

**Effects of Beaver (*Castor canadensis*)
Impoundments on Stream Temperature and
Fish Community Species Composition and
Growth in Selected Tributaries of Miramichi
River, New Brunswick**

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Fisheries and Aquatic Sciences 2227

1998

Effects of Beaver (*Castor canadensis*) Impoundments on Stream Temperature and
Fish Community Species Composition and Growth in Selected Tributaries of
Miramichi River, New Brunswick¹

by

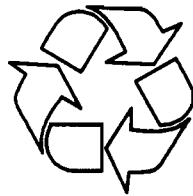
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ABSTRACT

M.D. Alexander. 1998. Effects of Beaver (*Castor canadensis*) Impoundments on Stream Temperature and Fish Community Species Composition and Growth in Selected Tributaries of Miramichi River, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. 2227: ix + 44p.

Beavers (*Castor canadensis*) alter the structure and function of aquatic ecosystems when they build dams on streams. Beaver dams act as natural barriers to migration in the stream and form areas of impounded water behind them. The objective of this study was to identify the effects of beaver impoundments on stream temperature and fish community species composition and growth.

Two beaver impoundments, located on separate but nearby tributaries of the Miramichi River in central New Brunswick, were selected for the study. From June to August 1997 the streams were monitored for changes in stream temperature and differences in fish community species composition upstream and downstream of beaver dams. It was hypothesized that 1) water temperature increases as it moves through an impoundment resulting in higher outflow temperatures; 2) differences in stream temperature and habitat characteristics in and directly downstream of impoundments would be reflected by alteration in fish community species composition; and 3) growth indices would be influenced for those species that inhabit impoundments as a result of the altered temperature regime.

Results indicated that stream temperatures were affected by beaver impoundments and cause outflow temperatures to be considerably greater than inflow temperatures. Temperature effects from the beaver impoundment can extend a few hundred meters downstream of the dam before stream temperature recovers to what it was at the inflow. Fish community species composition was altered upstream of the beaver dam because of differences in habitat characteristics and because the beaver dam impeded upstream movement of migratory fishes. It was also found that growth indices were greater for those species that occupy impoundments. It was also observed, that even during this short study period, beaver activity was extensive and consequent effects could therefore be significant.

RÉSUMÉ

M.D. Alexander. 1998. Effects of Beaver (*Castor canadensis*) Impoundments on Stream Temperature and Fish Community Species Composition and Growth in Selected Tributaries of Miramichi River, New Brunswick. Rapp. tech. can. des sc. hal. et aquat. 2227: ix + 44p.

Lorsque des castors (*Castor canadensis*) érigent des barrages dans des cours d'eau, ils modifient la structure et la fonction des écosystèmes aquatiques. Un barrage de castors agit en effet comme un obstacle naturel à la migration d'amont et crée un bassin de retenue par derrière. L'objectif de la présente étude était de déterminer les effets des barrages de retenue érigés par les castors sur la température de l'eau du cours d'eau et sur la composition et le taux de croissance du peuplement ichthyologique du cours d'eau.

Deux barrages de retenue construits par des castors et situés dans des tributaires distincts mais proches de la rivière Miramichi, au centre du Nouveau-Brunswick, ont été choisis pour cette étude. Entre juin et août 1997, on a surveillé les cours d'eau afin d'y déceler tout changement dans la température de l'eau et toute différence dans la composition du peuplement ichthyologique, en amont et en aval des barrages de castors. Trois hypothèses ont été soulevées : 1) la température de l'eau augmente à mesure que l'eau traverse un bassin de retenue ce qui fait grimper la température du débit sortant; 2) toute différence dans la température d'un cours d'eau et dans les caractéristiques de l'habitat situé à l'intérieur et directement en aval des bassins aurait pour résultat d'altérer la composition des espèces du peuplement ichthyologique; 3) le régime de température ainsi modifié aurait une incidence sur les taux de croissance des espèces qui habitent les bassins de retenue d'un barrage de castors.

Les résultats des recherches démontrent que les températures des deux cours d'eau ont effectivement été affectées par les bassins de retenue des barrages de castors et que les températures du débit sortant étaient beaucoup plus élevées que celles du débit entrant. Les effets du changement de température provoqué par un barrage de castors peuvent s'étendre sur quelques centaines de mètres en aval du barrage avant que l'eau ne reprenne la température du débit entrant. La composition du peuplement ichthyologique situé en amont des barrages de castors a subi des altérations à cause de différences dans les caractéristiques de l'habitat et parce que le barrage faisait obstacle au mouvement en amont des poissons migratoires. On a aussi découvert que les indices de croissance étaient plus élevés pour les espèces occupant les bassins de retenue. On a en outre observé que même durant cette courte période d'étude, l'activité des castors était très étendue. Par conséquent, les effets possibles sont très importants.

1.0 INTRODUCTION

Beavers (*Castor canadensis*) alter the structure and function of aquatic ecosystems to better suit their living requirements (Cockrum 1962) including feeding activities when they build dams as barriers in streams (Naiman et al. 1986), thus augmenting pond and lake depth and volume. Beaver dams are built from sticks, mud and rocks to raise the water level enough to create a stable water body deep enough to over-winter. Increased water levels also allow access to greater areas in the open water season where beavers feed on leaves and the bark of trees. In recent years, as a result of declines in fur prices and consequent reduced trapping practices, beaver populations and beaver altered habitat have increased considerably throughout many streams (Cunjak et al. 1993). Consequently, their influence on stream systems is likely increasing.

A great variety of wildlife benefit from altered habitat provided by beaver impoundments (Cockrum 1962). Aquatic insects utilize ponds as excellent areas to lay their eggs because there is an abundant food source for their aquatic larvae (Bartlett et al. 1974). Brook trout (*Salvelinus fontinalis*) and/or other fish species feed on aquatic insects in these ponds. Increased water volume and expanded habitat provide areas for some fish species to more successfully over-winter (Cunjak et al. 1993). Moose (*Alces alces*) graze on shore vegetation and feed on aquatic vegetation in the ponds. Waterfowl nest and otherwise use habitat in and along the shores of beaver impoundments. Muskrats (*Ondatra sp.*) and otters (*Lutra sp.*) sometimes make their homes in walls of beaver lodges, while racoons (*Procyon lotor*), mink (*Mustela sp.*) and weasels (*Mustela sp.*) are some of the many other smaller animals seen around beaver ponds.

Conversely, beaver activity is detrimental to some organisms. There has been much concern over beaver dams as barriers to the upstream and downstream migration of Atlantic salmon (*Salmo salar*) (Cunjak et al. 1993) as well as to other migratory fish species. Beaver impoundments modify habitat, which ultimately influences community composition and diversity (Naiman et al. 1986). Beaver ponds collect sediment and organic matter that may affect water and sediment chemistry altering the function and structure of the biotic community (Smith et al. 1991). Furthermore, beaver impoundments are temporary structures (Komadina-Douthwright 1994) that can affect stream temperature. Impounded streams are exposed to solar radiation that can increase water temperature through the reduction of discharge, the retention of water in shallow wetland areas, and by the reduction of forest cover.

The objective of this study was to identify the effects of beaver impoundments on stream temperature and fish community species composition and growth. It was hypothesized that 1) water temperature increases as it moves through an impoundment resulting in higher outflow temperatures; 2) differences in stream temperature and habitat characteristics in and directly downstream of impoundments would be reflected by alteration in fish community species composition; and 3) growth

indices would be greater for those species that inhabit impoundments as a result of the altered temperature regime.

2.0 STUDY AREA

Two beaver impoundments were selected for study. One was an active beaver pond (< 10 years old) located on Tributary One (46° 51' 53" N, 66° 11' 23" W) of Catamaran Brook and the other was an abandoned beaver pond (> 15 years old) located on Otter Brook (46° 51' 44" N, 66° 11' 45" W). Both impoundments were located within the Little Southwest Miramichi River drainage basin in central New Brunswick (Figure 1). During the course of the study several new beaver impoundments were observed and although impacts can not be shown, influence of their abundance on the flow and temperature regime of Tributary One is suggested.

2.1 Tributary One

Tributary One is a relatively minor influence on the flow and temperature regime of Catamaran Brook and a relatively insignificant influence on the Miramichi River. However, there is little doubt that many tributaries have been or are influenced by beaver activity. Beaver activity has historically been a factor influencing the aquatic ecosystem on Tributary One. Beaver impoundments have been the focus of several studies (Cunjak et al. 1993 and Komadina-Douthwright 1994) in the past as part of the Catamaran Brook Habitat Research Project. That project is a long term (15 year) multi-disciplinary research study of a small stream catchment designed to quantify the effects of timber harvest on aquatic biota (Cunjak et al. 1993). Cunjak et al. (1990) described the general study characteristics and design of the project.

An active beaver impoundment located 495 meters (m) upstream of the confluence of Tributary One with Catamaran Brook was selected to be the primary focus of this study (Figure 1). The entire stream channel was blocked forming a large impounded area estimated (by surface measurements) to be about 5 hectares in size with an average depth of about 1 m. The dam was large and well maintained; over 25 m long (across the channel), 1 m wide (on top), 1.5 m high (from base to top) and solid in construction. The dam was constructed of woody debris, rocks and mud at the crossing of an old logging road. One beaver lodge, 2 m in diameter (at the water surface), was located approximately 100 m upstream from the dam. Beavers were observed in the area and beaver foraging activity was current. Streamflow was significantly altered from upstream of the pond and downstream of the dam.

A second, older, beaver impoundment was also identified on Tributary One. This was a small abandoned beaver pond, located near the headwaters of the tributary and estimated (by surface measurements) to be less than 0.25 hectares in size with an average estimated depth of 45 cm. No beaver lodge, bank or otherwise, was visible in the pond and from the condition of the dam it was apparent the pond had been abandoned for some years. High water conditions in spring probably caused a breach of the dam, as often is the case (Rue 1964). Stream depth and flow in the pond did not

vary significantly from that of the stream. Consequently this pond was excluded from further distinct study or observation.

2.2 Otter Brook

Beaver activity has also been a factor influencing the aquatic ecosystem in another tributary of the Little Southwest Miramichi River, Otter Brook. At the beginning of the study, one beaver impoundment was identified on Otter Brook. The impoundment was abandoned and according to local residents had been there for 15+ years (Figure 1). Moose and waterfowl are known and observed to frequent the area. The pond was estimated (by surface measurements) to be 2.25 hectares in size with an average depth of 75 cm. It was apparent from the condition of the dam, the absence of beaver observations or a beaver lodge (bank or otherwise) and lack of fresh beaver foraging activity that the pond had been abandoned. However, unlike the abandoned dam on Tributary One, the dam on Otter Brook had not been breached and still affected stream flow by backing up water. The pond on Otter Brook was selected for comparison with the pond on Tributary One. The pond on Otter Brook was also selected to determine if there would be differences in the effects produced from an active versus abandoned impoundment.

3.0 METHODOLOGY

3.1 Stream Temperature and Sampling Stations

Two types of temperature data recorders were used for the study; Sealog-TTM (Sealog) and MinilogTM (Minilog) both products of Vemco Ltd. (Vemco), Halifax County, Nova Scotia. The Sealog is an earlier version of the Minilog. The Sealog units measured 30 centimeters (cm) in length and 5 cm in diameter compared to the smaller Minilog units that were 10 cm in length and 2 cm in diameter. The Sealog recorders were calibrated in March 1996 at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. The Minilog recorders were calibrated by Vemco Ltd. Vemcos used in Tributary One were programmed for time triggered temperature readings every 15 minutes for 60 days during the period June 18 to August 18, 1997. The Vemcos used in Otter Brook were programmed for time triggered temperature readings every 15 minutes for 40 days during the period June 27 to August 5, 1997. During programming all Sealog and Minilog internal clocks were synchronized to record at the same time and calibration coefficients were ensured to be entered correctly.

The Vemcos used for the study on both streams were only capable of measuring a maximum temperature of 21.2 °C and in some instances stream temperature climbed above the maximum. Where stream temperature climbed above the maximum, temperatures were deleted and are indicated by a break in the line on the graphs. This would have some influence on maximum temperature records but is assumed to be negligible because it occurred only a few times for brief periods.

A Vemco was attached to 1 cm diameter rebar driven into the substrate of the stream channel at each temperature station and held in position using plastic electrical ties, electrical tape and safety rope. Where stream depth was sufficient, Vemcos were deployed to a depth of 30 cm below the water surface (depth at which the sensor on the Vemco was positioned) and at shallower stations Vemcos were deployed to a depth of 20 cm below the water surface (Table 1). Deploying the Vemcos to this depth allowed for changes in stream discharge and depth. Following recovery of the Vemcos temperature data was downloaded using Vemco Ltd. software on a computer and temperature graphs were constructed for comparison analysis between stations.

For comparison analysis with stream temperatures, atmospheric temperatures were measured at the meteorological station in the Middle Reach of the Catamaran Brook drainage basin (Figure 1). Stream discharge and precipitation levels were measured at the hydrometric station for relationship analysis with stream temperature trends. The hydrometric station was also located in the Middle Reach of the Catamaran Brook drainage basin (Figure 1).

Ten sampling stations in Tributary One and three sampling stations in Otter Brook were selected for monitoring stream temperature. Stations were numbered for both streams in increasing order moving from upstream to downstream. Measurements for stream width and depth were recorded at each sampling station using a tape measure. Stream velocity was classified using an "orange test method" as follows: a 5 m length of stream was marked off and the time it took a floating orange to travel that distance was used to approximate the stream velocity. Stream velocity was then rated as either a) calm (< 0.5 m/s), b) moderate (> 0.5 m/s and < 1 m/s) or c) fast (> 1 m/s). Habitat-type was classified visually as either a) flat, b) riffle, c) run or d) pool, according to habitat-types defined by Cunjak et al. (1993). Stream shade was determined as the percentage of shade coverage provided by riparian vegetation. Stream shade was rated visually as either a) non existent (0 to 20%), b) poor (21 to 40%), c) fair (41 to 60%), d) good (61 to 80%) or e) excellent (81 - 100%).

3.1.1 Tributary One

The first Vemco was placed in a run approximately 2 m downstream of the Little Southwest Road overpass and 2.5 km upstream from the beaver dam on Tributary One. This station was referenced as T-T1 (Tributary One - Temperature Station 1; Figure 1). Station co-ordinates (latitude and longitude) were determined using a Global Positioning System (GPS) and are provided in Appendix A. At the time of instrument placement the stream channel was 1.83 m wide and 71 cm deep with a velocity rated as fast. The stream meandered through a thick forest of mixed tree species that included eastern white pine (*Pinus strobus*), eastern white cedar (*Thuja occidentalis*), balsam fir (*Abies balsamea*), spruce (*Picea* spp.), white birch (*Betula papyrifera*), yellow birch (*B. lutea*), trembling aspen (*Populus tremuloides*), speckled alder (*Alnus rugosa*), sugar maple (*Acer. saccharum*) and red maple (*A. rubrum*) that provided excellent stream shade. Physical parameters and location for this station and all other temperature sampling stations are summarized by station number in Table 1.

Up to this point, stream temperature had not been influenced by beaver activity so this station served as a reference for stream temperature of Tributary One.

A second Vemco, T-T2, was placed in the last riffle of the inflow to the beaver pond a distance of 690 m upstream of the dam (Figure 1). Remnants of a very old beaver dam were observed at this station that had a stream channel 7.62 m wide, 53 cm deep and a velocity rated as fast. A thick mixed forest of predominantly coniferous trees (eastern white pine, eastern white cedar, balsam fir and spruce) was located 5 m distant from either bank and provided fair stream shade. This station was selected to monitor stream temperature before the stream was influenced by the beaver impoundment.

A third Vemco, T-T3, was placed in the pond at a distance of 7.6 m upstream of the beaver dam (Figure 1). The stream channel was over 25 m wide, 1.19 m deep, had a velocity rated as calm and a habitat-type classified as a pool. A variety of shrubs and bushes were the only riparian vegetation that grew within 5 m of the shoreline. Consequently, stream shade was determined to be non-existent due to the loss of trees to beaver foraging. This station was selected to monitor the stream temperature after it had moved through the pond (690 m) and before it returned to a free flowing regime.

A fourth Vemco, T-T4, was placed in a run a distance of 21 m downstream of the dam (Figure 1). The stream channel was 3.20 m wide and 66 cm deep with a velocity rated as fast. The channel narrowed as the stream returned to free flowing conditions and stream shade was determined to be poor due to the loss of tree species to beavers. Speckled alder and a variety of shrubs and bushes were the dominant riparian vegetation. This station was selected to monitor stream temperature of the outflow from the beaver pond.

A fifth Vemco, T-T5, was placed in a flat on Tributary One 228 m downstream of the dam, 14 m upstream of the junction with the left hand braid from mainstem Catamaran Brook (Figure 1). The stream channel was 6.10 m wide and 91 cm deep with a velocity rated as moderate. The riparian forest was located at a distance of 10 m from either bank. This, according to Komadina-Douthwright (1994), is because the station was located in an area that had once been part of a series of beaver impoundments. Speckled alder were the dominant riparian vegetation and stream shade was determined to be poor. This station was selected to monitor stream temperature of Tributary one before it merged with the left hand braid from mainstem Catamaran Brook (Figure 1).

A sixth Vemco, T-T6, was placed in a run on the left hand braid from mainstem Catamaran Brook, 23 m upstream of the junction with Tributary One (Figure 1). Previous beaver activity in the area (Komadina-Douthwright 1994) has developed a series of braided channels and islands and this braid is a remnant of that activity. The stream channel was 3.05 m wide and 91 cm deep with a velocity rated as moderate. The riparian vegetation consisted of a mixed forest (eastern white pine, eastern white cedar, balsam fir and spruce), though speckled alder was the most dominant species,

and stream shade was determined to be good. This station was selected to monitor stream temperature of the left hand braid from mainstem Catamaran Brook before it merged with Tributary One. To this point stream temperature had not been influenced by beaver activity so this station also served as a reference for stream temperature of Catamaran Brook.

A seventh Vemco, T-T7, was placed in a riffle of Tributary One, 11 m downstream of the junction with the left hand braid from mainstem Catamaran Brook (Figure 1). The stream channel was 3.66 m wide, 56 cm deep, had a velocity rated as fast, and was located on a sharp bend in the stream 253 m downstream of the dam. A large amount of woody debris had been washed ashore and the shoreline was devoid of any old growth forest possibly because of previous beaver activity in the area (Komadina-Douthwright 1994). Speckled alder had become the dominant riparian species with stream shade determined to be fair. This station was selected to monitor stream temperature after the left hand braid from mainstem Catamaran Brook merged with Tributary One.

An eighth Vemco, T-T8, was placed in a pool on Tributary One 22 m upstream of the confluence with Catamaran Brook, a distance of 452 m downstream of the dam (Figure 1). The stream channel was 8.53 m wide and 66 cm deep with a velocity rated as moderate. On the true left bank the old growth forest consisted of eastern white pine, spruce, balsam fir, white birch, and trembling aspen and on the true right bank the dominant species was speckled alder. Stream shade was determined to be poor. This station was selected to monitor stream temperature before Tributary One merged with mainstem Catamaran Brook.

A ninth Vemco, T-T9, was placed in riffle of mainstem Catamaran Brook, 21 m upstream of the confluence with Tributary One (Figure 1). The stream channel was 3.96 m wide and 51 cm deep with a velocity rated as moderate. Speckled alder was the dominant riparian tree species and stream shade was determined to be good. This station was selected to monitor stream temperature of Catamaran Brook before it merged with Tributary One. This station also served as a reference for stream temperature of Catamaran Brook because stream temperature, to this point, had not been influenced by a beaver impoundment.

A tenth Vemco, T-T10, was placed in a riffle 33 m downstream of the confluence of Tributary One with Catamaran Brook, a distance of 507 m downstream of the dam (Figure 1). The stream channel was 5.49 m wide and 41 cm deep with a velocity rated as fast. Old growth forest that consisted of eastern white pine, spruce, balsam fir, white birch and trembling aspen grew on the true left bank of the stream. On the true right bank speckled alder was the dominant tree species. Stream shade was determined to be fair. This station was selected to monitor stream temperature after Tributary One and Catamaran Brook merged and to determine if beaver activity on Tributary One affected stream temperature of Catamaran Brook.

3.1.2 Otter Brook

Two tributaries flowed into the pond on Otter Brook but due to instrument limitations only the tributary that appeared to have a more direct influence on the flow and temperature regime of the pond was selected for the study (Figure 1). The first Vemco was placed in the last riffle of the inflow to the pond 150 m upstream of the dam on Otter Brook. This station was referenced as O-T1 (Otter Brook - Temperature Station 1; Figure 1). At the time of instrument placement the stream channel was 2.75 m wide and 41 cm deep with a flow rated as fast. The riparian vegetation that grew on the shoreline included balsam fir, eastern white cedar, spruce, white birch and yellow birch. Stream shade was determined to be poor because past beaver activity had removed the forest to 5 m distant on both banks. This station was selected to monitor stream temperature before the stream was influenced by a beaver pond.

A second Vemco, O-T2, was placed in the pond 1 m upstream of the dam (Figure 1). The stream channel was greater than 50 m wide, 81 cm deep, a flow rated as calm and a habitat-type classified as a pool. Stream shade was determined to be non-existent because a variety of shrubs and bushes were the only riparian vegetation that grew within 5 m from the stream. This station was selected to monitor stream temperature after it had moved through the pond (140 m) but before returning to a free flowing regime.

A third Vemco, O-T3, was placed in the first riffle of the outflow 15 m downstream of the dam (Figure 1). The stream channel was 3.05 m wide and 76 cm deep with a flow rated as fast. The true left bank was devoid of any forest. A mixed forest of eastern white pine, eastern white cedar, balsam fir and spruce grew 5 m from the stream edge on the true right bank. Stream shade was determined to be poor. This station was selected to monitor stream temperature of the outflow from the beaver pond.

3.2 Fish Community Species Composition and Sampling Stations

Fish were captured using baited minnow-traps upstream, in and downstream of the beaver impoundment of both streams to obtain an impression of overall fish community species composition. The minnow-traps used for this study were 60 cm in length, constructed of 2 millimeter (mm) mesh wire and had two cone shaped openings (beveled inward) 4 cm in diameter. Traps were set on a 1 to 4 m radius (depending on channel width) around a rebar placed at each station. Traps were secured using a length of rope tied to the rebar at each station and two rocks, each approximately 500 g in weight, were placed inside each trap to weight them down. Stream width and depth (average derived from several points around the rebar at each station) was measured in several locations at each station and an average was determined. Stream flow was rated using the "orange test method" and stream shade and habitat-type were classified visually. Table 2 summarizes the location and physical parameters of the minnow-trap sampling stations.

Fish samples were collected from most locations on Tributary One during two sample periods that each consisted of two sample intervals. The first sample period was from August 5 to 7, 1997 and had two 24 hour sample intervals. The second sample period was from August 12 to 16, 1997 and had two 48 hour sample intervals. Fish were collected for a total of 18 trap nights during the first sample period (three traps per station/rebar x three stations x two 24 hour intervals = 18 trap nights). Fish were collected for a total of 48 trap nights during the second sample period. Fish samples were collected on Otter Brook during one sample period that consisted of two sample intervals; the sample period was from July 31 to August 2, 1997 and had two 24 hour sample intervals. Fish were collected for a total of 18 trap nights during the sample period on Otter Brook.

All captured fish were collected from the minnow-traps and retained in a live box. Fish were then anesthetized, identified to species, measured (fork length - cm), weighed (g) and given a partial fin clip (for identifying recaptures) unique to the trapping period. After full recovery, fish were released back to the water. On Tributary One a partial lower caudal fin clip (LCC) was given to all fish captured during the first sample period. A partial upper caudal fin clip (UCC) was given to all fish captured during the second sample period. Consequently, during the second sample interval of the second sample period some fish trapped had both partial fin clips and were identified as having both (LCC + UCC). On Otter Brook a partial upper caudal fin clip was given to all fish captured upstream of the dam. Those fish captured downstream of the dam were given a partial lower caudal fin clip.

3.2.1 Tributary One

Minnow-traps were set upstream, in and downstream of the impoundment on Tributary One and were numbered in an increasing fashion moving in a downstream direction. Initially three stations were selected to sample and three traps were set per station during that sample period. Traps were sampled 24 hours after being set (first sample interval) and then returned to the water and sampled again 24 hours later (second sample interval). For a better representation of species composition in the impoundment, an additional five new stations (5 + 2) were fished in the pond during a second sample period (total of 7 in the pond). During the second sample period only two traps were set, per station, and emptied for two successive 48 hour sample intervals. The number of traps per station was reduced for the second sample period because of a limited number of traps.

The first minnow-trap station was located in pool 700 m upstream of the dam and was referenced as T-M1 (**T**ributary One - **M**innow-trap station 1; Figure 1). The average depth was 90 cm, stream shade was classified as poor and the stream velocity was rated as calm. A second minnow-trap station, T-M2, was in a riffle at the same location as the second temperature sampling station, T-T2, (Figure 1). Average stream depth of the station was 38 cm, stream width was 7.62 m, stream velocity was rated as fast and stream shade was classified as fair. Stations three to six, T-M3 to T-M6, were located approximately 150 m apart moving in a downstream direction toward the dam (Figure 1). All stations in the pond were classified as pools with a stream velocity rated

as calm and average stream depth ranged from 75 cm to 150 cm (Table 2). The seventh minnow-trap station, T-M7, was in a pool at the same location as the third temperature sampling station, T-T3. Average stream depth of the station was 1.5 m, stream velocity was rated as calm and stream shade was classified as non existent. The eighth minnow-trap station, T-M8, was the only station downstream of the dam and it was in a run at the same location as the fourth temperature sampling station, T-T4 (Figure 1). Average stream depth of the station was 52 cm, stream width was 3.20 m, stream velocity was rated as fast and stream shade was classified as poor.

3.2.2 Otter Brook

In Otter Brook baited minnow-traps were set in and downstream of the impoundment to obtain an impression of overall fish community species composition as for Tributary One. A station was not sampled upstream of the impoundment because at the time of sampling there was insufficient water depth available to set traps. Three minnow-traps were set per station for two successive 24 hour intervals. Locations corresponded to the second and third temperature sampling stations, O-T2 and O-T3, respectively. Stations were numbered in an increasing fashion moving in a downstream direction. The first minnow-trap station was located in a pool upstream of the dam and was referenced as O-M1 (**O**tter Brook - **M**innow-trap station 1; Figure 1). The average stream depth was 92 cm, with a stream width of 50 m, a velocity rated as calm and stream shade classified as non existent. The second minnow-trap station, O-M2, was located in a riffle downstream of the dam. This station had an average stream depth of 72 cm, a stream width of 3.05 m, a velocity rated as fast and stream shade classified as poor.

4.0 RESULTS AND DISCUSSION

4.1 Stream Temperature

Historically, many studies on beaver impoundments have focused on the modification of stream ecosystems as it applies to invertebrate production and nutrient cycling upstream and downstream of dams (Cunjak et al. 1993). Surprisingly, few studies have addressed the effects of beaver activities on stream temperature downstream of the dam.

Solar radiation is the greatest source of heat that warms most stream environments. The effects of solar radiation depend on the angle at which it strikes the stream surface (Macan 1964), although flow conditions, stream depth, stream width and stream shade are also contributing factors. Small streams generally experience diel temperature fluctuations with maximum temperatures occurring in the afternoon and minimum temperatures occurring in the latter half of the night (Hynes 1970). Air temperature and groundwater inputs have more influence on stream temperature than direct solar radiation in heavily shaded streams (Hauer et al. 1996). Small streams usually follow air temperature fluctuations closely and thermal stratification is usually

absent because of their shallow depths and high turbulence (Welch 1935). Beaver ponds also reflect air temperature trends because of their relatively shallow depth, large surface area and low flow rate relative to volume (Welch 1935). Surface temperatures, however, tend to be higher than those of a free flowing regime because the open canopy zone formed by the pond permits more influence from direct solar radiation. A temperature gradient is usually present in ponds (Allan 1995) because they are bodies of standing water in which there is a negligible amount of vertical mixing in the water column.

4.1.1 Tributary One

Mean daily stream temperature at the reference station, T-T1, for the period June 18 to August 18, 1997 (day 169 to 230) was calculated to be 13.5 ± 1.5 °C and ranged from 9.5 to 17.3 °C (Table 3 and Figure 2 a). During the same period the mean daily air temperature was calculated as 17.3 ± 5.3 °C with a fairly large range from 5.1 to 31.7 °C (Table 3 and Figure 2 b).

Mean stream temperature at this point, for the entire study period, was 3.8 °C lower than that calculated for air temperature and reflects the slower absorption of heat by water than air. Dam building and beaver foraging activity were not factors affecting stream temperature at or above this point. Mean stream temperature at the reference station suggests that air temperature had a more direct affect on stream temperatures than did solar radiation. Solar radiation was less of a factor because of the excellent stream shade provided there (Table 1). Daily temperatures recorded at the reference station followed closely to air temperature trends; high daily mean stream temperatures were recorded during periods of high daily mean air temperatures. The daily stream temperature range (the difference between daily minimum and maximum temperatures) was narrower than that recorded for air temperature and was because of the high latent heat of water. According to Hauer and Lamberti (1996) this is typical for stream temperature.

The highest stream temperatures measured at the reference station occurred during the period June 30 to July 3, 1997 (day 181 - 184) (Figure 2 a). High stream temperatures recorded for this period may be attributed to low levels of precipitation (less than 20 mm), reduced stream discharge (less than 0.5 m³/s) and high air temperatures recorded for the same period (Table 3 and Figures 2 b and 3). Reduced stream discharge in the latter half of the study period would have allowed stream temperatures to follow air temperature trends much more closely because of the reduced water volume to be heated or cooled.

Some of the highest stream temperatures measured at the reference station appeared to follow rain events (more than 10 mm of precipitation). Macan (1964) found that some of the highest stream temperatures occur in the sunshine just after rain. He speculates that this may be due in part to the reduction of cooling by evaporation owing to the high humidity following the rain. To prove such a relationship for this study would require further investigation (Figure 3).

The thermograph at the inflow station, T-T2, was installed seven days later than all the others on Tributary One because of severe access restrictions. As a result temperatures were not measured for the first seven days. For comparison analysis of stream temperatures this station and the reference station were plotted together on a graph (Figure 4). The mean daily stream temperature for the study period was calculated to be 14.8 ± 1.7 °C and ranged from 10.2 to 19.3 °C (Table 2).

Mean stream temperature there was 1.4 °C greater than mean stream temperature calculated at the reference station for the same study period. The increase in mean temperature may be attributed to the differences in stream shade and broadening of the channel as the stream went from a free flowing regime approaching a pond environment. Solar radiation would have had more of a direct influence on stream temperature here, at T-T2, than it did at the reference station because of the reduced forest canopy for stream shade (Table 1). Elevated stream temperatures near the end of the study period may also be a result of a new beaver dam that was under construction but incomplete and located approximately 5 m upstream of this station. This dam was first noticed on August 5, 1997 (Day 217), referenced as N-D1 (**New - Dam 1**), and began to back up water. Increasing differences in mean stream temperature from that of the reference station began during the period July 16 to July 22, 1997 (day 197 to 203). The increase in temperature may further reflect the construction of the beaver dam (Table 3).

The mean daily stream temperature calculated for the study period at the pond station, T-T3, was 15.9 ± 1.7 °C and ranged from 11.4 to 21.2 °C (Table 3). Mean daily stream temperature was 1.1 °C greater than that at the inflow station, T-T2, and 2.4 °C greater than that at the reference station. The results suggest that water temperatures were directly influenced by solar radiation as it traveled from the inflow station to this station (690 m). Solar radiation would have had more of a direct influence on stream temperature because of the lack of forest canopy cover over this distance (Table 1).

The highest mean daily stream temperatures were recorded during the second half of the study period, July 19 to August 18, 1997 (day 200 to 230). For this period, stream discharge and rainfall amounts (< 0.5 m³/s and < 60 mm, respectively) were reduced from those measured during the first half of the study period and may contribute to the higher values (Figures 3 and 5). Because of the reduction in stream volume, the effects of heat absorption on stream temperature would be greater during the second half of the study.

The mean daily stream temperature calculated for the study period at the outflow station, T-T4, was 17.3 ± 2.3 °C and ranged from 11.3 to 21.2 °C (Table 3). Of all the stations monitored on Tributary One, the outflow station had the greatest deviation from those mean temperatures measured at the reference station by 3.9 °C (Figure 6). This station had a calculated mean daily stream temperature equal to that calculated for air temperature and was the only station where this occurred for the study

period. The second half of the study period had increased stream temperatures and may be attributed to low stream discharge and low rainfall amounts (Figures 3 and 6).

No instruments were set for direct measurement of vertical thermal gradient in the beaver pond. However there are indications that a thermal gradient was present. These indications include: 1) the mean daily stream temperature at the outflow station was 1.4 °C higher than at the pond station, 2) temperature variation from minimum and maximum was greater for the outflow station than in the pond and 3) high stream temperatures measured for the pond station occurred during periods of low stream discharge and low rainfall when the probe on the Vemco was higher in the water column (Table 3 and Figures 3, 5 and 6). At time of instrument placement the Vemco in the pond was deployed to a depth of 30 cm below the water surface. When stream discharge dropped temperatures in the pond increased indicating the Vemco was measuring temperatures higher up in the water column. Similarly, when water levels decreased in the pond the Vemco would have measured temperatures closer to those at the surface.

The mean daily stream temperature for the study period at the station upstream of the junction with the left hand braid from mainstem Catamaran Brook, T-T5, was calculated to be 16.0 ± 1.9 °C and ranged from 11.4 to 21.0 °C (Table 3). Mean daily stream temperature was 2.6°C greater than that calculated for the reference station and 1.3 °C less than that calculated for the outflow station, T-T4. Daily stream temperatures and the daily temperature range was greater than that of the reference station. However, measurements appear to follow trends similar to those measured at the reference station (Figure 7). Measurements recorded at this station, 228 m downstream of the dam, demonstrate that stream temperatures have begun to decrease. Mean daily stream temperature calculated at this station was 0.16 °C greater than in the pond. This appears to show that a thermal gradient was present in the beaver pond. A new dam, N-D2, was being constructed half way between this station and the outflow station. It was first noticed on August 18, 1997 when the thermographs were removed from the stream. The effects from this new dam were considered to be negligible because of its incomplete nature.

The mean daily stream temperature calculated for the study period at the first reference station on Catamaran Brook, T-T6, was 14.7 ± 1.9 °C and ranged from 10.3 to 19.4 °C (Table 3). Mean daily reference stream temperature of Catamaran Brook was 1.2 °C greater than the mean daily reference stream temperature of Tributary One (Figure 8). The slightly higher mean daily temperature and greater daily temperature range may be attributed to differences in stream shade of the two streams (Table 3). Differences may also be attributed to differences in the size of the headwaters, undetected beaver dams or other characteristics.

Tributary One was a smaller stream (stream width) and had more forest canopy cover that contributed to stream shade than did Catamaran Brook. Solar radiation appeared to have a more direct affect on stream temperature on Catamaran Brook than it did on Tributary One. Geographic Information System (GIS) analysis by

St. Hilaire et al. (1996) showed a higher percentage of crown closure on Tributary One (70 - 90%) than on main Catamaran Brook (50 - 70%). Variations of reference temperature between the two streams may also be attributed to the differences in headwater characteristics. Catamaran Lake, a small, shallow and unshaded lake served as the headwaters for Catamaran Brook (Figure 1). A small relatively well shaded pond served as the headwaters for Tributary One. Consequently, headwaters of Catamaran Brook would have been subjected to more direct influences of solar radiation than the headwaters of Tributary One.

The mean daily stream temperature calculated for the study period at the junction station, T-T7, was 15.8 ± 1.5 °C and ranged from 11.2 to 20.6 °C (Table 3). Mean daily stream temperature was 2.4 °C and 1.2 °C greater than that recorded at the reference station on Tributary One and at the first reference station on Catamaran Brook, respectively. Mean daily stream temperature decreased on average by 0.2 °C from that of the previous station, T-T5, on Tributary One because of mixing that occurred with the left hand braid from mainstem Catamaran Brook. Stream temperatures in the latter half of the study period were considerably higher than those recorded at the reference station on Tributary One. The higher stream temperatures may be attributed to low stream discharge and low amounts of precipitation (Figures 3 and 9). A new beaver dam, referenced as ND-3, had been constructed at this station and may have contributed to the increased temperatures. The new beaver dam, noticed on August 18, 1997, was definitely recent.

The mean daily stream temperature calculated at the station upstream of the confluence with Catamaran Brook, T-T8, was 15.8 ± 2.0 °C and ranged from 11.2 to 20.3 °C (Table 3). Mean daily stream temperature was 2.3 °C and 1.1 °C greater than that calculated for the reference station on Tributary One and the first reference station Catamaran Brook, respectively. Increased stream temperatures upstream, reduced forest canopy cover for stream shade and slowed water velocity may have contributed to higher stream temperatures especially during the second half of the study period (Figure 10). A new beaver dam, N-D4, was under construction approximately 60 m upstream of this station, however, effects from the dam are not known because it was first noticed only on August 18, 1997.

The mean daily stream temperature calculated for the study period at the second reference station on Catamaran Brook, T-T9, was calculated to be 14.7 ± 1.9 °C and ranged from 10.3 to 19.4 °C (Table 3). Mean daily stream temperature was 1.2 °C greater than that calculated for Tributary One and the daily temperature range was also greater (Figure 11). The variations were probably due to the differences between the two streams as mentioned earlier for the first reference station on Catamaran Brook, T-T6.

The mean daily stream temperature calculated for the study period at the confluence station, T-T10, was 15.5 ± 2.0 °C and ranged from 11.1 to 20.2 °C (Table 3). Mean daily stream temperature was 2.0 °C greater than that calculated for the reference station on Tributary One. The mean daily stream temperature was 0.8 °C greater than

that calculated for the reference stations on Catamaran Brook (average between the two reference stations on Catamaran Brook). Again daily temperatures and daily temperature range are greater than those measured at the reference station on Tributary One. However, temperatures follow a similar pattern perhaps as a result of mixing from mainstem Catamaran brook (Figure 12).

4.1.2 Otter Brook

Mean daily stream temperature at the reference station, O-T1, for the period June 27 to August 5, 1997 (day 178 to 217) was calculated to be 14.6 ± 3.6 °C and ranged from 6.1 to 21.2 °C (Table 4 and Figure 13 a). During the same period the mean daily air temperature was calculated as 18.0 ± 5.4 °C with a fairly large range from 5.1 to 31.7 °C (Table 4 and Figure 13 b).

Mean stream temperature at this station was 3.4 °C lower than that calculated for air temperature during the entire study period and reflects the slower absorption of heat by water than air. The low stream temperature also reflects the input by groundwater sources which generally contributes to 30 - 40% of streamflow (Viessman and Lewis 1996). Daily temperatures recorded at the reference station followed closely to air temperature trends; high daily mean stream temperatures were recorded during periods of high daily mean air temperatures. Nevertheless, the daily stream temperature range was narrower than that recorded for air temperature.

The highest stream temperatures recorded at the reference station occurred during the first half of the study period from June 27 to July 16, 1997 (day 178 - 197) (Figure 13 a). The highest air temperatures were also recorded during this period (Figure 13 b). For the first half of the study period stream discharge and rainfall amounts were high, > 0.5 m³/s and >90 mm respectively (Figure 14). The highest stream temperatures recorded on Otter Brook did not appear to follow rain events in contrast to Tributary One.

The mean daily stream temperature calculated for the study period at the pond station of Otter Brook, O-T2, was 15.1 ± 4.0 °C and ranged from 4.9 to 21.2 °C (Table 4). Mean daily stream temperature for the period was 0.5 °C greater than that recorded for the reference station noted above. The higher mean daily temperature may be attributed to the loss of forest canopy cover for stream shade and the effects of reduced stream velocity in the pond. Solar radiation appeared to have a greater effect on stream temperature than did air temperature. Stream temperatures at this station follow closely to those measured at the reference station, although they were slightly higher (Figure 15).

The mean daily stream temperature calculated for the study period at the outflow station, O-T3, was 15.3 ± 3.9 °C and ranged from 5.5 to 21.2 °C (Table 4). Mean daily stream temperature for the period was 0.7 °C greater than that calculated for the reference station and 0.2 °C greater than that calculated at the station in the pond, O-T2. As for Tributary One the difference in temperatures from the pond station and the outflow station suggest that a temperature gradient was present in the beaver pond.

Again stream temperatures at this station followed closely to those measured at the reference station (Figure 16).

Greater variation in temperature between daily minimum and maximum temperatures increased as the study progressed for all three stations (Figures 13, 15 and 16). The cause of the increase in temperature variation was likely a result of reduced stream discharge as the study progressed reducing the volume of water in the stream to be heated or cooled (Figure 14). Stations in Otter Brook experienced a much greater daily temperature variation than the stations in Tributary One (Tables 3 and 4). The large temperature variation in Otter Brook suggests that it is largely fed by groundwater sources. Usually groundwater tends to regulate stream temperature because it is generally constant at approximately 6 °C (Viessman and Lewis 1996). The groundwater interface can be found beneath the stream bed or within the riparian zone and is referred to as the hyporheic zone (Hynes 1970). Groundwater, which is believed to be more stable in volume, impacted on the stream temperature of Otter Brook. During the study on Otter Brook there was only a small stream volume, increasing the effects by groundwater input. When there was little solar radiation groundwater influence was the dominant factor governing stream temperature but during the day solar radiation was the dominant factor.

Daily temperature variation on Otter Brook extended above 21.2 °C and down to 4.9 °C beginning half way through the study period. Variation between minimum and maximum temperatures was not as great during the first half of the study period because water levels were much higher. Perhaps higher stream discharge resulted in the dilution of the groundwater inputs and reduced the variation in temperatures. By mid way through the study stream discharge had reduced to a point where stream temperature was more directly influenced by groundwater (Figure 15). Stream temperatures reached a minimum during the evening hours due to the influence of cold groundwater influences. By mid afternoon, each day, stream temperatures reached a maximum due to the impacts of solar radiation.

4.1.3 Summary of Stream Temperature Results

Stream temperatures on Tributary One followed a steady increase in temperature traveling from the reference station on Tributary One (T-T1) to the outflow station (T-T4). The increase in temperature was a direct result of dam building and beaver foraging activity (Figure 17). Stream temperatures reduced as water flowed from the outflow station (T-T4) to the confluence station (T-T10) with the main stream. The decrease in stream temperature was a result of mixing from mainstem Catamaran Brook at the Junction station, T-T7, and again at the confluence station, T-T10. The temperature of Catamaran Brook was lower than the outflow temperature from the beaver impoundment on Tributary One and resulted in a stream temperature reduction. However, the active beaver impoundment on Tributary One appeared to affect the temperature of Catamaran Brook. This is because the temperature at the confluence station was greater than that recorded for the two reference stations on Catamaran Brook (Figure 17). It is usual for headwaters to be cooler than the stream outlet due to geomorphology. There is also a normal increase in stream temperature moving in a

downstream direction due to stream kinetics, however the effect is considered to be negligible for consideration in this report.

Stream temperatures on Otter Brook also followed a steady increase in temperature traveling from the reference station, O-T1, to the outflow station, O-T3. The increase in temperature was a direct result of the abandoned beaver dam and past beaver activity (Figure 17). Differences in stream temperature from one station to the next were not as great as differences found on Tributary One. However, daily stream temperature variation of Otter Brook was much greater than that found for Tributary One. This could be attributed to cold ground water influences on Otter Brook that appear to be greater than inputs found on Tributary One.

4.2 Fish Community Species Composition

The minnow-traps used for sampling fish species were selective of species and size groups. The traps also depended on fish movement that, undoubtedly, varied from place to place and from time to time (Hynes 1970). Nevertheless the results obtained from this study present some insight to the overall species composition and growth, within the impoundment and directly downstream for an active as well as an abandoned beaver dam.

4.2.1 Tributary One

In total, 7 species of fishes were collected from Tributary One of Catamaran Brook during two separate sample periods, August 5 to 7, 1997 and August 12 to 16, 1997, respectively. Tables 5 and 6 show the trapping results for the first sample period and Tables 7 and 8 show the trapping results for the second sample period. Five species, the brook trout, blacknose dace (*Rhinichthys atratulus*), common shiner (*Notropis cornutus*), golden shiner (*Notemigonus crysoleucas*) and lake chub (*Couesius plumbeus*) were collected upstream of the dam (Table 9). Downstream of the dam two additional species from those captured upstream were collected, the Atlantic salmon (parr) and white sucker (*Catostomus commersoni*).

Blacknose dace were the most abundant species captured and represented 40 % and 53 % of the total fish captured upstream and downstream of the dam, respectively (Table 9). No Atlantic salmon (parr) were trapped in the impoundment and only 4 % of the those fish trapped in the impoundment were brook trout. Trapping results for Atlantic salmon suggest that beaver impoundments are rarely beneficial to these species after the first two or three years of their life. Bradt (1947) suggests that beaver dams often become distinctively detrimental to migratory fish species when they remain for a long time.

In total, 4 species of fishes were collected as recaptures during both sample periods. Recaptures were made for the blacknose dace, common shiner, golden shiner and lake chub (Tables 7 and 8). Recaptures were greater for those fish collected downstream of the dam than those collected upstream; eight versus seven, respectively. The results suggest that blacknose dace had the greatest fidelity for the

habitat they occupied. Perhaps the lower recapture rate in the impoundment is due to lower fish densities, movement upstream of the impoundment or decreased movement of fish.

Trapping results revealed that all species captured within the impoundment had greater values for fork length and weight, except for brook trout and lake chub (Table 9). Greater values recorded for those species occupying the impoundment may be attributed to greater amounts of nutrients in the impoundment. The impoundment may act as a "sink" for valuable nutrients required by these species for increased growth rate. This is only speculation because minnow-traps are "activity" based traps. It is surprising that few brook trout were trapped in the beaver pond because according to popular belief beaver impoundments make great trout habitat. The pond habitat also experienced a lack of competition by Atlantic salmon and there was likely a greater availability of forage/prey items such as aquatic insects, zooplankton and small fish.

Other factors may also be attributed to the differences in fork length and weight of those species trapped within and downstream of the impoundment. Fish species density in the impoundment is less than downstream of the dam, as suggested from the trapping results (Tables 5, 6, 7 and 8). Eight minnow trap stations were fished in the impoundment compared to one station that was fished downstream of the dam. Except for one trapping interval, the single station located downstream of the dam, T-T8, consistently had greater numbers of fish captured than the sum of all those stations in the impoundment. Greater numbers of fish trapped downstream of the dam may be attributed to the beaver dam that impeded the upstream migration of fish species by forming a natural barrier. Higher stream temperature in the impoundment did not appear to be detrimental to fish species trapped there. The absence of brook trout and Atlantic salmon suggests that stream temperature of the impoundment may exceed limits tolerable by these species. On the other hand, large brook trout are often found there.

4.2.2 Otter Brook

In total, 6 species of fishes were collected from Otter Brook during one sample period, July 31 to August 2. Tables 10 and 11 show the trapping results for the sample period and its respective trapping intervals. Four species, the Atlantic salmon, brook trout, blacknose dace and three spine stickleback (*Gasterosteus aculeatus*) were collected in the impoundment (Table 12). Downstream of the dam two additional species from those captured upstream were collected, the lake chub and white sucker.

Three spine stickleback were the most numerous species trapped in the impoundment and represented 78% of the total catch for the sample period (Table 12). Downstream of the dam brook trout were the most numerous species and they represented 38% of the total catch. Atlantic salmon (parr) and brook trout were captured upstream and downstream of the abandoned beaver dam. Fish captured upstream and downstream of the impoundment were given a unique fin clip according to location. See methodology for fin clip description. From the presence of Atlantic salmon and brook trout upstream and downstream of the dam and from recapture

results it is apparent that fish were able to pass freely through the abandoned beaver dam on Otter Brook (Tables 10 and 11).

Trapping results show a mixture of greater fork lengths and weight upstream and downstream of the dam depending on the species (Table 12). These mixed results may be because fish had the ability to pass through the abandoned beaver dam from the impoundment to the proximal stream. Again this is speculative because of the biases of the minnow-traps used for sampling.

4.2.3 Summary of Fish Species Composition Results

It is apparent from fish species sampling results of the two impoundments and their respective outflows that active impoundments can impede the upstream movement of juvenile anadromous fishes whereas abandoned impoundments may not. The dam constructed on Tributary One was active and represented an effective barrier to the movement of some fish species. The absence of juvenile Atlantic salmon within the impoundment on Tributary One suggests the effects of beaver dams as barriers to fish movement, specifically spawning adult salmon (Cunjak et al. 1993). The abandoned beaver dam on Otter Brook did not appear to inhibit the upstream migration of migratory fishes because they were trapped upstream and downstream of the dam.

5.0 CONCLUSION

It was hypothesized that 1) water temperature increases as it moves through an impoundment resulting in higher outflow temperatures; 2) differences in stream temperature and habitat characteristics in and directly downstream of impoundments would be reflected by alteration in fish community species composition; and 3) growth indices would be greater for those species that inhabit impoundments as a result of the altered temperature regime.

It was found that water temperature does indeed increase as it moves through an impoundment and water temperature measured at the outflow is considerably greater than that measured at the inflow. Higher stream temperatures are a result of reduced water velocities and lack of forest canopy cover for stream shade due to beaver activity. Beaver impoundments produce an effect on stream temperature downstream of the impoundment that can last for a considerable distance before stream temperature returns to what it was at the inflow to the impoundment. Both active and inactive impoundments affect stream temperature. The abandoned beaver dam on Otter Brook appeared to have less of an impact on stream temperature because of the obvious groundwater influences and low water conditions found there.

The active beaver dam served as an effective natural barrier to the upstream movement of Atlantic salmon. The abandoned beaver dam did not appear to affect the migration of Atlantic salmon because the fish were able to freely pass through the dam.

Higher stream temperatures and habitat characteristics of the impoundment appear to have been beneficial to those species trapped there as indicated by their growth indices. This may not be true for all species or for abandoned beaver impoundments, reflected by the results obtained.

It can be concluded that 1) stream temperatures are affected by beaver impoundments, active and inactive impoundments alike; 2) active beaver impoundments markedly affect fish community species composition by altering habitat and impeding migrations, inactive impoundments do not appear to have as great of an affect; 3) that growth indices are greater for those species that occupy impoundments. It can also be concluded that by the number of new beaver dams constructed within this short study period that beaver dams may have a potential impact on stream temperature and fish species composition and growth. The beaver impoundments studied were from two small tributaries of the Miramichi River that is fed by hundreds of tributaries. Cumulative effects from numerous beaver impoundments on these tributaries may have a direct effect on the stream temperature and fish population of the Miramichi River.

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Table 1. Physical parameters and descriptor, by station identification number, for thermograph stations on Tributary One of Catamaran Brook and on Otter Brook. Note: Measurements were made at the beginning of each study.

Station ID Number	Station Descriptor	Stream Width (m)	Stream Depth (m)	Stream Velocity*	Habitat Type	Stream Shade**	Study Start (M/D/Y)	Study End (M/D/Y)	Sample Frequency
T-T1	reference station (Tributary One)	1.83	0.71	fast	run	excellent	6/18/97	8/18/97	15 min
T-T2	inflow station	7.62	0.53	fast	riffle	fair	6/18/97	8/18/97	15 min
T-T3	pond station	25.00	1.19	calm	pool	non existent	6/18/97	8/18/97	15 min
T-T4	outflow station	3.20	0.66	fast	run	poor	6/18/97	8/18/97	15 min
T-T5	upstream of junction (Tributary One)	6.10	0.91	moderate	flat	poor	6/18/97	8/18/97	15 min
T-T6	reference station 1 (Catamaran)	3.05	0.41	moderate	run	good	6/18/97	8/18/97	15 min
T-T7	junction station	3.66	0.56	fast	riffle	fair	6/18/97	8/18/97	15 min
T-T8	upstream of confluence (Tributary One)	8.53	0.66	moderate	flat	poor	6/18/97	8/18/97	15 min
T-T9	reference station 2 (Catamaran)	3.96	0.51	moderate	riffle	good	6/18/97	8/18/97	15 min
T-T10	confluence station	5.49	0.41	fast	riffle	fair	6/18/97	8/18/97	15 min
O-T1	inflow/reference station	2.75	0.41	fast	riffle	poor	6/27/97	8/5/97	15 min
O-T2	pond station	50.00	0.81	calm	pool	non existent	6/27/97	8/5/97	15 min
O-T3	outflow station	3.05	0.76	fast	riffle	poor	6/27/97	8/5/97	15 min

* calm = < 0.5 m/s, moderate = > 0.5 m/s and < 1 m/s, fast = > 1 m/s

** non existent = 0 - 20 % coverage, poor = 21 - 40 % coverage, fair = 41 - 60% coverage, good = 61 - 80% coverage, excellent = 81 - 100 % coverage

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Table 2. Physical parameters and descriptor, by station identification number, for minnow-trap stations on Tributary One of Catamaran Brook and on Otter Brook. Note: Measurements were made during the first sample period at each station.

Station ID Number	Station Descriptor	Average Stream Width (m)	Average Stream Depth (m)	Average Stream Velocity*	Overall Habitat Type	Stream Shade**	First Study Period Julian Date	Duration of Trapping Intervals (hrs)	Second Study Period Julian Date	Duration of Trapping Intervals (hrs)
T-M1	inflow station	-	0.90	calm	pool	poor	-	-	224 - 228	48
T-M2	inflow station	7.62	0.53	fast	riffle	fair	217 - 219	24	-	-
T-M3	pond station	-	0.75	calm	pool	fair	-	-	224 - 228	48
T-M4	pond station	-	0.80	calm	pool	fair	-	-	224 - 228	48
T-M5	pond station	-	1.40	calm	pool	non existent	-	-	224 - 228	48
T-M6	pond station	-	1.50	calm	pool	non existent	217 - 219	24	224 - 228	48
T-M7	pond station	-	1.50	calm	pool	non existent	217 - 219	24	224 - 228	48
T-M8	outflow station	3.20	0.66	fast	run	poor	212 - 214	24	-	-
O-M1	pond station	50.00	0.81	calm	pool	non existent	212 - 214	24	-	-
O-M2	outflow station	3.05	0.76	fast	riffle	poor	212 - 214	24	-	-

* calm = < 0.5 m/s, moderate = > 0.5 m/s and < 1 m/s, fast = > 1 m/s

** non existent = 0 - 20 % coverage, poor = 21 - 40 % coverage, fair = 41 - 60% coverage, good = 61 - 80% coverage, excellent = 81 to 100 % coverage

Table 3. Minimum, mean, maximum and standard deviation calculations for stream temperature measured at thermograph stations on Tributary One of Catamaran Brook, and for air temperature measured at the meteorological station in the Middle Reach of the Catamaran Brook basin. Measurements were recorded within the period June 18 to August 18, 1997.

Period in Julian Days	Calculations	Station Temperature										Air Temperature
		T-T1	T-T2	T-T3	T-T4	T-T5	T-T6	T-T7	T-T8	T-T9	T-T10	
169 - 175	min	9.5	13.1	11.9	11.8	11.7	10.3	11.4	11.3	10.5	11.1	6.1
	mean	12.0	13.9	13.6	15.1	14.5	13.1	14.1	14.0	13.2	13.8	16.1
	max	14.5	14.2	17.6	18.9	18.1	16.8	17.7	17.5	16.9	17.4	23.9
	std. dev.	1.1	0.4	1.0	1.4	1.3	1.4	1.3	1.3	1.3	1.3	4.4
176 - 182	min	10.2	10.2	11.4	11.3	11.4	10.3	11.2	11.2	10.3	11.1	5.6
	mean	13.5	13.8	14.2	15.3	15.2	14.2	14.9	14.8	14.2	14.7	17.8
	max	17.0	17.4	16.3	19.5	19.6	18.8	19.4	19.3	18.8	19.2	31.7
	std. dev.	1.7	2.0	1.3	2.2	2.2	2.2	2.2	2.2	2.2	2.3	5.8
183 - 189	min	11.8	11.9	12.7	12.9	12.7	11.5	12.3	12.3	11.5	12.1	6.3
	mean	14.7	15.2	15.5	16.6	16.4	15.1	16.1	16.0	15.1	15.8	19.2
	max	17.3	17.9	16.8	20.4	20.4	19.4	20.3	20.1	19.4	20.0	29.5
	std. dev.	1.1	1.3	0.9	1.6	1.6	1.6	1.6	1.6	1.6	1.7	4.8
190 - 196	min	10.6	11.8	13.4	13.6	13.1	11.4	12.6	12.6	11.4	12.3	5.8
	mean	13.8	14.8	15.6	17.0	16.1	14.5	15.7	15.6	14.5	15.4	17.6
	max	16.6	18.7	18.4	21.2	21.0	19.1	20.6	20.3	19.1	20.2	27.4
	std. dev.	1.3	1.4	1.0	2.0	1.9	1.8	1.9	1.9	1.8	1.9	5.3
197 - 203	min	9.8	11.4	14.5	15.8	12.5	10.8	12.1	12.0	10.8	11.7	5.3
	mean	13.0	14.7	16.4	18.0	16.2	14.4	15.8	15.6	14.3	15.3	16.4
	max	15.7	18.4	20.3	21.2	20.1	18.4	19.7	19.5	18.4	19.4	28.5
	std. dev.	1.4	1.6	1.3	1.4	1.8	1.7	1.8	1.8	1.7	1.8	4.9
204 - 210	min	10.3	11.4	15.1	15.2	12.5	10.9	12.4	12.0	10.9	11.7	6.7
	mean	13.6	15.2	16.6	18.9	17.2	15.4	16.7	16.7	15.4	16.3	17.9
	max	16.2	18.4	19.3	21.2	20.9	19.1	19.2	20.3	19.4	19.9	29.8
	std. dev.	1.5	1.7	0.9	1.7	2.1	2.0	1.7	2.1	2.1	2.1	5.6
211 - 217	min	10.8	12.5	16.3	16.7	14.1	12.1	15.4	13.6	12.1	13.2	5.1
	mean	14.0	15.6	17.5	19.2	17.0	15.8	17.2	17.1	15.7	16.7	17.7
	max	16.3	19.3	21.2	21.2	19.6	19.1	18.8	20.2	18.9	19.9	28.7
	std. dev.	1.4	1.7	0.9	1.5	1.4	1.8	0.8	1.8	1.8	1.8	5.5
218 - 224	min	10.3	11.4	15.8	15.6	13.2	12.0	14.5	12.9	11.5	12.6	6.9
	mean	13.6	15.3	17.7	19.1	16.3	15.6	16.2	17.0	15.5	16.5	17.7
	max	16.7	19.3	21.2	21.2	19.7	18.9	19.4	20.0	18.8	19.5	29.2
	std. dev.	1.4	1.8	1.1	1.7	1.4	1.8	0.9	1.8	1.8	1.8	5.5
225 - 230	min	11.1	11.6	13.3	14.1	13.2	11.7	14.5	12.7	11.7	12.3	6.6
	mean	13.2	14.5	16.8	17.9	15.8	14.8	16.0	16.1	14.8	15.7	16.3
	max	15.3	16.6	18.1	19.1	18.3	16.9	18.3	17.6	17.2	17.5	22.6
	std. dev.	0.9	1.0	1.2	1.2	1.0	1.2	0.8	1.2	1.2	1.2	3.7
169 - 199 First Half of Study Period	min	9.5	10.2	11.4	11.3	11.4	10.3	11.2	11.2	10.3	11.1	5.6
	mean	13.5	14.6	14.8	16.2	15.6	14.3	15.3	15.2	14.3	15.0	17.7
	max	17.3	18.7	18.4	21.2	21.0	19.4	20.6	20.3	19.4	20.2	31.7
	std. dev.	1.6	1.7	1.3	2.1	2.0	1.9	2.0	2.0	1.9	2.0	5.2
200 - 230 Second Half of Study Period	min	9.8	11.4	13.3	14.1	12.5	10.8	12.1	12.0	10.8	11.7	5.1
	mean	13.4	15.0	17.0	18.4	16.4	15.1	16.4	16.4	15.1	16.0	16.9
	max	16.7	19.3	21.2	21.2	20.9	19.1	19.4	20.3	19.4	19.9	29.8
	std. dev.	1.4	1.8	1.3	1.9	1.7	1.9	1.4	1.9	1.9	1.9	5.3
169 - 230 Entire Study Period	min	9.5	10.2	11.4	11.3	11.4	10.3	11.2	11.2	10.3	11.1	5.1
	mean	13.5	14.8	15.9	17.3	16.0	14.7	15.8	15.8	14.7	15.5	17.3
	max	17.3	19.3	21.2	21.2	21.0	19.4	20.6	20.3	19.4	20.2	31.7
	std. dev.	1.5	1.7	1.7	2.3	1.9	1.9	1.5	2.0	1.9	2.0	5.3

Table 4. Minimum, mean, maximum and standard deviation calculations for stream temperature measured at thermograph stations on Otter Brook, and for air temperature measured at the meteorological station in the Middle Reach of the Catamaran Brook basin. Measurements were recorded within the period June 27 to August 5, 1997.

Period in Julian Days	Calculations	Station Temperatures			Air Temperature
		O-T1	O-T2	O-T3	
178 - 184	min	12.5	12.9	12.7	7.9
	mean	17.5	17.6	18.0	19.8
	max	21.2	21.2	21.2	31.7
	std. dev.	2.3	2.0	2.2	5.1
185 - 191	min	13.4	13.6	13.6	6.3
	mean	16.4	16.7	16.9	17.6
	max	21.2	20.9	21.2	27.4
	std. dev.	1.9	1.7	2.0	4.5
192 - 198	min	9.4	9.4	9.7	5.8
	mean	15.0	15.2	15.7	18.2
	max	21.0	21.2	21.2	28.5
	std. dev.	3.2	3.3	3.4	5.9
199 - 205	min	6.7	6.0	6.5	5.3
	mean	12.4	13.1	13.2	16.1
	max	18.9	21.2	21.2	27.2
	std. dev.	3.4	4.5	4.2	5.3
206 - 212	min	7.6	6.8	7.6	9.5
	mean	12.9	13.7	13.6	18.6
	max	19.5	21.2	21.2	29.8
	std. dev.	3.5	4.8	4.4	5.3
213 - 217	min	6.1	4.9	5.5	5.1
	mean	13.0	14.1	13.9	18.5
	max	18.0	21.2	20.9	27.7
	std. dev.	3.3	4.9	4.4	5.4
178 - 197 First Half of Study Period	min	9.4	9.4	9.7	5.8
	mean	16.4	16.6	16.9	18.4
	max	21.2	21.2	21.2	31.7
	std. dev.	2.6	2.5	2.7	5.2
198 - 217 Second Half of Study Period	min	6.1	4.9	5.5	5.1
	mean	12.8	13.5	13.5	17.7
	max	19.5	21.2	21.2	29.8
	std. dev.	3.4	4.7	4.3	5.5
178 - 217 Entire Study Period	min	6.1	4.9	5.5	5.1
	mean	14.6	15.1	15.3	18.0
	max	21.2	21.2	21.2	31.7
	std. dev.	3.6	4.0	3.9	5.4

Table 5. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook. Results are from the first 24 hour interval (August 5 to 6, 1997) of the first sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
T-M2	-	-	-	BND	6.2	2.36	-	-	-
T-M7	GS	7.5	4.32	-	-	-	-	-	-
	GS	7.1	3.96	-	-	-	-	-	-
	GS	7.0	3.95	-	-	-	-	-	-
	LC	7.7	4.36	-	-	-	-	-	-
	LC	8.6	6.70	-	-	-	-	-	-
	LC	8.8	6.72	-	-	-	-	-	-
	LC	10.0	11.23	-	-	-	-	-	-
T-M8	AS	8.9	7.02	BT	14.7	30.60	BND	4.5	0.88
	BND	5.5	1.65	BND	5.2	-	BND	5.0	1.22
	BND	5.6	1.77	BND	5.0	-	GS	6.5	2.56
	BND	5.6	2.07	BND	5.0	1.28	GS	8.6	7.59
	BND	5.4	1.56	BND	4.9	1.72	GS	7.3	4.50
	BND	5.3	1.56	BND	5.5	1.65	GS	8.5	6.79
	BND	5.0	-	BND	4.8	1.18	LC	9.0	8.24
	BND	5.3	1.54	BND	5.0	1.34	LC	-	-
	CS	6.2	2.59	BND	5.5	1.66	LC	11.0	14.77
	CS	6.0	2.40	BND	5.5	1.77	LC	11.0	15.63
	CS	5.8	2.18	BND	6.4	2.49	LC	13.5	25.32
	CS	5.7	2.04	BND	5.1	1.36	LC	10.1	11.44
	CS	6.4	2.80	BND	5.1	1.33	WS	7.2	3.87
	CS	5.9	2.32	BND	6.4	2.55	WS	8.1	6.06
	CS	6.7	3.34	BND	5.3	1.62	-	-	-
	CS	6.1	2.46	BND	5.5	1.66	-	-	-
	CS	5.7	2.15	BND	5.3	1.36	-	-	-
	GS	5.7	1.82	BND	5.3	1.63	-	-	-
	LC	5.5	1.64	BND	6.5	2.87	-	-	-
	LC	6.1	2.32	BND	5.5	1.66	-	-	-
	WS	7.0	3.32	BND	-	-	-	-	-
	-	-	-	BND	5.6	1.82	-	-	-
	-	-	-	BND	5.1	1.26	-	-	-
	-	-	-	BND	5.1	1.36	-	-	-
	-	-	-	BND	5.6	1.84	-	-	-
	-	-	-	BND	5.4	1.58	-	-	-
	-	-	-	BND	5.6	1.78	-	-	-
	-	-	-	BND	5.3	1.44	-	-	-
	-	-	-	BND	5.3	1.58	-	-	-
	-	-	-	BND	5.2	1.42	-	-	-
	-	-	-	BND	5.7	1.74	-	-	-
	-	-	-	BND	5.2	1.31	-	-	-
	-	-	-	BND	5.6	1.70	-	-	-
	-	-	-	BND	5.6	1.89	-	-	-
	-	-	-	BND	5.4	1.53	-	-	-
	-	-	-	BND	5.5	1.63	-	-	-
	-	-	-	CS	5.7	2.00	-	-	-
	-	-	-	GS	5.9	1.89	-	-	-
	-	-	-	LC	6.0	-	-	-	-
	-	-	-	WS	8.2	6.22	-	-	-

*Species Codes: see Appendix B

Table 6. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook. Results are from the second 24 hour interval (August 7 to 8, 1997) of the first sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
T-M2	-	-	-	BT	5.5	1.64	-	-	-
T-M7	-	-	-	-	-	-	-	-	-
T-M8	BND	4.8	1.05	BND	5.0	1.44	AS	8.1	6.13
	BND	6.2	2.43	BND	5.4	1.69	BND	5.3	1.49
	BND	5.5	1.54	BND	5.1	1.22	BND	5.5	1.41
	BND	5.1	1.26	BND	5.5	1.72	GS	6.0	2.29
	BND	6.4	2.92	BND	5.8	2.13	WS	6.5	3.34
	BND	7.5	4.66	BND	5.1	1.33	-	-	-
	BND	6.9	3.58	BND	5.3	1.53	-	-	-
	BND	7.1	3.51	BND	5.2	1.24	-	-	-
	BND	5.4	1.58	GS	4.6	0.91	-	-	-
	GS	5.1	1.47	GS	5.8	1.99	-	-	-
	GS	4.4	0.89	GS	4.9	1.11	-	-	-
	GS	6.3	2.63	-	-	-	-	-	-
	GS	6.0	1.97	-	-	-	-	-	-
	GS	6.0	1.93	-	-	-	-	-	-
	GS	5.1	1.60	-	-	-	-	-	-
	GS	4.9	1.15	-	-	-	-	-	-
	GS	5.0	1.24	-	-	-	-	-	-
WS	8.3	6.00	-	-	-	-	-	-	

*Species Codes: see Appendix B

Table 7. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook. Results are from the first 48 hour interval (August 12 to 14, 1997) of the second sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
T-M1	-	-	-	BT	9.5	9.42	NA	NA	NA
T-M3	BT	5.9	2.07	BT	9.3	7.90	NA	NA	NA
	-	-	-	BND	6.3	2.71	-	-	-
	-	-	-	BND	6.3	2.82	-	-	-
	-	-	-	BND	5.2	1.40	-	-	-
	-	-	-	BND	5.2	1.34	-	-	-
	-	-	-	BND	6.1	2.37	-	-	-
	-	-	-	BND	5.6	1.63	-	-	-
	-	-	-	BND	5.6	1.82	-	-	-
	-	-	-	BND	6.2	2.64	-	-	-
	-	-	-	BND	5.7	1.92	-	-	-

*Species Codes: see Appendix B

(Continued)

Table 7. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook. Results are from the first 48 hour interval (August 12 to 14, 1997) of the second sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
T-M3	-	-	-	BND	5.7	1.83	-	-	-
	-	-	-	BND	6.0	2.22	-	-	-
	-	-	-	BND	5.5	1.64	-	-	-
	-	-	-	GS	8.6	6.62	-	-	-
	-	-	-	GS	7.7	4.77	NA	NA	NA
	-	-	-	LC	6.7	3.30	-	-	-
	-	-	-	LC	7.9	5.99	-	-	-
	-	-	-	LC	7.5	4.20	-	-	-
T-M4	-	-	-	LC	8.4	7.26	-	-	-
	-	-	-	BND	5.1	1.29	NA	NA	NA
	-	-	-	BND	6.1	2.29	-	-	-
	-	-	-	BND	7.4	4.42	-	-	-
	-	-	-	BND	6.1	2.38	-	-	-
	-	-	-	BND	6.2	2.33	-	-	-
	-	-	-	BND	5.9	1.69	-	-	-
	-	-	-	BND	5.5	1.64	-	-	-
	-	-	-	BND	5.8	2.07	-	-	-
	-	-	-	BND	5.5	1.49	-	-	-
	-	-	-	BND	6.0	2.06	-	-	-
	-	-	-	BND	5.4	1.66	-	-	-
	-	-	-	BND	5.3	1.54	-	-	-
	-	-	-	GS	7.4	4.35	-	-	-
	-	-	-	GS	7.4	4.50	-	-	-
	-	-	-	GS	8.4	6.44	-	-	-
	-	-	-	GS	6.0	2.33	-	-	-
	-	-	-	GS	8.4	5.33	-	-	-
	-	-	-	GS	8.5	6.34	-	-	-
	-	-	-	GS	6.2	2.88	-	-	-
-	-	-	LC	6.1	2.37	-	-	-	
-	-	-	LC	7.2	3.95	-	-	-	
-	-	-	LC	7.8	5.03	-	-	-	
-	-	-	LC	6.5	2.91	-	-	-	
-	-	-	LC	7.4	4.21	-	-	-	
-	-	-	LC	8.1	5.37	-	-	-	
-	-	-	LC	7.6	4.79	-	-	-	
T-M5	BND	4.5	0.96	-	-	-	NA	NA	NA
	GS	6.3	2.62	-	-	-	-	-	-
	GS	5.6	1.88	-	-	-	-	-	-
	GS	5.2	1.56	-	-	-	-	-	-
	LC	5.2	1.66	-	-	-	-	-	-
-	-	-	LC	5.7	1.87	-	-	-	
T-M6	BND	5.7	2.13	CS	7.5	4.63	NA	NA	NA

*Species Codes: see Appendix B

(Continued)

Table 7. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook. Results are from the first 48 hour interval (August 12 to 14, 1997) of the second sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
T-M8	BND	5.3	1.54	AS	8.3	6.39	NA	NA	NA
	-	-	-	BND	5.5	1.86	-	-	-
	-	-	-	BND	5.6	1.90	-	-	-
	-	-	-	BND	5.5	1.70	-	-	-
	-	-	-	BND	6.5	2.80	-	-	-
	-	-	-	BND	5.8	1.89	-	-	-
	-	-	-	BND	5.4	1.51	NA	NA	NA
	-	-	-	BND	4.8	1.29	-	-	-
	-	-	-	BND	5.1	1.44	-	-	-
	-	-	-	BND	5.2	1.44	-	-	-
	-	-	-	BND	5.9	2.15	-	-	-
	-	-	-	BND****	5.5	1.65	-	-	-
	-	-	-	BND***	5.5	1.63	-	-	-
	-	-	-	BND	5.6	1.89	-	-	-
	-	-	-	BND	5.6	2.03	-	-	-
	-	-	-	BND	5.3	1.56	-	-	-
	-	-	-	BND***	5.6	1.70	-	-	-
	-	-	-	BND	5.7	1.90	-	-	-
	-	-	-	BND	5.2	1.41	-	-	-
	-	-	-	BND****	5.2	1.35	-	-	-
	-	-	-	BND	5.4	1.62	-	-	-
	-	-	-	BND	5.2	1.43	-	-	-
	-	-	-	CS	5.6	1.74	-	-	-
	-	-	-	CS	6.7	2.87	-	-	-
	-	-	-	CS	6.8	3.51	-	-	-
	-	-	-	CS	6.1	2.70	-	-	-
	-	-	-	CS	6.5	3.12	-	-	-
	-	-	-	CS	7.0	3.77	-	-	-
	-	-	-	CS	5.8	1.98	-	-	-
	-	-	-	CS	9.6	10.64	-	-	-
	-	-	-	CS	6.1	2.39	-	-	-
	-	-	-	CS	7.4	4.62	-	-	-
	-	-	-	CS	5.3	2.02	-	-	-
	-	-	-	CS	6.1	2.62	-	-	-
	-	-	-	CS	6.9	3.64	-	-	-
	-	-	-	CS***	5.8	2.09	-	-	-
	-	-	-	CS	5.5	1.68	-	-	-
	-	-	-	CS	7.5	4.78	-	-	-
	-	-	-	GS	5.9	2.41	-	-	-
	-	-	-	GS	5.2	1.44	-	-	-
	-	-	-	LC	6.1	2.22	-	-	-
	-	-	-	WS	6.9	3.22	-	-	-
	-	-	-	WS	7.7	5.07	-	-	-

*Species Codes: see Appendix B ** LCC *** UCC **** LCC + UCC

Table 8. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook. Results are from the second 48 hour interval (August 14 to 16, 1997) of the second sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
T-M1	-	-	-	-	-	-	NA	NA	NA
T-M3	-	-	-	-	-	-	NA	NA	NA
T-M4	-	-	-	BND**	6.5	2.77	NA	NA	NA
	-	-	-	BND**	5.6	2.00	-	-	-
	-	-	-	BND	5.0	1.26	-	-	-
	-	-	-	BND	5.3	1.38	-	-	-
	-	-	-	BND	5.2	1.30	-	-	-
	-	-	-	BND	4.9	1.08	-	-	-
	-	-	-	BND	5.2	1.34	-	-	-
	-	-	-	BND**	5.3	1.41	-	-	-
	-	-	-	BND	5.8	2.22	-	-	-
	-	-	-	BND	5.2	1.38	-	-	-
	-	-	-	BND	5.3	1.32	-	-	-
	-	-	-	GS**	8.4	-	-	-	-
	-	-	-	GS	5.5	1.77	-	-	-
	-	-	-	LC**	8.0	5.60	-	-	-
	-	-	-	LC**	7.2	4.00	-	-	-
	-	-	-	LC	5.9	2.18	-	-	-
	-	-	-	LC	7.0	3.70	-	-	-
	-	-	-	LC	5.7	1.96	-	-	-
	-	-	-	LC**	7.4	4.22	-	-	-
	-	-	-	LC	8.2	6.05	-	-	-
	-	-	-	LC	7.9	5.42	-	-	-
T-M5	GS	7.4	4.73	-	-	-	NA	NA	NA
T-M6	-	-	-	CS	6.0	2.32	NA	NA	NA
	-	-	-	CS	6.2	2.40	-	-	-
	-	-	-	CS	5.9	2.51	-	-	-
	-	-	-	CS	5.9	2.22	-	-	-
	-	-	-	CS	7.8	5.53	-	-	-
	-	-	-	CS	7.5	5.03	-	-	-
	-	-	-	GS	8.5	5.90	-	-	-
T-M8	BND***	5.0	1.27	BND****	4.7	1.18	NA	NA	NA
	-	-	-	BT	10.7	12.26	-	-	-
	-	-	-	CS**	6.2	2.70	-	-	-
	-	-	-	GS	5.8	2.04	-	-	-
	-	-	-	GS	5.9	2.15	-	-	-

*Species Codes: see Appendix B ** LCC *** UCC **** LCC + UCC

Table 9. Total number of fish, proportion of fish caught and fork length and weight characteristics, by species, of fish captured within and downstream of the active beaver impoundment on Tributary One of Catamaran Brook.

Species Code*	Total Number of Fish Caught**	Proportion by species of Fish Caught**	Upstream											
			Fork Length					Weight						
			n***	Mean (cm)	Std Dev (cm)	Min (cm)	Max (cm)	n***	Mean (g)	Std Dev (g)	Min (g)	Max (g)		
AS	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BT	4	4	4	7.6	1.9	5.5	9.5	4	5.26	3.45	1.64	9.42		
BND	38	41	35	5.7	0.5	4.5	7.4	35	1.88	0.65	0.96	4.42		
CS	7	7	14	7.0	0.8	5.9	8.1	14	3.81	1.24	2.22	5.53		
GS	19	20	18	7.2	1.1	5.2	8.6	18	4.13	1.61	1.56	6.62		
LC	26	28	15	7.4	1.3	5.2	10.0	15	4.84	2.52	1.66	11.23		
TSSB	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WS	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species Code*	Total Number of Fish Caught**	Proportion by species of Fish Caught**	Downstream											
			Fork Length					Weight						
			n***	Mean (cm)	Std Dev (cm)	Min (cm)	Max (cm)	n***	Mean (g)	Std Dev (g)	Min (g)	Max (g)		
AS	3	2	3	8.4	0.3	8.1	8.9	3	6.51	0.37	6.13	7.02		
BT	2	1	2	12.7	2.0	10.7	14.7	2	21.43	9.17	12.26	30.60		
BND	87	53	80	5.5	0.5	4.5	7.5	77	1.75	0.59	0.88	4.66		
CS	32	19	25	6.4	0.9	5.3	9.6	25	3.05	1.74	1.68	10.64		
GS	23	14	22	5.9	1.1	4.4	8.6	22	2.38	1.70	0.89	7.59		
LC	10	6	9	8.7	2.7	5.5	13.5	8	10.20	7.77	1.64	25.32		
TSSB	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WS	8	5	8	7.5	0.6	6.5	8.3	8	4.64	1.25	3.22	6.22		

*Species Code: See Appendix B

** Values include both trapping periods and their respective trapping intervals

***Represents total number of actual fork lengths and weights recorded, recaptures were excluded

Table 10. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the abandoned beaver impoundment on Otter Brook. Results are from the first 24 hour interval (July 31 to August 1, 1997) of the sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
O-M2	BT	14.7	32.25	BND	4.5	1.06	AS	7.2	3.87
	BT	12.9	21.72	BND	4.6	0.68	BT	5.8	1.96
	BT	14.9	32.37	BT	15.7	35.45	TSSB	4.7	0.97
	BT	12.5	20.53	BT	15.9	42.33	TSSB	5.0	0.99
	BT	14.2	30.89	BT	12.6	19.04	TSSB	4.6	0.86
	BT	13.9	27.53	TSSB	-	-	TSSB	4.1	0.57
	BT	11.0	13.29	TSSB	5.1	1.16	TSSB	4.6	0.92
	BT	14.3	27.42	TSSB	4.4	0.76	TSSB	4.8	1.14
	BT	13.1	22.89	TSSB	4.8	0.72	TSSB	4.3	0.65
	BT	13.3	25.28	TSSB	4.6	0.85	TSSB	5.0	1.06
	TSSB	4.6	0.86	TSSB	4.4	0.88	TSSB	4.4	0.92
	TSSB	4.7	0.96	TSSB	5.0	1.32	TSSB	5.1	1.06
	TSSB	4.0	0.79	TSSB	4.7	1.06	TSSB	4.3	0.83
	-	-	-	TSSB	4.9	1.09	TSSB	4.3	0.86
	-	-	-	TSSB	4.7	0.83	TSSB	4.4	0.83
	-	-	-	TSSB	4.9	0.89	-	-	-
	-	-	-	TSSB	4.6	0.71	-	-	-
	-	-	-	TSSB	4.8	0.79	-	-	-
	-	-	-	TSSB	4.6	0.99	-	-	-
	-	-	-	TSSB	5.0	1.08	-	-	-
	-	-	-	TSSB	4.7	0.88	-	-	-
	-	-	-	TSSB	5.0	1.04	-	-	-
	-	-	-	TSSB	5.0	1.22	-	-	-
	-	-	-	TSSB	4.4	0.72	-	-	-
	-	-	-	TSSB	4.7	0.97	-	-	-
	-	-	-	TSSB	4.7	0.76	-	-	-
	-	-	-	TSSB	4.5	1.02	-	-	-
	-	-	-	TSSB	4.9	1.26	-	-	-
	-	-	-	TSSB	4.6	0.84	-	-	-
	-	-	-	TSSB	4.5	0.92	-	-	-
	-	-	-	TSSB	5.1	1.22	-	-	-
	-	-	-	TSSB	5.4	1.32	-	-	-
	-	-	-	TSSB	4.5	0.79	-	-	-
	-	-	-	TSSB	4.5	0.86	-	-	-
	-	-	-	TSSB	4.1	0.68	-	-	-
	-	-	-	TSSB	4.9	1.00	-	-	-
	-	-	-	TSSB	4.5	0.75	-	-	-
	-	-	-	TSSB	4.7	0.96	-	-	-
	-	-	-	TSSB	4.7	0.91	-	-	-
	-	-	-	TSSB	5.7	1.62	-	-	-
-	-	-	TSSB	5.6	1.60	-	-	-	
-	-	-	TSSB	4.6	0.69	-	-	-	
-	-	-	TSSB	4.6	0.69	-	-	-	
-	-	-	TSSB	4.6	0.73	-	-	-	
-	-	-	TSSB	4.7	0.90	-	-	-	
-	-	-	TSSB	4.7	0.82	-	-	-	
-	-	-	TSSB	4.5	0.65	-	-	-	
-	-	-	TSSB	4.7	0.86	-	-	-	
-	-	-	TSSB	5.2	1.35	-	-	-	
-	-	-	TSSB	5.1	1.13	-	-	-	

* Species codes: see Appendix B

(Continued)

Table 10. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the abandoned beaver impoundment on Otter Brook. Results are from the first 24 hour interval (July 31 to August 1, 1997) of the sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
O-M1	-	-	-	TSSB	4.5	0.77	-	-	-
	-	-	-	TSSB	4.9	0.93	-	-	-
	-	-	-	TSSB	4.8	0.89	-	-	-
	-	-	-	TSSB	5.7	1.62	-	-	-
	-	-	-	TSSB	4.9	0.88	-	-	-
	-	-	-	TSSB	4.6	0.84	-	-	-
	-	-	-	TSSB	-	-	-	-	-
	-	-	-	TSSB	-	-	-	-	-
	-	-	-	TSSB	-	-	-	-	-
	-	-	-	TSSB	-	-	-	-	-
	-	-	-	TSSB	-	-	-	-	-
	-	-	-	TSSB	-	-	-	-	-
O-M2	BND	6.1	2.34	-	-	-	AS	7.8	4.52
	-	-	-	-	-	-	BT	15.1	37.32
	-	-	-	-	-	-	BT	15.3	31.16
	-	-	-	-	-	-	BT	12.0	16.72
	-	-	-	-	-	-	BND	5.3	1.46

* Species codes: see Appendix B

Table 11. Minnow-trap results (species, fork length and weight), by station, of fish captured within and downstream of the abandoned beaver impoundment on Otter Brook. Results are from the second 24 hour interval (August 1 to 2, 1997) of the sample period.

Station	Trap One			Trap Two			Trap Three		
	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)	Species Code*	Fork Length (cm)	Weight (g)
O-M1	TSSB	4.6	0.78	BT**	14.6	32.17	AS	8.3	5.70
	TSSB	4.8	0.97	BT**	12.9	21.25	BT	17.5	50.76
	TSSB	5.2	1.41	TSSB	4.6	0.84	TSSB	4.6	0.86
	TSSB	4.0	0.54	-	-	-	-	-	-
O-M2	BND	5.0	1.34	BND	5.6	1.86	AS	8.7	6.16
	BND	5.6	1.69	BT	12.2	16.72	BT	12.6	18.32
	BND	5.4	1.72	BT	12.3	17.72	BT	13.7	26.81
	BND	5.7	1.76	WS	8.2	6.30	BT**	14.7	30.74
	BND	6.1	2.30	-	-	-	BT**	13.8	27.19
	LC	8.8	8.23	-	-	-	BT	14.3	26.33
	TSSB***	4.9	0.99	-	-	-	WS	8.1	5.90
	WS	9.4	9.78	-	-	-	-	-	-
	WS	7.7	4.66	-	-	-	-	-	-

*Species Codes: see Appendix B ** LCC *** UCC **** LCC + UCC

Table 12. Total number of fish, proportion of fish caught and fork length and weight characteristics, by species, of fish captured within and downstream of the abandoned beaver impoundment on Otter Brook.

Species Code*	Total Number of Fish Caught**	Proportion by species of Fish Caught**	Upstream									
			Fork Length					Weight				
			n***	Mean (cm)	Std Dev (cm)	Min (cm)	Max (cm)	n***	Mean (g)	Std Dev (g)	Min (g)	Max (g)
AS	2	2	2	7.8	0.6	7.2	8.3	2	4.79	0.92	3.87	5.7
BT	17	18	17	13.5	2.4	5.8	17.5	17	26.89	10.77	1.96	50.76
BND	2	2	2	4.6	0.1	4.5	4.6	2	0.87	0.19	0.68	1.06
CS	-	-	-	-	-	-	-	-	-	-	-	-
GS	-	-	-	-	-	-	-	-	-	-	-	-
LC	-	-	-	-	-	-	-	-	-	-	-	-
TSSB	74	78	70	4.7	0.3	4.0	5.7	70	0.94	0.23	0.54	1.62
WS	-	-	-	-	-	-	-	-	-	-	-	-

Species Code*	Total Number of Fish Caught**	Proportion by species of Fish Caught**	Downstream									
			Fork Length					Weight				
			n***	Mean (cm)	Std Dev (cm)	Min (cm)	Max (cm)	n***	Mean (g)	Std Dev (g)	Min (g)	Max (g)
AS	2	8	2	8.3	0.5	7.8	8.7	2	5.34	0.82	4.52	6.16
BT	10	38	10	13.6	1.2	12.0	15.3	10	24.90	6.84	16.72	37.32
BND	8	31	8	5.6	0.4	5.0	6.1	8	1.81	0.33	1.34	2.34
CS	-	-	-	-	-	-	-	-	-	-	-	-
GS	-	-	-	-	-	-	-	-	-	-	-	-
LC	1	4	1	8.8	0.0	8.8	8.8	1	8.23	0.00	8.23	8.23
TSSB	1	4	1	4.9	0.0	4.9	4.9	1	0.99	0.00	0.99	0.99
WS	4	15	4	8.4	0.6	7.7	9.4	4	6.66	1.74	4.66	9.78

*Species Code: See Appendix B

** Values include both trapping periods and their respective trapping intervals

***Represents total number of actual fork lengths and weights recorded, recaptures were excluded

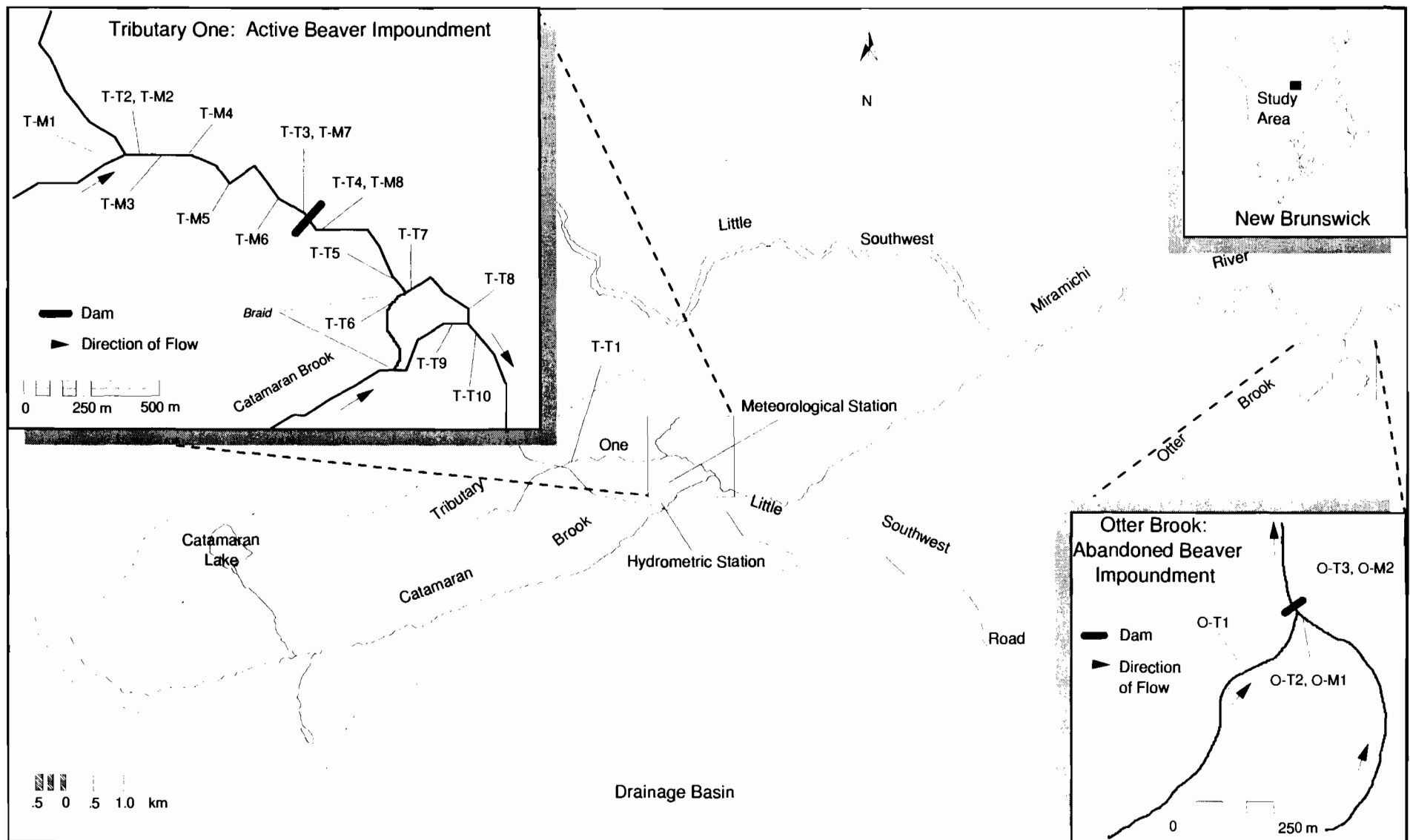


Figure 1. Map of the Catamaran Brook drainage basin. Insets depict the location of the study area, the two impoundments studied and the locations of stream temperature sampling stations (T-T and O-T series) and minnow-trap sampling stations (T-M and O-M series).

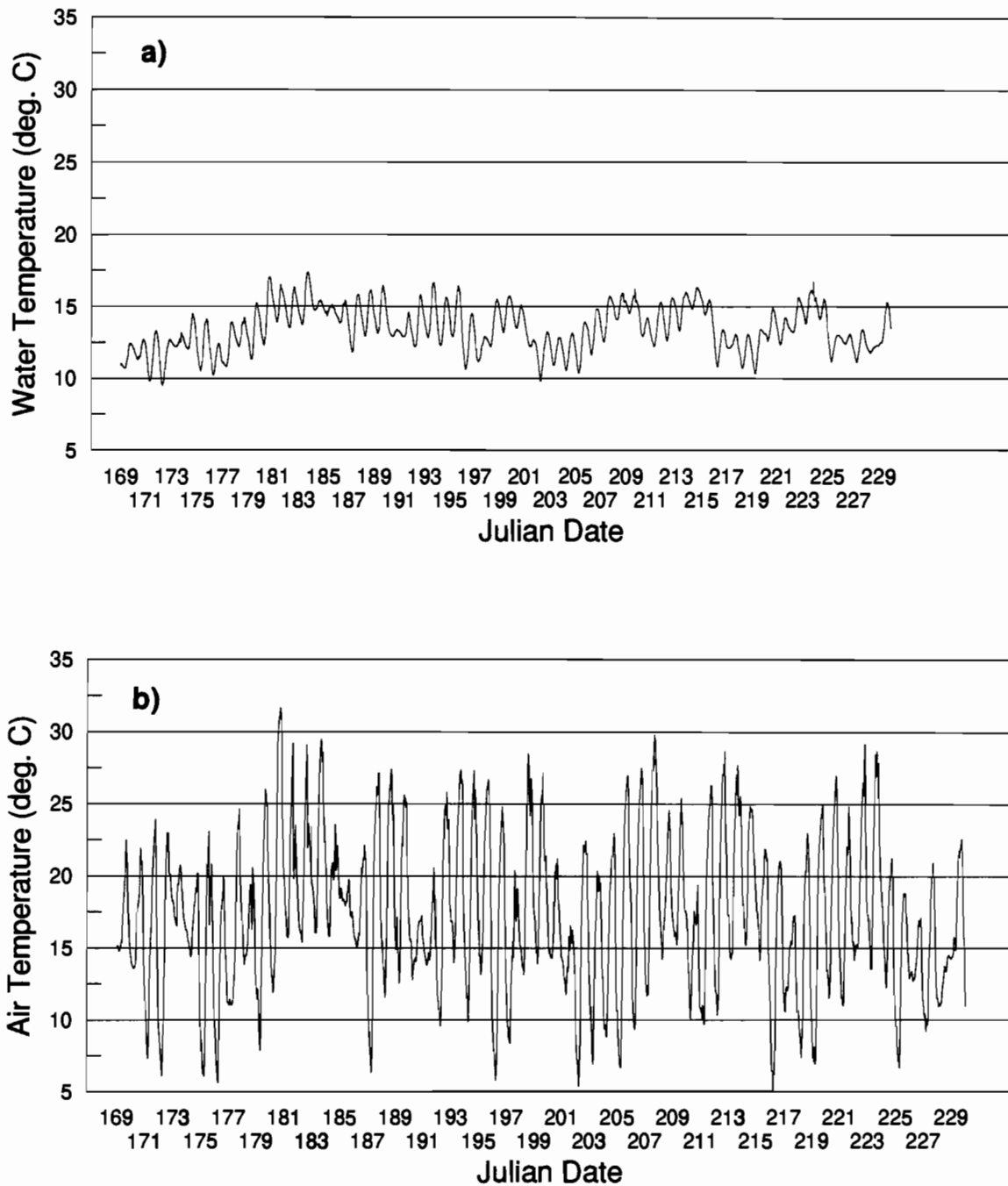


Figure 2. Stream temperature measured at the reference station, T-T1, on Tributary One of Catamaran Brook (panel a). Hourly air temperature measured at the meteorological station in the Middle Reach of the Catamaran Brook basin (panel b). Measurements for stream temperature and air temperature were recorded for the period June 18 to August 18, 1997.

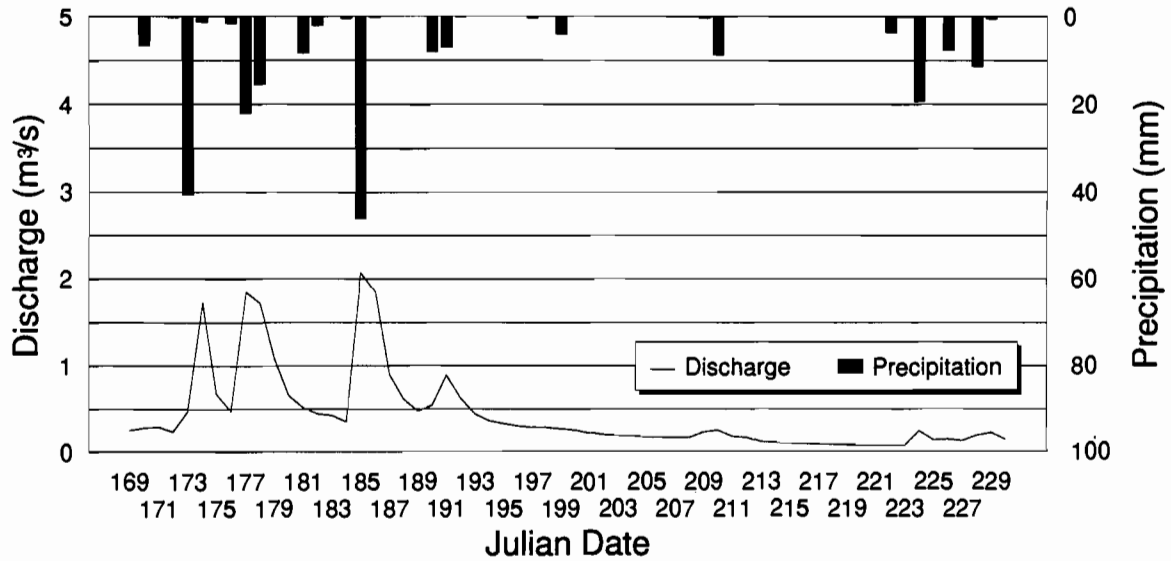


Figure 3. Stream discharge and rainfall measurements recorded at the meteorological station in the Middle Reach of the Catamaran Brook basin for the period June 18 to August 18, 1997.

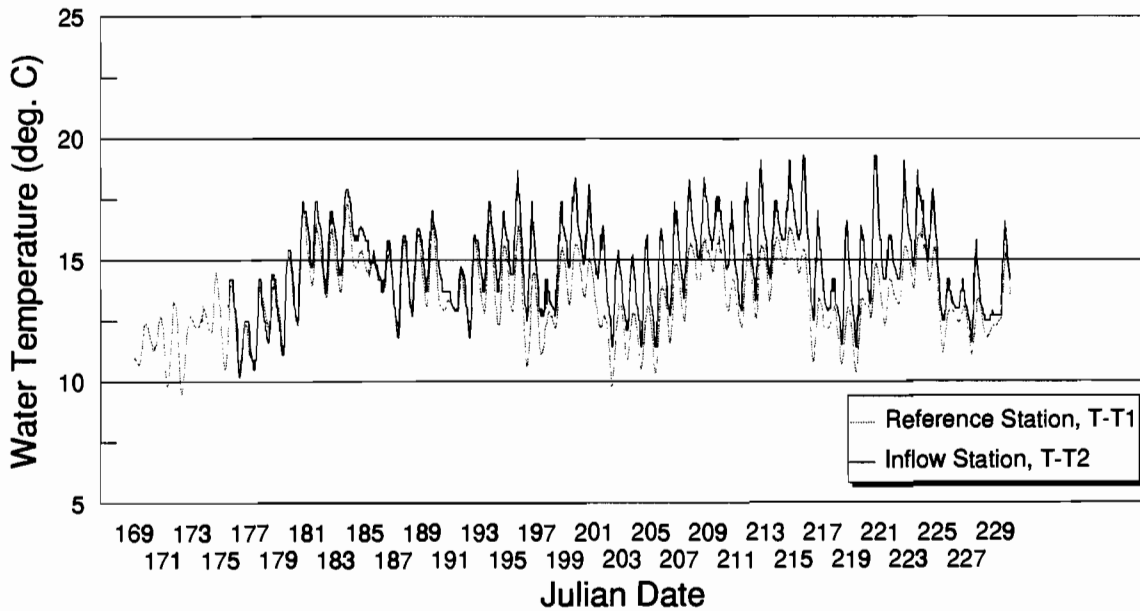


Figure 4. Stream temperature measured at the inflow station, T-T2, on Tributary One of Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station, T-T1, was plotted for comparison.

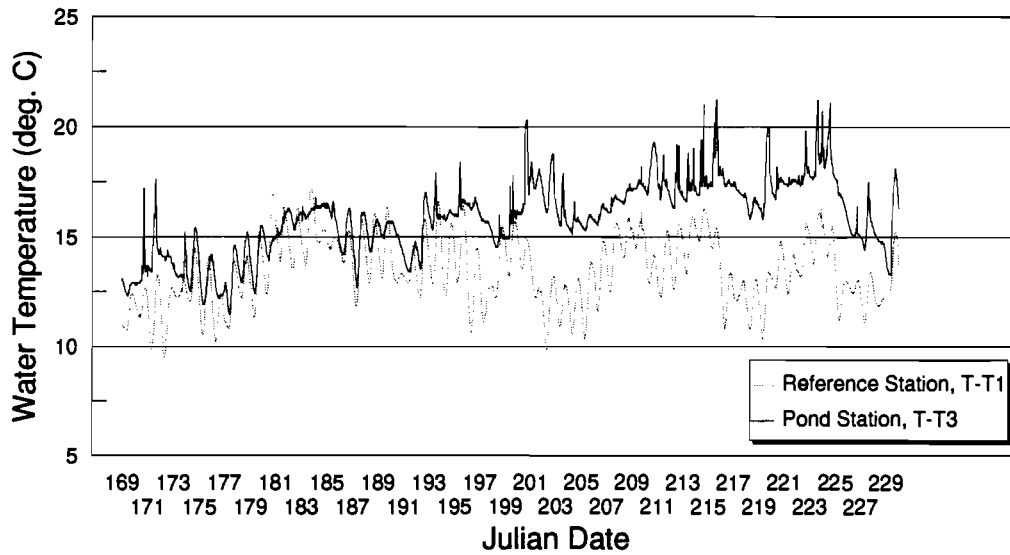


Figure 5. Stream temperature measured at the pond station, T-T3, on Tributary One of Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station, T-T1 was plotted for comparison.

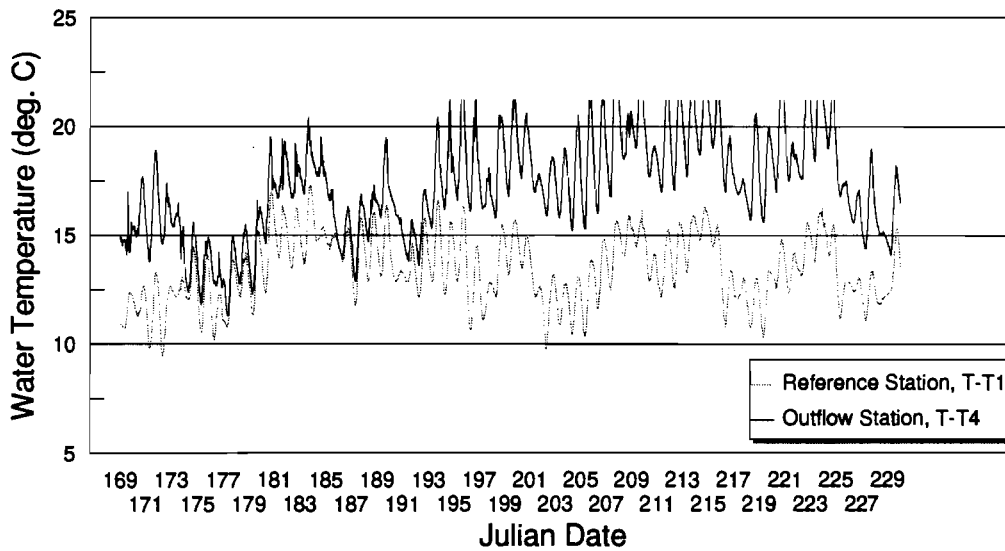


Figure 6. Stream temperature measured at the outflow station, T-T4, on Tributary One of Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station, T-T1, was plotted for comparison. Note: The thermographs were only capable of recording a maximum temperature of 21.2 deg. C.

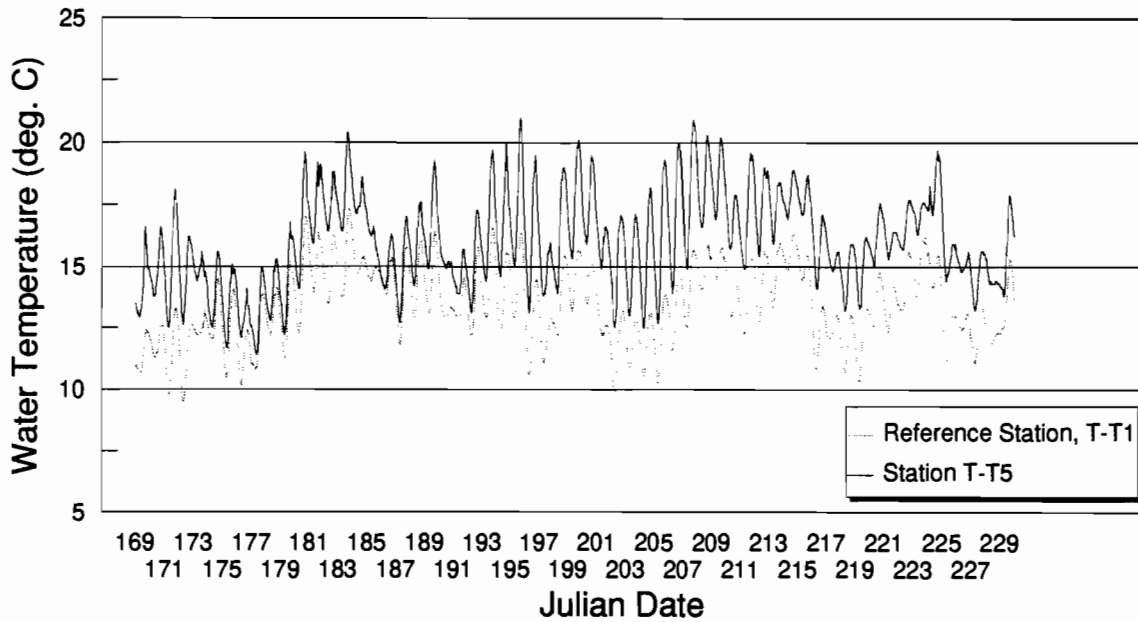


Figure 7. Stream temperature measured on Tributary One at the station, T-T5, upstream of the junction with Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station, T-T1, was plotted for comparison.

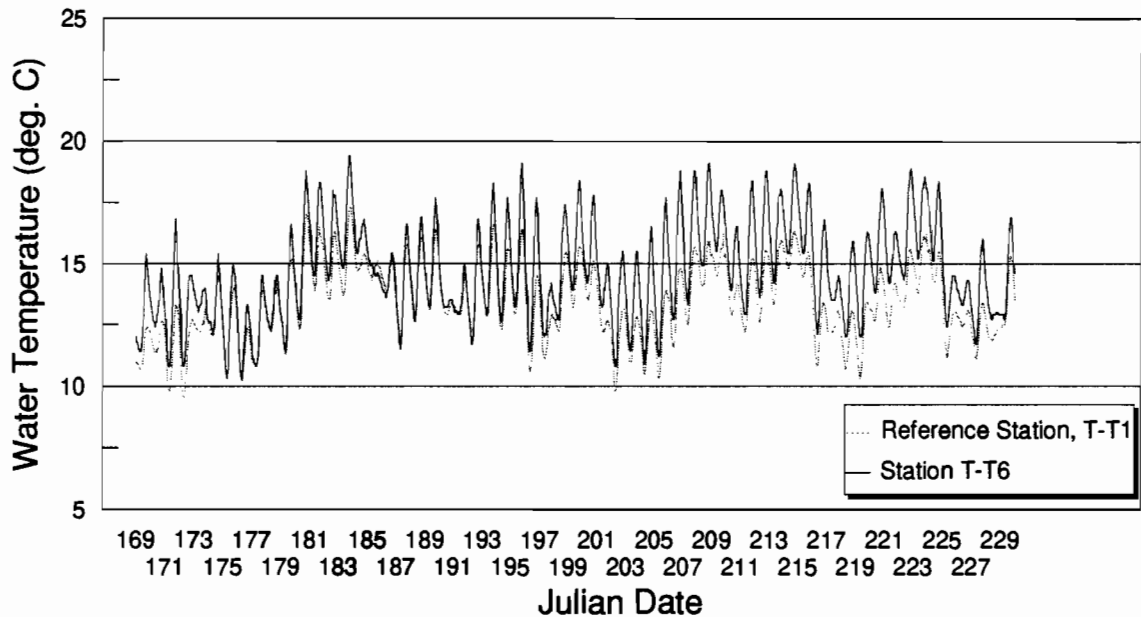


Figure 8. Stream temperature measured at the first reference station on Catamaran Brook, T-T6, for the period June 18 to August 18, 1997. Stream temperature measured at the reference station on Tributary One, T-T1, was plotted for comparison.

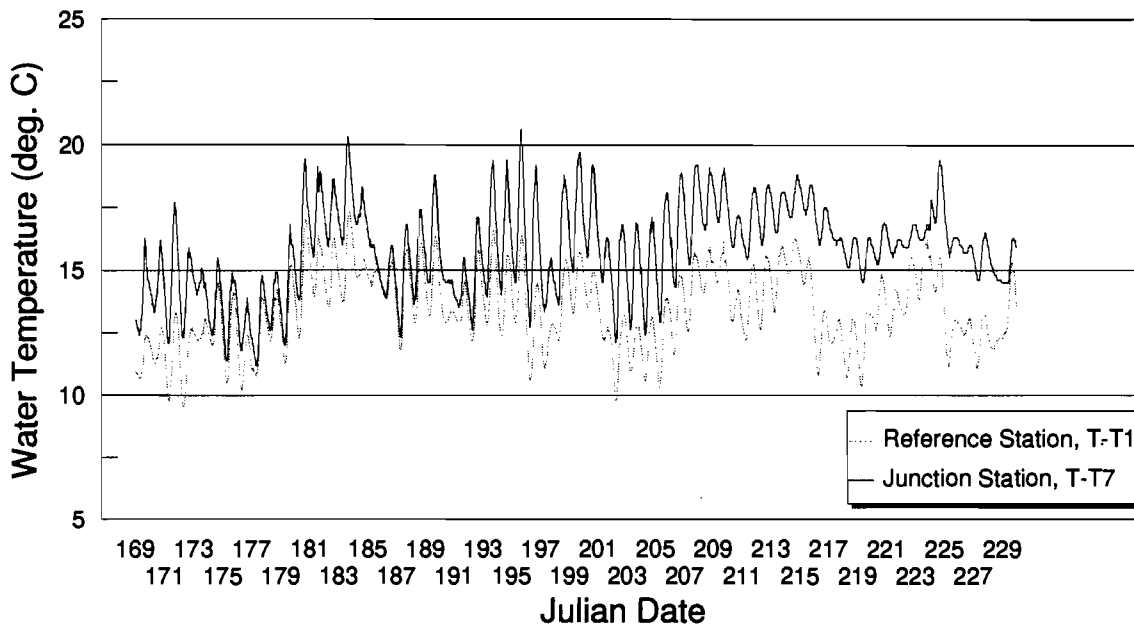


Figure 9. Stream temperature measured at the junction station, T-T7, on Tributary One of Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station on Tributary One, T-T1, was plotted for comparison.

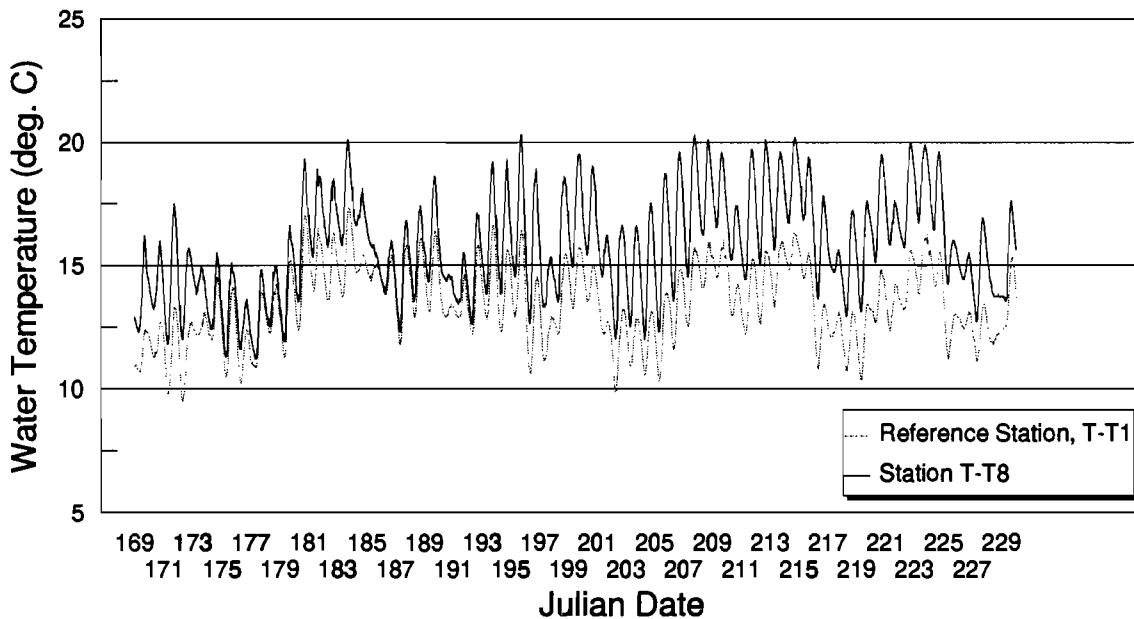


Figure 10. Stream temperature measured on Tributary at the station, T-T8, upstream of the confluence with Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station on Tributary One, T-T1, was plotted for comparison.

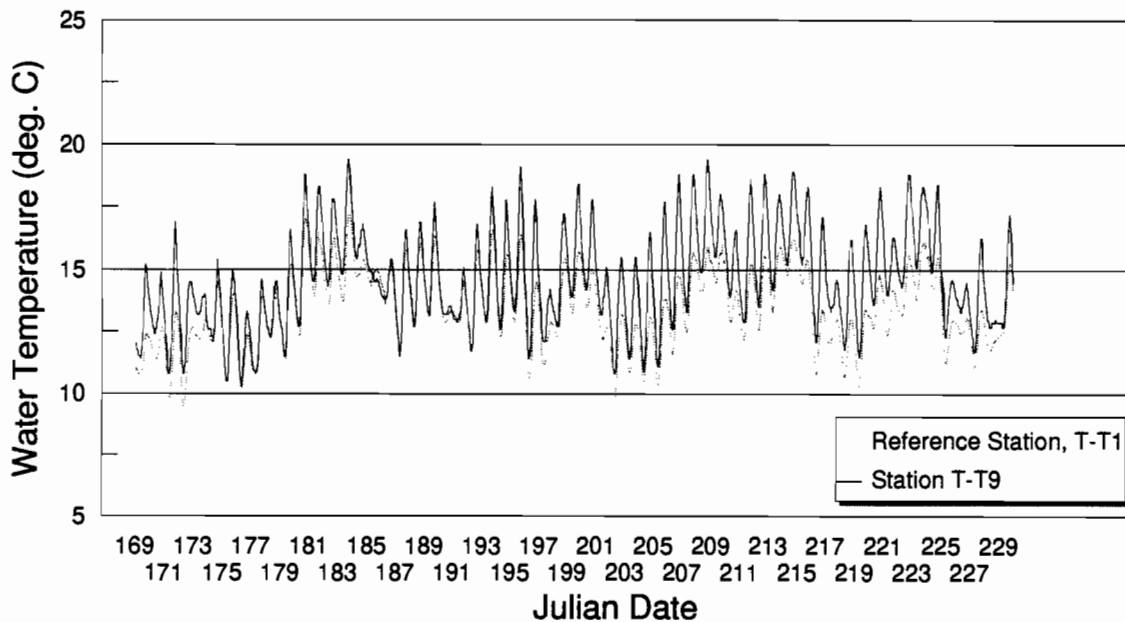


Figure 11. Stream temperature measured at the second reference station, T-T9, on Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station on Tributary One, T-T1, was plotted for comparison.

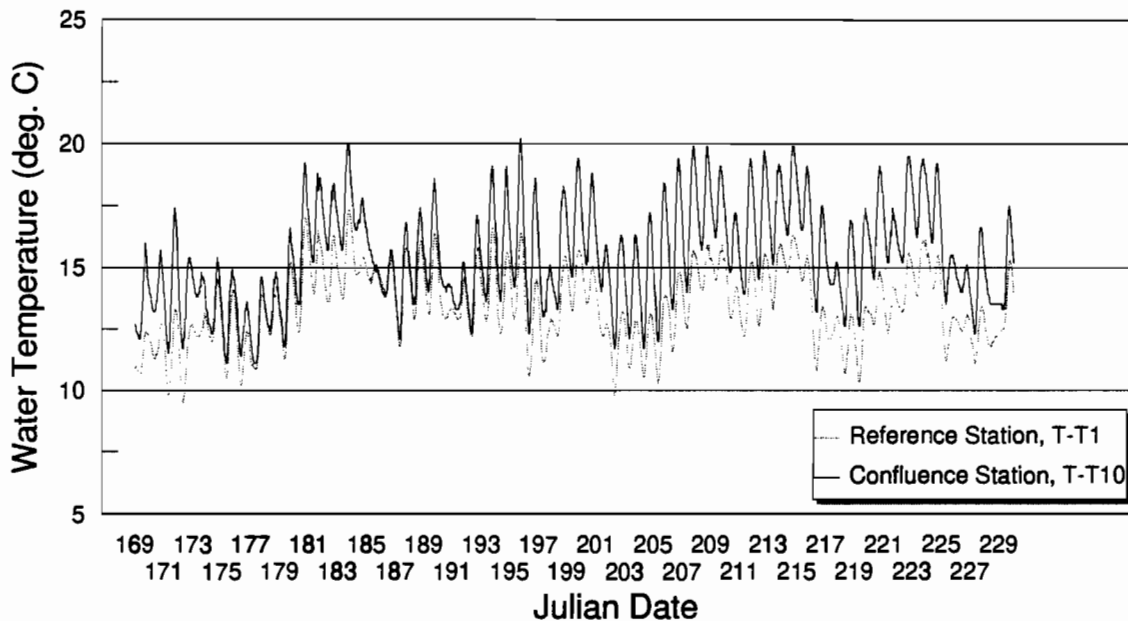


Figure 12. Stream temperature measured at the confluence station, T-T10, on Catamaran Brook for the period June 18 to August 18, 1997. Stream temperature measured at the reference station on Tributary One, T-T1, was plotted for comparison.

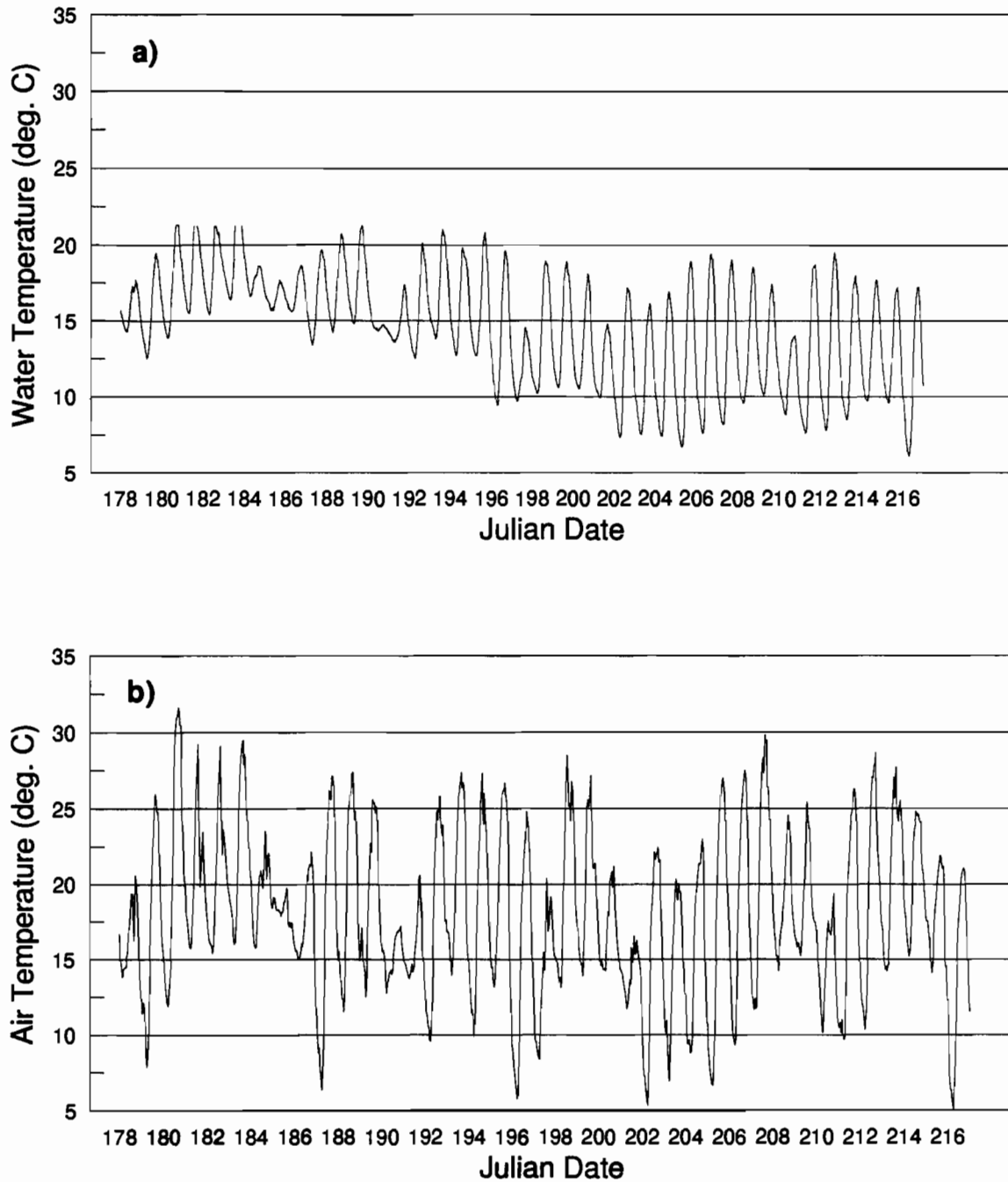


Figure 13. Stream temperature measured at the reference station, O-T1, on Otter Brook (panel a). Hourly air temperature measured at the meteorological station in the Middle Reach of the Catamaran Brook basin (panel b). Measurements for stream temperature and air temperature were measured for the period June 27 to August 5, 1997. Note: The thermograph used to record stream temperature measurements was only capable of measuring a maximum temperature of 21.2 deg. C.

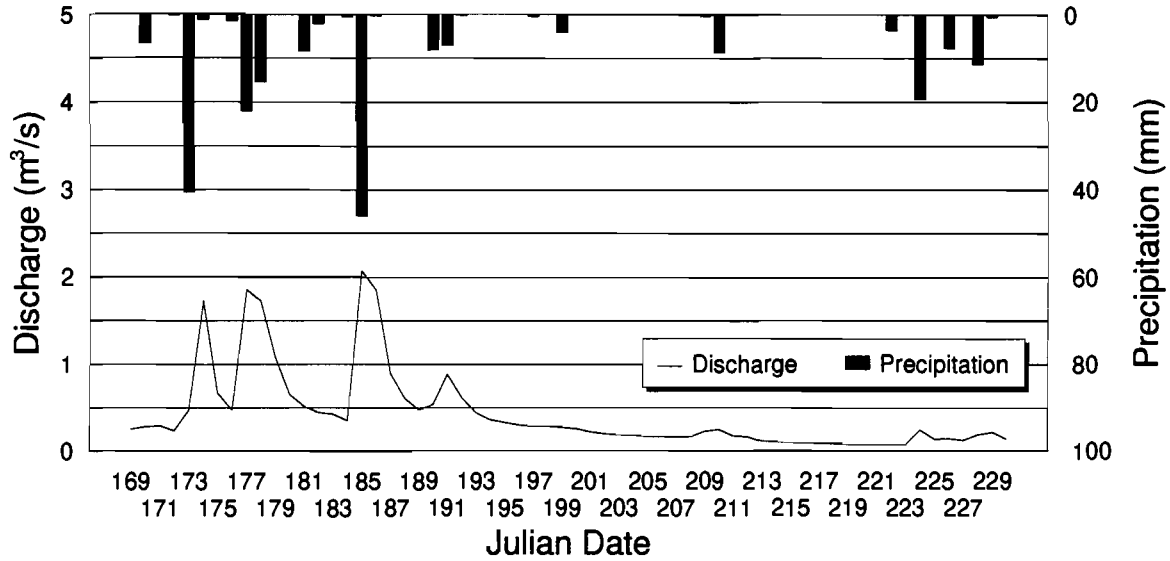


Figure 14. Stream discharge and rainfall measurements recorded at the meteorological station in the Middle Reach of the Catamaran Brook basin for the period June 27 to August 5, 1997.

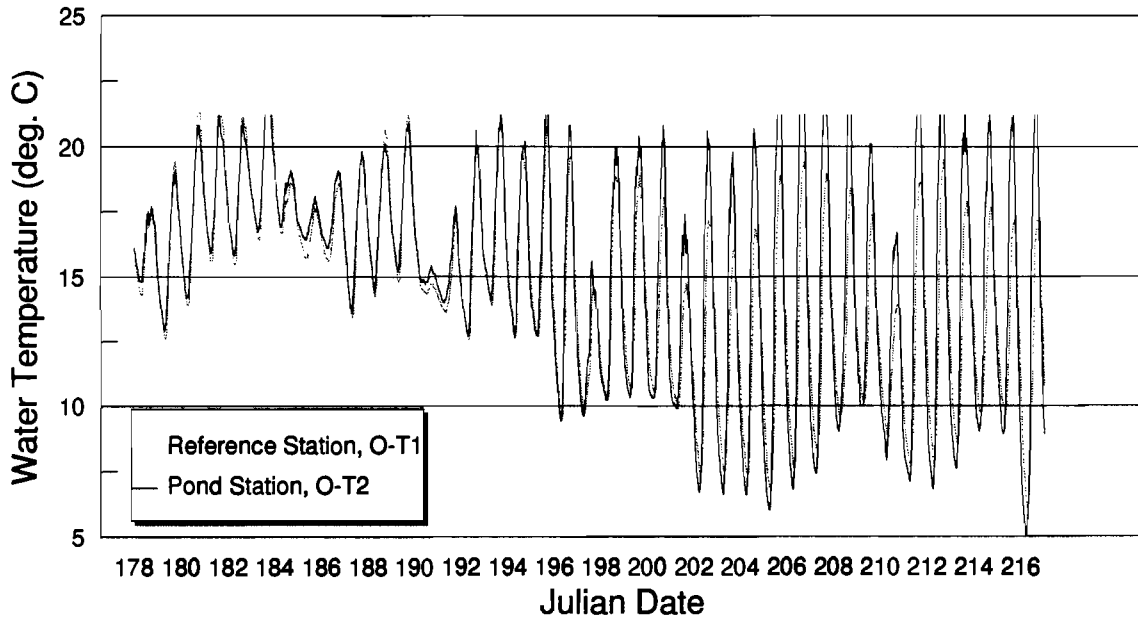


Figure 15. Stream temperature measured at the pond station, O-T2, on Otter Brook for the period June 27 to August 5, 1997. Stream temperature measured at the reference station, O-T1, was plotted for comparison. Note: The thermographs were only capable of recording a maximum temperature of 21.2 deg. C.

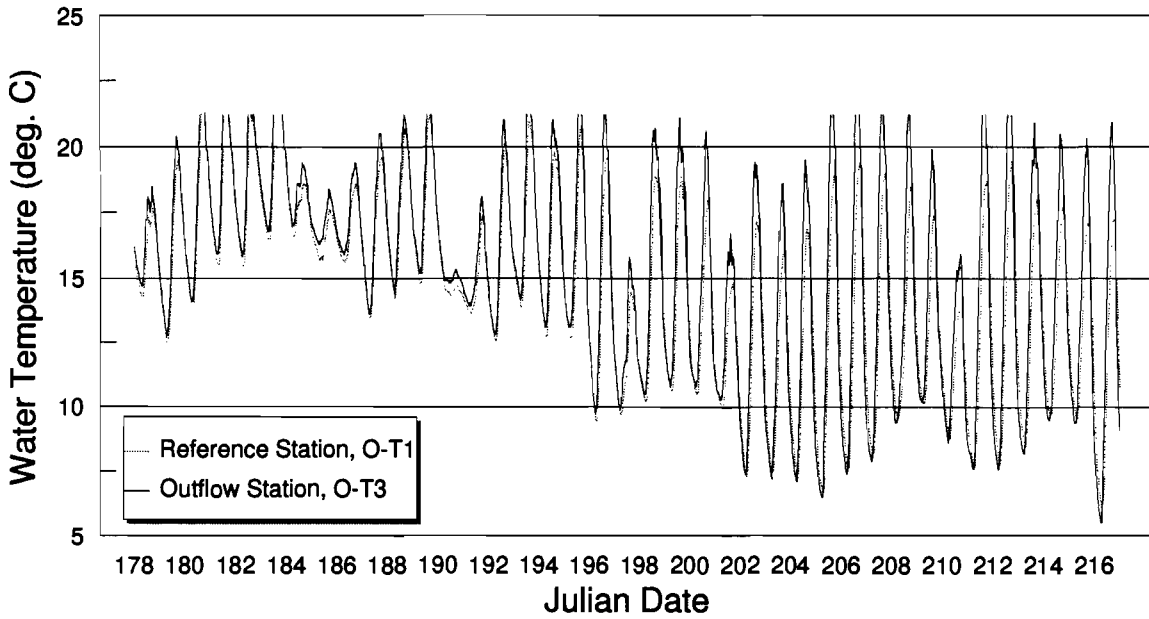


Figure 16. Stream temperature measured at the outflow station, O-T3, on Otter Brook for the period June 27 to August 5, 1997. Stream temperature measured at the reference station, O-T1, was plotted for comparison. Note: The thermographs were only capable of recording a maximum temperature of 21.2 deg. C.

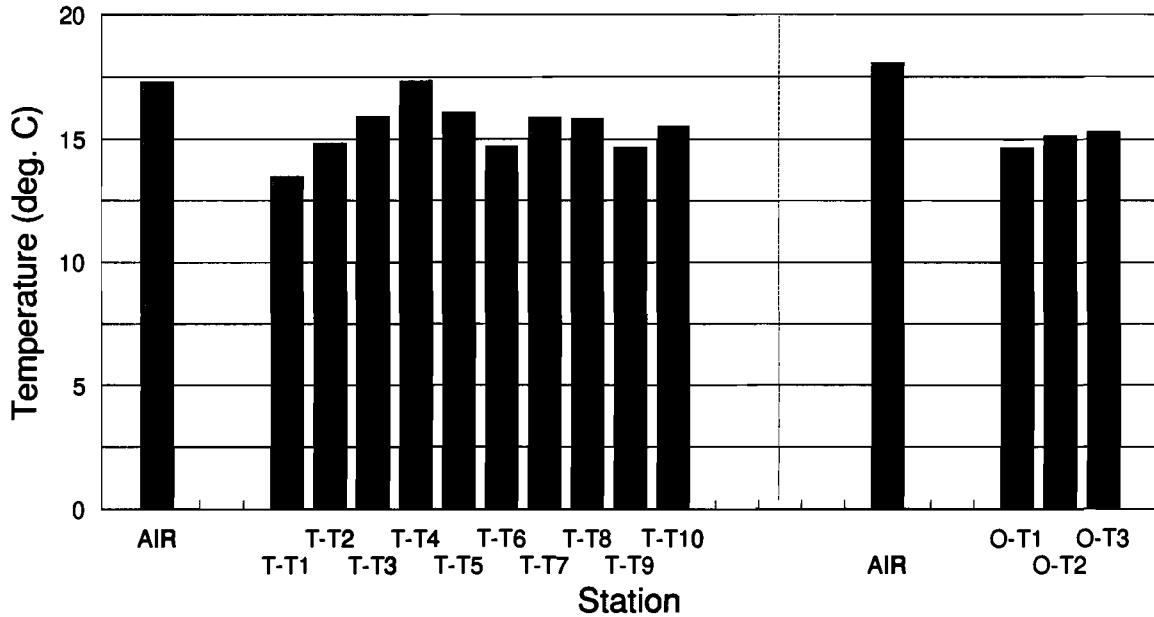


Figure 17. Mean temperatures for all stations during study periods. Those stations on Tributary One recorded temperatures from June 18 to August 18, 1997 and those on Otter Brook recorded temperatures from June 27 to August 5, 1997.

Appendix A

Latitude and Longitude Co-ordinates

Table A-1. Latitude and longitude co-ordinates, by station identification number, for thermograh sampling stations, minnow trap sampling stations and new dam sites on Tributary One of Catamaran Brook and on Otter Brook.

Station	Station Descriptor	Latitude	Longitude
T-T1	reference station (Tributary One)	46° 51' 47.9" N	66° 12' 53.3" W
T-T2	inflow station	46° 51' 51.9" N	66° 11' 20.3" W
T-T3	pond station	46° 51' 50.9" N	66° 10' 55.8" W
T-T4	outflow station	46° 51' 49.2" N	66° 10' 55.4" W
T-T5	downstream of junction (Tributary One)	46° 51' 43.2" N	66° 10' 37.6" W
T-T6	reference station 1 (Catamaran)	46° 51' 40.0" N	66° 10' 44.9" W
T-T7	junction station	46° 51' 35.9" N	66° 10' 49.9" W
T-T8	upstream of confluence (Tributary One)	46° 51' 41.7" N	66° 10' 47.4" W
T-T9	reference station 2 (Catamaran)	46° 51' 41.6" N	66° 10' 42.5" W
T-T10	confluence station	46° 51' 40.0" N	66° 10' 35.9" W
O-T1	inflow/reference station	46° 52' 43.1" N	66° 02' 12.9" W
O-T2	pond station	46° 52' 31.7" N	66° 02' 06.6" W
O-T3	outflow station	46° 52' 28.2" N	66° 02' 08.3" W
T-M1	inflow station	46° 51' 51.9" N	66° 11' 20.3" W
T-M2	pond station	46° 51' 50.9" N	66° 10' 55.8" W
T-M3	pond station	46° 51' 49.2" N	66° 10' 55.4" W
T-M4	pond station	46° 51' 52.9" N	66° 10' 59.6" W
T-M5	pond station	46° 52' 03.9" N	66° 11' 10.6" W
T-M6	pond station	46° 51' 54.2" N	66° 11' 17.4" W
T-M7	pond station	46° 51' 49.0" N	66° 11' 04.0" W
T-M8	outflow station	46° 51' 47.9" N	66° 11' 03.7" W
O-M1	inflow/reference station	46° 52' 43.1" N	66° 02' 12.9" W
O-M2	pond station	46° 52' 31.7" N	66° 02' 06.6" W
O-M3	outflow station	46° 52' 28.2" N	66° 02' 08.3" W
N-D1	upstream of pond (Tributary One)	46° 51' 50.9" N	66° 10' 55.8" W
N-D2	between outflow and junction (Tributary)	-	-
N-D3	downstream of junction (Tributary One)	46° 51' 40.0" N	66° 10' 44.9" W
N-D4	upstream of confluence (Tributary One)	46° 51' 53.1" N	66° 11' 23.1" W

Appendix B

Codes and Abbreviations Used in Report

Table B-1. List of species codes.

Species Code	Latin Name	Common Name
AS	<i>Salmo salar</i>	Atlantic salmon
BT	<i>Salvelinus fontinalis</i>	brook trout
BND	<i>Rhinichthys atratulus</i>	black nose dace
CS	<i>Notropis cornutus</i>	common shiner
GS	<i>Notemigonus crysoleucas</i>	golden shiner
LC	<i>Couesius plumbeus</i>	lake chub
TSSB	<i>Gasterosteus aculeatus</i>	three spine stickleback
WS	<i>Catostomus commersoni</i>	white sucker

Table B-2. Stream velocity codes.

Code	Value
Calm	< 0.5 m/s
Moderate	> 0.5 m/s and < 1 m/s
Fast	> 1 m/s

Table B-3. Stream shade codes.

Code	Percent Coverage
non existent	0 - 20
poor	21 - 40
fair	41 - 60
good	61 - 80
excellent	81 - 100

Table B-4. Habitat types and their characteristics.

Habitat Type	Characteristics
Flat	long, wide, slow flowing, gentle slope and unbroken (smooth) water surface
Riffle	shallow, fast flowing, shallow depth, marked gradient and broken water surface
Run	intermediate to flats and riffles
Pool	long, wide, slow flowing, negligible slope and deeper than flats

Table B-5. Other codes used for report.

Code	Definition
LCC	lower caudal clip
UCC	upper caudal clip
LCC + UCC	lower caudal clip and upper caudal clip
T-T#	Tributary One - temperature station #
O-T#	Otter Brook -temperature station #
T-M#	Tributary One - minnow-trap station #
O-M#	Otter Brook - minnow-trap station #
N-D#	New - Dam #