and while competition is likely high, the effects on native salmonids are unknown. Observations have been made of competition and aggression between salmon and brook trout during spawning seasons (R.Swainson, pers com) and competition for rearing and feeding habitats at the fry stage (pers. obs.). Research into brook trout rainbow trout interactions has produced variable results, indicating that in some cases site differences in habitat use allow for sympatric populations to survive (Cunjak and Green 1983, Strange and Habera 1998). Alternatively, the overlap in these niches puts brook trout at a disadvantage due to their smaller size and rainbow trout's ability to utilize brook trout habitat (Larson and Moore 1985, Rose 1986).

These data combined with observations of species presence and absence at various sites on study tributaries indicates that density estimates for rainbow trout and brook trout within these tributaries combined with more extensive assessment of temperature variability may provide valuable insights into interactions of brook trout and exotic salmonid species and the impact of these interactions on production and habitat use.

To date, the results of data collected and analyzed highlights the need to link reach level and site level data to larger scale variables (e.g. watershed area) and to increase resolution on specific habitat variables. Temperature maxima and temperature variability appear to partially separate out potential coaster streams from resident streams. Flow variability, from observations, also appears to be a factor in differentiating coaster streams from resident streams. These two variables may work together to create an environment in some streams that encourage brook trout to seek better habitat through migration. Brook trout do exhibit a range of life history strategies dependent upon specific habitat variables (i.e. Power 1980).

Figure 15 depicts the conceptual framework of variables that likely influence Coaster brook trout populations. Year 1 of this research has concentrated on physical habitat variables and temperature. Findings to date suggest that temperature and flow variability appear to differentiate potential coaster streams from resident streams, although the data to date is not conclusive. Therefore, there is a need for further resolution of key habitat variables such as temperature, as well as collection of new variables that measure conditions such as flow stability and variability as well as pool quality. In addition, Year 2 should expand data collection to biological information related to food web structure, population densities, and additional genetic assessment

We are using the conceptual framework shown in Figure 15 as a guide towards to development of a framework model that identifies the key variables that trigger Coaster brook trout behaviour in streams. Follow-up to the genetic work is necessary, as is collection of additional biological information for food web analysis and salmonid use and densities in the study streams. As well, we will be exploring the larger scale conditions that drive the temperature and flow characteristics that appear to be encouraging Coaster behaviour.

Work Plan for Year Two (field season)

The 2004 field season is scheduled to commence May 17th, 2004 with the deployment of temperature data loggers. Data loggers will be deployed at approximately five sites on each tributary and will be recording data from mid May to mid September. These data will expand the dataset from year one by adding data for the early season, capturing data on the Jackpine River and increasing the resolution of longitudinal temperature characteristics and variability. This information will be extremely useful for identifying the thermal regime, variability and dynamics of each study stream. In addition to the data loggers, spot flow measurements will be done to develop temperature maps for each tributary to aid in the identification of groundwater inflows which act as temperature regulators. These data will be collected using a method created to identify stream fish assemblages in Ontario (G.Wichart, Pers. Com.).

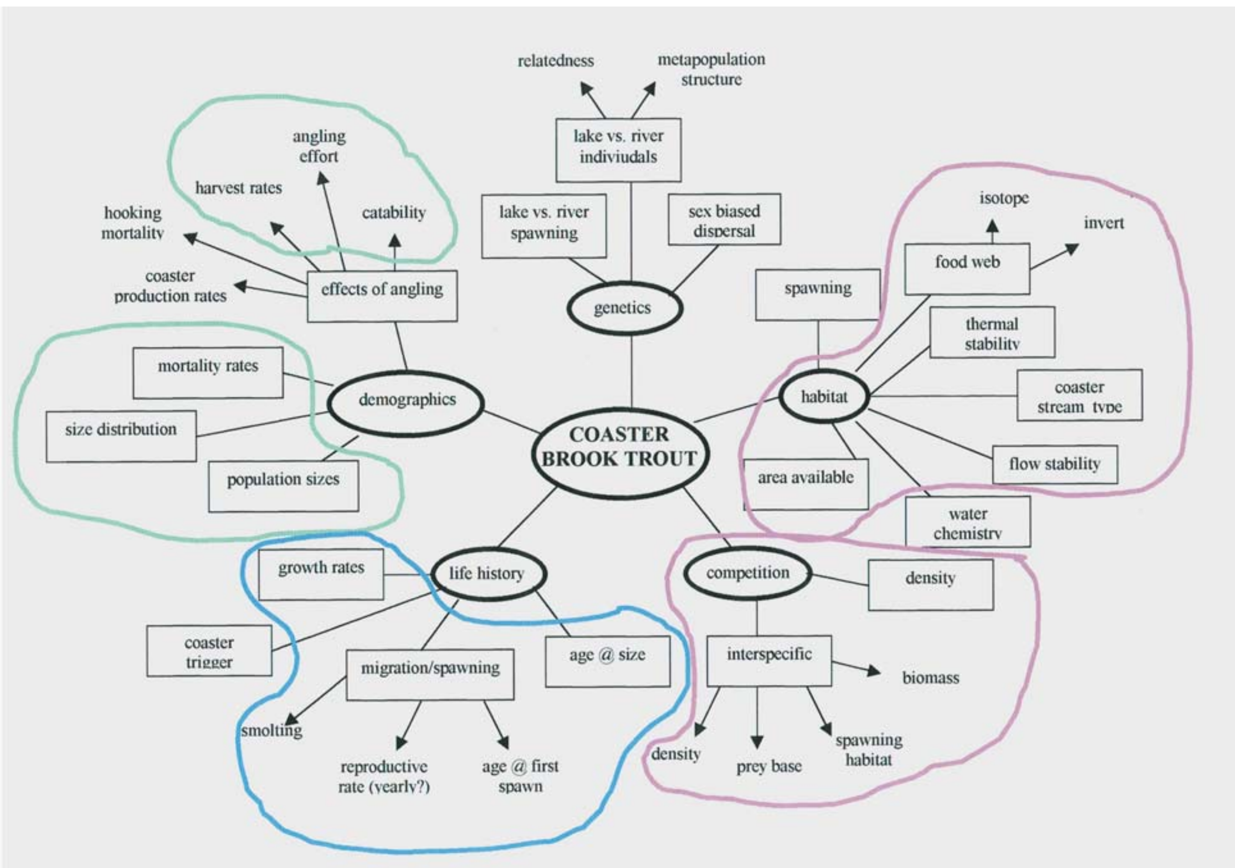

Figure 15: Coaster brook trout research – conceptual framework

In consultation with the study committee that assisted with the original work last year, habitat variables will be expanded on the original streams to include identification of site type (pool versus riffle) and flow characteristics. In addition, simplified flow gauging will be conducted at a control cross-section (likely at the bridges/culverts of Highway 17) to monitor flow rates following storm events at each tributary. This information will be compared with precipitation information from the closest weather station (we are exploring the possibility of establishing a basic weather station closer to our sites). A flow meter will be utilized to quantify the base outflow for each tributary and provide baseline data for flow estimates throughout the year.

Electroshocking will be utilized to estimate population densities for brook trout and rainbow trout for each of the tributaries. This will be done at four different sampling dates through the course of the season to identify potential temporal variability. Data will be collected on all fish species collected to investigate species presence/absence and potentially prey biomass. Length and weights will be taken from each trout at each site to investigate differences in growth rates in addition to biomass estimates. As an added benefit scale samples will be collected from stream and lake fish to investigate growth rates, migration and spawning and age/length curves.

Invertebrate sampling at multiple sites in each tributary will be combined with stable isotope analysis on tissue samples (taken from sampled fish) in order to elucidate the differences in food web usage among tributaries and between tributaries and the lake. These samples will be taken at various times throughout the field season to identify potential temporal variability. This information will be combined with habitat information in order to construct an understanding of food web characteristics and differences between lake feeding and stream feeding .

Project Status

The launch of the second year of this project began with the news that Fishing Forever Foundation is the first to confirm their support of the second year of this research program with the single largest grant they have awarded in the amount of $9,000. In addition the Canada-Ontario Agreement has granted a second year of funding in the amount of $20,000. Grant proposals are in place for an additional $77,000 which will cover all of year two.

The field season will commence in May of 2004 and end in September 2004 with the goals of adding new variables and increasing the resolution on data collected in year one (please see work plan). In addition tissue samples will be collected for genetic analysis to confirm coaster brook trout production in the tributaries assessed. These data will be combined with data collected in year one in addition to watershed level data to identify predictive factors or variables which will aid in the identification of coaster brook trout producing tributaries.

Following the conceptual framework that the research program is based on (Figure 13) it is hoped that we will directly be able to shed light on two major aspects of coaster brook trout biology, habitat and competition (outlined in purple). Indirectly, through the collection of scale samples we hope to begin to shed light on some of the aspects of life history (outlined in blue), and lastly we will be aiding a group of volunteers and biologists with a tagging program aimed at describing some basic coaster brook trout demographics.

A third year is currently being proposed for this program to resolve any potential data gaps, but most importantly this last year will be dedicated to outreach and the development of rehabilitation and restoration plans for Coaster brook trout. This portion of the program will focus on public talks, posters, handouts, web site maintenance and information sessions aimed at providing managers and conservation groups with the data and tools produced.

References

Annable, W.K. 1996. Morphologic Relationships of Rural Watercourses in Southern Ontario and Selected Field Methods in fluvial Geomorphology. Ontario Ministry of Natural Resources.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Seattle, W.A.

Blanchfield, P.J. and Ridgway, M.S. 1997. Reproductive timing and use of redd sites by lake-spawning brook trout (*Salvelinus fontinalis*). Can. J. Fish. Aquati. Sci. 54:747-756.

Crawford, S.S. 2001. Salmonine Introductions to the Laurentian Great Lakes: an historical review and evaluation of ecological effects. Can. Spec. Publ. Fish. Aquatic. Sci. No.132.

Cunjak, R.A., and Green J.M. 1982. Habitat utilization by brook char (*Salvelinus fontinalis*) and rainbow trout (*Salmo gairdneri*) in Newfoundland streams. Can. J. Zool. 61: 1214-1219.

D'Amelio, S. 2002. Conservation genetics and metapopulation structure of brook trout (*Salvelinus fontinalis*) in Nipigon Bay (Lake Superior, Ontario). M.Sc. thesis, Trent University, Peterborough, Ontario.

Fry, R.E.J., Hart, J.S. and Walker, K.F. 1946. Lethal temperature relations for a sample of young speckled trout *Salvelinus fontinalis*. Publ. Ontario Fish. Res. Lab. 54:9-35.

Hutchings, J.A. 1996. Adaptive phenotypic plasticity in brook trout, *Salvelinus fontinalis*, life histories. Ecosience. 3(1):25-32.

Kelso, J.R., and Demers, J.W. 1993. Our Living Heritage: The Glory of the Nipigon. Mill Creek Press, Echo Bay, Ontario.

Larson, G.L., and Moore, S.E. 1985. Encroachment of exotic rainbow trout into stream populations of native brook trout in the southern Appalachian mountains. Trans. Am. Fish. Soc. 114:195-203.

Levin, P.S., and Schiewe, M.H. 2001. Preserving salmon biodiversity. Amer. Sci. 89:220-227.

MacCallum, W.R., and Selgeby, J.H. 1987. Lake Superior Revisited 1984. Can. J. Fish. Aquat. Sci. 44(Suppl.2): 23-36.

Magoulick, D.D. and Wilzbach, M.A. 1998. Microhabitat selection by native brook trout and introduced rainbow trout in a small Pennsylvania stream. J. Freshw. Ecol. 12(4):607-614.

Newman, L.E., Dubois, R.B., and Halpern, T.N. (ed), 1999. A brook trout rehabilitation plan for Lake Superior. Great Lakes Fish. Comm.

Ontario Ministry of Natural Resources. 1985. Lake Superior Strategic Fisheries Plan 1985-2000. Government of Ontario. Queen's Publisher, Toronto, ON.

Peck, J.W., MacCallum, W.R., Schram, W.T., Schreiner, D.R., and Shively, J.D. 1994. Other Salmonines. *In* Hansen, M.J. *Editor*. The State of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1. p35-52.

Power, G. 1980. the brook charr, *Salvelinus fontinalis. In*Charrs: salmonid fishes of the genus *Salvelinus. Edited by* E.K. Balon. E.K. Kluwer Boston Inc. USA. Pp141-203.

Prent, M.T.H. 2002. Determination of Field Sampling Strategy. Ontario Ministry of Natural Resources Report.

Rosgen, David. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO. 395pp.

Scott, W.B., and Crossman, E.J. 1973. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa.

Sokal, R.R. and Rohlf, F.J. 1995. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company. New York, 850pp

Stanfield, L., Jones, M, Stoneman, M, Kilgour, B., Parish, J. and Wichert, G. 2002. Stream Assessment Protocol for Southern Ontario. V.4.2. Ontario Ministry of Natural Resources.

Strange, R.J. and Habera, J.W. 1998. No net loss of brook trout distribution in areas of sympatry with rainbow trout in Tennessee streams. Trans. Amer. Fish. Soc. 12(4):607-614.

White, K. 1998. Carroll Creek Watershed Research Project; Relationships between Riparian Land Cover and Aquatic Habitat Characteristics. Trout Unlimited Canada Report.

Wisconsin Department of Natural Resources. 1000. Lake Superior Basin Brook Trout Management Plan – 2000. State of Wisconsin Department of Natural Resources.

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Appendices

Appendix 1
Deliverables and Milestones (planned versus completed)

Deliverables	Proposed	Completed
Talks and handouts for public education	July 1/03	July 30/03
Data analysis and results (predictive variables)	March 1/04	March 1/04
Interim report to Living Legacy Trust	April 30/04	April 30/04
Incorporation of 2nd year's data analysis and results	March 1/05	
Technical report	May 1/05	
Scientific and popular publications	June 30/05	
Outreach (posters/handouts/talks) for public and scientific venues	various dates	ongoing

Milestone	Timeline	Completed Date	Notes
Field and information transfer preparations: • Assemble steering committee: project coordination and planning of first field season • Gather and collate existing habitat and watershed data from partner agencies (OMNR) and provincial data warehouse (OLIW) • Gap analysis of aquatic habitat data	April 1/03 – June 30/03	July 7, 2003	Provincial data will be obtained for year 2
Preliminary field work and information transfer: • Characterize habitat variables from known coaster producing and non-producing tributaries within Nipigon Bay	July 1/03 – August 31/03	September 23, 2003	
Data analysis and model building: • data entry (GIS and field data) • statistical analyses • construct habitat suitability indices (HSI) for measured habitat variables • data analysis of known coaster / brook trout populations • develop a GIS-based habitat model to predict potential coaster production of tributary rivers and streams	Sept 1/03- May 31/04	March, 2004	HSI and GIS work has been moved to year 2 due to time constraints
Habitat data and tissue collection: • Characterize habitat variables from additional target tributaries to test model • Collect tissues from brook trout for genetic analysis for model confirmation	June 1/04- August 31/04		Year 2
Testing the model: • test and validate model with data from additional sampling sites (use model to identify/predict potential coaster producing and non-producing tributaries; verify predictions with genetic analysis and individual assignment tests).	Sept. 1/04- January 30/05		Year 2
Report writing: • final report: document variables for identifying coaster habitats; describe GIS model an potential applications	Feb. 1/04- April 30/05		Year 2

Appendix 2
Monitoring Report to the Living Legacy Trust (Financial Report)

LLT Project Number: 08-049/078-02

Final Report (notes)
1) Five thousand dollars of the LLT funding was used to purchase field gear, though none was budgeted for. This is due to the fact that we were unable to obtain the $3,000 for field gear through TUC, but were able to extend our salary expenditures. This shift in allocation of salary and field gear costs was approved by LLT representatives with the condition that it represented no more that 10% of the budget.
2) The steering committee was not gathered for a formal meeting due to time constraints and a delayed start to the field season. Project coordinators communicated with the steering committee via e-mail and phone and are scheduling a meeting prior to this years field season. The GIS component of this research was pushed to year two as project coordinators were not able to gain access to the provincial databases in time for this report.
3) The project is currently on budget

Line Items	Year 1 Proposed	Year 1 Actual	LLT Proposed	LLT Actual	TUC Cash/In-Kind Proposed	TUC Cash/In-Kind Actual	MNR Cash/In-Kind Proposed	MNR Cash/In-Kind Actual	NRDPFC In-Kind	NRDPFC In-Kind Actual
Salary	$112,000	$92,163	$60,000	$56,398	$8,000	$20,800	$44,000	$14,965		
Steering committee	$2,000		$400				$1,600			
Field equipment	$6,000	$11,835		$5,076	$3,000		$3,000	$8,835		
Field costs	$34,000	$12,545	$8,000	$5,915			$26,000	$ 6,630		
Office Equipment	$3,000	$4,623	$1,000	$1,916	$2000	$2,707				
GIS analysis	$20,000						$15,000	$0	$5,000	$0
Tech. Transfer	$3,000	$6,095	$2,000	$2,095	$1,000	$4,000				
Total	$180,000	$127,261	$71,400	$71,400	$14,000	$27,507	$89,600	$30,403	$5,000	

Prepared By: ____

Sr. Financial Officer: ____

Appendix 3
Project Abstract

Habitat availability and distribution can greatly affect fish behaviour and development. It has been suggested that the availability of appropriate habitat can drive the development of ecotypes within salmonids. Coaster brook trout, a potadromous form of river resident brook trout are currently the focus of many rehabilitative and conservation efforts in both Canada and the U.S. They utilize both tributary and lake habitats, but previous genetic studies have shown that not all tributaries produce significant numbers of coaster brook trout.

This study investigated habitat features at both the site and watershed scale for tributaries known to be coaster producing or non-producing. Variables assessed included those factors known to directly and indirectly influence brook trout production and survival such as watershed size, surficial geology, temperature, woody debris, and stream structure. Data analysis revealed that these characteristics alone do not account for the variability observed among tributaries assessed. Several of the variables assessed suggest trends and highlight the need to link reach level and site level data to larger scale variables (i.e. watershed level data). These data will be expanded in year two with the incorporation of food web structure, population densities and flow rates and addition of watershed level data to identify differences between coaster brook trout producing and non-producing tributaries. The ultimate goal of this research is to identify predictive features for the identification of coaster brook trout producing tributaries. Our ability to use this information to identify 'best bets' for coaster brook trout conservation and rehabilitation will greatly focus efforts and potentially increase overall success.

Appendix 4

Outreach and publications

This research has been featured in both a national and bin-national newsletter. Trout Unlimited Canada has to date published two articles in its newsletter currents (page 35 and 36) which is available online at www.tucanada.org. These newsletters are archived on this site for future use. Bi-nationally, Trout Unlimited and Trout Unlimited Canada have developed a coaster brook trout newsletter which is distributed electronically to individuals and groups engaged in coaster brook trout conservation, management and rehabilitation.

A coaster brook trout information kit was produced as a proportional package for use in engagement and in particular fundraising. The package provides detailed background on the history, current status, and a complete outline of this research, its goals and implications. This kit is available from Trout Unlimited Canada upon request. This information kit was used as the basis for the coaster brook trout website, soon to be launched at www.tucanada.org (summer 2004).