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The Catamaran Brook (New Brunswick) Habitat Research Project: Biological, Physical and Chemical Conditions (1990-1992)

Cunjak, R.A, D. Caissie, N. El-Jabi, P. Hardie, J.H. Conlon,
T.L. Pollock, D.J. Giberson, and S. Komadina-Douthwright

Department of Fisheries and Oceans
Gulf Region, Science Branch
Fish Habitat and Enhancement Division
P.O. Box 5030, Moncton, N.B., E1C 9B6

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The Catamaran Brook (New Brunswick) Habitat Research Project: Biological, Physical and Chemical Conditions (1990-1992)[1]

by

R.A. Cunjak[2], D. Caissie[2], N. El-Jabi[3], P. Hardie[2], J.H. Conlon[2],
T.L. Pollock[4], D.J. Giberson[5], and S. Komadina-Douthwright[2]

Department of Fisheries and Oceans
Gulf Region, Science Branch
Fish Habitat and Enhancement Division
P.O. Box 5030, Moncton N.B., E1C 9B6

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[1] Contribution No. 5 of the Catamaran Brook Habitat Research Project
[2] Department of Fisheries and Oceans, Gulf Region
[3] Université de Moncton, École de génie, Moncton, NB, E1A 3E9
[4] Environment Canada, Water Quality Branch, Moncton, NB, E1E 1E1
[5] University of Prince Edward Island, Department of Biology, Charlottetown, PEI, C1A 4P3

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ABSTRACT

Cunjak, R.A., D. Caissie, N. El-Jabi, P. Hardie, J.H. Conlon, T.L. Pollock, D.J. Giberson, and S. Komadina-Douthwright. 1993. The Catamaran Brook (New Brunswick) Habitat Research Project: Biological, Physical and Chemical Conditions (1990-1992). Can. Tech. Rep. Fish. Aquat. Sci. 1914: 81p.

The Catamaran Brook project is a long-term (15 y) multi-disciplinary research study of a small stream basin (50 km^2) in the Miramichi River catchment of New Brunswick. The aim of the study is to quantify the effects of timber harvest on the aquatic [illegible] and their habitat. Initiated in 1990 by a group of seven agencies, the project has grown rapidly and, in 1993, involves 3 federal and 2 provincial government departments, 8 universities and colleges, 1 industry, and 4 private organizations. Biological, physical and chemical conditions are detailed at spatial scales of stream basin, reach, and habitat-type, as measured between 1990 and 1992. Where possible, integration of the various sources of data is emphasized. For example, temporal changes in fish movement at the counting-fence or of fish densities are compared with hydrologic dynamics within the basin and with site-specific physical habitat characteristics. Storm events are closely monitored for quantifying the inter-relationships between meteorological variables, stream discharge pattern, water chemistry, and suspended sediments. These data will form part of the baseline studies of natural environmental variability to be used for detecting changes due to forestry activity, scheduled to begin in 1995. Finally, the report provides a synopsis of the variety of research activities undertaken between 1990 and 1992, and ongoing.

RÉSUMÉ

Cunjak, R.A., D. Caissie, N. El-Jabi, P. Hardie, J.H. Conlon, T.L. Pollock, D.J. Giberson, and S. Komadina-Douthwright. 1993. The Catamaran Brook (New Brunswick) Habitat Research Project: Biological, Physical and Chemical Conditions (1990-1992). Can. Tech. Rep. Fish. Aquat. Sci. 1914: 81p.

Le projet du ruisseau Catamaran Brook constitue une approche de recherche multidisciplinaire à long terme (15 ans) d'un petit ruisseau (50 km^2) du bassin versant de la rivière Miramichi au Nouveau-Brunswick. Cette étude à pour objectif d'étudier les impacts sur l'habitat du poisson dus aux travaux forestiers. Initié par sept agences en 1990, ce projet regroupe en 1993 trois ministères fédéraux et deux ministères provinciaux, huit universités et collèges, une compagnie industrielle et quatre agences privées. Le présent rapport fournit des détails sur les analyses biologiques, physiques et chimiques effectuées sur différents tronçons du cours d'eau et types d'habitat de 1990 à 1992. Lorsque possible, une intégration multidisciplinaire dans les analyses de données à été effectuée. Par exemple, les changements temporelles du mouvement des poissons à la barrière de dénombrement ou les changements dans les densités de poisson ont été comparés avec les variations hydrologiques au niveau du bassin versant et des unités spécifiques d'habitat. Les tempêtes sont observées de près afin de quantifier les interactions entre les variables météorologiques, le débit du cours d'eau, la qualité des eaux et les sédiments en suspension. Ces données feront partie de la base des informations dans les études de variabilités naturelles et pour détecter des changements dus aux activités forestières qui débuteront en 1995. Finalement, le rapport fournit également un sommaire des différentes activités de 1990 à 1992 et des activités en cours.

1.0 INTRODUCTION

The Catamaran Brook project is a long-term (15 year) multi-disciplinary research study of a small stream catchment (50 km^2) in the Miramichi River system of New Brunswick. With a primary focus on the aquatic biota (particularly salmonid fishes) and their habitats, the broad objective of the study is to quantify the effects of timber harvest. Initiated in 1990, the project has grown quickly and has developed into a truly multidisciplinary project involving many agencies and individuals from various disciplines (Appendix 1) to investigate aquatic as well as terrestrial and atmospheric components, and their inter-relationships.

Cunjak et al. (1990) described the general characteristics of the basin and the study design. Briefly, the project comprises three phases. A 5-year, pre-logging phase (1990-1994) to collect background data will serve as the basis for comparison with the logging phase (1995-1999). Schindler (1987) discussed the importance of such long-term baseline studies of ecosystems for detecting the effects of anthropogenic stress in relation to natural variations in the environment. Within the logging (or "treatment") phase, studies will involve investigation of the effects of road construction/access (1995) as well as timber harvest per se (1996-1999) in pre-determined harvest blocks which constitute approximately 12% of the stream basin. The third phase, or post-logging phase (2000-2004), will serve as a post-treatment assessment of habitat changes and a period for testing hypotheses developed during the previous years.

The purpose of this report is to provide a summary of research activities undertaken during the first three years of study. Exhaustive data analyses and complete descriptions of scientific methodologies are not contained herein but will be the focus of subsequent publications. In addition to providing a means for characterizing the physical, chemical and biological components of the ecosystem, this report serves the equally valuable role of data management and organization. With so many sub-projects and agencies involved, a massive amount of data has been generated. This is largely a function of the variety of studies being carried out at Catamaran Brook, which are pictorially represented in Figure 1. Our decision to summarize and publish this information now (rather than at the end of the pre-logging phase in 1994) was to provide a preliminary view of developing trends which could, thereby, be more precisely addressed within the next 2 years prior to the commencement of logging activities.

The report has been organized by general discipline (i.e. biological, physical, and chemical studies) in order to facilitate presentation and interpretation by the different individuals involved. It does not imply a separation of these various disciplines as is too often the case in ecosystem studies. Indeed, one goal of the project is to integrate the data from various sources to better explain observed phenomena. Many examples of such integration can be found in the respective sections of the present report.

2.0 THE STUDY DESIGN

The general plan of study and description of the basin characteristics were outlined by Cunjak et al. (1990). The present section provides the detail of the adopted plan and the various scales of study together with the rationale for the choices.

2.1 The Stream Reaches

Four stream reaches were chosen for the study (Figure 2) based on their proximity to the proposed timber harvest blocks in the catchment (see Figure 3 in Cunjak et al. 1990). The **Upper Reach**, near the headwaters of Catamaran Brook, includes the lower section of the Catamaran Lake Outflow (CLO) tributary and that section of the main watercourse (flowing easterly) extending from the confluence with the outflow tributary and 150 m upstream. The CLO branch will serve as an "immediate (or proximal) impact" zone for monitoring any impacts from the proposed timber harvest in the adjacent Timber Management Block (TMB) #2021. These data will be compared with those collected in the "control" section in Catamaran Brook, above the confluence. Water discharge in the two branches averages 0.227 and 0.201 $m^3 \cdot s^{-1}$, respectively, although gradient is somewhat higher in the CLO branch (Figure 3).

The **Gorge Reach** is located approximately 5 km upstream from the mouth of the brook and 1 km downstream from the mouth of Tributary One (Figure 2). The Gorge Reach serves as the second "immediate impact" zone for the proposed TMB #2036 located along the south side of the brook here. This reach is characterized by a steep gradient (Figure 3) and a prevalence of bedrock exposure in the stream. The average flow for the Gorge Reach is approximately 0.892 $m^3 \cdot s^{-1}$.

The **Lower Reach** (lower 2 km of brook) and the **Middle Reach** (near mid-basin) both serve as "reduced impact" zones because of their locations distant from any proposed harvest blocks. Hypothesizing that impacts will be greatest near to harvest areas, the resultant data from these reaches will be compared with those from the Upper and Gorge Reaches. The Middle Reach, because of its location (Figure 2), serves a second function of "control" for the downstream Gorge (treatment) Reach. Both the Middle and Lower Reaches have relatively low stream gradients (Figure 3) with mean annual discharges in the former of approximately half that of the latter at 0.686 and 1.23 $m^3 \cdot s^{-1}$, respectively.

2.2 Habitat-types

Site-specific studies are performed at the spatial level of habitat-type. Four habitat-types have been identified in the Catamaran Brook: a) flats, b) riffles, c) runs and d) pools. Initially, habitat-types were identified visually and then their physical characteristics were measured.

Flats are typically long, wide, slow-flowing sections of the stream with a nearly homogenous substrate of small-medium particle sizes throughout the area; they have a very gentle slope with an unbroken (smooth) water surface. Riffles are shallow, fast-flowing sections of stream with a relatively shallow depth, marked gradient, a broken (turbulent) water surface and heterogenous substrate often with significant amount of rubble and boulder. The runs are intermediate to flats and riffles and are characterized by heterogenous flow patterns and substrate sizes, are usually deeper than riffles and shallower than flats. In the Gorge and Lower Reaches, where bedrock predominates in some stream sections, separate "bedrock run" sites were also chosen for study. Pools, like flats, are slow-flowing stream sections but, unlike the former, pools are more depositional in character with an obvious reduction in mean water velocity relative to adjacent habitat-types; this is reflected in the predominant particle sizes of the substrate which includes significant amounts of sands and fines (silt). In general, pools have negligible slopes and the greatest average depth of all habitat-types.

Replicates of habitat-types were selected in each reach. In all, 30 sites were monitored during the first three years of the project. The physical characteristics of representative habitat-types are presented in Table 1. Average width generally increases from headwaters to the Lower Reach (Table 1). Riffles have a steeper gradient with all the slopes greater than 1.2 % (Table 1). The slopes for the flats are quite gentle, ranging from 0.090 to 0.213 %; runs have slopes in the range of 0.6 %. However, some runs have slopes as steep as 0.851 % (such as for MRU1) whereas others have negligible slopes (e.g. LBRU2).

2.3 Habitat Surveys

Having established the criteria for designating the various habitat-types in Catamaran Brook (see above), it was then possible to quantify the representation of each within the complete watercourse. These data would subsequently be useful for extrapolating fish density and production estimates for the entire stream. Further, the relative frequencies and areal percentages of the different habitat-types could be monitored over time to note changes among reaches and changes related to environmental impacts. Therefore, the area of each habitat-type was measured in August, 1991, during low water conditions. The survey began from an impassable barrier to fish migration (waterfall) on the CLO tributary 1.5 km upstream of its confluence with Catamaran Brook and continued along the main watercourse downstream to the counting-fence (approximately 15 km). Calculated areas were the product of thalweg length (m) and average width (from 3-5 measurements per habitat-type). It was decided to repeat the survey every second year during low flow conditions, and following the July electrofishing surveys.

Results from the 1991 habitat survey are shown in Table 2. Riffles and runs are the predominant habitat-types in all reaches, with runs being the most frequent and constituting the most area of stream in Catamaran Brook. Flats are moderately abundant in the Upper Reach but they comprise a significant amount of available habitat in the Lower Reach, probably a function of the lower gradient in this section of stream. Pools are rare in all reaches.

3.0 PHYSICAL STUDIES

To best understand the effects of forestry practices on aquatic habitat, one has to study how physical factors (such as precipitation and climate) influence streamflow. As previous researchers have shown, timber harvest can modify streamflow (Bosch and Hewlett 1982) and changes in streamflow can subsequently modify instream physical habitats (Bovee 1982).

To monitor these changes, climatic and hydrologic data have been collected for 3 years at Catamaran Brook. Because the research basin is situated close to climatic and hydrologic stations operated by Environment Canada since the mid-1960's, data from these stations will be used for regional comparisons and as a historical database. Many site-specific physical data from Catamaran Brook have also been collected (e.g. stream depth and velocity, substrate measurements, and others).

3.1 Meteorology

To establish the climatic conditions, and ultimately the hydrologic budget of the Catamaran Brook basin, a primary meteorological station was installed at mid-basin (see Figure 3 in Cunjak et al. 1990) and has been in operation since February 1990. The station monitors the following variables: air temperature, relative humidity, solar radiation, wind speed and direction, precipitation (liquid and solid), snow depth, barometric pressure, dew point, groundwater depth, and groundwater temperature.

Historical data on air temperature and precipitation have been collected from the nearby McGraw Brook DNR station since 1969. Annual precipitation (Figure 4) ranged between 860 mm in 1971 and 1365 mm in 1974, a significant difference of 505 mm. The long-term average precipitation (excluding 1972) was calculated at 1142 mm, with a coefficient of variation of 0.134. Annual precipitation measured in the Catamaran Brook basin was above average for 1990 and 1991 at 1287 mm and 1301 mm, respectively, and below average for 1992, at 1011 mm. As described in Bobee and Ashkar (1991), the Wald-Wolfowitz's (1943) non-parametric test for independence was performed on the mean annual precipitation data from 1973 to 1992. The independence was accepted at a 5% level of significance. Therefore no autocorrelation was detected in the data. The Grubbs and Beck (1972) outlier test was also performed and no outliers were detected at a 10% confidence level.

Table 3 presents the monthly precipitation distribution for 1990 to 1992 and long-term monthly statistics from 1969 to 1992 using data from the McGraw Brook meteorological station. Monthly precipitation amounts to approximately 90 to 110 mm except for February which receives only 71.7 mm on average (Table 3).

The lowest recorded monthly precipitation in the Catamaran Brook region was observed in January 1970 at only 7.1 mm; the lowest monthly precipitation recorded during the course of the project was 34.1 mm in December 1992. The highest recorded monthly precipitation was observed in August 1991, at 245.2 mm. During August 1991, one particular event was responsible for 108 mm of rain in 14 hours. This was the result of Hurricane Bob on August 20, the biggest storm recorded at Catamaran Brook and will be described in detail later.

The long-term minimum, mean monthly, and maximum air temperatures were also calculated by using data from the McGraw Brook DNR station (Table 3). January has the coldest mean monthly temperature with a long-term mean of -11.8 °C, a mean minimum of -18.1 °C and a mean maximum of -5.5 °C. July is the warmest month with a mean monthly temperature of 18.8 °C, a mean minimum of 11.8 °C and a mean maximum of 25.7 °C.

Relative to the long-term data set, air temperatures monitored at Catamaran Brook between 1990 and 1992 indicated some extreme values (Table 3). February and July of 1992 experienced the coldest mean monthly temperatures recorded (1969-1992) at -15.3 and 16.1 °C, respectively. However, August of 1990 and December of 1992 had the warmest recorded mean monthly temperatures at 19.9 and -1.8 °C, respectively (Table 3). Since the installation of the meteorological station at Catamaran Brook, the coldest recorded air temperature was -33.9 °C on February 27, 1990, while the warmest temperature was recorded on May 22, 1992, at 35.1 °C.

3.2 Hydrology

Water plays an important role in Catamaran Brook as in all streams, by transporting nutrients and ions, forming the channel, and providing habitat for many species. To monitor discharge, a hydrometric gauge was installed at mid-basin in October 1989 by Environment Canada, as part of their national network. The gauge consists of a stilling well connected to the stream via a pipe. Water level is measured using a float and chart recorder along with a pressure transducer connected to a data logger. Hourly discharge estimates are then obtained using a relation between the water level and a precalibrated rating curve. In the autumn of 1992, a pressure transducer water level recorder was also installed at the mouth of Catamaran Brook.

Long-term historical data on discharge at Catamaran Brook were calculated using prorated values from the Renous River hydrometric station. Figure 5 shows the mean annual flow at Catamaran Brook based on prorated values from the Renous River, except for 1990 and 1991 when actual discharge was measured. The mean annual flow, in the Middle Reach, was estimated at 0.686 $m^3 \cdot s^{-1}$ or 754 mm of runoff with a median flow of 0.331 $m^3 \cdot s^{-1}$. The median flow is less than half of the mean annual flow and 754 mm of runoff represents 66% of the annual precipitation. Figure 5 also shows the annual variability of flow with the highest mean annual flow at 0.977 $m^3 \cdot s^{-1}$. The Wald-Wolfowitz's (1943) non-parametric test for independence was performed on the mean annual flow data and the independence was accepted at a 5% level of significance. Therefore, no autocorrelation was detected in mean annual flow data. An outlier test (Grubbs and Beck 1972) was also performed and no outliers were detected at a 10% confidence level.

Monthly discharge during the first three years of the project ranged from 0.135 $m^3 \cdot s^{-1}$ in July 1991 to 2.18 $m^3 \cdot s^{-1}$ in April and May of 1991 (Table 4). In fact, 1991 experienced both the highest and lowest monthly flows on record. The long-term monthly flows (Table 4) show that the high flow month occurs in May, at 2.15 $m^3 \cdot s^{-1}$, as a result of spring flooding due to snow melt, usually in combination with rainfall events. Although the month of May generally has the highest flows, spring floods can peak in late April.

The low flow month is August with an average flow of 0.256 $m^3 \cdot s^{-1}$ (Table 4). July and September monthly flows are often of similar magnitude to August. Low flows can also be experienced in winter, as seen for February of 1991 and 1992. On a longer term, January has the lowest winter flow at 0.283 $m^3 \cdot s^{-1}$, only 11% higher than August, the lowest flow month. Winter low flows, therefore, can be as important as the summer low flows in terms of effects on aquatic habitat, especially when ice conditions are factored into the equation.

The discharge hydrograph can show marked variability within months and between years. This was obvious from 1990 to 1992 at Catamaran Brook (Figure 6). During the spring flood period of late April to early May, an extreme flood of 13.0 $m^3 \cdot s^{-1}$ was recorded on May 3, 1991 (not shown on Figure 6 as it exceeds the range of the graph). The 1992 spring flood was unusual as the discharge increased to only 3.2 $m^3 \cdot s^{-1}$. The lowest daily flows on record occurred July 31 - August 1 of 1991, and also on October 10, 1992, at 0.036 $m^3 \cdot s^{-1}$ for both years.

Floods have been found to have many effects on fishes and aquatic invertebrates (Pearson et al. 1992; Erman et al. 1988). To obtain some insight into flooding and its possible effects on fish habitats at Catamaran Brook, a flood frequency analysis was performed using long-term, prorated discharges from the Renous River (an adjacent river basin). To carry out the flood frequency analysis, three different types of probability distributions were used to fit the annual flood series data as describe by Kite (1978); the 3 parameter lognormal, the Type I extremal, and the Pearson type III distribution function. A partial duration series analysis (Caissie and El-Jabi 1991) was also performed. Flood frequency analysis for Catamaran Brook was performed for recurrence intervals ranging from 2 to 100 years (Table 5). The median value from the different distribution functions was used to estimate floods for each recurrence interval. The 2-year flood was estimated at 6.1 $m^3 \cdot s^{-1}$ with the estimate for the 100-year flood at 16.2 $m^3 \cdot s^{-1}$. The magnitude of the May 3, 1991 flood, at 13.0 $m^3 \cdot s^{-1}$, would be between that of a 20 and 50-year flood event (Table 5). It should be noted that the accuracy of the flood estimate decreases as the recurrence interval increases, and a recurrence interval of 50 years represents an extrapolation. This is due to the number of years of data used for the analysis which was 25 (1966-91).

As much as high flows can affect fish population, the low flow period is also very important, especially when it is coupled with high water temperatures in the summer or very cold temperatures during winter. A low flow frequency analysis was carried out using the Type III extremal distribution function (Kite 1978). The 1, 7 and 14-day low flow are presented (Table 6) because unlike flooding, low flows occur over a longer period of time. The 7-day low flow, for instance, represents a moving average of 7 days for which the minimum flow of each year was selected and fitted to the distribution function listed above. The 2-year 1-day low flow for Catamaran Brook was estimated at 0.063 $m^3 \cdot s^{-1}$ while the 5 year low flow was estimated at 0.037 $m^3 \cdot s^{-1}$ (Table 6). The 14-day low flow is greater than the 1-day low flow, however, the difference is relatively small (in the range of 30%). The lowest flow recorded, to date, at Catamaran Brook was 0.036 $m^3 \cdot s^{-1}$, estimated to be within the range of a 5-year low flow.

3.3 Hurricane Bob

With the instrumentation and data loggers at Catamaran Brook, information is being collected every hour, providing detailed analysis of particular events, such as storms. To illustrate how hydrologic information from the stream gauge and data collected at the meteorological station can be linked with each other, the passing of Hurricane Bob through the Catamaran basin in August 1991 is described (Figure 7).

Hurricane Bob originated in the Bahamas and was followed into New Brunswick by Atmospheric and Environment Service (J.F. Amirault, pers. comm.).

> "A Tropical Depression formed east of the Bahamas Friday morning (August 16) and moved slowly westward then northward, tracking along the east coast of Florida through Friday and Saturday. Gradual strengthening of the system resulted in the depression being upgraded first to Trupical Storm Bob and then to Hurricane Bob. By Saturday afternoon (August 17), Hurricane Bob was about 600 kilometres south of Cape Hatteras and following a north-northeast track. Bob continued on this track through Sunday (August 18) passing just west of Cape Cod Monday afternoon (August 19). Weakened by its encounter with Cape Cod, Bob moved across the Gulf of Maine and made landfall near Brunswick, Maine, Monday evening. The National Hurricane Center (NHC) downgraded Bob to a tropical storm late Monday evening and to an extra-tropical system early Tuesday morning (August 20) as the post-tropical system moved across Chatham, New Brunswick and into the northern Gulf of St Lawrence."

As Hurricane Bob, then downgraded to a tropical storm, approached Catamaran Brook, the barometric pressure fell from a high of 1000 mb on August 19, 1991 to a low of 979 mb on August 20 at 0700h (Figure 7b). The barometric pressure rose again to almost 1005 mb as the storm left the area. Solar radiation reached a maximum of 1919 $kJ{\cdot}m^{-2}$ on August 20, with a daily total of 11646 $kJ{\cdot}m^{-2}$. In contrast, the day following Hurricane Bob was more overcast, with solar radiation reaching a maximum of only 660 $kJ{\cdot}m^{-2}$ and 4791 $kJ{\cdot}m^{-2}$ for the daily total (Figure 7b).

Air temperature and wind speed were inversely related (Figure 7a). Air temperature reached a minimum of 11.9°C at 0100h then increased to a maximum of 13.2°C at 0700h during the peak of the storm (Figure 7a). The air temperature then decreased to 12.0°C at 1000h following the storm and increased to a daily maximum of 16.2°C at 1500h. Hourly wind speeds increased to a maximum of 26.4 $km{\cdot}h^{-1}$ gusting to 52 $km{\cdot}h^{-1}$ at 0300h prior to the storm peak; the wind direction at the time was northeast. By the peak of the storm at 0700h, the winds had diminished to 8 $km{\cdot}h^{-1}$, gusting to 18 $km{\cdot}h^{-1}$ before increasing again during the day (Figure 7a); wind direction had shifted northwest.

Rainfall started late in the day of August 19 and increased to an hourly maximum of 14.7 mm at 0700h, the following day, which corresponded to the peak of storm and lowest barometric pressure (Figure 7c). The total rainfall during the passing of Hurricane Bob was 108 mm in only 14 hours. Based on extreme rainfall statistics for a 12 hour duration, precipitation during Hurricane Bob was estimated to have a recurrence interval of over 100 years (Hogg and Carr 1985).

Discharge increased from a base flow level of 0.095 $m^3{\cdot}s^{-1}$ to a peak of 6.15 $m^3{\cdot}s^{-1}$, while the suspended sediment increased to a maximum of 37 $mg{\cdot}l^{-1}$ (Figure 7c). Suspended sediments measured during Hurricane Bob were the highest recorded at Catamaran Brook (see Tables 7 and 8 for other storm and non-storm events). The suspended sediment peak preceded the discharge peak by approximately 2 hours (Figure 7c). For other storm events at Catamaran Brook, the suspended sediments peak concentrations also precede the discharge peak by 1 to 3 hours. Characterizing such storm events at Catamaran Brook is important for understanding the inter-relationships of meteorologic and hydrologic parameters in a small stream basin. Such an exercise will be especially relevant in the future for relating response curves of discharge and suspended sediments before and after timber harvest, for storm events of similar magnitude.

The description of the events surrounding Hurricane Bob was derived mainly from the meteorological and hydrometric station data situated in mid-basin. However, five other stations equipped with data loggers exist throughout the basin and the following data are being collected every hour: water and air temperature, stream level, precipitation and stream water conductivity. These will permit detailed determinations of localized hydro-meteorological conditions (i.e. at sub-basin level).

3.4 Physical Habitat Characteristics

All the above variables affect habitat by modifying streamflow, water chemistry, discharge, water temperature, etc. To monitor the physical habitat characteristics, hydraulic and cross-sectional data are collected at the same sites as the biological data. The physical characteristics for three representative habitat-types (i.e. riffle, flat and run) in the Middle Reach are shown in Table 9. Each habitat-type ranges in length from 12.5 m (Middle Run 2, MRU2) to 17.3 m (Lower Flat 2, LF2). Other measured variables include date of survey, discharge during the survey, slope of the habitat-type, and others (Table 9). For example, the slope of the riffle was calculated at 2.3% while the run and flat had slopes of 0.6% and 0.1%, respectively. Also presented for each habitat-type, is the surface area, wetted area, volume of water, Froude number, Reynolds number, and substrate size (Table 9).

The substrate sizes identified are D_{50} and D_{84}. D_{50} represents the median substrate diameter (size) while the D_{84} (i.e. 84%) relates more to the variability of the substrate size distribution. MR2 (Riffle) has the highest median substrate size at 8.0 cm while LF2 (Flat) has the lowest, at 4.0 cm (Table 9).

The Reynolds (Re) number is a measure of turbulence, expressed by a dimensionless term that relates the inertial force to the viscous force of a fluid (Chow 1959). The Reynolds number is expressed as:

$$Re=\frac{VD}{\nu} \qquad (3.1)$$

where V is the velocity, D the depth of flow and ν the kinematic viscosity. When the Re < 2000, the flow is laminar, and it is turbulent for values > 2000. The Reynolds number calculated in Table 9 shows that the flow was turbulent for all three sites.

The Froude number (Fr) is another dimensionless parameter in hydraulics that relates inertial to gravitational forces (Chow 1959). The equation is given by:

$$Fr=\frac{V}{\sqrt{gD}} \qquad (3.2)$$

where g is the acceleration due to gravity. When Fr<1, the flow is subcritical and when Fr>1 the flow is supercritical. The flow becomes critical when Fr=1, however, such a Froude number rarely exists as it only passes through unity when the flow changes from supercritical to subcritical, or vice versa. Both Re and Fr are parameters recommended for use in fisheries studies to better understand the physical properties affecting fish habitat (Heede and Rinne 1990).

To calculate the physical habitat characteristics, data from five cross-sections were collected per site. Statistics were calculated on the parameters to show the homogeneity of the habitat units (Table 9). For example, the coefficient of variation (Cv) for stream width at MR2 is 26% in comparison with 4.1% and 7.6% for LF2 and MRU2, respectively, which suggests a more variable stream width for MR2. A more heterogeneous depth pattern was suggested for MRU2 with a Cv of 16.9% compared with 11.1% and 12.0% for MR2 and LF2, respectively. Such a physical habitat cross-sectional analysis makes it possible to compare all the different habitat-types.

3.5 Physical Habitat Modelling

The collected cross-sectional data can be used to simulate the available physical habitat using models such as the Physical Habitat Simulation or PHABSIM (Milhous et al. 1989). PHABSIM is the computer model portion of the Instream Flow Incremental Methodology (IFIM) developed by Bovee (1982). Simulation of habitat is used mainly: a) to study impacts of water withdrawal on fish habitat and populations (i.e. instream flow assessment), and b) to correlate the physical habitat with existing productive capacity of the stream. This latter approach can be used to estimate fish abundance when physical habitat acts as the limiting factor. The PHABSIM model simulates physical habitat variables such as depth, substrate and velocities for different discharges. Based on biological preference of habitat for specific species of fish, a habitat preference curve (values ranging from 0 to 1) is established for each habitat variable (depth, velocity and substrate). A value of 0 indicates no habitat preference by the fish and 1 indicates highly preferable habitat. Using the substrate data with the simulated depth and velocities for different discharge, PHABSIM calculates the overall suitable habitat or Weighted Usable Area (WUA).

Such an analysis was carried out for 20 sites at Catamaran Brook including three different habitat-types (riffles, runs and flats). Figure 8 shows the habitat (WUA) - discharge relation for fry of sites MR2 and MRU2 using PHABSIM (Milhous et al. 1989). The habitat is expressed as an area of suitable habitat (m^2) per 1000 m of stream length. In general, the habitat-discharge curve indicates an increase in usable habitat to a threshold value, followed by a decrease in habitat area as discharge continues to increase. For the three sites at Catamaran Brook, the maximum amount of usable habitat occurs at a discharge similar to the mean annual flow (0.686 $m^3 \cdot s^{-1}$). Riffle, MR2, has more usable habitat space than does the run, MRU2 (Figure 8b). The confidence intervals are influenced by the homogeneity of cross sections in relation to the simulated depth and velocities. The habitat-discharge curve produced by PHABSIM makes the assumption that the stream water temperature is suitable although it could also be incorporated into the modelling equation with depth, velocity and substrate.

3.6 Stream Temperature Modelling

Two approaches exist for modelling stream water temperature: deterministic and stochastic. The deterministic approach predicts stream water temperature using the different physical processes involved in the change of water temperature. The stochastic approach uses a time series analysis technique and predicts future stream water temperature based on the internal structure of the series and using a transfer function that establishes a relationship between air and water temperature.

The deterministic approach used at Catamaran Brook involves an input-output type model based on causative factors that heat and cool stream water. This type of modelling approach for water temperature involves energy budget equations. In such a model, input parameters such as solar radiation, air temperature, evaporation, and precipitation are important.

The present report will only briefly discuss the modelling of stream water temperature using the stochastic approach. For further discussion on the subject at Catamaran Brook the readers are referred to the study of El-Kourdahi (1993).

In the stochastic approach, the seasonal and non-seasonal components of the time series were studied. The nonseasonal component is the part of the series which represents the long-term annual variation of stream temperatures. This component at Catamaran Brook takes the form of a Fourier series given by:

$$f(t)=\frac{A_o}{2}+\sum_{n=1}^{\infty}\left(A_n\cos\frac{2n\pi t}{N}+B_n\sin\frac{2n\pi t}{N}\right) \tag{3.3}$$

where

$$A_n=\frac{2}{N}\sum_{t=1}^{N}f_t\cos\frac{2\pi nt}{N} \tag{3.4}$$

and

$$B_n=\frac{2}{N}\sum_{t=1}^{N}f_t\sin\frac{2\pi nt}{N} \tag{3.5}$$

In equation 3.3, n represents the number of harmonics, Ao/2 the arithmetic mean of function f(t) and N is the number of observations. For the present study, the stream water temperature modelling at Catamaran Brook using only 1 harmonic will be discussed. The calculated equation for nonseasonal variation is given by:

$$\begin{aligned} f(t)= 11.96 - 7.22\cos\frac{2\pi(t-119)}{204} \\ + 2.84\sin\frac{2\pi(t-119)}{204} \end{aligned} \tag{3.6}$$

For the seasonal variation, a Box and Jenkins (1976) type model was calculated using the residuals between the nonseasonal variation and the actual measured water and air temperatures. Using the procedure ARIMA (SAS 1988) the following transfer function was obtained:

$$\begin{aligned} \mathbf{R_e(t) = 1.236\, R_e(t\text{-}1) - 0.355\, R_e(t\text{-}2) + 0.274\, R_a(t)} \\ \mathbf{-0.130\, R_a(t\text{-}1) - 0.066\, R_a(t\text{-}2)} \\ \mathbf{+ a(t) - 0.454\, a(t\text{-}1)} \end{aligned} \tag{3.7}$$

with $R_e(t)$ and $R_a(t)$ being the residual of stream water and air temperature and time t (or day t). The last components of equation a(t) and a(t-1) represents the white noise at time t and t-1. The white noise can be modelled using a random generated number distributed normally with a mean of 0 and standard deviation of 0.72 as calculated by SAS (1988). Finally, the predicted stream water temperature, P_{wt}, is obtained by summation of the seasonal and nonseasonal variations:

$$\mathbf{P_{wt}(t) = R_e(t) + f(t)} \tag{3.8}$$

Figure 9 shows the simulated and measured stream water temperature at Catamaran Brook for the years 1991 and 1992. The smoothed line represents the nonseasonal variation which is the result of the Fourier analysis of equation 3.6 using one harmonic.

The residuals were modelled using equation 3.7 and the predicted stream water temperature was obtained using equation 3.8. A very good fit was obtained for both years. However, in 1991, the model calibration year, stream temperature followed the nonseasonal variation curve very closely with an increase in temperature reaching a maximum on day 202 (Figure 9a). The nonseasonal variation curve has a maximum value on day 210. As pointed out previously, July 1992 was the coldest July since 1969 and the effect on water temperature is evident in Figure 9b. In fact, during 1992, the stream water temperature was below normal from approximately day 175 to day 235. It should be noted that the predictions during the below-normal temperatures of 1992 were very good. This suggest that the model is quite robust in predicting stream water temperature even during abnormal years.

3.7 Snow Depth and Density

Snow is a significant portion of the precipitation contributing to streamflow in Catamaran Brook. Determining snow quantity and its water equivalent is necessary to quantify the hydrologic budget in the Catamaran Basin, and for predicting ground water levels and spring flood events. Present timber harvest practises (i.e. clear-cutting) may affect snow accumulation, melting rates and, subsequently, flood timing and magnitude.

Snow survey plots were selected in 1991 and are monitored bi-monthly during the snow season. Two of these plots are located in harvest blocks scheduled for cutting in 1996. Replicates of these plots were selected in adjacent non-harvest areas, with similar tree species, stem density, canopy closure, slope and aspect. In each plot, ten points are sampled for depth and water content at 2 m intervals along a transect line. Subsequent sampling, within the same season, is carried out on a line parallel to, but 2 m distant from the previous transect line. Monitoring will continue throughout the life of the project.

4.0 WATER CHEMISTRY

The Monitoring and Evaluation Branch of the Water Resources Directorate of Environment Canada has contributed to the Catamaran Brook project by maintaining a stream gauge and by analyzing water samples since the project began in 1990. Water samples are collected on a monthly basis from 3 locations: (i) the Middle Reach, just upstream of the road bridge which is approximately 7 km from the stream mouth; (ii) the Lower Reach, between the counting-fence and the stream mouth; and, (iii) the Little Southwest Miramichi River approximately 50 m upstream from the confluence with Catamaran Brook. Water samples are analyzed for 25 chemical variables (Tables 10, 11, and 12).

The monthly data (Tables 10,11,12), augmented by some storm event data (unpubl.), show that stream water chemistry at the mouth of Catamaran Brook is not significantly different from that in the Middle Reach. However, major ion values in Catamaran Brook are always greater than those in the Little Southwest Miramichi River as can be seen in the time plot of specific conductance (Figure 10). The observed seasonal pattern is typical of groundwater baseflow interrupted by sudden summer events, autumn rains, and spring snowmelt. Average pH in Catamaran Brook is 7.25 and 7.26 for the Middle and Lower Reaches, respectively, whereas pH in the Little Southwest Miramichi River is slightly lower, averaging 6.84. The time plot of alkalinity (Figure 10) demonstrates that Catamaran Brook is sufficiently well-buffered that none of the acidifying events are able to reduce alkalinity to zero, as occurred in the Little Southwest Miramichi River in early May 1991. On that date, the spring spate/snowmelt depressed pH to 5.3, the lowest recorded during our study; pH in Catamaran Brook remained between 6.9 and 7.1 (Tables 10, 11, and 12).

Turbidity is a measure of the water column's ability to scatter light and is most often associated with the suspended sediment load in the water column. That load has the potential to settle out in quiescent sections of the stream and adversely affect fish habitat. Turbidity values <1 are indicative of concentrations which will not impact on fish habitat. The data in Figure 11 all meet that criterion except for one sample collected from the Lower Reach after during the Hurricane Bob event. Data such as these provide the background values for determining the effects of road construction (1995) and timber harvest (1996-1999).

In general, the concentrations of dissolved nitrates, phosphorus, and potassium are close to the laboratory equipment's detection limits (Table 10, 11, and 12) and, therefore, typical of streams draining "healthy" forested catchments. Another important nutrient that may be exported via the water column is dissolved organic carbon (DOC). During those periods where streamflow is derived mainly from groundwater (i.e. at baseflow), concentrations of neither DOC, nor of aluminum, are elevated. This is in accordance with the known insolubility of Al salts at near neutral pH's and further suggests that DOC is being removed from the soil column before it reaches the groundwater. The time plot of Al and DOC in the Lower Reach of Catamaran Brook (Figure 12) does show Al concentrations >0.1 mg·L^{-1} which is the CCME (Canadian Council of Ministers of the Environment) guideline value for the protection of aquatic life. However, the Al is associated with DOC when it is measured at these higher concentrations and, therefore, chemically complexed so as to be unavailable to the aquatic biota.

5.0 BIOLOGICAL STUDIES

The list of fish species found in Catamaran Brook has been expanded from that originally noted at the start of the project (Cunjak et al. 1990). A total of 16 species representing 8 families has been identified (Table 13) based on sampling results from all habitat-types within the catchment, as well as from the counting-fence. Of these, juvenile Atlantic salmon, brook trout, blacknose dace, lake chub, and slimy sculpin are the most common species resident in the brook. Brook trout are most abundant in the Middle and Upper Reaches of the catchment whereas lake chub occur mainly in the Lower Reach, in the pools and deep runs.

5.1 The Fish-Counting Fence

The fish-counting fence used at Catamaran Brook is a single-trap, two compartment design permitting simultaneous capture of upstream and downstream-moving fishes, similar to that described by Mullins et al. (1991). The fence portion consists of a series of vertical conduit pipe, spaced 12 mm apart, angled so as to direct fish and water flow into the trap.

In 1990, the fence was constructed within 50 m of the mouth of Catamaran Brook. However, the relatively narrow width and high banks in this location precluded an efficient operation of the trap and contributed to the damage sustained during a late October flood event. Consequently, the fence was moved to a more suitable location 250 m upstream of the river mouth where it has been operated for the 1991 and 1992 seasons.

Fence operation begins in early May as soon as possible following the spring thaw/freshet while water temperatures are still low (<5°C) and prior to significant fish movement into or out of the brook (Figure 13). The trap is checked at least twice per day; more often during peak migrations. In general, all fish are identified to species (and life-stage for salmonids), measured (fork-length (FL), cm) and weighed following anaesthetization, before being released into the stream. Adult salmon and smolts are handled slightly differently. Adults are identified as grilse (<63 cm FL) or multi-sea-winter (MSW) salmon, sexed on the basis of phenotypic features, sampled for scales, measured (FL) and tagged (beginning in 1992); smolts are only counted, although 5 of every 200 are subsampled for determinations of FL and age (i.e. scales are taken). Operation of the counting-fence ended in mid-November in 1991 and 1992, just prior to freeze-up in the stream and well after the spawning run of salmon (Figure 13).

Capture efficiency at the fence was estimated in 1991 and in 1992 by mark-recapture of down-migrant smolts during May. A sample of 50 smolts was trapped in fyke-nets at a location 300 m upstream of the counting-fence; they were marked with a Panjet dye-innoculator, and released back to the stream. Subsequent recaptures at the counting-fence indicated a trapping efficiency of 70% in 1991 and 86% in 1992 (Table 14). The improvement likely reflects modifications made to the fence/trap design in 1992 based on experience from the previous years. That time of inoperation of the fence (as a result of flood events) declined in 1992 provides further evidence of the improved efficiency of the counting-fence since 1990 (Table 14).

Most of the movement of fish through the counting-fence at Catamaran Brook in 1990 - 1992 occurred during late May and June (Figure 13). The predominant direction of movement was downstream with an annual average of 4,924 fish moving out of Catamaran Brook compared with an average of 1,491 fish moving into the brook each year. This net "loss" of fish from the brook reflects the importance of such tributary streams for spawning, and as juvenile rearing habitats (e.g. for Atlantic salmon, lake chub). However, it should be noted that capture efficiency of the counting-fence is better for downstream-moving fish than for those moving upstream and also more effective for retaining larger individuals (see Symons 1969; Cunjak et al. 1989). Therefore, fence totals in both directions would tend to underestimate very small (e.g. young-of-the-year) emigrants as well as relatively small-bodied fishes (e.g. cyprinids) entering the brook to spawn.

Fish movement generally slows down through August and mid-September before increasing again in the autumn (Figure 13), as water temperatures decline and water discharge generally increases. This autumnal movement is almost exclusively of salmonid species.

A breakdown of fish movement, by family shows that cyprinids were the predominant group of fishes emigrating from Catamaran Brook during June of 1990 and 1991 making up between 82% and 45% of the monthly downstream movement, respectively (Figure 14a,b). However, in 1992, relatively few cyprinids moved downstream in June except for a peak emigration during the last week of the month which coincided with a sudden increase in discharge (Figure 14c). This similarly stimulated other fishes to emigrate from Catamaran Brook (Figure 13). In contrast, in 1992, cyprinids accounted for much (73%) of the upstream movement during June.

Species differences characterized the movement patterns of cyprinids from 1990-1992. In 1990, golden shiners (*Notemigonus crysoleucas*) were the predominant cyprinid species counted through the fence at Catamaran Brook (n=2229 downstream). By 1991, their numbers had dropped significantly such that lake chub (*Couesius plumbeus*) and shiners were equally abundant (n≈580). During 1992, shiner numbers continued to decline (n≈210) whereas lake chub numbers increased with >900 chub entering Catamaran Brook (presumably to spawn) in early to mid-June before emigrating back to the little Southwest Miramichi River from late June through July (Figure 14c). Blacknose dace (*Rhinichthys atratulus*), a common fish species throughout the river system as shown by the electrofishing surveys [illegible] below) shows little movement between the Little Southwest Miramichi River and Catamaran Brook suggesting a more restricted home range and migratory pattern.

It is difficult to explain the inter-annual differences in movement patterns of these spring/summer-spawning fishes. Water temperature regimes were similar during the spring of all three years. Discharge did, however, differ markedly in the spring of 1992, being atypically dry until the freshet at the end of June. Such conditions may have been conducive to an immigration pattern rather than emigration, which was the characteristic situation in 1990 and 1991 when river flows were higher. The marked decline in golden shiner abundance in the lower reaches of Catamaran Brook might be explained by proximity to the Little Southwest Miramichi River. In 1990, the fence was located at the mouth of the stream. Filamentous algae and macrophytes, abundant in the main river but scarce in Catamaran Brook, are essential for spawning of golden shiners (Cooper 1935, in Scott and Crossman 1973). Therefore, movement around the fence in 1990 may have been related to the proximity of suitable spawning habitat nearby, a situation which did not occur in the two subsequent years when the fence was situated farther upstream.

Salmonid fishes are the first fish observed in the fence traps each spring with net movement in a downstream direction. Of these, Atlantic salmon smolts are the most numerous (Figure 15a-c) with the annual number of emigrants ranging between 760 (1990) and 2131 (1992). Based on the trapping efficiency results (Table 14) and assuming similar capture efficiency in 1990 and 1991, the estimated number of smolts leaving Catamaran Brook each year varies from 988 - 2430. Movement of smolts is stimulated by a combination of suitable water temperatures (>5°C daily average) and an increase in discharge. This was particularly evident in mid-May of 1990, when falling water temperatures failed to stimulate smolt emigration despite rising water levels (Figure 15a). Similarly, in the relatively dry spring of 1991, a significant number of smolts were delayed in leaving Catamaran Brook until the third week of June when discharge increased sufficiently (Figure 15c). The fate of these late smolts is unknown with regards to their ability to complete smoltification at so late a date when surface water temperatures in the Miramichi estuary were >15°C. Peak movements generally coincided with mean daily water temperatures of 9-10°C and a discharge near $1 m^3 s^{-1}$.

Smolts from Catamaran Brook have a modal age of 2-3, depending on the year (Table 15). For example, age-2 smolts were numerically dominant in 1991 yet rare in 1992, based on sub-sampling at the counting-fence. This pattern is typical for the Miramichi system (Randall and Paim 1982; Randall et al. 1987; Moore et al. 1992). Mean fork length of smolts in Catamaran Brook was between 11 and 14 cm with the larger smolts being older, on average (Table 15).

Size of smolts increased during the period of emigration in 1990 and 1992; no such increase was obvious in 1991 (Figure 16). The large size and scale circuli of the late-run smolts in 1992 (Figure 16) attest to the rapid growth of these fish while in the stream prior to emigration. Snorkeling observations found these fish to be feeding voraciously on invertebrates and young-of-the-year (YOY) fishes, including salmon which typically emerge **after** the smolt migration. The "normal" timing of emergence seems, therefore, to be adaptive for YOY salmon by avoiding predation by these older conspecifics.

Coincident with, but extending longer than, the smolt out-migration, salmon parr displayed a net movement downstream in each of the three years (Figure 17a-c). Upstream movement of parr was also occurring, but to a lesser extent, with peak upstream movement often coinciding with high water temperatures in June/July (Figure 17a-c). This phenomenon, also observed for trout, will be discussed in more detail below.

A secondary peak in parr movement (both upstream and downstream), during the autumn, was most obvious in 1990 and 1992 (Figure 17a,c). This movement was largely, but not exclusively, associated with the adult spawning run. Indeed, many of the parr were mature (precocious) males (Table 16). Apparently, some parr of Little Southwest Miramichi River origin contributed to the reproductive effort in Catamaran Brook as evidenced by the upstream movement of precocious parr each year. It should be noted that the counts of parr in the autumn are minimum estimates. High water discharge and leaf litter accumulation, typical during October, often necessitate the removal of every second conduit. This situation and the relatively small size of salmon parr reduce the trapping efficiency for this life-stage.

Parr emigration has been noted previously, from other river systems (Buck and Youngson 1982; Chadwick and Léger 1986) including the Miramichi (Saunders 1976). That the migration involves such significant numbers, both into and out of streams such as Catamaran Brook, highlights the need to view riverine production of salmonid fishes as involving more than just smolt output.

Adult Atlantic salmon begin entering Catamaran Brook to spawn in late September with the majority of fish entering during October, often in response to an autumn freshet. Spawning takes place during late October and early November with redds having been identified from the river mouth to upstream of the Middle Reach depending on the year, water levels, and incidence of beaver dams. Grilse (1 sea-winter fish) are 2-3 times as abundant as MSW (multi-sea-winter) salmon in Catamaran Brook and are mainly males whereas MSW salmon are predominantly female (Table 17). Post-spawned salmon (kelts) emigrate from Catamaran Brook soon after spawning, presumably to overwinter in the main stems of the Miramichi system, in the deep pools, which are scarce in Catamaran Brook. For example, in 1992, by the time of fence removal in mid-November, 84% of the adults counted into the stream had already moved out of Catamaran Brook after spawning.

Brook trout (Figure 18), along with Atlantic salmon parr (Figure 16), are among the first fishes to move through the counting-fence in Catamaran Brook each spring, at daily water temperatures as low as 5°C. During 1990, upstream and downstream movements of trout were of similar magnitude through May and June with another, lesser period of movement in the autumn (Figure 18a). However, in mid-July, a marked movement into Catamaran Brook occurred, coincident with low water and high water temperature. A similar peak in upstream movement was noted in mid-June of 1992 (Figure 18c) and, to a lesser degree, in mid-July of 1991 (Figure 18b). In general, brook trout show a net emigration during May, a net immigration during June (some of appear to be sea-run trout), and a secondary period of movement during the autumn, mainly associated with spawning. Of all species enumerated at the counting-fence, brook trout are the only species having a net movement into Catamaran Brook, which was the case in each of the three years (Figure 18).

Closer examination of the upstream movement by brook trout during low water conditions suggests that the movement may be a response to high temperature stress. After 14 July, 1990, maximum water temperature in the Little Southwest Miramichi River measured 23°C and continued to increase for the next few days, peaking at >26°C (Figure 19). During this period (approximately 6 d) of very high water temperature, 139 brook trout entered Catamaran Brook despite the low water levels which generally inhibit fish movement. By comparison, only 71 trout entered the brook during the remainder of the month when water levels (and temperatures) were more favourable. We believe that the immigration was a response to high temperature stress and that the trout were using Catamaran Brook as a thermal refuge with water temperatures being 2-3°C cooler and with more shade cover than in the Little Southwest Miramichi River.

Previous studies (Fry 1951; Cherry et al. 1977; Meisner 1990) have shown that water temperatures of 24-25°C are avoided (or lethal) for brook trout. That this phenomenon of upstream movement was observed in 1991, and again in 1992 during high water temperature conditions, provides further support for our theory. In addition to brook trout, salmon parr were similarly affected. During the high temperature period in July of 1990, 178 salmon parr entered the brook compared with only 50 parr during the other 25 days of the month (Figure 19). These results underline the importance of small streams and seeps as areas of temporary refuge from environmental stressors such as high water temperature.

5.2 Fish Density and Distribution Within Catamaran Brook

Electrofishing surveys are carried out using a Smith-Root Type XI backpack electrofisher (500v, 60 pulses·s^{-1}) in 24 study sites (habitat-types) each summer, in mid-July, when water levels are generally low. Pool sites (6) are excluded and are censused by snorkeling observations. In late autumn (November), electrofishing is repeated at the same study sites as in summer, with the exception of the Gorge Reach sites (8). These sites were not electrofished in 1990-92 due to time constraints, high flows, and freezing conditions. In the autumn of 1992, both pool habitats in the Middle Reach were electrofished for the first time. All surveys involved 3-4 passes, generally using 2 barrier nets (in some cases in the autumn, only a lower barrier net was used). All captured fish were removed during a sweep and retained in a live-box until all sweeps were completed. Fish were then anesthetized, weighed, measured, and sexed phenotypically (if possible); after full recovery , fish were returned to the site. Areal dimensions of the site and water temperature were also measured.

Calculated fish densities (all spp. combined) varied markedly over time (season and year) and space (between habitat-types and stream reaches). Appendix II shows the results of all electrofishing surveys from 1990-1992. In general, highest densities were recorded during the summer; in July, 1991, 4 sites (3 runs and 1 riffle) had densities > 3.2 fish·m^{-2}. Lowest densities are consistently measured in the Upper Reach, varying between 0.15 and 1.1 fish·m^{-2}.

Inter-seasonal comparisons of total fish density among the habitat-types (Figure 20a-c) show that runs and riffles were more important to fish in the summer than the autumn whereas flats were better used in the autumn. The autumnal use of flats was more obvious in the Middle Reach which we attribute to the deeper, slower nature of these flats compared with those in the Lower Reach. If overwintering fishes prefer habitats where energy expenditure would be minimized (e.g. Bustard and Narver 1975; Cunjak and Power 1986a), then deep flats and pools would provide such conditions. In contrast, the shallow, fast flow environment of a riffle may be less preferable for overwintering as suggested by the low densities of fish measured in riffles in November of each year (Figure 20). The microhabitat heterogeneity which is characteristic of runs may explain the high densities in this habitat-type relative to others, within any season or reach (Figure 20).

The extremely high densities measured in the summer of 1991 had virtually disappeared by the autumn when fish densities declined to values similar to other years (Figure 20). The only explanation offered for the observed reduction is the high discharge realized during August of 1991, associated with Hurricane Bob (Figure 7c). This sudden storm and subsequent flooding were higher than experienced during 1990 or 1992 and may have reduced stream populations of fishes directly by injury, or by displacement from the brook. Elwood and Waters (1969), Hoopes (1975), and Erman et al. (1988) have also documented the reduction in stream fish populations due to flood events.

Densities of different age-classes of juvenile Atlantic salmon between 1990 and 1992 showed that YOY salmon were absent in the Upper Reach sites except in the autumn of 1991 (Figures 21 and 22) when 4 YOY were captured at 2 sites. That no fry were found here in the summer of 1991 (Figure 21) suggests that these fry moved here late in the season from downstream in Catamaran Brook where spawning occurred in the autumn of 1990. The occurrence of salmon parr (1+ and older) in the Upper Reach in all 3 years (Figures 21, 22) supports the theory that larger (older) juvenile salmon will move upstream to colonize areas not accessed by adult spawners. Similar results have been noted for Newfoundland streams (R.J. Gibson, D.F.O., St. John's, Nfld., pers. comm.). The scarcity of YOY salmon in the Middle Reach in 1990 (Figures 21 and 22) was likely the result of mainstem beaver dams found between the Middle and Gorge Reaches in the autumn of 1989 (Cunjak et al. 1990) which may have precluded access by spawning salmon.

YOY densities were very high during the summer of 1991 (Figure 21) with > 2.3 fry·m^{-2} recorded from some sites in the Gorge and Lower Reaches. However, by the autumn, the dominance of 1991 YOY had declined markedly, particularly in the Lower Reach (Figure 22). This may be a consequence of the mid-summer flooding associated with Hurricane Bob, as discussed above. Inter-seasonal comparisons of YOY densities show that riffles decline in use from summer to autumn when flats and runs are relatively more important (Figures 21 and 22).

The lack of spawning above the Gorge Reach in 1989 was evident in the low densities of 1+ salmon parr in the Middle Reach in 1991 (Figures 21 and 22) and of 2+ parr in the summer of 1992 (Figure 21). What is more difficult to explain is the summer scarcity of 2+ parr in 1992 in the Gorge and Lower Reach sites which were below the beaver dam barrier in 1989 and where 1+ densities were average (or better) in the previous autumn (1991). That winter mortality would explain the decline seems unlikely as 1+ parr and age-3 smolts (which presumably would have been similarly affected) were abundant in the summer and spring of 1992, respectively (Figures 15 and 21). Emigration as smolts in the spring of 1992 also does not explain the summer scarcity of this cohort as very few age-2 smolts were identified (Table 15).

Of further interest is the apparent *increase* in density of 2+ parr in the autumn of 1992 (Figure 22). The most likely explanation is that these were immigrant, mainly precocious, male parr from the Little Southwest Miramichi River which entered the river as part of the spawning run into Catamaran Brook (see Figure 17c). Large numbers of precocious parr were moving through the fence in October and November of 1992, more than the previous 2 years (Table 16). Examination of parr captured during electrofishing also showed a high incidence of precocious males among 2+ parr in 1992 (Table 18). Many of these immigrant parr, however, were immature. Their occurrence (specifically their diurnal activity at low water temperatures) was puzzling (see Rimmer et al. 1983; Cunjak 1988) although many were found to have distended stomachs full of salmon eggs. It is tempting to speculate that such a food resource (i.e. eggs) might be the stimulus for movement into the brook for some of the parr.

Electrofishing in July after emergence of fry, and again in November at the end of the growing season, permits an assessment of growth rates and of size-at-age comparisons betwen years and stream reaches. For example, mean size attained by YOY salmon in November was consistently greater in 1990 compared with subsequent years, for both Lower and Middle Reaches (Figure 23). Water temperatures during the growing season in 1990 indicated fewer extreme high temperatures than in 1991 and a thermal environment more more favourable for growth compared with the cool conditions experienced in 1992. These conditions may have created a longer growing season in 1990 which resulted in larger mean sizes for YOY salmon about to experience their first winter as free-swimming fishes. The importance of size for winter survival has been documented for a variety of fish species including salmonids (Mason 1976; Toneys and Coble 1979; Post and Evans 1989) and is especially critical for YOY salmon (Lindroth 1965).

A comparison between stream reaches suggests that the Middle Reach provided more favourable growing conditions than the Lower Reach, for YOY and 1+ salmon (Figure 23). In 5 of 6 cases, mean size-at-age in November was greater in the Middle Reach; the only exception was for 1+ salmon in 1990 which may reflect the markedly higher summer densities of 1+ salmon in the Middle Reach compared with the Lower Reach that year (Figure 21b). Similarly, a lack of density-dependent effects may explain the large mean size (5.8 cm FL) attained by YOY salmon in the Middle Reach in 1990 (Figure 23), a consequence of the beaver dam downstream which precluded spawning in the Middle Reach the previous autumn (see above). Also, the Middle Reach is characterized by groundwater discharge zones, more so than the Lower Reach (unpubl. data). These conditions tend to moderate the thermal regime (Meisner 1990) and generally improve growing conditions (Hunt 1969; Edwards et al. 1979).

Appendix III provides a table summarizing the mean sizes attained at the end of the growing season by each age-class of Atlantic salmon, by stream reach and year. Age-class separation was determined after examination of length-frequency distributions. It will be noted that, in 1991, the largest mean size of YOY was measured in the Upper Reach (6.1 cm FL, n=9). As there is no spawning in the immediate area (note absence of summer densities of YOY each year - Figure 21), we believe that this finding is an artifact of upstream colonization by larger members of the cohort rather than a reflection of optimal growing conditions in the reach.

5.3 Snorkeling Observations

Monthly snorkeling observations began in 1991 (July, September, and November), in the pool habitats, to supplement the electrofishing surveys for censusing fish abundance and distribution in Catamaran Brook. Generally, pool habitats are too deep to effectively electrofish (>1.5m). In 1992, the frequency and duration of observations were increased (monthly from May - November) to provide a more seasonal assessment of abundance and distribution. This protocol will be followed each year in the future. In addition to quantifying abundance, fish behaviour (specifically position choice and agonistic interactions) were noted during the underwater observations.

Preliminary results of observations made during 1991 and 1992 are summarized in Table 19. During the May & June, 1992 dives, when water temperatures ≤9°C, few fish were seen actively swimming or positioned above the stream substrate during the day in the pools, or elsewhere. Gibson (1978), Rimmer et al. (1983), Cunjak (1988), and Cunjak and Power (1986a,b) have noted the same for Atlantic salmon and cyprinids. The exception to this was salmon smolts which were abundant and active, often in aggregations, in pools and runs in the Lower Reach.

During July and August, salmon fry and parr were abundant in pools in all three reaches but especially in the Middle and Lower Reach pools (Table 19). Salmon and dace were most common in the Lower and Gorge Reach pools whereas brook trout were also common in the Middle Reach pools. Groundwater discharge is most prevalent in the Middle Reach (unpubl. data) and is often associated with preferred brook trout habitat (Cunjak and Power 1986a; Hunt 1969). It should be noted that the counts given in Table 19 are underestimates of actual population size in the pools. In 1993, electrofishing surveys will follow snorkeling surveys in the 2 Middle Reach pools, in July, to compare the two counts, similar to the method employed by Cunjak et al. (1988).

By September, fish abundance had generally declined in all pools relative to July and August (Table 19). By October, when spawning adult salmon were common in the Lower Reach, significant numbers of salmon fry and parr were still seen actively swimming or holding stationary positions at water temperatures of 3-4°C (Table 19). Typically, salmon parr are assumed to be photonegative and occupy positions beneath stones at these low water temperatures (Cunjak 1988; Rimmer and Paim 1990). As noted in Section 4.2, many precocious parr were active at this time and could account for some of the parr observed underwater. However, immature parr and fry require another explanation. Some were found to be feeding on salmon eggs at this time (see Section 5.2). Perhaps, the typical winter behaviour pattern is delayed for some juvenile salmon attempting to take advantage of this high energy food resource. By November, at near-freezing water temperatures and following spawning, no fish other than salmon kelts were seen underwater.

In 1992, microhabitat measurements associated with fish positions were made during monthly snorkeling observations in each of four habitat-types in the Lower Reach (i.e. riffle, run, flat, pool). This practice will continue in 1993 and in 1994. The purpose of this exercise is to develop habitat suitability curves (as per Bovee 1982) specific for Catamaran Brook fishes, and life-stages, for use in refining Weighted Usable Area (WUA) estimates within the PHABSIM model (see Section 3).

5.4 Fish Census of the Pools

In 1992, baited minnow-traps (4 per site) were set in each of 6 study pools in the Middle, Gorge, and Lower Reaches of Catamaran Brook. Traps were set for 2-3d duration at approximately monthly intervals between late-May and September. All fish species captured from May - July were given fin-clips unique for the particular study site. In addition, fish were identified and measured (FL) before release. The objective of the study was to quantify fish populations in the pool habitats for comparison with the snorkeling observations (see Section 5.3).

In total, 333 fish were captured in the minnow-traps during the 1992 study, of which 99% were represented by 4 species - Atlantic salmon, brook trout, blacknose dace, and lake chub. Lake chub were most numerous although they were absent from the Middle Reach pools (Table 20) which suggests that the beaver dams between the Gorge and Middle Reaches act as a barrier to upstream movement by this species. The abundance of chub in the pools is in marked contrast to the snorkeling results wherein no lake chub were observed during 1992, or 1991. That lake chub were nocturnally active, or at least crepuscular, could serve as explanation, although the literature suggests otherwise (Kavaliers 1981; Kavaliers and Ross 1981). Possibly, the presence of potential competitors and/or predators has led to the adoption of a facultatively nocturnal activity pattern. This phenomenon certainly warrants further investigation.

Atlantic salmon and blacknose dace were present in all three stream reaches whereas brook trout most common in the Middle Reach pools (Table 20). The distribution of these other fish species confirmed the findings from the snorkeling observations. As noted above, the Middle Reach is near to groundwater discharge; this factor and the greater amount of instream cover, especially woody debris, in the Middle Reach pools may produce preferred habitat for brook trout in Catamaran Brook.

Preliminary examination of the frequency of recaptures for the different species between May and late August indicates that lake chub had greatest fidelity for the pools they occupied; 22 of 73 chub marked were subsequently recaptured (30% fidelity), in the same pool, or in the replicate pool of the same reach. Blacknose dace were more mobile showing the least fidelity for the pools within which they were marked; only 1 recapture of the 44 marked (2% fidelity). Fidelity of salmon and of trout were also low, at 11% and 7%, respectively.

5.5 Woody Debris

Coarse Woody Debris (CWD) is an important component of, stream ecosystems (Bilby and Ward

1989) and (Robison and Beschta 1990). It can effect stream morphology by changing or stabilizing stream structure. Through retention of organic and inorganic particulate matter CWD contributes to overall stream productivity. Accumulations of CWD create both micro- and macro-habitats and provide cover for many fish species as well as creating impediments to fish movements.

To assess possible changes in the quantity and quality of CWD due to timber harvest, annual CWD surveys throughout the four different reaches of Catamaran Brook were carried out (Figure 2). All debris items, (> 10 cm diameter and > 2 m in length) are measured for overall length, butt diameter, mid diameter, and length in water; stream width is measured at each item location; and, the orientation, species and origin of each debris item determined. Log jams, debris dams, and beaver dams are identified and the surface area of these structures are calculated. Beginning in 1992, representative items were tagged using numbered plastic tags to track these items over time.

From surveys conducted in 1990-1992, (Table 21) it was observed that the Upper Reach had a greater number of items per length of stream surveyed, and a smaller volume per item, compared with reaches downstream. Similar trends were noted in other streams (Robison and Beschta 1990; Bilby and Ward 1989). Riffle habitats contained a greater number of items than did runs, even though runs are the most common habitat type in Catamaran Brook (Table 2). CWD jams were often associated with pools (Table 21). Balsam Fir (*Abies balsamea*), was the predominant species observed in the brook, with Eastern White Cedar (*Thuja occidentalis*), and Sugar Maple (*Acer saccharum*), close seconds in some areas. Most debris items occurred as blowdowns or deadfalls.

5.6 Sedimentation

One of the presumed effects to stream habitats, as a result of poor forestry practices, is increased erosion and loadings of fine sediments of terrestrial origin. To monitor such increases, we began, in the autumn of 1991, to measure sedimentation rates in various habitat-types during *Phase I* of the project. Whitlock-Vibert plastic boxes were planted in the stream substrate, in triplicate, in all stream reaches according to the technique described by Wesche et al. (1989). A total of 12 habitat-types were chosen for the initial set in late August, 1991. The boxes were removed in early June, 1992 (i.e. 9.5 mo. duration), and the accumulated sediments placed in sample bags for subsequent drying, weighing, and sieving in the laboratory. Boxes were replaced in the stream or, in the case where boxes had been displaced by flood events, new boxes were set in place.

Movement and subsequent settling of the largest particle sizes (>1-2mm diameter) was most common in those habitat-types and reaches where gradient, and hence the ability to entrain a particle of given size (similar to *critical tractive force*, Morisawa 1968), were highest. This included the riffle habitats and the Gorge Reach (Table 22). The similarly high accumulation of large particle sizes in the Upper Reach run was somewhat surprising for this relatively small stream channel but probably reflects the high gradient of the Outflow branch - as high as the Gorge Reach (see profile, Figure 3). The fines were expected to accumulate in the more depositional habitat-types and reaches which was generally found to be the case. Silts (< 0.125 mm ∅) were mostly found in the flat and pool habitats of the low gradient Lower Reach (Table 22).

This collection and monitoring will continue for the remainder of Phase I with one exception. Boxes will now be collected twice per year and the duration of accumulation reduced to 5-7 mo. from 10-11 mo. In general, sedimentation will be measured for the period November - April and May - October.

5.7 Beaver Activity / Impacts

The modification of stream ecosystems by beaver has been well documented (e.g. Naiman et al. 1986; Smith et al. 1991), particularly as it applies to invertebrate production and nutrient cycling in the stream above and below beaver dams. In recent years, with declining fur prices and consequent declines in trapping, beaver numbers have increased markedly in many streams including Catamaran Brook (see Figure 2, Cunjak et al. 1990). Still to be determined, is the impact of beaver activity on fish habitat and production. Stock and Schlosser (1991) noted the short-term negative impacts to a warmwater stream fish community from the collapse of a beaver dam, and Leidholtbruner et al. (1992) noted the effect of beaver dams on distribution of juvenile coho salmon. In Catamaran Brook, our studies have focussed on (1) the changes in the physical and chemical parameters of the stream near to the beaver dam; (2) the loss of fish-producing / rearing habitat above dams where spawners are denied access; and, (3) the ecological consequences (e.g growth, competition) of increased fish density below, and decreased density above, dams for different cohorts of stream fishes.

One of the first studies undertaken was an investigation of the sediments behind beaver dams and the possibility of accumulation of contaminants. The objective was to test for the existence and, if present, to measure the concentration of contaminants such as the insecticide, fenitrothion, and its more toxic predecessor, DDT. Both insecticides were sprayed for many years over much of New Brunswick's forests as a means of controlling the spruce budworm. We hypothesized that, as sediments accumulate for many years behind beaver dams (even after beaver colonies had emigrated), contaminants in the environment could also accumulate, and persist, in these 'sinks'. During the summer of 1991, sediment core samples were taken from 3 locations: (i) in the beaver pond immediately above an old (>20y), abandoned dam just upstream of the Upper Reach; (ii) in a more recent (approx. 10y old) beaver pond in the lower end of Tributary One (near the Middle Reach); and, (iii) in a "control" site from the mainstem of Catamaran Brook, in the Lower Reach.

No traces of polychlorinated biphenyls (PCB's) or of organochlorines were detected in the samples; nor was there any evidence of fenitrothion, or its derivatives in the Catamaran Brook samples. However, DDT and its derivatives were detected, mainly in the beaver pond sediments; only minute traces were found in the mainstem sediments (Table 23). That the concentration of breakdown products (i.e. DDD and DDE) was higher than the parent compound signals that DDT was past its half-life. Highest concentrations were found in the Upper Reach beaver pond, the oldest pond. This pond was probably active prior to the ban placed on the use of DDT in the mid-70's and may explain the high concentrations. DDT and its breakdown products were most often found in the upper strata (within 10 cm of substrate surface) of the sediment cores (Table 23). This may reflect the persistence of these chemicals in the vegetation of the catchment, such as in balsam fir needles (Ayer et al. 1984) subsequently leached and washed into the stream over many years.

A second study of the effects of beaver activity in Catamaran Brrok focussed on changes in water chemistry. Deoxygenation of water behind beaver dams has been reported, especially during winter, under an ice cover, when atmospheric aeration is precluded but microbial (anaerobic) decomposition continues in the organically rich sediments. To investigate this possibility in Catamaran Brook, dissolved oxygen and other chemical parameters were measured weekly in proximity to beaver dams (near the confluence of Tributary One and the main stream) during the winter of 1991/92 (Nov.-Apr.).

Anoxic conditions were not found in the beaver pond waters of the mainstem or in Tributary One (Figure 24). Dissolved oxygen declined soon after formation of an ice cover (week 2) and the depression was most pronounced in the "Old Pond" site of Tributary One (Figure 24). However, the lowest recorded oxygen concentration was still >80% saturation and, hence, would not be a limiting factor for overwintering fishes, including salmonids, in these impounded areas. Similarly, other measured chemical parameters indicated no detrimental effects of the beaver dams, in this regard. Indeed, the impoundment and increased water volume may increase habitat space and availability over winter. For so shallow a stream such as Catamaran Brook, ice thickness can exceed 80 cm and is often in contact with the stream substrate.

The effects of beaver dams as barriers to fish movement, specifically spawning adult salmon, and the subsequent changes in juvenile densities have already been discussed (Section 5.2). In the autumn of 1992, another mainstem dam was built immediately above the Lower Reach sites. This dam served as an effective barrier to upstream movement by spawning adults until a flood event in late October overtopped the dam and permitted some adults to move farther upstream. The effects of this dam will continue to be monitored.

Much of the concern over beaver dams as barriers to movement is focussed on the *upstream* movement of fish. However, smolts must also overcome these obstacles during their *downstream* migration in the spring. During the spring of 1992, we investigated the ability of salmon smolts to get by beaver dams by uniquely marking smolts from above or below beaver dams and subsequently identifying the frequency of recaptures at the counting fence. Using fyke-nets set at night, smolts were captured, marked and released in (i) the Middle Reach which was above 2 mainstem beaver dams, and in (ii) the Gorge Reach (below any dams). Despite below-average spring flows, the beaver dams did <u>not</u> appear to affect downstream movement of salmon smolts (Table 24). This experiment will be continued in 1993.

5.8 Stream Invertebrates

Aquatic invertebrates play a key role in the cycling of energy and nutrients through a stream. Consumers affect nutrient cycling by transporting nutrients from one part of an ecosystem to another, by transforming or modifying nutrient material, and by storing nutrients in consumer standing crop (Merritt et al. 1984). Aquatic insects process nutrients by direct feeding, bioturbation, uptake and excretion of phosphorus and nitrogen, and filtration of material from the water column. The cycling and retention of nutrients varies both with stream type, and along the length of a stream. In 1980, the "River Continuum Concept" was proposed by Vannote et al. (1980) as a framework for describing these changes. Generally, headwater areas are dominated by invertebrates that feed on large particles (shredding invertebrates or collectors feeding on Coarse Particulate Organic Matter, or CPOM) that enter the stream from the adjoining watershed. Invertebrates feeding on these particles, coupled with physical abrasion processes, cause a reduction in particle size as material moves down the stream. In addition, with increasing stream width, riparian processes become less important. Therefore, particle size decreases as stream order increases, and invertebrates become more specialized for capture and assimilation of smaller particles. As a general rule, then, Vannote et al. (1980) suggest that Shredders are usually co-dominant with Collectors in headwater streams, with both groups feeding on CPOM. Collectors, particularly those specializing on FPOM (Fine Particulate Organic Matter) become more abundant as stream size increases, and the food web becomes more dependent upon "leakage" of food resources from upstream. The proportion of invertebrates that are Scrapers (herbivores, feeding on attached algae) should increase with increasing stream width, as riparian shading becomes less important, and more sunlight is allowed to enter the system. Predators remain fairly constant throughout the system (Vannote et al. 1980). Tributaries can modify this pattern (Minshall et al. 1983), and unstable or high gradient rivers also show some differences, particularly with respect to the proportion of large particle shredders.

Investigation of the invertebrate community in Catamaran Brook began in 1990, to characterize the community and trophic pathways in the brook, as background to investigating potential logging impacts on the upper trophic levels. Qualitative invertebrate samples were collected using kick samples from three habitat types (riffle, run, and flat) in the four study reaches in July, August, and October 1990, and every three to four weeks in four habitat types (riffle, run, flat, and pool) from May to December during 1991 and 1992. In 1992, artificial substrate samplers (wire baskets containing *in situ* substrate materials) of known volume were placed in the riffle sites in each reach to obtain a semi-quantitative sample for comparison between sites and sample dates. Also in 1992, emergence traps were place in several sites to monitor emergence phenologies and obtain adults specimens for confirmation of identifications. Only the 1990 samples have been completely processed; samples from 1991 are sorted but not identified, and those from 1992 are currently being sorted.

Samples were collected from Riffle, Run, Flat, and Pool habitats within each reach using a D-ring kick net (Net mesh 500μm in 1990, 200μm for subsequent sampling periods). In the habitats with current, the substrate was disturbed immediately upstream of the net, allowing the current to sweep displaced invertebrates into the net. Five kicks were taken in this matter across the stream. In the pool areas the net was used to disturb the sediment in three areas from the stream bank to the centre of the pool, then the net was swept back and forth through the disturbed area until the water cleared. Samples were collected July 30/31, August 25/29, and October 28/November 3 1990, and every 3 - 4 weeks from the beginning of May to early December in 1991 and 1992. Samples were preserved in the field in 10% Formalin, and returned to the lab for sorting and identification.

The majority of the invertebrates collected from Catamaran Brook in 1990 were aquatic insects, and included representatives from all aquatic insect groups (Table 25). Excluding the Chironomidae, 81 genera in 43 aquatic insect families were found in the creek. The greatest diversity was found in the Ephemeroptera and the Trichoptera, with 23 genera in 8 families and 19 genera in 12 families, respectively (Table 25). Ephemeroptera were also numerically dominant in all samples, comprising approximately half of the invertebrates found in each reach (Figure 25). Note, however, that samples in 1990 were collected only from flowing water sites using a very large mesh net, which would underestimate the presence of smaller taxa and those resticted to pool habitats.

The highest total taxa richness (all sites combined) was found in the lower reach, although the highest site-specific richness was found in the upper reach sites (Table 26). Within the reaches, there was a general trend for higher taxa richness in the areas of moderate current, classified as runs, than in slower current (flats) or rapid current (riffles). Mean numbers of invertebrates per kick were highest in the Middle Reach, particularly in the riffle and run, and within reaches, was generally highest in the fast water sites (Table 26). There was no seasonal pattern in taxa richness, although mean numbers found per kick sample were generally higher in October than in the summer.

Non-insect invertebrates collected from Catamaran Brook in 1990 included Oligochaete worms (Annelida), Turbellarian flatworms (Platyhelminthes), Mites (Arachnida; Hydracarina), and Amphipods (Crustacea). With the exception of the Oligochaetes which were common in the middle and lower reaches, the non-insect invertebrates were generally rare (Table 25).

Invertebrates were separated into feeding groups based upon their mechanism of feeding. There was a trend for Collectors (Collector/gatherers and Collector/filterer categories combined) to have their greatest abundance in the Middle reach, then decline with increasing stream size to the lower reach (Figure 26). Herbivores in the Scraper category increased in relative abundance with increasing stream size, although they too reached their highest abundance in the Middle reach. Shredders did not make up more than 6% of the benthos in any reach, but were most abundant in the Upper reach. Predators declined slightly with increasing stream size, but generally made up 1/5 to 1/4 of the benthos at all sites.

Species richness has been demonstrated to change with stream size and season in a number of mid-latitude temperate streams (Minshall et al. 1985). There are generally more taxa in mid-order stream sites compared to headwaters or higher order streams, and richness was reported to be highest in summer in low-order streams and in autumn in larger streams. These patterns were not noted in Catamaran Brook, however. The highest site-specific taxa richness was found in the upper reach sites, and no seasonal pattern was noted in any site. However, when sites were pooled, there was a tendency for taxa richness to increase with increasing stream size, presumably because of the availability of more habitat types.

Taxa richness in Catamaran Brook appears to fall within the range of that generally reported for mid-lattitude streams, using the same level of identification as the current study (genus for most, but higher taxonomic level for some groups). The total of 40-44 taxa in the upper reaches and 31-40 taxa in the downstream sites represents the combined total for three sampling periods, and actual numbers of taxa found in a given site on a given sample day ranged from 14-28, and showed no pattern with stream site. Minshall et al. (1985) and Stout and Vandermeer (1975) reported finding 15 to 49 taxa in study streams ranging from 35° to 45° north latitude, with the higher numbers generally found in the mid-sized streams. However, the 1990 Catamaran samples were collected using a relatively large net mesh, and it is likely that small specimens were overlooked, leading to underestimates in estimates of mean number per kick sample and in taxa richness.

The trophic pattern of the invertebrates in the brook did not conform to the predictions of the River Continuum Concept (Vannote et al. 1980), particularly with respect to the Shredder group. Shredders were expected to co-dominate with Collectors in the upper reaches, but were not common in any site, and predators declined in importance with increasing stream size, rather than remaining constant as predicted. The Scraper group showed the predicted pattern of an increase with increasing stream size, but in the headwater zone (Upper Reach), made up a much greater proportion of the benthos than expected given the amount of shading on the stream by riparian vegetation.

These data have a number of implications for the future evaluation of timber harvesting impacts on the lower trophic levels of the stream. This preliminary study indicates that benthic faunal diversity is similar and relatively high (for small streams) in all sites, and that invertebrate abundance is also similar in most sites. Therefore, comparison of forestry impacts on invertebrate diversity and abundance in the different reaches should be valid. Analysis of the trophic patterns within the brook suggests that the herbivore (Scraper) component is important along the entire length of the brook, rather than just in the wider stream sections, as predicted by the River Continuum Concept (RCC). According to the RCC, deforestation should cause a local shift in the physical stream environment downstream; i.e., the stream temperatures should rise, sediment-load increase, CPOM and shredder invertebrates decline, and the trophic pattern shift toward autotrophy (Vannote et al. 1980, Webster et al. 1990, Garman and Moring 1991). Since shredders appear to be relatively unimportant in Catamaran Brook, and autotrophic processes are already important throughout the stream, it is difficult to predict what sort of shift might occur following timber harvest. It is likely that shredders will remain relatively unaffected, and the proportions of collectors and herbivores (scrapers) may depend upon the effect of sedimentation on the amount of sunlight reaching the stream bottom.

Future investigation of the invertebrates in the brook will include monitoring of the benthic populations in all four reaches to confirm trophic patterns and to determine year-to-year variability in abundance and species composition. In addition, the effects of natural disturbance (e.g. floods) on abundance, diversity, and life histories will be evaluated as a basis for future comparison with logging disturbances.

6.0 ADDITIONAL RESEARCH AT CATAMARAN BROOK

The project has, in a few years, already attracted numerous research studies, in addition to those described above. Following are brief summaries of the graduate projects and collaborative efforts completed, and ongoing. Together, they promise a better understanding of the complexities inherent to drainage basin processes and, therefore, the potential of quantifying environmental effects on stream biota.

6.1 Graduate Studies

As of January 1993, 3 M.Sc. (Biology) and 3 M.A.Sc. (Hydrology) projects have been initiated at Catamaran Brook.

Influence of natural environmental stressors on short-term growth (S. Arndt, Dept. of Biology, University of New Brunswick). Flood events and high water temperatures are common in salmon rivers of eastern Canada. However, the frequency of occurrence often increases after deforestation by timber harvest or fire. In the short growing season of eastern Canadian rivers, any factors which reduce growth rate could affect winter survival of younger fish (due to a decrease in size and energy reserves) and production (by increasing the number of years to reach smolting size).

The primary objective of this project is to determine if, and to what extent, natural environmental stressors such as flood events and periods of high water temperature influence the short-term growth rates of juvenile Atlantic salmon and blacknose dace. A second objective is to investigate whether a change in growth is caused by a decrease in feeding, or by another physiological mechanism which diverts energy for uses other than growth.

During the growing season of 1992, field collections of fish were made in sets of three sample days. Each set is used to monitor one period of relatively constant conditions (control), or one environmental stressor event. Two reaches of Catamaran Brook (Gorge and Lower) and one in the Little Southwest Miramichi River were chosen for study sites. Changes in growth rates are determined using tissue analyses of muscle RNA and DNA concentrations. This method reflects rates of protein synthesis, and has proven to be a useful index of short-term responses in fish. Indices of gut fullness and stored energy content are obtained from wild specimens, and laboratory experiments are being conducted to aid in the interpretation of the field data.

Environmental isotopes to trace trophic pathways to salmon (R. Doucett, Dept. of Biology, University of Waterloo). Stable isotope analysis is being used to identify and measure the relative importance of the sources of carbon sources leading to Atlantic salmon in Catamaran Brook. This approach utilizes differences in the natural abundance of stable isotopes as tags, or tracers, which move through the food chain with little, or predictable, alteration. The method has been successful in identifying perturbations in stream ecosystems and it is in this connection that it will be applied here. The relative importance of autocthonous and allocthonous carbon will be assessed along temporal (season, year) and spatial (between habitat-types and stream reaches) gradients. Primary pathways in the food web will be followed using a combination of both stable carbon and nitrogen isotopes. Application of the technique to other fish species (e.g. brook trout) may provide a means of predicting changes in the aquatic environment following deforestation.

The variation in isotope ratios is generally measured by mass spectrometry where purified CO_2 produced by the consumption of organic material is compared with a CO_2 standard. The analysis is being carried out in the Environmental Isotope Laboratory (Dept. of Earth Sciences, U. of Waterloo). Field samples were initially collected between May and September in 1992, and will be continued in 1993. Unlike stomach content analysis, an important advantage offered by stable isotope analysis is that, even with sacrificing relatively few animals, the results reflect an integration of all food sources.

Allometric and ecological determinants of territory size in juvenile Atlantic salmon (E. Keeley, Dept. of Biology, Concordia University). The objective of this study is to develop a predictive model of territory size for juvenile Atlantic salmon. Two approaches were adopted which are often used to examine the size of areas defended by animals. First, because juvenile salmon undergo a large increase in body size before smolting, territory size was measured for each fish within age-classes resident in Catamaran Brook. This was done to account for variation in territory size which might be explained by body size. In addition to this allometric approach, a wide range of ecological factors were measured which have been predicted to influence territory size. These include food abundance, intrusion pressure, habitat structure, and current velocity.

From 25 May until 02 September, 1992, the territories of 49 salmon were measured by observing focal individuals by the use of a video camera or directly, by snorkeling. By observing fish in several stream reaches (Middle, Gorge, and Lower), it was possible to measure territories over a wide range of environmental conditions. The resultant data will be used to build a multiple regression model predicting territory size for juvenile Atlantic salmon. Because of the potential importance of territorial behaviour in limiting population density, this model may be valuable to biologists interested in determining the carrying capacity for stream salmonids.

Preliminary results indicate that body size may account for approximately 70% of the variation in territory size, and food abundance an additional 10-15%.

Modélisation de l'habitat physique du saumon de l'Atlantique avec PHABSIM: cas du ruisseau Catamaran, (Modelling of physical habitat for Atlantic Salmon: Application on Catamaran Brook, G. Bourgeois, École de génie, Universté de Moncton). This research consists of modelling habitat using the Instream Flow Incremental Methodology (IFIM) followed by a validation study to determine the applicability of such a model for different habitat types: riffles, runs and flats. The IFIM model is being used widely throughout North America (USA and Canada) but with very little validation, especially in Atlantic Canada. A sensitivity analysis was also carried out to determine the effects on input parameters such as Habitat Suitability Index (HSI) curves, velocities, etc. on the results of the model. It was found that the predicted habitat is not sensitive to water velocities, depth, and substrate when applying random errors of different magnitude. However, the selection and the number of cross-sections are very important. This analysis was carried out using resampling techniques (bootstrap). The relationship between fish densities (from electrofishing) and predicted habitat availability was also investigated.

Étude hydro-météorologique du bassin Catamaran, (Hydrometeorlogical study of the Catamaran Brook basin, P.P. Loua, École de génie, Universté de Moncton). Hydrological and meteorological characteristics are very important to study water related processes in the Catamaran Brook drainage basin. This study involved the determination of different flow characteristics such as average, high and low flows, based on a regional analysis. Two approaches were considered: multiple regression and transfer of hydrological information. The first uses regional information to developed the multiple regression equation with physiographic parameters. The second approach involves identifying a representative hydrometric station in the studied region and transferring hydrological information between basins. Double mass curve analyses were also considered to study the homogeneity of the region both with discharge and precipitation.

Modélisation déterministre et stochastique de la température de l'eau du ruisseau Catamaran, (Deterministic and stochastic modelling of stream water temperature for the Catamaran Brook, G. El-Kourdahi, École de génie, Universté de Moncton). This study focuses on modelling stream water temperature using a deterministic and stochastic prediction model. The deterministic approach uses meteorological data and physical characteristics of the stream as input parameters. These parameters are then used in heat flux (or energy) equations (solar radiation, convection, evaporation, and others) to predict changes in water temperature. Following calibration of the models, their applicability was determined for particular sites within a drainage basin.

The stochastic approach uses a time series analysis technique (Box-Jenkins) to determine relationships between air and water temperatures. Two main components are identified in this analysis, seasonal and nonseasonal. The seasonal component was applied using Fourrier series analysis and represents long term variation in the time series. The nonseasonal component represents short term variation in water temperature as a function of past water temperatures (autocorrelation), heat flux by air temperature (cross correlation), and random errors.

It was determined that groundwater in the Catamaran Brook basin plays an important role in affecting stream temperatures. The results obtained were similar to previous studies, with the stochastic approach being superior in predictability.

6.2 Collaborative Projects

Fungal diversity and activity in Catamaran Brook (Dr. F. Bärlocher, Dept. of Biology, Mount Allison University). Plant detritus (dead leaves, needles, twigs) represents a major source of food and energy for many streams and rivers. They consist primarily of complex carbohydrates (e.g. cellulose, lignin) that cannot be digested by most animals. Microorganisms generally act as intermediaries between plant materials and animal consumers. In streams, a specialized group of fungi, the aquatic hyphomycetes, performs this function. Their growth increases the protein and lipid content of dead leaves, and breaks down the complex carbohydrates into digestible subunits. This puts the fungi at the very base of the food web of streams.

The overall objectives of these studies are characterization of fungal diversity and activity in Catamaran Brook and an investigation of factors that influence them. Monthly filtration of water samples (begun in 1992) traps fungal spores (conidia) which can be identified. Their numbers give a rough estimate of fungal activity in the river. Generally, there are two annual peaks in spore production: one a few weeks after leaf-fall, the second in spring, when snow melt/runoff introduces additional leaves from the river banks. This sampling regimen will be continued for several years to track large-scale changes in the ecosystem at the level of allocthonous matter supply.

In a more detailed study, to begin in the spring of 1993, an honours student will investigate the breakdown of leaves at selected stream sites. Factors that might influence this process include influx of groundwater, water current, and temperature (e.g. a site above and below beaver dams), and riparian vegetation. Decomposition will be studied by estimating weight loss, changes in protein, phenolics, and lipid content, and fungal colonization of the leaves. This latter will be characterized by identifying fungal species, as well as determining total biomass, based on measuring ergosterol (by HPLC), a sterol unique to higher fungi.

Winter survival of, and the effects of density on, precocious parr (Drs. J.-L. Baglinière and E. Prévost, I.N.R.A., Rennes, FRANCE) Precocious male salmon parr and their relevance to population dynamics and production in streams are of interest to salmon biologists in Europe and North America. In 1991, collaborative research studies were initiated to investigate some of the ecological relationships associated with male precocity in salmon parr.

Comparative research studies in Catamaran Brook and two salmon rivers in France (Oir, Scorff) were formulated with the following objectives: to study winter mortality in precocious parr relative to immature parr; and, to study the effect of localized densities on growth rate and incidence of male precocity in 1+ salmon parr.

Stream habitats of juvenile sea lamprey (Drs. R. Young and J.R.M. Kelso, D.F.O., Sault Ste. Marie). In 1991, we initiated a study of the habitats used by lamprey ammocoetes in Catamaran Brook and those used in several streams feeding the Great Lakes. The objective was to compare the habitats chosen by ammocoetes of truly anadromous sea lamprey with those of landlocked forms (see Young et al. 1990). All lamprey captured during electrofishing surveys are measured, weighed, and densities calculated. In addition, 2 'new' lamprey sites have been added to the electrofishing survey, and microhabitat variables are measured where the ammocoetes are found.

Fish Health Analyses (Mr. M.I. Campbell, D.F.O., Moncton)
Environmental stressors, natural (e.g. high water temperature) or anthropogenic (e.g. forestry activities in a stream basin), may affect the health of fishes. Therefore, a fish health program was implemented to annually monitor the status of populations in Catamaran Brook.

In July 1991 and again in July 1992 fish were collected for fish health analyses from the Upper Reach and Lower Reach portions of Catamaran Brook and from the Little Southwest Miramichi River upstream of the mouth of Catamaran Brook. Fish were collected by electrofishing and were transported fresh on ice to the

DFO Fish Health Service Unit lab in Halifax where they were examined for viral and bacterial fish pathogens.

The 1991 samples consisted of 6 brook trout, 5 juvenile Atlantic salmon and 2 blacknose dace from the Upper Reach; 3 brook trout and 19 juvenile Atlantic salmon from the Lower Reach and 11 juvenile Atlantic salmon, 2 blacknose dace and 5 lake chub from the Little Southwest Miramichi River.

The 1992 samples consisted of 3 brook trout, 12 juvenile Atlantic salmon, 6 blacknose dace and 10 lake chub from the Lower Reach; 10 brook trout, 5 juvenile Atlantic salmon, 3 blacknose dace and 2 lake chub from the Upper Reach and 27 juvenile Atlantic salmon from the Little Southwest Miramichi River.

In 1991, no viruses were identified from any of the fish. In addition to the expected ubiquitous bacterial species found in most of the gut cultures, the Bacterial Kidney Disease (BKD) pathogen, *Renibacterium salmoninarum*, was identified in 2 of the 19 Atlantic salmon kidney smears from the Lower Reach, by using the 'direct fluorescent antibody technique' (DFAT) staining method. Although there was no evidence of a clinical BKD problem in Catamaran Brook it is worth noting that the pathogen exists in the drainage basin. No bacterial or viral fish pathogens were identified from any of the 1992 fish.

Although the number of fish sampled for fish health purposes is small it is believed that by sampling annually a significant fish health data base will be accumulated which will accurately reflect the fish health status/changing status of Catamaran Brook through the three phases of the project.

Hydrochemical separation of streamflow in Catamaran Brook (Dr. T.L. Pollock, Water Quality Branch, Environment Canada, Moncton). In 1991, water chemistry samples were collected on a weekly basis and during particular storm events to determine surface water / groundwater interactions. The stream water chemistry was found to change during storm events as a result of dilution. However, certain variables peaked in concentration prior to the peak in discharge. This study will also help us to understand the dynamics of chemical concentrations during low flow or base flow conditions in summer. Hydrograph separation techniques will be compared with the chemical analysis approach to quantify the baseflow (groundwater) component of streamflow.

Groundwater research in the Catamaran Brook basin (Dr. K.T.B. MacQuarrie, Dept. of Civil Engineering, University of New Brunswick). Forestry activities, particularly large clear-cut areas, are known to affect groundwater by causing shallow groundwater levels to increase on average and to fluctuate much more rapidly in response to precipitation events. Also, groundwater discharge to streams is known to have a significant effect on fish habitat and production by providing thermal refugia, maintaining stable flow regimes which maximize growth and survival, and by providing suitable sites for embryo development within the stream substrate.

This study has the following objectives: i) establish pre-logging hydraulic interactions between groundwater and Catamaran Brook by quantification of groundwater discharge; ii) establish pre-logging shallow groundwater discharge chemistry and to relate this to infiltration and local geology; iii) and to assess the impact on groundwater discharge, in terms of changes in quantity and chemistry, which may arise when logging resumes in the drainage basin.

Rainfall interception by the forest canopy (Drs. R. Barry and E. Robichaud, École de sciences forestières, Université de Moncton, Edmonston). A significant aspect of the hydrological balance of a forested catchment is the loss of precipitation through canopy interception. The proportion of precipitation intercepted and evaporated directly from the leaves and branch surfaces is highly site-specific. The purpose of this study is to estimate the proportion of the gross precipitation intercepted by the different forest types of the Catamaran Brook catchment. The method used for estimating interception is by measurements of throughfall in networks of raingauges and stemflow collectors installed under the canopies of the main forest types of the watershed.

In 1992, a network of 20 raingauges and 16 stemflow collectors was installed under a hemlock-spruce canopy in a 100 m^2 plot in the Lower Reach. Twelve rain events were measured between August 20 and October 29. An evaluation of the forest cover composition has been done with the DNRE forest inventory m.

In 1993 the following work is scheduled in early May, re-installation of the hemlock-spruce plot and of 3 other plots in stands representative of the forest cover in the catchment: 1) in a mature cedar stand: 2) in a mature tolerant hardwood stand; and 3) in a mixed stand (with more than 30% tolerant hardwood). The interception relationships for spruce-fir stands are already well documented in available literature. After every rain event between May and September, throughfall and stemflow will be measured by a student. Data analysis will be done within the framework of a senior thesis for February 1994 (F. Coté).

7.0 CONCLUSION

As noted in the Introduction to this report, it was not our intention to provide exhaustive analyses of the data being collected , or complete descriptions of scientific methodologies. However, it is apparent from the size of this document and the list of activities being carried out at Catamaran Brook that the amount of data already generated is substantial. The first year (1990) was very important in firming up sampling logistics, study design and technique(s) based on our experiences in the field. For example, the change in location of the counting-fence and subsequent trap modifications have greatly improved trapping efficiency and, hence, estimates of fish migrants.

The years 1991-1992 have seen a marked increase in the number of sub-projects being carried out. Many of these are independent studies in that they deal with specific scientific questions such as how environmental isotopes trace trophic pathways or whether deterministic or stochastic models best fit the water temperature fluctuations in Catamaran Brook. However, beyond their immediate goals, these studies also provide important pieces for understanding the complex puzzle of a stream ecosystem.

Two years remain before the end of the "pre-logging" phase of data collection in Catamaran Brook. Further to the existing research program, additional research studies have already been confirmed for 1993. This is an encouraging prospect for establishing a reliable data-base for predicting relative effects of timber harvest, scheduled to begin in 1995.

The ultimate value of this project for assessing the impacts of forestry practices will not be known for several years. This is the drawback of long-term research. Despite the recognized importance of multi-year research, goals are not always realized because of alterations or the premature terminations of programs. The Carnation Brook project in British Columbia (Hartman and Scrivener 1990) exemplifies the usefulness of long-term studies of the impacts of forestry practices. No such project has been carried out in eastern Canada. The long-term studies of forestry impacts at Coweeta (North Carolina) and Hubbard Brook (New Hampshire) have focused on forest hydrology and have yielded valuable information. However, the applicability of their findings to the forest region of Maritime Canada is yet to be determined. The Catamaran Brook project proposes to identify the inter-relationships of stream biota and their habitats in an Acadian forest catchment in order to quantify the effects from subsequent anthropogenic stress. To compare Catamaran Brook with the likes of Carnation Creek, Coweeta, and Hubbard Brook is presumptuous at present, but they serve as excellent examples of what can be achieved.

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Table 1. Selected physical attributes of the habitat-types under study in the different reaches in Catamaran Brook. Values for width and depth were calculated for an approximation of the mean annual flow in the stream.

Site	Habitat	Length (m)	Width (m)	Depth (m)	Slope (%)
			Lower Reach		
LRI2	riffle	12.6	10.5	0.253	2.37
LRU2	run	17.5	8.0	0.458	0.148
LBRU2	run	10.0	6.2	0.408	0.000
LF2	flat	17.3	12.9	0.340	0.295
LRU1	run	18.8	7.2	0.495	0.410
LBRU1	run	10.0	8.6	0.629	0.298
LRI1	riffle	11.5	9.4	0.309	1.37
LF1	flat	21.2	12.5	0.346	0.090
LF3	flat	14.1	8.8	0.285	0.092
LP1	pool	9.1	8.8	0.601	0.000
			Middle Reach		
MRU1	run	13.4	5.7	0.308	0.851
MRI1	riffle	11.4	6.4	0.184	2.24
MF1	flat	17.6	8.2	0.395	0.199
MRU2	run	12.5	6.9	0.215	0.584
MRI2	riffle	14.8	7.7	0.222	1.70
MF2	flat	21.1	6.3	0.371	0.213
			Gorge Reach		
BGR2	riffle	11.7	5.3	0.160	2.92
BGRU2	run	17.6	7.3	0.200	0.653
BRU3	run	16.2	6.7	0.318	0.099
GRU1	run	15.2	8.0	0.192	0.164
GRI1	riffle	15.0	6.7	0.184	1.57
GRU2	run	15.4	5.1	0.174	0.584
			Upper Reach		
MTRIB1	run	13.0	4.5	0.248	1.19
MTRIB2	run	16.4	4.5	0.287	2.41
LAKEO1	run	24.2	3.2	0.248	2.97
LAKEO2	run	17.5	3.2	0.242	2.67

Table 2. Areal (A, m^2) and frequency (n) representation of habitat-types in the four stream reaches of Catamaran Brook based on the 1991 (summer) survey.

Stream Reach	Habitat - Type							
	Riffle		Run		Flat		Pool	
	n	A	n	A	n	A	n	A
Upper	5	80	33	866	10	181	0	-
Middle	16	1454	17	1703	4	231	2	170
Gorge	9	1456	13	1646	0	-	2	211
Lower	30	6027	38	6306	10	2174	3	208
Totals	60	9017	101	10521	24	2586	7	589

Table 3. Monthly mean precipitation and air temperature recorded annually (1990 - 1992) in the Catamaran Brook basin and over the long-term (1969-92) using McGraw Brook meteorological station data (1969-92).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					Precipitation (mm)							
1990	128.3	53.5	43.8	71.9	160.6	59.3	157.6	102.8	77.9	158.2	125.4	147.9
1991	93.0	24.0	149.6	88.6	152.8	81.8	36.8	245.2	173.8	136.0	56.5	63.0
1992	113.0	129.8	38.8	40.6	27.2	113.4	141.4	81.2	46.8	170.8	73.6	34.1
Avg.[1]	91.8	71.7	91.2	90.5	105.8	95.2	100.8	96.5	96.3	100.4	109.0	108.9
					Mean minimum temperature (°C)							
1990	-16.3	-20.9	-12.7	-3.0	1.9	9.6	11.9	12.7	5.4	3.2	-2.6	-10.9
1991	-20.6	-16.8	-7.2	-3.5	3.4	8.4	10.7	12.6	5.3	1.9	-2.2	-16.7
1992	-16.9	-21.2	-13.2	-3.1	2.8	9.1	9.7	11.8	7.5	2.1	-5.4	-9.0
Avg.[1]	-18.1	-16.7	-10.0	-3.0	2.8	8.5	11.8	10.9	5.5	0.4	-4.5	-13.7
					Mean monthly temperature (°C)							
1990	-10.3	-14.4	-5.9	2.5	8.4	16.7	18.8	19.9	11.8	7.4	0.4	-6.0
1991	-14.0	-9.6	-2.0	3.3	11.0	16.2	18.5	18.9	11.6	6.9	1.6	-11.4
1992	-11.6	-15.3	-6.1	2.8	11.0	15.5	16.1	17.7	14.1	7.0	-1.0	-1.8
Avg.[1]	-11.8	-10.1	-3.8	2.9	10.1	15.6	18.8	17.7	12.1	6.2	0.0	-8.2
					Mean maximum temperature (°C)							
1990	-4.3	-7.9	0.9	7.9	14.8	23.8	25.6	27.0	18.2	11.6	3.3	-1.0
1991	-7.3	-2.4	3.2	10.0	18.5	23.9	26.2	25.1	17.9	11.9	5.4	-6.1
1992	-5.8	-9.4	0.7	8.7	19.2	21.8	22.5	23.5	20.6	11.9	3.5	5.5
Avg.[1]	-5.5	-3.4	2.5	8.7	17.3	22.7	25.7	24.5	18.7	12.0	4.4	-2.8

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[1] Avg. = long term monthly average from 1969 to 1992.

Table 4. Annual (1989-1992) and historical (1965-1990) mean monthly discharge ($m^3 \cdot s^{-1}$) measured in the Middle Reach of Catamaran Brook.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	-	-	-	-	-	-	-	-	-	-	0.618	0.183
1990	0.224	0.268	0.268	1.90	1.69	0.492	0.361	0.594	0.273	1.09	1.07	1.14
1991	0.486	0.148	0.413	2.18	2.18	0.497	0.135	0.432	0.716	1.12	0.755	0.327
1992	0.253	0.144	0.213	1.13	1.43	0.384	0.479	0.500	0.139	0.458	0.540	N/A
1965-90*	0.283	0.354	0.403	1.82	2.15	0.629	0.295	0.256	0.282	0.512	0.658	0.587

* Long term monthly discharge based on prorated values from Renous River (station 01BO002)

Table 5. Estimates of flood magnitude ($m^3 s^{-1}$) for Catamaran Brook at various recurrence intervals using four approaches of measuring flood frequency. Calculations are based on long-term prorated discharge data from Renous River (1966-91).

	Recurrence interval (y) of floods					
	2	**5**	**10**	**20**	**50**	**100**
3 Parameter Lognormal	6.2	8.9	10.8	12.7	15.2	17.1
Type I Extremal	6.3	8.4	9.8	11.2	13.0	14.3
Pearson Type III	5.8	8.5	10.7	12.9	16.0	18.3
Partial Duration Series	6.5	8.8	10.3	11.8	13.7	15.1
Median	6.1	8.6	10.3	12.1	14.4	16.2

Table 6. Estimates of low flow ($m^3 s^{-1}$) for Catamaran Brook at various recurrence intervals using three periods of duration. Calculations are based on long-term prorated discharge data from Renous River (1966-91) using the Type III Extremal Distribution function.

	Recurrence of low flows ($m^3 s^{-1}$) of interval T (years)				
	2	**5**	**10**	**20**	**50**
1-day low flow	0.063	0.037	0.025	0.017	0.009
7-day low flow	0.074	0.044	0.031	0.022	0.013
14-day low flow	0.082	0.049	0.035	0.026	0.018

Table 7. Suspended sediment concentration (Conc.) of water samples collected from Catamaran Brook during storm events in 1990 and 1991. Q refers to river discharge estimated at the time of sampling.

Year	Date	Time (h)	Q (m^3s^{-1})	Conc. (mg/l)
1990	Aug 11	1950	0.967	23
1990	Aug 12	1450	3.77	7
1990	Aug 12	1845	2.88	2
1990	Aug 14	1830	0.905	8
1990	Aug 14	1530	1.2	4
1990	Aug 14	1835	2.02	4
1990	Aug 14	2130	2.2	4
1990	Aug 15	0030	2.3	3
1990	Aug 15	0340	1.96	2
1990	Aug 15	0631	1.85	2
1990	Aug 15	1015	1.69	2
1990	Aug 15	1305	1.54	2
1990	Sep 23	0953	0.147	3
1990	Sep 23	1301	0.235	3
1990	Sep 23	1639	0.786	18
1990	Sep 23	2017	1.33	11
1990	Sep 23	2357	1.45	7
1990	Sep 24	0907	1.15	3
1991	Aug 10	1800	0.09	1
1991	Aug 10	2300	0.102	3
1991	Aug 11	0300	0.234	5
1991	Aug 11	0700	0.897	25
1991	Aug 11	0900	1.6	15
1991	Aug 11	1100	2.33	11
1991	Aug 11	1300	2.51	8
1991	Aug 11	1500	2.49	8
1991	Aug 11	1700	2.29	5
1991	Aug 11	2300	1.4	6
1991	Aug 12	0700	0.909	4

Table 8. Concentration (Conc.) of suspended sediments in water sampled from Catamaran Brook during 1990, excluding storm events. Q = river discharge ($m^3 s^{-1}$) at time of sampling.

Date	Time (h)	Q ($m^3 s^{-1}$)	Conc. (mg/l)
Jun 13	1035	0.372	1
Jun 13	1145	0.374	3
Jul 18	1455	0.081	1
Jul 18	1614	0.081	1
Jul 19	1700	0.073	2
Jul 20	0945	0.102	1
Aug 1	1016	0.343	2
Aug 2	0825	0.418	1
Sep 15	1225	0.128	1
Sep 16	1348	0.773	4
Oct 16	1030	0.894	2
Oct 16	1345	0.85	1
Nov 14	1305	1.09	3
Nov 14	1415	1.08	1

Table 9. Physical habitat characteristics of representative habitat-types in Catamaran Brook based on cross-sectional measurements made in 1990. All tablular values are in metres (m) except for area (m^2), and velocity (m·s^{-1}); Manning's "roughness" coefficient (n), Froude's Number (Fr) and Reynold's Number (Re) are dimensionless. D_{50} refers to the median substrate particle diameter; D_{84} = the bed material size for which 84% of the material is finer (see Bray 1991).

Middle Riffle 2 (MR2)

Date of survey: Nov 14 / 1990
Reach identification: Middle Riffle 2 (MR2)
Site length: 14.8 m
Discharge: 0.626 cms
Slope: 0.02345 m/m

Section	Water Surf. Elevation	Wetted Area	Width	Wetted Perimeter	Hydraulic Radius	Hydraulic Depth	Manning's n	Velocity	Fr
0+0.00	9.573	2.056	9.900	10.139	0.203	0.208	0.1736	0.[illegible]4	0.2133
0+3.70	9.453	1.727	9.450	9.563	0.181	0.183	0.1350	0.[illegible]	0.2707
0+7.40	9.386	1.403	5.850	6.143	0.228	0.240	0.1282	0[illegible]	0.2939
0+11.10	9.353	1.392	5.750	6.978	0.200	0.206	0.1163	0[illegible]	0.3160
0+14.80	9.226	1.389	5.870	6.285	0.221	0.237	0.1242	0[illegible]	0.2958
	Mean	1.593	7.564	7.822	0.206	0.215	0.135	[illegible]	0.2774
	Std	0.296	1.967	1.890	0.019	0.024	0.022	[illegible]	0.0393
	CV	0.186	0.260	0.242	0.091	0.111	0.165	[illegible]	0.1415

Surface Area = 110.76 m²
Wetted Area = 114.32 m²
Volume = 23.11 m³
Fr = 0.2775
Re = 57658 at 10.0 °C
D_{50} = 8.0 cm
D_{84} = 17.3 cm

Middle Run 2 (MRU2)

Date of survey: Nov 14 / 1990
Reach identification: Middle Run 2 (MRU2)
Reach length: 12.5 m
Discharge: 0.626 cms
Slope: 0.00576 m/m

Section	Water Suf Elevation	Wetted Area	Width	Wetted Perimeter	Hydraulic Radius	Hydraulic Depth	Manning's n	Velocity	Fr
0+0.00	9.805	1.220	7.100	7.263	0.168	0.172	0.0450	0.513	0.3953
0+3.13	9.770	1.774	7.400	7.608	0.233	0.240	0.0814	0.353	0.2302
0+6.25	9.757	1.526	6.450	6.606	0.231	0.237	0.0697	0.410	0.2693
0+9.38	9.748	1.590	6.300	6.430	0.247	0.252	0.0759	0.394	0.2503
0+12.50	9.733	1.350	7.400	7.754	0.174	0.182	0.0511	0.464	0.3464
	Mean	1.492	6.930	7.132	0.211	0.217	0.065	0.4268	0.2983
	Std	0.215	0.524	0.592	0.037	0.037	0.016	0.0625	0.0698
	CV	0.144	0.076	0.083	0.175	0.169	0.245	0.1465	0.2341

Surface Area = 85.63 m²
Wetted Area = 87.98 m²
Volume = 19.29 m³
Fr = 0.2928
Re = 68844 at 10.0 °C
D_{50} = 7.3 cm
D_{84} = 14.0 cm

Lower Flat 2 (LF2)

Date of survey: July 30 / 1990
Reach identification: Lower Flat (LF2)
Reach length: 17.3 m
Discharge: 0.672 cms
Slope: 0.00127 m/m

Section	Water Suf. Elevation	Wetted Area	Width	Wetted Perimeter	Hydraulic Radius	Hydraulic Depth	Manning's n	Velocity	Fr
0+0.00	9.373	2.676	12.400	12.617	0.212	0.216	0.0505	0.251	0.1726
0+4.32	9.370	2.679	11.950	12.199	0.220	0.224	0.0517	0.251	0.1692
0+8.65	9.363	2.381	12.100	12.262	0.194	0.197	0.0424	0.282	0.2031
0+12.97	9.359	2.210	13.100	13.210	0.167	0.169	0.0356	0.304	0.2364
0+17.30	9.351	2.117	11.850	11.923	0.178	0.179	0.0355	0.317	0.2398
	Mean	2.413	12.280	12.442	0.194	0.197	0.043	0.2811	0.2042
	Std	0.260	0.503	0.495	0.022	0.024	0.008	0.0303	0.0337
	CV	0.108	0.041	0.040	0.114	0.120	0.181	0.1076	0.1648

Surface Area = 213.11 m²
Wetted Area = 216.00 m²
Volume = 41.81 m³
Fr = 0.2023
Re = 41793 at 10.0 °C
D_{50} = 4.0 cm
D_{84} = 7.0 cm

Table 10. Monthly Water Chemistry Analyses for Catamaran Brook at Middle Reach, November 1989 - June 1992.

PARAMETERS	1989		1990												1991												1992					
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE
Colour Apparent (Rel. Units)	65	15	5	10	10	40	20	33	<5	70	16	40	35	35	15	20	22	36	25	30	25	65	15	45	30	10	12	5	5	5	25	10
Specific Conductance (uS/cm)	43	64	73	62	66.7	31.3	40.7	55.2	77.5	75	72	43	36.5	46	46	68	67	35	32	64	72	42	49	36	45	52	48	72	65	44	46	65
Turbidity (JTU)	0.6	0.2	0.2	0.3	0.2	0.6	0.3	1.3	0.3	0.6	0.1	0.5	0.4	0.3	0.3	0.2	0.5	0.7	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.1	0.2
Carbon Dissolved Organic (mg/l)	5	2.6	2.6	2.4	2.2	6.5	4.1	2.8	1.9	3.7	2.7	7.8	5.1	2.6	2.7	2.1	7.6	3.6	3.8	4	3.3	9.9	2.7	6.5	1.4	2.1	1.2	1.5	2.3	2.6	1.5	2.0
Carbon Dissolved Inorganic (mg/l)																									4.9							
Nitrogen Dissolved NO3 & NO2 (mg/l)	L.01	0.38	0.1	0.1	0.13	0.04	0.01	L.01	0.04	0.05	L.01	0.01	0.04	0.09	0.16	0.15	0.22	0.05														
Nitrogen Dissolved Nitrate (mg/l)													0.05	0.1	0.14	0.146	0.24	0.07	0.02	L.01	0.003	0.03	L.01	0.02	L.01	0.1	0.12	0.14	0.29	0.31	0.25	0.01
Nitrogen Total (mg/l)	0.22	0.18	0.17	0.18	0.21	0.21	0.14	0.09	0.14	0.22	0.1	0.18	0.13	0.14	0.22	0.18	0.29	0.17	0.11	0.1	0.14	0.24	0.33	0.39	0.1	0.18	0.33	0.17	0.25	0.18		
Fluoride Dissolved (mg/l)	L.05			L.05	L.05	L.05	0.06	L.05	0.05	L.05	0.05	L.05	L.05	L.05	L.05	0.05	L.05	L.05	L.05	L.05	0.05	L.05	0.05	L.05		L.05	L.05	L.05	L.05	L.05	L.05	L.05
Alkalinity Total (mg/l)	24.2	25.4	28.6	24.9	25.1	9.1	13.8	22.1	34	32.4	31.1	13.5	32	17.2	14.8	27.1	16.7	22.6														
Gran Alkalinity Total (mg/l)																			9	10	14.1	13.8	29.8	12.8	27.1	19.4	17.1	29.1	21.5	16.4	14.3	27.2
pH (pH Units)	7.1	7.1	7.6	7	7.6	6.9	7.3	7.4	7.8	7.3	7.3	7	7.1	7.2	7.1	7.6	6.9	7.1	6.9	7.3	7.6	7.3	7.5	6.9	7.3	7.3	7	7.6	7.3	7.2	7.3	7.6
Sodium Dissolved (mg/l)	1.3	1.8	1.9	1.7	1.8	1.2	1.2	1.4	1.7	1.2	1.6	1.6	1.2	1.4	1.4	1.7	1.3	1.3	1	1.2	1.6	1.3	1.6	1.2	1.4	1.5	1.5	1.8	1.6	1.3	1.3	1.5
Magnesium Dissolved (mg/l)	1.8	2	2.7	2.3	2.6	1.1	1.4	2	1.1	2.2	2.8	1.5	1.1	1.6	1.7	2.7	2.2	1.2	0.99	1.6	2.8	1.4	2.75	1.1	1.6	2	1.8	2.0	2.2	1.4	1.5	2.4
Aluminum Extractable (mg/l)	0.095	0.1	0.071	0.04	0.344	0.14	0.29	0.046	0.032	0.21	0.32	0.15	0.09	0.055	0.094	0.24	0.073	0.277	0.082			0.13		0.19	0.06	0.06	0.048	0.03	0.041	0.061	0.055	0.037
Silica Extractable (mg/l)	6																															
Silica (MB)-TRAACS 800 mg/l		5.2	7.3	6.9	6.7	4.4	4.6	4.5	5.07	5.5	5.3	5.4	3.6	4.2	6.3	7	5.2	5.1	4.3	4.54	5.3	5	4.6	5.09	5.4	3.7	6.5	6.6	6.2	5.1	2.9	7.1
Phosphorus Total (mg/l)	0.009	0.002	0.002	0.001	0.001	0.004	0.003	0.004	0.004	0.004	0.003	0.007	0.002	0.005	0.003	0.001	0.018	0.007	0.004		0.005	0.008	0.001	0.004	0.003	0.001	0.005	0.002	0.004	0.009	0.009	0.005
Sulphate Dissolved (mg/l)	4.2	4.5	4.8	4.9	4.5	3.7	3.7	5.2	3.7	3.3	4.5	4.1	4.3	3.6	4.3	4.4	4.2	3.7	3.3	3.7	3.7	4.5	2.8	3.9	3.3	4.4	4.6	4.7	3.8	3.2	2.7	3.4
Sulphate MTB-TRAACS 800 mg/l	4.23	4.44	4.37	4.51	5.05	4.08	3.83	4.49	3.95	3.97	4	4.5	3.9	3.5	3.5	4.4	4.7	3.6														
Chloride Dissolved (mg/l)	1.1	0.9	0.9	0.9	0.8	0.6	0.5	0.5	0.67	0.5	0.6	1.4	1.2	0.7	0.7	0.9	0.67	0.6	L.5	L.5	0.6	0.5	1.1	1.3	0.7	1	0.9	0.7	0.9	0.9	0.7	0.8
Potassium Dissolved (mg/l)	0.12	0.14	0.15	0.17	0.29	0.26	0.16	0.19	0.24	0.13	0.19	0.21	0.13	0.16	0.18	0.42	0.22	0.2	0.17	0.1	0.16	0.15	0.22	0.22	0.23	0.18	0.21	0.27	0.31	0.26	0.4	0.24
Calcium Dissolved (mg/l)	5.7	7.6	8.9	7.2	7.6	3.6	4.4	6.3	9.2	6.7	8.9	5.2	4.2	5.3	5.5	8.1	7.6	4.1	3.9	5.2	9.2	5.3	6.4	4.3	3.3	4.4	5.7	8.1	7.2	5.2	4.4	8.1
Manganese Extractable (mg/l)	L.010	L.010	L.010	L.010	L.010	0.01	L.010	L.01	L.01	L.01	L.010	L.010	L.01	L.010	L.010	L.010	L.010	L.010	L.010			L.010		L.01	L.010	0.01	L.010	L.01	L.01	L.01	L.01	L.01
Iron Extractable-Atomic Ab. (mg/l)	0.07			0.35	0.36	0.30				0.11		0.1	0.35	0.25	0.05							0.08		0.47		0.35		0.25	0.35	0.06		
Iron Extractable-(MIBK) (mg/l)		0.041	0.038				0.040	0.05	0.016		0.044					0.249	0.25	0.043	0.08						0.045		0.042				0.032	0.032
Copper Extractable (mg/l)	L.002	L.007	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002			L.002		L.002	L.002	0.006	L.002	L.002	L.002	L.002	L.002	L.002
Zinc Extractable (mg/l)	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01			L.01		L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01
Cadmium Extractable (mg/l)	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001			L.001		L.001	L.0009			L.001	L.001	L.001	L.001	L.001
Mercury Extractable (mg/l)		L.02	L.02	L.02			L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02		L.02	L.02			L.001	L.001	L.001	L.02	L.02	L.02	L.02	L.02
Lead Extractable (mg/l)	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002			L.002		L.002	L.004	L.002	L.002	L.002	L.002	L.002	L.002	L.002
Total Nitrogen-Hydrazine meth. (mg/l)														0.14	0.11	0.18	0.27	0.13														

L less than detection level

Table 11. Monthly Water Chemistry Analyses for Catamaran Brook at the Lower Reach, November 1989-June 1992.

Parameters	1989		1990								1991												1992					
	NOV	DEC	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Colour Apparent (Rel. Units)	40		25	10	L5	60	5	60	35	20	15	20	20	30	30	30	20	80	10	45	40	10	5	10	L5.0	5	35	15
Specific Conductance (uS/cm)	47		40.3	54.2	74.1	31	72	45	38.5	45	47	64	43	35	32	41	67	44	64	36	42	50	51	65	66	45	38	62
Turbidity (JTU)	0.7		0.4	0.3	0.4	0.6	0.2	0.5	0.6	0.1	0.4	0.3	0.9	0.6	0.4	0.6	0.6	0.5	0.3	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.3
Carbon Dissolved Organic (mg/l)	5.3		4.4	3.1	1.9	6.3	2.3	9.4	5.6	3.1	3	2.2	4.3	5.8	4.7	4.9	2.7	11.6	2.2	7.4	3.9	2.9	5.5	1.6	1.5	2.9	1.3	2.6
Nitrogen Dissolved NO3 & NO2 (mg/l)	L.01		0.01	L.01	0.05	0.03	L.01	0.01	0.04	0.08	0.16	0.15	0.22	0.05														
Nitrogen Dissolved Nitrate (mg/l)									0.06	0.09	0.16	0.11	0.2	0.07	0.02	L.01	0.06	0.06	L.01	0.01	0.01	0.15	0.12	0.16	0.16	0.1	0.06	0.04
Nitrogen Total (mg/l)	0.22		0.11	0.1	0.16	0.21	0.07	0.2	0.12	0.13	0.22	0.19	0.26	0.18	0.11	0.13	0.14	0.29	0.12	0.18	0.1	0.17	0.22	0.18	0.22	0.16		
Fluoride Dissolved (mg/l)	L.05		0.05	L.05	0.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	0.05	L.05	0.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05	L.05
Alkalinity Total (mg/l)	15		13.3	20.6	10.5	10.2	30	13.3	11.7	14.8	15.8	24.9	17.5	12.4														
Gran Alkalinity Total (mg/l)															10.4	17.5	29.2	14.9	19.8	12.8	15.9	19	16.2	26.6	25.3	26.5	13	24.8
pH (pH Units)	7.1		7	7.4	7.7	7	7.7	7.1	7.1	7.2	7	7.6	6.8	7.1	7.1	7.2	7.5	7	7.6	7	7.3	7.4	7.2	7.4	7.4	7.3	7.2	7.5
Sodium Dissolved (mg/l)	1.3		1.3	1.5	1.9	1.3	1.8	1.4	1.2	1.4	1.4	1.8	1.2	1.1	1	1.3	1.6	1.3	1.7	1.2	1.5	1.6	1.5	1.8	1.8	1.3	1.3	1.6
Magnesium Dissolved (mg/l)	1.8		1.3	1.6	2.7	1.1	2.5	1.5	1.2	1.9	1.7	2.4	1.4	1.2	0.94	1.9	2.5	1.6	2.58	1.1	1.5	1.9	1.8	2.3	2.4	1.5	1.2	2.4
Aluminum Extractable (mg/l)	0.095		0.09	0.044	0.04	0.14	0.02	0.16	0.097	0.056	0.067	0.017	0.084	0.083	0.12			0.14		0.11	0.072	0.058	0.054	0.029	0.057	0.067	0.07	0.082
Silica Extractable (mg/l)	6.3																											
Silica (MB)-TRAACS 800 mg/l			4.3	4.6	5.5	5	5.3	5.7	5.3	6	6.1	6.7	5.4	5	4.4	4.12	5.2	5	4.5	5.2	5.4	5.9	6.1	6.5	6.1	4.9	2.8	3.2
Phosphorus Total (mg/l)	0.004		0.003	0.002	0.004	0.006	0.001	0.006	0.002	0.002	0.002	0.001	0.005	0.004	0.005		0.001	0.009		0.003	0.004	L.002	0.003	L.001	0.003	0.007	0.009	0.004
Sulphate Dissolved (mg/l)	4.5		4	3.4	3.7	3.4	3.9	4.1	3.8	3.6	4.6	4.6	4.4	4.2	3.3	3.3	4	4.9	4.2	3.7	4.1	3.3	5	5	4.4	3.5	2.9	3.4
Sulphate NTS-TRAACS 800 mg/l	4.6		3.98	5.32	4.09	3.88	3.6	4.9	3.9	3.8	4.1	4.7	4.5	4.2														
Chloride Dissolved (mg/l)	1.2		0.6	0.6	0.76	L.5	1.6	1.5	1.2	0.7	0.9	0.7	0.7	0.5	1.5	1.5	0.7	0.5	1.2	1.5	1.7	1.5	0.9	1.7	0.8	1	0.7	0.4
Potassium Dissolved (mg/l)	0.14		0.19	0.22	0.36	0.1	0.24	0.26	0.15	0.17	0.18	0.2	0.19	0.16	0.17	0.14	0.23	0.18	0.23	0.18	0.28	0.34	0.2	0.24	0.29	0.26	0.44	0.29
Calcium Dissolved (mg/l)	5.9		4.6	6.2	8.7	4	8.9	5.7	4.3	5	5.5	7.6	4.9	4.1	3.6	5.4	8.4	5.9	8.4	4.6	5.2	6.5	6	7.7	8	5.4	4.2	7.4
Manganese Extractable (mg/l)	L.010		L.010	L.01	L.01	L.01	L.010	L.010	L.01	L.010	L.010	L.010	L.010	L.010	L.010			L.010		L.01	L.010	L.01	L.01	L.01	L.01	L.01	L.01	L.01
Iron Extractable-Atomic As. (mg/l)	0.11		0.05			0.09		0.11	0.09	0.05	0.05		0.06	0.05	0.07			0.13		0.09	0.09	0.06	0.07	0.06	0.08	0.09		
Iron Extractable-(MIBK) (mg/l)				0.046	0.013		0.011					0.042															0.043	0.086
Copper Extractable (mg/l)	L.002		L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002			L.002		L.002	L.002	L.002	L.002	L.002	L.002	L.002	0.004	L.002
Zinc Extractable (mg/l)	L.01		L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01			L.01		L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01	L.01
Cadmium Extractable (mg/l)	L.001		L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001			L.001		L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001	L.001
Mercury Extractable (mg/l)			L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02	L.02		L.02	L.02					L.02	L.02	L.02	L.02	L.02	L.02
Lead Extractable (mg/l)	L.002		L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002			L.002		L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002	L.002
Total Nitrogen-Hydrazine meth. (mg/l)										0.16	0.26	0.19	0.22	0.13														

L-less than detection limit

Table 12. Monthly Water Chemistry Analyses for Little Southwest Miramichi River, June 1990 - June 1992.

Parameters	1990						
	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Colour Apparent (Rel. Units)	15	5	110	15	80	45	25
Specific Conductance (uS/cm)	26.1	31.2	20.6	30	26	24.5	27
Turbidity (JTU)	0.3	0.5	0.7	0.3	0.6	0.6	0.3
Carbon Dissolved Organic (mg/l)	3.5	2.3	14.4	2.7	8.1	5.4	2.8
Nitrogen Dissolved NO3 & NO2 (mg/l)	L 0.01	L 0.01	0.04	L 0.01	0.06	0.07	0.17
Nitrogen Dissolved Nitrate (mg/l)						0.11	0.16
Nitrogen Total (mg/l)	0.1	0.11	0.24	0.07	0.22	0.2	0.21
Fluoride Dissolved (mg/l)	0.07	0.09	0.06	0.08	0.06	0.06	0.07
Alkalinity Total (mg/l)	7.5	10.5	4.2	10	5.5	5.1	7
Gran Alkalinity Total (mg/l)							
pH (pH Units)	7	7.4	6.3	7.2	6.6	6.8	6.9
Sodium Dissolved (mg/l)	1.5	1.9	1	1.7	1.4	1.4	1.6
Magnesium Dissolved (mg/l)	0.46	1.9	0.46	0.56	0.54	0.45	0.5
Aluminum Extractable (mg/l)	0.072	0.05	0.29	0.032	0.2	0.1	0.064
Silica (MB)-TRAACS 800 mg/l	6.6	7.2	6.7	7.6	7.1	7.1	7.9
Phosphorus Total (mg/l)	0.005	0.005	0.01	0.003	0.006	0.002	0.008
Sulphate Dissolved (mg/l)	2.3	2	4	2.8	4.1	4.2	3.2
Sulphate MTB-TRAACS 800 mg/l	3.06	2.73	4.15	2.6	3.9	3.7	2.9
Chloride Dissolved (mg/l)	0.6	0.65	1.5	0.7	1	1.2	0.7
Potassium Dissolved (mg/l)	0.36	0.44	0.26	0.37	0.44	0.28	0.37
Calcium Dissolved (mg/l)	2.6	3.4	3	3.3	2.9	2.4	2.8
Manganese Extractable (mg/l)	L 0.01	L 0.01	0.01	L 0.010	L 0.010	L 0.01	L 0.010
Iron Extractable-Atomic As. (mg/l)	0.07	0.05	0.22		0.17	0.09	0.06
Iron Extractable-(MIBK) (mg/l)				0.04			
Copper Extractable (mg/l)	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002
Arsenic Total (mg/l)		L 0.000					
Zinc Extractable (mg/l)	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	0.02
Cadmium Extractable (mg/l)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001
Mercury Extractable (mg/l)					L 0.02	L 0.02	L 0.02
Lead Extractable (mg/l)	L 0.004	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002
Total Nitrogen-Hydrazine meth. (mg/l)							0.2

Parameters	1991											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Colour Apparent (Rel. Units)	15	20	20	40	45		30	95	20	65		
Specific Conductance (uS/cm)	29	36	30	22	15		28	27	32	22		
Turbidity (JTU)	0.3	0.4	0.5	0.4	0.7		0.5	0.7	0.4	0.6		
Carbon Dissolved Organic (mg/l)	2	1.8	3.1	3.9	5.5		3.1	9	2.7	5.2		
Nitrogen Dissolved NO3 & NO2 (mg/l)	0.2	0.21	0.21	0.15								
Nitrogen Dissolved Nitrate (mg/l)	0.18	0.2	0.19	0.16	0.06		0.02	0.08	L 0.01	0.06		
Nitrogen Total (mg/l)	0.24	0.3	0.25	0.24	0.14		0.14	0.26	0.22	0.23		
Fluoride Dissolved (mg/l)	0.07	0.09	0.06	L 0.05	0.05		0.08	0.07	0.09	0.06		
Alkalinity Total (mg/l)	8.2	11.3	8.3	5.2								
Gran Alkalinity Total (mg/l)					0.5		9.9	7.7	11.3	5.2		
pH (pH Units)	6.9	7	6.9	6.8	5.3		6.9	6.6	7.3	6.4		
Sodium Dissolved (mg/l)	1.7	2.1	1.6	1.2	0.9		1.6	1.5	1.8	1.5		
Magnesium Dissolved (mg/l)	0.54	0.68	0.58	0.4	0.27		0.51	0.6	0.59	0.47		
Aluminum Extractable (mg/l)	0.052	0.037	0.073	0.11	0.14			0.16		0.18		
Silica (MB)-TRAACS 800 mg/l	9.1	10.7	8.1	6.45	5		7.1	6.8	7.7	7.6		
Phosphorus Total (mg/l)	0.002	0.003	0.002	0.003	0.009		L 0.001	0.014	0.022	0.005		
Sulphate Dissolved (mg/l)	3.1	3.2	3.2	3.2	2.4		2.7	3.1	2.6	2.9		
Sulphate MTB-TRAACS 800 mg/l	2.9	3	3.5	3								
Chloride Dissolved (mg/l)	0.6	0.9	0.63	0.5	0.5		0.5	0.5	1.3	0.8		
Potassium Dissolved (mg/l)	0.39	0.55	0.34	0.32	0.39		0.35	0.35	0.36	0.37		
Calcium Dissolved (mg/l)	3	3.9	3.2	2.3	1.4		3.2	3.2	3.5	2.5		
Manganese Extractable (mg/l)	L 0.010	L 0.010	L 0.010	L 0.010	L 0.01			0.01		0.01		
Iron Extractable-Atomic As. (mg/l)	0.09		0.08	0.09	0.08			0.19		0.18		
Iron Extractable-(MIBK) (mg/l)		0.053										
Copper Extractable (mg/l)	L 0.002	L 0.002	L 0.002	0.003	L 0.002			L 0.002		L 0.002		
Arsenic Total (mg/l)												
Zinc Extractable (mg/l)	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01			L 0.01		L 0.01		
Cadmium Extractable (mg/l)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001			L 0.001		L 0.001		
Mercury Extractable (mg/l)	L 0.02	L 0.02	L 0.02	L 0.02	L 0.02		L 0.02	L 0.02				
Lead Extractable (mg/l)	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002			L 0.002		L 0.002		
Total Nitrogen-Hydrazine meth. (mg/l)	0.24	0.26	0.2	0.15								

Parameters	1992					
	JAN	FEB	MAR	APR	MAY	JUN
Colour Apparent (Rel. Units)	5	10	5	15	40	40
Specific Conductance (uS/cm)	28	34	35	25	20	28
Turbidity (JTU)	0.3	0.4	0.4	0.5	0.5	0.3
Carbon Dissolved Organic (mg/l)	2.6	1.6	1.7	2.9	4.2	2.5
Nitrogen Dissolved NO3 & NO2 (mg/l)						
Nitrogen Dissolved Nitrate (mg/l)	0.19	0.2	0.2	0.14	0.06	0.02
Nitrogen Total (mg/l)	0.29	0.27	0.25	0.21		
Fluoride Dissolved (mg/l)	0.08	0.08	0.08	0.06	L 0.05	0.07
Alkalinity Total (mg/l)						
Gran Alkalinity Total (mg/l)	12	11.3	11.3	8.2	4.5	8.6
pH (pH Units)	7.2	7	7	6.3	6.7	7.1
Sodium Dissolved (mg/l)	2.1	2	1.9	1.4	1.2	1.7
Magnesium Dissolved (mg/l)	0.73	0.64	0.65	0.45	0.3	0.45
Aluminum Extractable (mg/l)	0.052	0.058	0.03	0.072	0.092	0.058
Silica (MB)-TRAACS 800 mg/l	11.1	10.5	10.1	4.77	5.5	5
Phosphorus Total (mg/l)	0.001	0.001	0.001	0.004	0.009	0.004
Sulphate Dissolved (mg/l)	3.7	3.2	2.5	2.2	2.5	2.6
Sulphate MTB-TRAACS 800 mg/l						
Chloride Dissolved (mg/l)	1	1.2	2.4	1	0.7	0.6
Potassium Dissolved (mg/l)	0.48	0.44	0.46	0.39	0.49	0.42
Calcium Dissolved (mg/l)	4.4	3.8	4.1	2.7	2.3	3
Manganese Extractable (mg/l)	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01
Iron Extractable-Atomic As. (mg/l)	0.06	0.05	0.05	0.07	0.05	
Iron Extractable-(MIBK) (mg/l)						
Copper Extractable (mg/l)	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002
Arsenic Total (mg/l)						0.059
Zinc Extractable (mg/l)	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01
Cadmium Extractable (mg/l)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001
Mercury Extractable (mg/l)	L 0.02	L 0.02	L 0.02	L 0.02	L 0.02	L 0.02
Lead Extractable (mg/l)	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002	L 0.002
Total Nitrogen-Hydrazine meth. (mg/l)						

L-less than detection limit

Table 13. List of fish species identified in Catamaran Brook (1990-1993).

Family	Scientific Name	Commom Name
Salmonidae	*Salmo salar*	Atlantic salmon
	Salmo trutta	Brown trout*
	Salvelinus fontinalis	Brook trout
Cyprinidae	*Rhinichthys atratulus*	Blacknose dace
	Semotilus atromaculatus	Creek chub
	Couesius plumbeus	Lake chub
	Chrosomus eos	Northern redbelly dace
	Chrosomus neogaeus	Finescale dace
	Notropis cornutus	Common shiner
	Notemigonus crysoleucas	Golden shiner
Catostomidae	*Catostomus commersoni*	White sucker
Clupeidae	*Alosa pseudoharengus*	Gaspereau*
Cottidae	*Cottus cognatus*	Slimy sculpin
Gasterosteidae	*Gasterosteus aculeatus*	Threespine stickleback
Anguillidae	*Anguilla rostrata*	American eel
Petromyzontidae	*Petromyzon marinus*	Sea lamprey

*Rare; <5 specimens found

Table 14. Efficiency of operation and trapping (smolt) at, the fish-counting fence at Catamaran Brook, 1990-1992.

Year	Time(d) that fence was inoperative			Smolt Capture Efficiency	
	May-June	July-Sept	Oct-Nov	# marked	# recaptured
1990*	4.3	4.2	1.4**	--	--
1991	1.8	4.1	1.4	50	35
1992	0	0.8	2.4	50	43

* - location of counting-fence was different in 1991 and 1992.
**- fence prematurely removed 25/10/90 due to flood damage.

Table 15. Age distribution and mean fork length (FL) ± 1 s.d. of Atlantic salmon smolts sampled at the counting-fence at Catamaran Brook, 1990-1992; n=sample size.

Year	Age	n	Mean FL (cm)
1990	2	10	11.9 ± 1.04
	3	26	13.6 ± 0.98
1991	2	32	12.3 ± 0.61
	3	24	13.3 ± 0.78
1992	2	3	11.8 ± 0.42
	3	101	13.5 ± 1.34

Table 16. Frequency of occurrence of mature (precocious) male parr of Atlantic salmon sampled in the autumn (i.e. after 01 October) at the counting-fence at Catamaran Brook , 1990-1992; N = total number of parr (mature and immature); bracketed values refer to percentage of parr sampled which were precocious.

Year	Upstream	Downstream	N
1990*	45 (37%)	39 (18%)	338
1991	11 (39%)	53 (39%)	164
1992	34 (56%)	207 (41%)	563
MEAN	30 (47%)	100 (33%)	355

*- fence prematurely removed 25/10/90 due to flood damage.

Table 17. Annual counts and sex ratios of grilse and MSW (multi-sea winter) Atlantic salmon captured moving upstream at the counting-fence inCatamaran Brook, 1990-1992.

Year	Grilse		MSW	
	Male : Female	Total	Male : Female	Total
1990*	7 : 1	83	5 : 7	28
1991	4 : 1	79	2 : 5	48
1992	11 : 2	127	3 : 8	64

*- fence prematurely removed 25/10/90 due to flood damage.

Table 18: Frequency of occurrence and percent representation of precocious Atlantic Salmon Parr in various reaches of Catamaran Brook, Autumn 1991, 1992.

Year	Upper Reach				Middle Reach				Lower Reach*			
	1+Parr		2+Parr		1+Parr		2+Parr		1+Parr		2+Parr	
	Total Number	Percent Precocious	Total Number	Percent Precocious	Number	Percent Precocious	Total Number	Percent Precocious	Total Number	Percent Precocious	Total Number	Percent Precoicious
1991	11	0	2	0	41	19.5	24	8.3	166	2.4	46	10.9
1992	11	9.1	3	33.3	170	42.9	11	54.5	95	10.5	39	30.8

*Only four of eight sites surveyed in 1992

Table 19. Results of snorkeling observations in pools in different reaches of Catamaran Brook during 1991 and 1992. Numbers represent the average frequency (Freq.) of fish from 2 pools per reach.

B = Brook trout; S = Atlantic Salmon; D = Blacknose Dace; G = Stickleback; W = White Sucker; Y = YOY; P = Parr; A = Adult

Date	Lower Reach			Middle Reach			Gorge Reach		
(mmyy)	Water (°C)	Species/stage	Freq.	Water (°C)	Species/stage	Freq.	Water (°C)	Species/stage	Freq.
0691	15.0	Sy Sp D G	53 4 4 1	15.0	Sy Sp D By Bp	10 7 12 2 7			
0991	12.5	Sy Sa D	2 1 2	12.0	Sy D Bp	2 7 1	12.5	Sy D	3 1
1191	0.5	-none seen-	-	0.5	-none seen	-	-	-	-
0592	7.5	-none seen-	-	-	-	-	-		-
0692	9.0	Sp	2	-	-	-	-	-	-
0792	13.5	Sy Sp D	10 12 13	13.0	Sy Sp Bp	7 15 14	14.0	Sy Sp	15 10
0892	15.0	Sy Sp D	33 9 15	15.0	Sy Sp D Bp	12 14 19 7	15.0	Sy Sp D	19 8 8
0992	11.0	Sy Sp D	18 15 15	10.0	Sy Sp D By Bp	4 6 4 3 1	11.0	Sy Sp D Bp W	7 3 1 1 1
1092	3.0	Sy Sp Sa Bp	3 7 9 4	4.0	Sy Sp Bp	4 4 6	3.5	Sy	6
1192	1.0	-none seen-		-	-	-	-		

Table 20. Abundance of four fishes in pool habitats from different reaches in Catamaran Brook, as determined by capture in minnow-traps, 27 May - 25 August, 1992. Numbers are the totals from 2 pools in each of the stream reaches.

Species	Middle Reach	Gorge Reach	Lower Reach	Total
Atlantic salmon	31	16	29	76
Brook trout	32	12	0	44
Blacknose dace	18	24	44	86
Lake chub	0	37	87	124

Table 21:Summary of Coarse Woody Debris Surveys during the summers of 1990-1992 in different reaches of Catamaran Brook.

Year	Reach Total Length Surveyed	# of Items per 100m Stream Length	Volume(m3) per 100m Stream Length	Habitat Type	# of Items Per Habitat	Mean Butt Diam. (cm)	Mean Mid Diam. (cm)	Mean Overall Length (cm)	Mean Length in Water(m)	# of Jams Per Habitat Type	Mean Surface Area of Jams(m2)	Most Freq. Tree Species
1990	UPOUT 116m	23.3	4.1	RI	27	21.8	16.6	7.4	4.2	0	0.0	Fir
				R	0					0		
	UPEW 116m	24.1	5.5	RI	23	23.0	17.0	6.9	6.2	0		Cedar
				F	5	24.1	18.6	5.4	4.8	0		Cedar
	MID 349m	14.3	5.0***	RI	38	33.9	25.7	5.1	5.1	2	19.0	Fir
				R	1					2	25.6	Unknown
				F	10	19.6	18.8	4.7	3.7	0		Poplar
	GORGE 436m	4.6	1.6	RI	12	26.1	16.6	10.5	7.4	1	0.0	Fir
				R	3	27.7	19.7	13.3	10.2	1	10.0	Fir
				P	5	19.5	17.6	5.7	5.5	1	21.0	Fir
	LOWER 1005m	13	3.7	RI	79	24.3	20.3	8.3	8.8	1	27.0	Fir
				R	41	29.2	20.7	8.6	5.4	1	49.0	Fir
				F	11	27.3	15.1	8.6	7.5	1	18.0	Fir
1991	UPOUT 172M	32.6	5.10	Ri	32	20.6	16.5	8.3	5.0	1	2.1	
				R	18	18.9	14.7	8.5	5.1	2	10.4	Fir
	UPEW 41M	22	3.4	Ri	6	24.4	13.6	8.8	6.0	0		Fir
				R	3	15.0	11.3	6.5	6.5	0		Fir
	MID 340M	6.5	5.7***	Ri	11	37.8	27.8	10.5	7.3	3	20.7	Unknown
				R	3	29.7	22.3	8.0	8.0	0		Fir
				P	6	36.7	30.8	5.7	5.7	1	27.6	Fir
	GORGE 475M	9.5	3.1	Ri	17	27.3	17.8	10.9	7.9	0		Fir
				R	18	24.4	16.5	9.0	6.6	1	10.0	Fir
				P	10	23.0	17.3	7.7	7.9	1	21.0	Cedar
	LOWER 1140M	9.9	4.0	Ri	47	26.2	19.5	8.6	7.7	2	19.7	Fir
				R	52	28.9	21.4	8.3	6.1	0		Fir
				P	2	37.0	22.5	13.1	12.0	0		Fir
				F	12	31.8	23.4	10.6	8.0	0		Fir **
1992	UPOUT 212m	25.9	3.9	Ri	4	24.0	15.8	11.0	4.5	0		Fir
				R	47	19.9	15.4	7.6	4.6	0		Fir
				F	4	14.8	11.5	6.3	4.9	0		Unknown Soft
	UPEW 50m	24.0	4.0	Ri	0					0		
				R	12	22.8	18.5	7.5	5.8	0		Fir/Soft
	MID 372m	7.0	5.3***	Ri	12	26.5	21.0	7.5	4.7	0		Fir/Soft
				R	10	37.0	16.4	9.2	6.3	0		Fir/W Pine
				P	3	33.3	25.3	6.0	6.0	3	21.2	Spruce/Cedar
				F	1	32	24	16	9	0		Fir
	GORGE 408m	9.6	2.5	Ri	16	22.6	16.4	10.3	7.1	0		Fir
				R	13	25.8	18.1	9.7	7.1	0		Fir
				P	9	20.3	16.3	5.7	5.7	1	16.4	Cedar/Soft
				F	1			5.4	5.4	0		Fir
	LOWER 1410m	8.1	3.0	Ri	36	25.6	20.1	7.8	6.1	0		Fir/Maple
				R	52	23.9	17.6	7.5	6.1	0		Fir/Maple
				P	3	28.0	20.3	9.6	8.4	0		Fir
				F	23	26.9	19.4	8.2	7.0	0		Fir/ spruce

* Includes only identified species. In most cases, unidentified debris items were most common

** Debris items identified in this reach were equally common for fir, spruce, pine, birch and unknown species

***Includes one very large item with a per 100m volume of 3.4m3

CODE	Description
UPEW	Upper East West Reach
UPOUT	Upper Outflow Reach
MID	Middle Reach
GORGE	Gorge Reach
LOWER	Lower Reach
RI	Riffle
R	Run
F	Flat
P	Pool

Table 22. Summary of particle sizes and dry weights, (wt.), from Wilock-Vibert Boxes placed in different habitat-types and reaches in Catamaran Brook for the period between August-1991 and June-1992.

		Sieve sizes in millimeters (i.e. particle size).							
Study site	**Average wt. (g)**	**2mm wt. (g)**	**1mm wt. (g)**	**0.5mm wt. (g)**	**0.025mm wt. (g)**	**0.125mm wt. (g)**	**0.038mm wt. (g)**	**Silt <0.038mm (g)**	**Total (g) Dry wt. (g)**
Gorge Pool #2		1.915	2.091	3.864	3.153	0.862	0.829	0.255	12.969
		58.334	123.367	140.335	41.174	7.350	3.260	0.786	374.606
		12.743	18.566	28.731	22.289	7.803	6.888	0.646	97.666
	Avg.	**24.331**	**48.008**	**57.643**	**22.205**	**5.338**	**3.659**	**0.562**	**161.747**
Gorge Run #1		118.696	79.980	79.537	39.048	7.332	3.64[illegible]	1.186	329.420
		109.992	80.248	94.187	56.798	11.202	4.7[illegible]	1.118	358.245
		91.091	86.220	64.494	21.532	5.341	2.661	0.434	271.773
	Avg.	**106.593**	**82.149**	**79.406**	**39.126**	**7.958**	**3.667**	**0.913**	**319.813**
Gorge Riffle #2		157.912	126.307	80.146	33.727	8.570	4.469	0.886	412.017
	Avg.	**157.912**	**126.307**	**80.146**	**33.727**	**8.570**	**4.469**	**0.886**	**412.017**
Lower Flat #2		8.701	24.452	35.351	21.555	13.081	8.735	1.887	113.762
		33.338	25.163	23.263	53.172	18.813	8.669	2.029	164.447
		142.360	127.554	92.700	50.661	11.965	4.965	0.837	431.042
	Avg.	**61.466**	**59.056**	**50.438**	**41.796**	**14.620**	**7.456**	**1.584**	**236.417**
Lower Pool #1		103.630	53.789	29.304	17.760	5.619	3.208	0.856	214.166
		34.430	64.710	105.720	50.840	7.960	4.790	1.300	269.750
		115.700	135.340	54.760	28.230	7.183	4.169	1.178	346.560
	Avg.	**84.587**	**84.613**	**63.261**	**32.277**	**6.921**	**4.056**	**1.111**	**276.825**
Lower Riffle #1		230.500	79.612	47.637	24.108	5.796	2.951	0.757	391.361
		144.645	62.933	46.345	27.111	6.079		0.756	287.869
	Avg.	**187.573**	**71.273**	**46.991**	**25.610**	**5.938**	**2.951**	**0.757**	**341.091**
Lower Run #1		7.000	21.000	30.000	38.000	14.000	1.000	2.000	113 000
		0.863	3.683	6.043	11.392	6.750	5.121	1.185	35.037
		2.350	0.740	1.680	0.660	0.470	0.210	0.001	6.111
	Avg.	**3.404**	**8.474**	**12.574**	**16.684**	**7.073**	**2.110**	**1.062**	**51.383**
Middle Pool #1		0.000	0.000	0.177	0.556	0.491	0.001	0.000	1.225
		1.798	1.020	3.451	3.443	1.812	0.392	0.087	12.003
		177.771	70.353	27.472	13.524	4.825	2.812	0.621	297.378
	Avg.	**59.856**	**23.791**	**10.367**	**5.841**	**2.376**	**1.068**	**0.236**	**103.535**
Middle Run #1		54.121	75.342	44.730	11.132	2.614	1.641	0.386	189.966
		1.892	0.000	4.232	3.729	0.678	2.018	1.081	13.630
		152.783	140.170	83.005	24.420	6.083	4.059	1.159	411.679
	Avg.	**69.599**	**71.837**	**43.989**	**13.094**	**3.125**	**2.573**	**0.875**	**205.092**
Upper Outflow Pool #2		3.302	8.712	12.352	11.437	4.721	2.186	0.247	42.957
		1.987	4.362	11.821	19.545	10.272	4.110	0.705	52.802
		1.821	7.299	18.317	19.467	7.782	3.133	0.781	58.600
	Avg.	**2.370**	**6.791**	**14.163**	**16.816**	**7.592**	**3.143**	**0.578**	**51.453**
Upper Outflow Run #1		42.193	66.845	39.138	19.518	6.378	2.908	0.311	177.291
		113.295	115.786	52.237	19.725	5.682	2.785	0.623	310.133
		136.562	76.888	23.801	10.667	3.615	1.639	0.145	253.317
	Avg.	**97.350**	**86.506**	**38.392**	**16.637**	**5.225**	**2.444**	**0.360**	**246.914**

(g)=Grams
Avg. = Average.

Table 23. Concentrations (ng/g dry wt) of DDT and its derivatives in sediment strata sampled from two beaver ponds and the mainstem of Catamaran Brook in August, 1991. N.D. = not detected.

Sampling location	Stratum (cm)	p,p^1-DDE	p,p^1-DDD	o,p^1-DDT	p,p$_1$-DDT
Beaver Ponds :					
Upper Reach	0-10	79.90	65.00	N.D.	N.D.
	10-20	8.22	9.11	N.D.	N.D.
	20-30	0.47	N.D.	N.D.	N.D.
Tributary One	0-10	8.90	2.56	N.D.	4.01
	10-20	4.65	3.46	N.D.	N.D.
	20-30	2.91	2.81	N.D.	N.D.
Mainstem (control) :					
Lower Reach	0-10	0.86	N.D.	N.D.	N.D.
	10-20	--	N.D.	--	--
	20-30	0.70	N.D.	N.D.	N.D.

Table 24. Numbers of smolts marked from above and below mainstem beaver dams, and subsequently recaptured at the counting-fence in Catamaran Brook during the spring of 1992. Numbers in brackets represent the recapture percentage.

Mark Location	Number Marked	Number Recaptured
Above beaver dams	91	68 (74)
Below beaver dams	56	31 (55)

Table 25. Total number collected, (all sites and dates) and feeding groups of invertebrates (after Merritt and Cummins 1984) found in Catamaran Brook, Summer 1990

Taxon			Functional Group	Total number collected
Annelida; Oligochaeta			Coll/gatherer	148
Platyhelminthes; Turbellaria			Predator	1
Arachnida; Hydracarina			Predator	3
Crustacea; Amphipoda			Shredder	1
Insecta; Ephemeroptera	Ephemeridae	*Ephemera*	Coll/gatherer	26
		Litobrancha recurvata	Coll/gatherer	[illegible]
	Leptophlebiidae	*Habrophlebia vibrans*	Coll/gatherer	[illegible]
		Habrophlebiodes	Scraper	14
		Paraleptophlebia	coll/gatherer	4
		Leptophlebia	coll/gatherer	29
	Ephemerellidae	*Drunella*	Scraper	39
		Eurylophella	Scraper	12
		Ephemerella	Scraper	137
		Serratella	Scraper	11
		Attenella	Scraper	1
	Tricorythodidae	*Tricorythodes*	Coll/gatherer	12
	Baetidae	*Baetis*	Scraper	59
		Pseudocloeon	Scraper	9
		Centroptilum	Scraper	13
		Cloeon	Scraper	2
	Heptageniidae	*Stenonema*	Scraper	178
		Stenacron	Scraper	13
		Heptagenia	Scraper	63
		Epeorus (Iron)	Coll/gatherer	60
		Rhithrogena	Coll/gatherer	41
	Oligoneuridae	*Isonychia*	Coll/filterer	7
	Siphlonuridae	*Ameletus*	Coll/gatherer	4
Odonata	Aeshnidae	*Boyeria*	Predator	25
	Gomphidae	*Lanthus*	Predator	76
		Stylogomphus	Predator	1
		Ophiogomphus	Predator	1
	Cordulegastridae	*Cordulegaster*	Predator	11
Plecoptera	Leuctridae	*Leuctra*	Shredder	11
	Capniidae	*Paracapnia?*	Shredder	13
	Taeniopterygidae	*Taeniopteryx*	Shredder	8
		Taenionoma	Shredder	1
	Pteronarcyiidae	*Pteronarcys*	Shredder	4
	Perlidae	*Agnetina*	Predator	93
		Acroneuria	Predator	18
		Hydroperla	Predator	1

Table 25. Cont'd

Taxon			Functional Group	Total number collected
	Perlodidae	*Isogenoides*	Predator	11
		Isoperla	Predator	3
	Chloroperlidae	*Sweltsa*	Scraper/pred	82
		Alloperla	Scraper/pred	2
Trichoptera	Limnephilidae	*Frenesia*	Shredder	1
		Limnephilus	Shredder	2
		Apatania	Scraper	2
		Hydatophylax	Shredder	6
		Pycnopsyche	Shredder	7
	Leptoceridae	?		3
	Lepidostomatidae	*Lepidostoma*	Shredder	4
	Phryganeidae	*Oligostomis*	Predator	3
	Odontoceridae	*Psilotreta labida?*	Scraper	33
	Philopotamidae	*Doliphilodes*	Coll/filterer	123
	Polycentropidae	*Polycentropus*	Predator	5
	Glossomatidae	*Glossosoma*	Scraper	15
		Agapetus	Scraper	2
	Rhyacophilidae	*Rhyacophila*	Predator	15
	Hydropsychidae	*Hydropsyche*	Coll/filterer	44
		Arctopsyche	Coll/filterer	9
		Cheumatopsyche	Coll/filterer	2
		Diplectrona	Coll/filterer	1
	Helicopsychidae	*Helicopsyche borealis*	Scraper	1
	Hydroptilidae	?	Coll/gatherer	1
Megaloptera	Corydalidae	*Nigronia*	Predator	22
	Sialidae	*Sialis*	Predator	7
Hemiptera	Gerridae	*Gerris?*	Predator	1
Coleoptera	Dytiscidae	?	Predator	1
	Psephenidae	*Psephenus*	Scraper	3
		Ectopria	Scraper	1
	Elmidae	*Optioservus*	Coll/gatherer	22
		Oulimnius	Coll/gatherer	1
		Dubiraphia	Coll/gatherer	2
	Hydraenidae	?	Coll/gatherer	1
Diptera	Dixidae	*Dixa*	Coll/gatherer	7
	Simuliidae	*Simulium*	Coll/filterer	19
	Chironomidae	Orthocladiinae	Coll/gatherer	36
		Chironominae	Coll/gatherer	26
		Tanypodinae	Predator	5
	Athericidae	*Atherix*	Predator	68

Table 25. Cont'd

Taxon		Functional Group	Total number collected
Tipulidae	*Tipula*	Shredder	4
	Hexatoma	Predator	22
	Dicronata	Predator	2
	Molophilus	?	2
	Pedicia	Predator	1
	Limonia	Shredder	1
	Pseudolimnephila?	?	1
Tabanidae	?	Predator	3
Ceratopogonidae	?	Predator	9

Table 26. Number of taxa (usually genus) and mean number per kick sample of aquatic invertebrates found in each study site and reach at Catamaran Brook, summer 1990.

	Upper Reach		Middle Reach			Gorge Reach			Lower Reach			
	LAKEO	TRIB	MF1	MRI1	MRU1	GBRU1	GRU1	GRI1	LBRU1	LRI1	LRU1	LF1
no. taxa	40	44	31	34	38	31	40	33	31	35	36	39
total no. taxa per reach	54		53			57			61			
mean no. per. kick	54	52	40	86	82	40	50	69	54	55	56	47

key: LAKEO = Catamaran Lake Outflow; TRIB = Main Tributary; MF1 = Middle Flat 1; MRI1 = Middle Riffle 1; MRU1 = Middle Run 1; GBRU1 = Gorge Bedrock Run 1; GRU1 = Gorge Run 1; GRI1 = Gorge Riffle 1; LBRU1 = Lower Bedrock Run 1; LRI1 = Lower Riffle 1; LRU1= Lower Run 1; LF1 = Lower Flat 1.

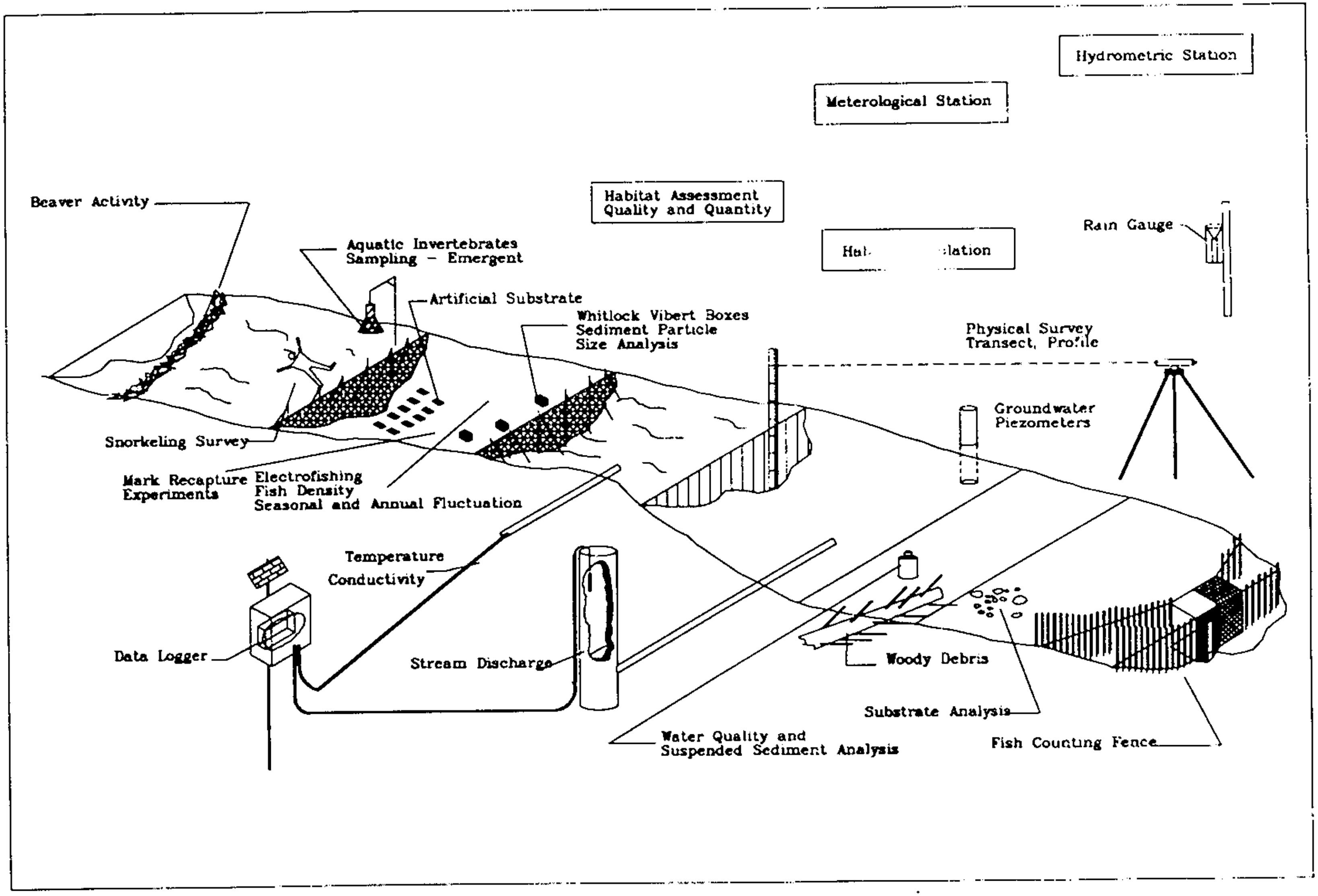

Figure 1. Pictorial representation of the various activities being conducted in a hypothetical section of Catamaran Brook.

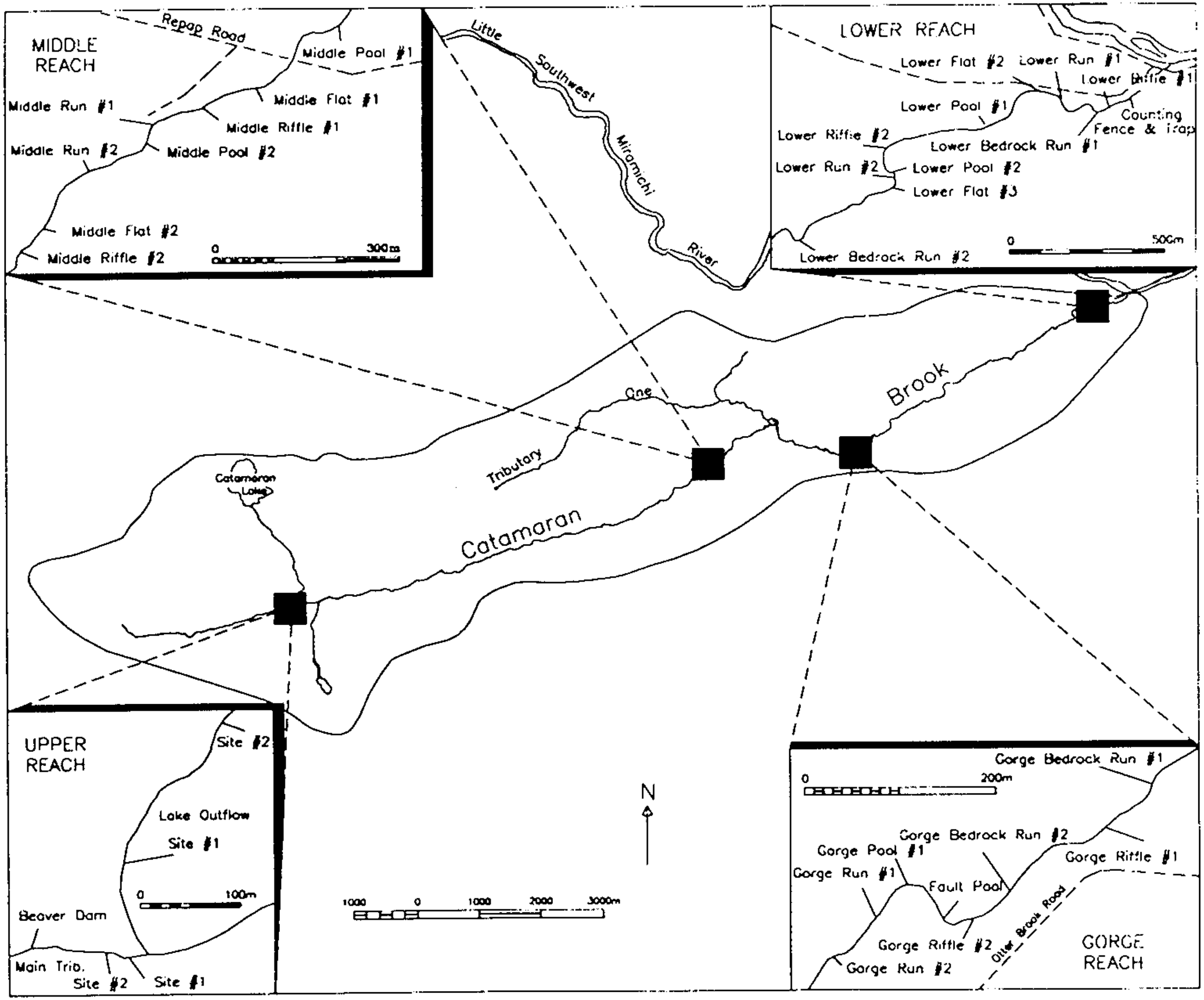

Figure 2. Map of the Catamaran Brook basin. Insets depict the four study reaches and the sampling sites.

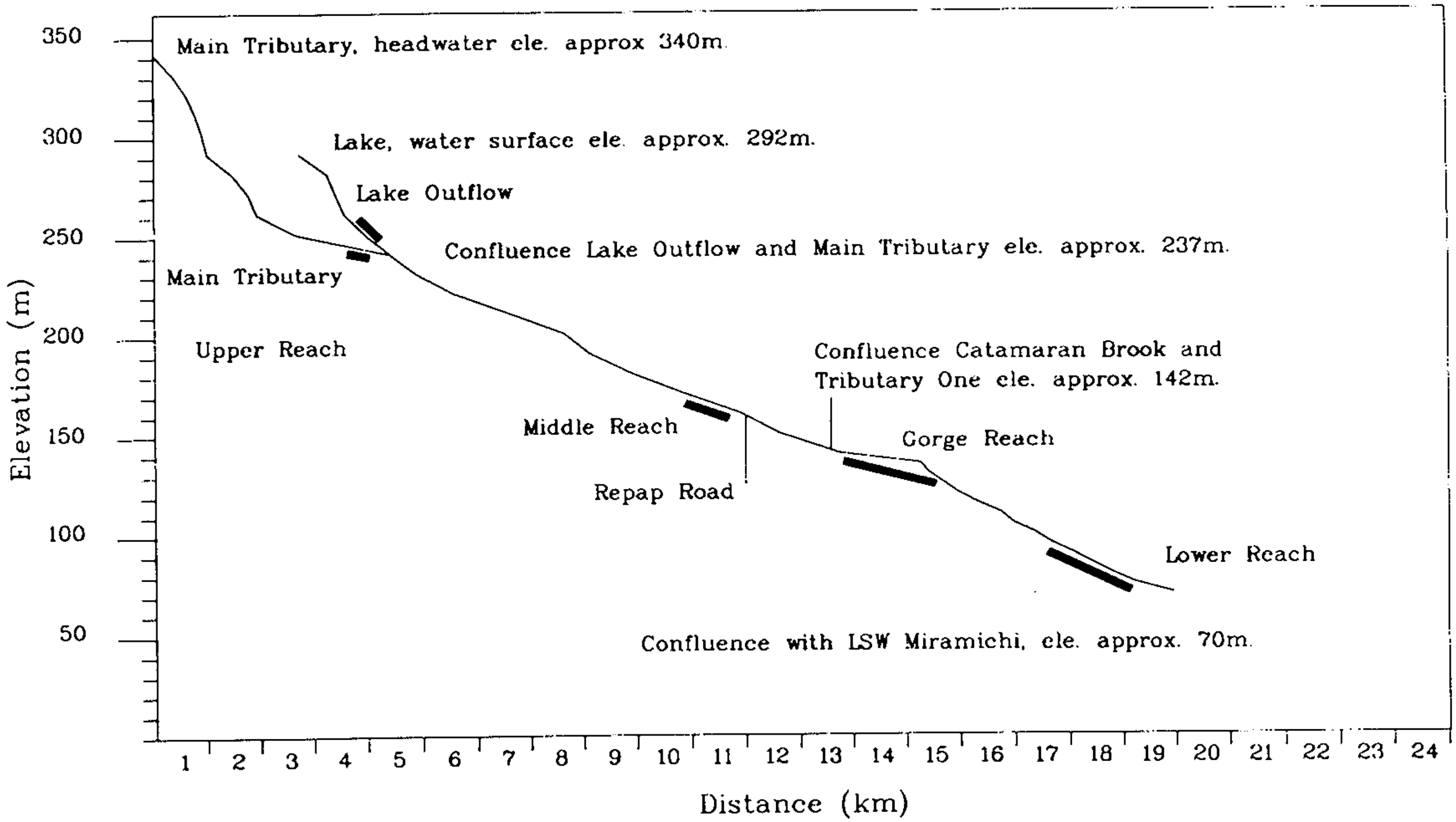

Figure 3. Profile of elevation change for Catamaran Brook showing location of study reaches and the tributary junctions.

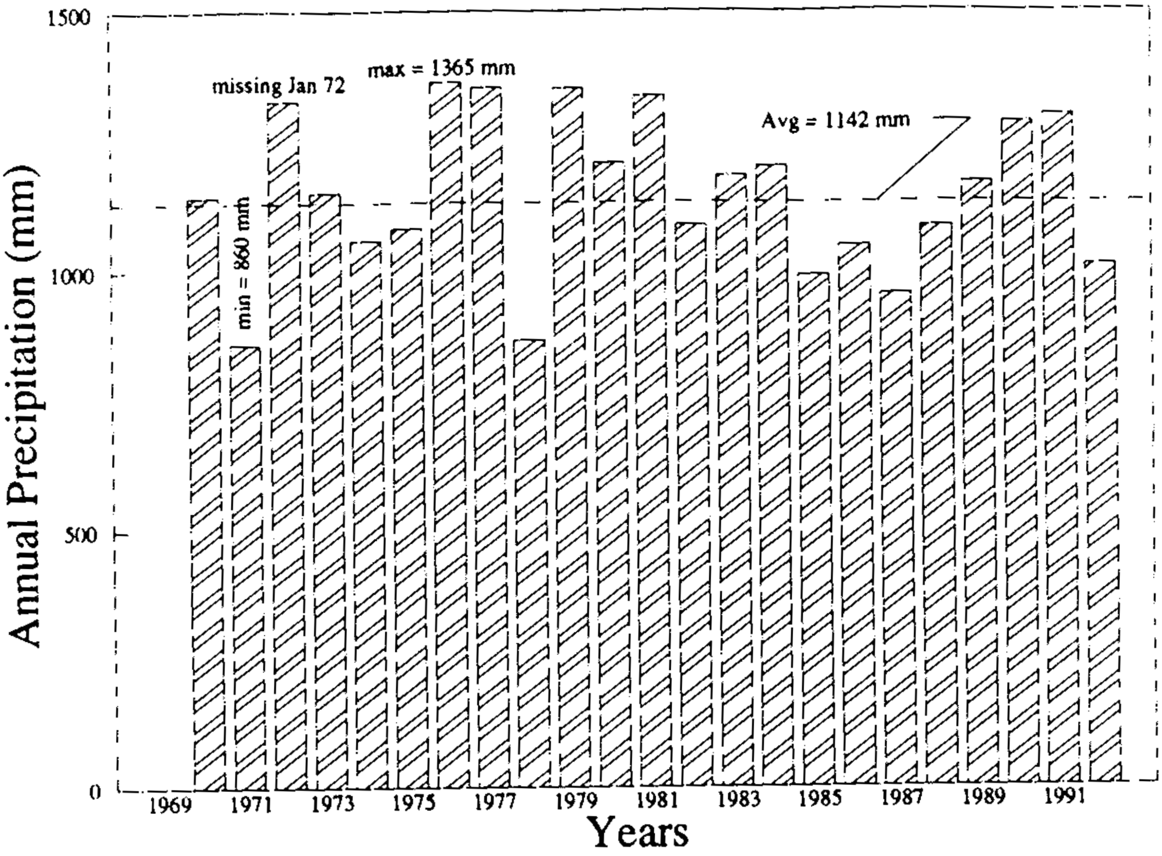

Figure 4. Mean annual precipitation (mm) measured in the Catamaran Brook basin from 1969 to 1992. Dashed horizontal line represents the long-term average.

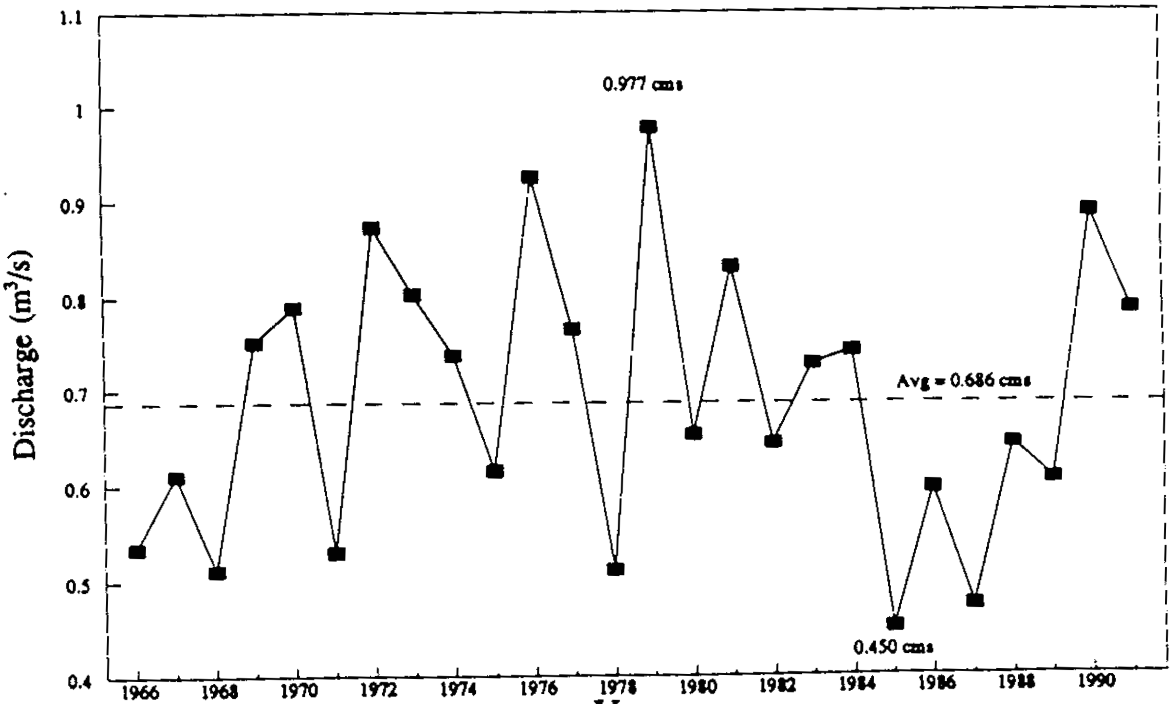

Figure 5. Mean annual discharge ($m^3 \cdot s^{-1}$) for Catamaran Brook between 1966 and 1991. Values prior to 1990 are estimates based on prorated discharges from nearby Renous River gauge station. Dashed line represents the long-term average.

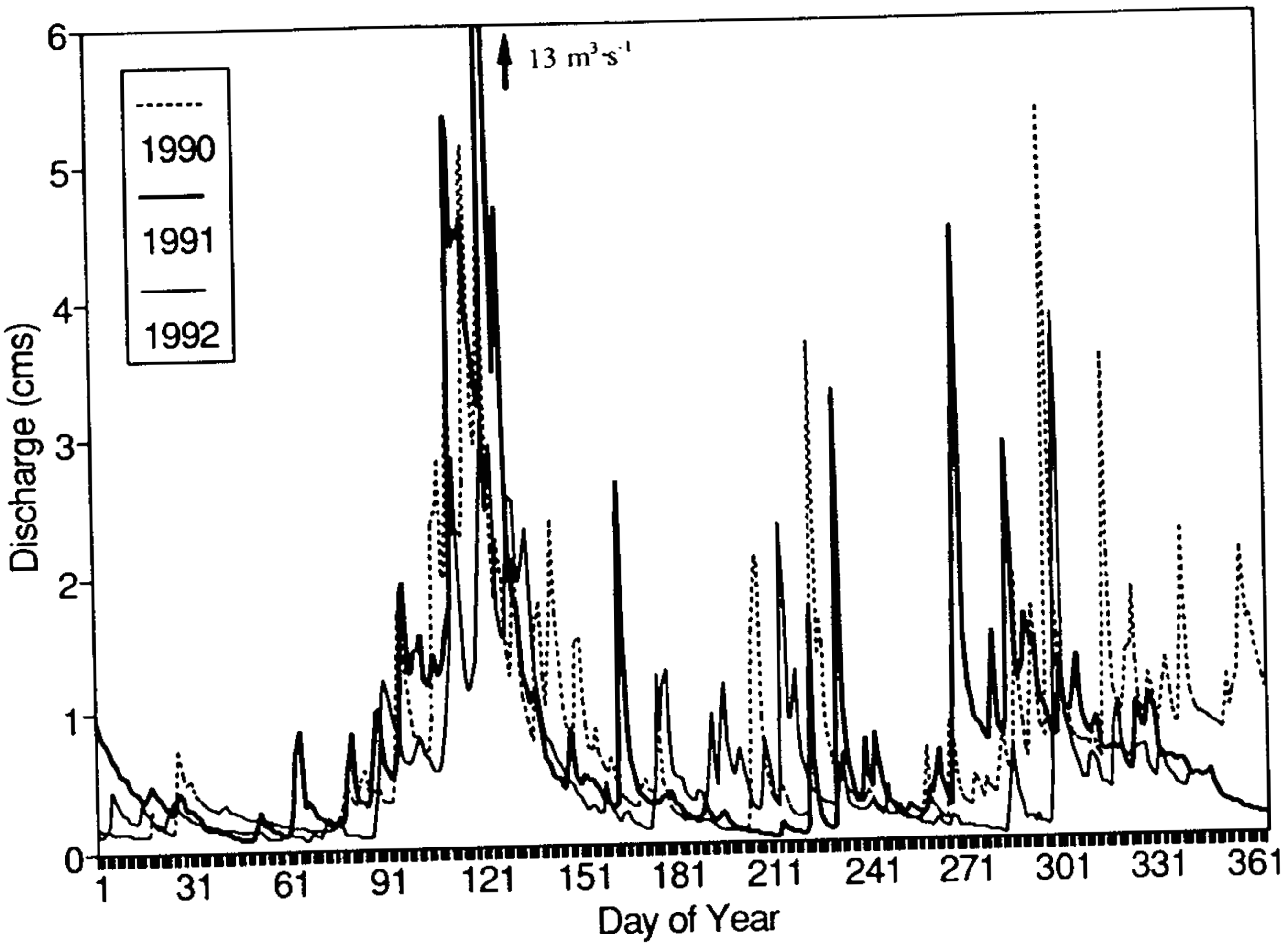

Figure 6. Catamaran Brook daily discharge ($m^3 \cdot s^{-1}$) between 1990 and 1992.

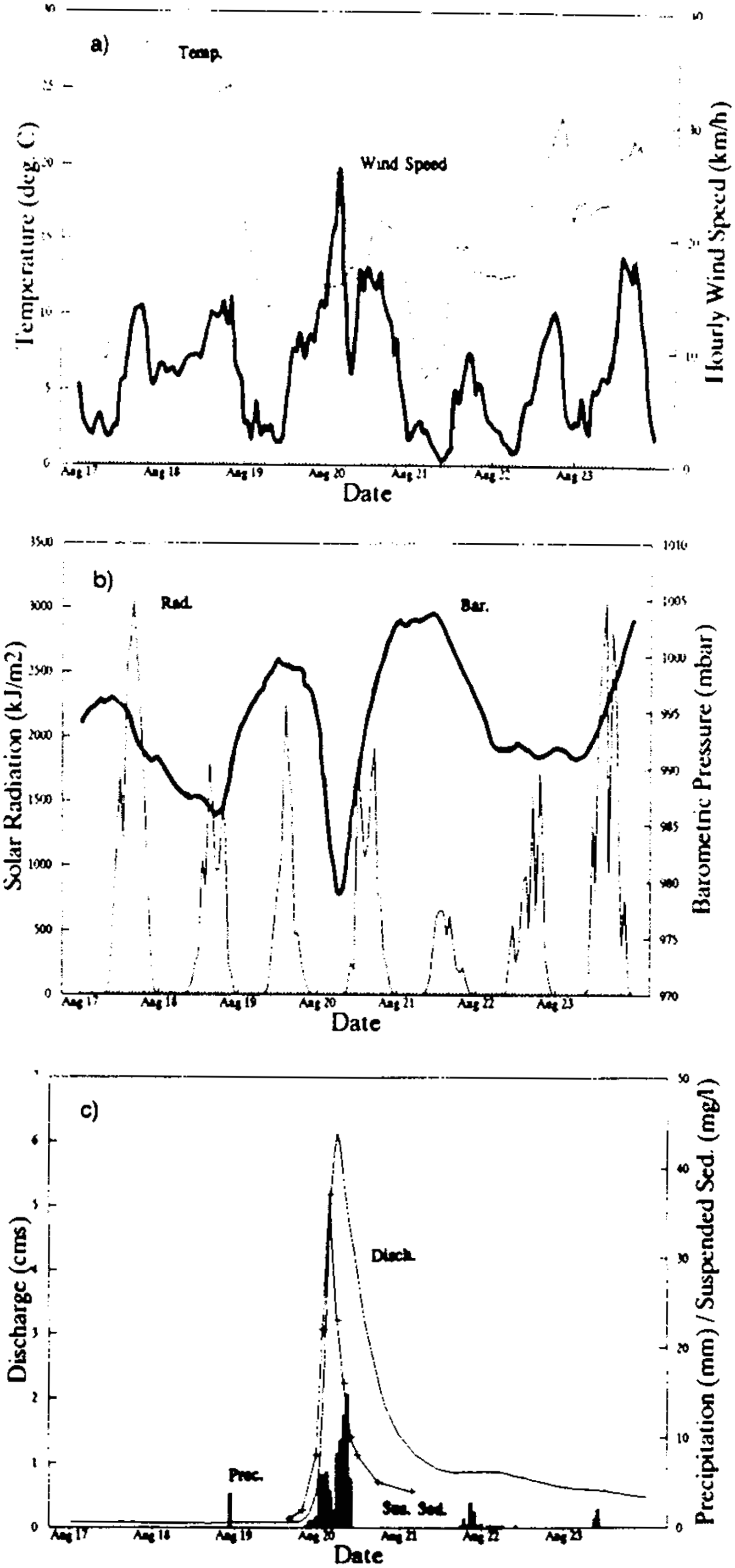

Figure 7. Tracking of Hurricane Bob through Catamaran Brook basin, August 17-23, 1991: (a) air temperature (temp.) and hourly wind speed as measured at the meteorological station; (b) solar radiation (Rad.) and barometric pressure (Bar.) also measured at the meteorological station; (c) precipitation (Prec., histogram), discharge (Disch.) measured for the Middle Reach, and suspended sediments (Sus. Sed.) concentration curve based on collections at the river mouth.

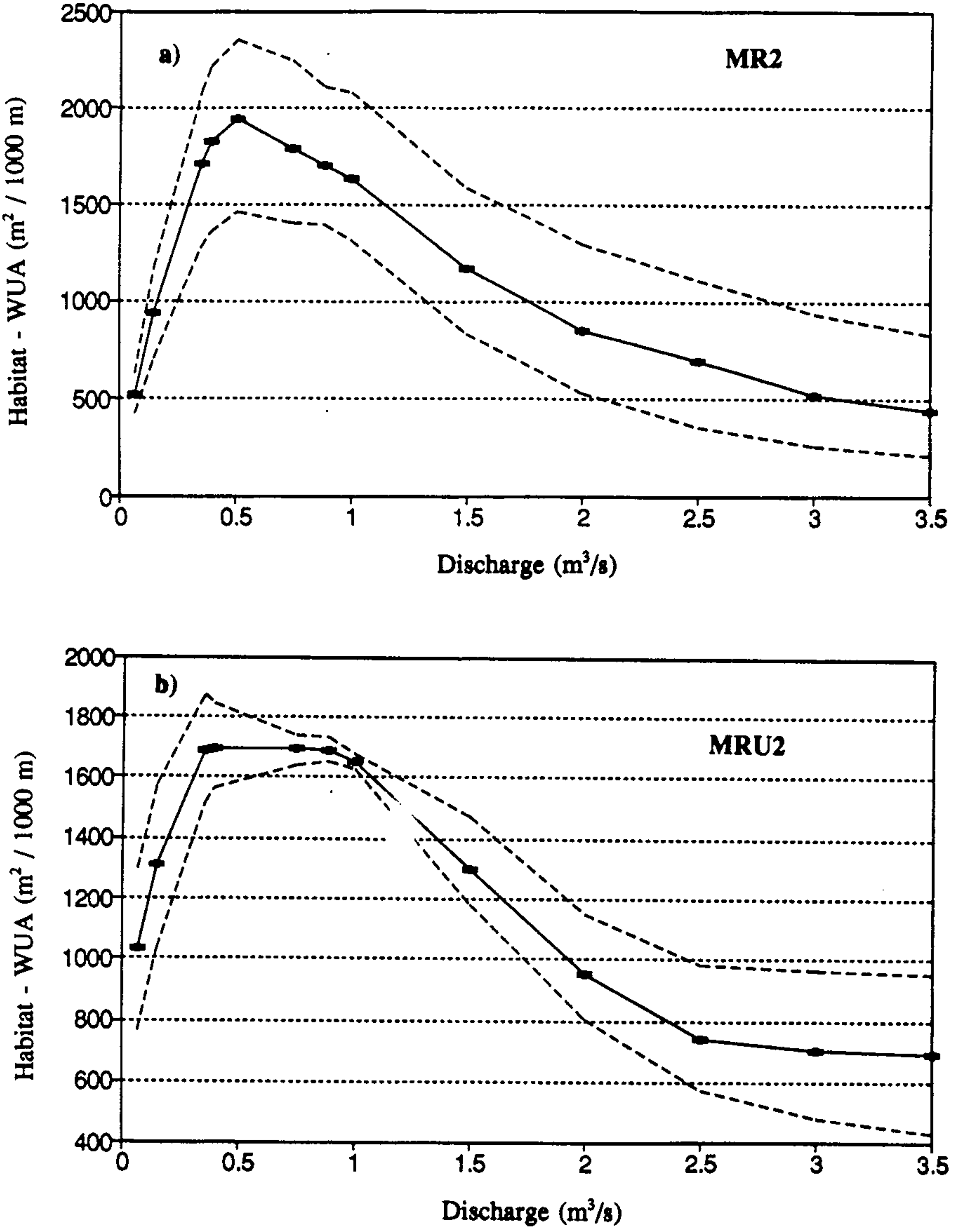

Figure 8.Habitat-discharge relationship for Atlantic salmon fry in sites MR2 (top panel) and MRU2 (bottom panel) using PHABSIM model. WUA = Weighted Usable Area. Dashed lines represent 95% confidence interval.

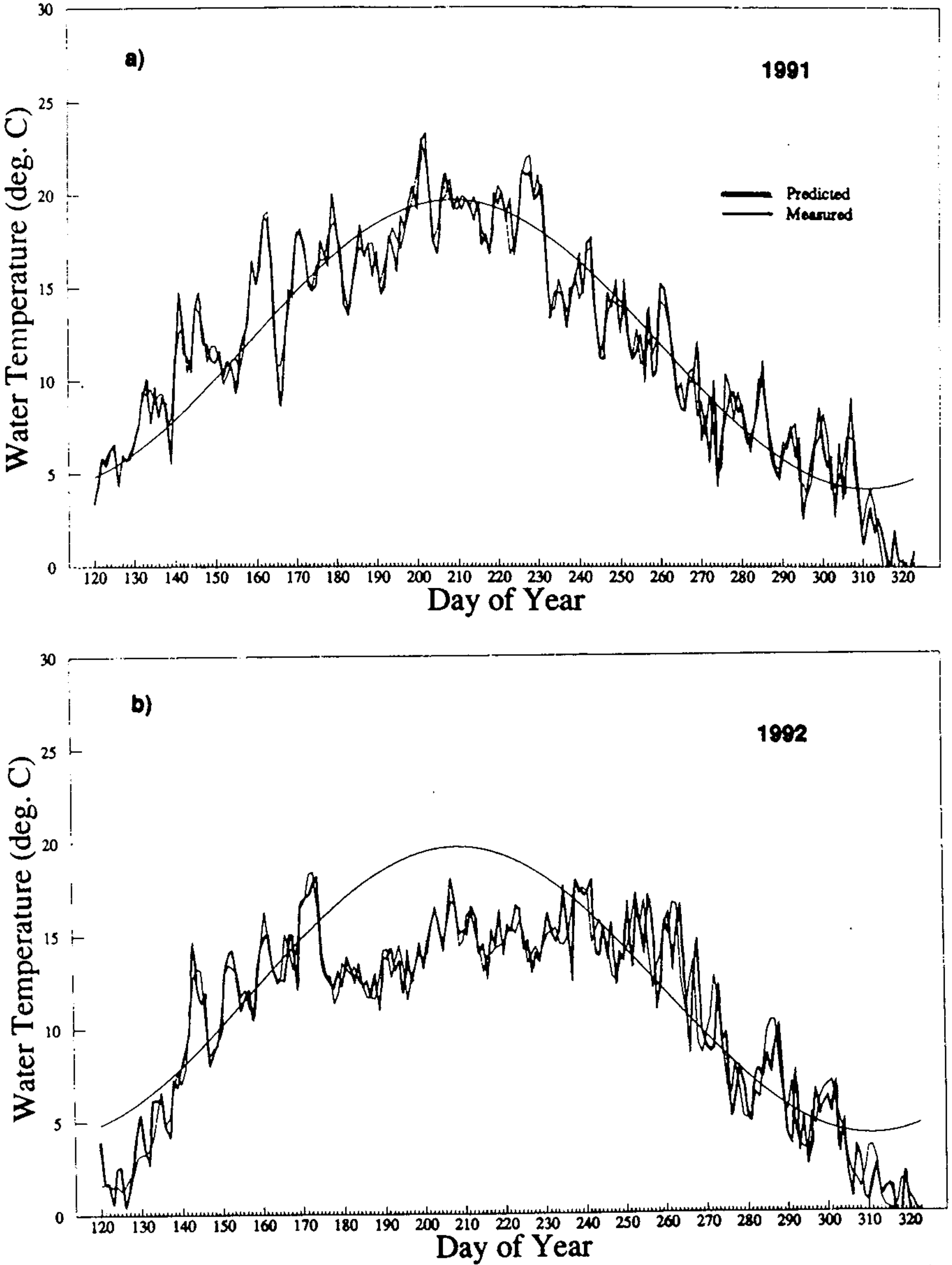

Figure 9. Predicted (heavy line) and measured (fine line) stream water temperatures for Catamaran Brook during 1991 and 1992. Smoothed curve represents nonseasonal variation from a Fourier analysis. Day 120 represents 30 April in 1991 and 29 April in 1992.

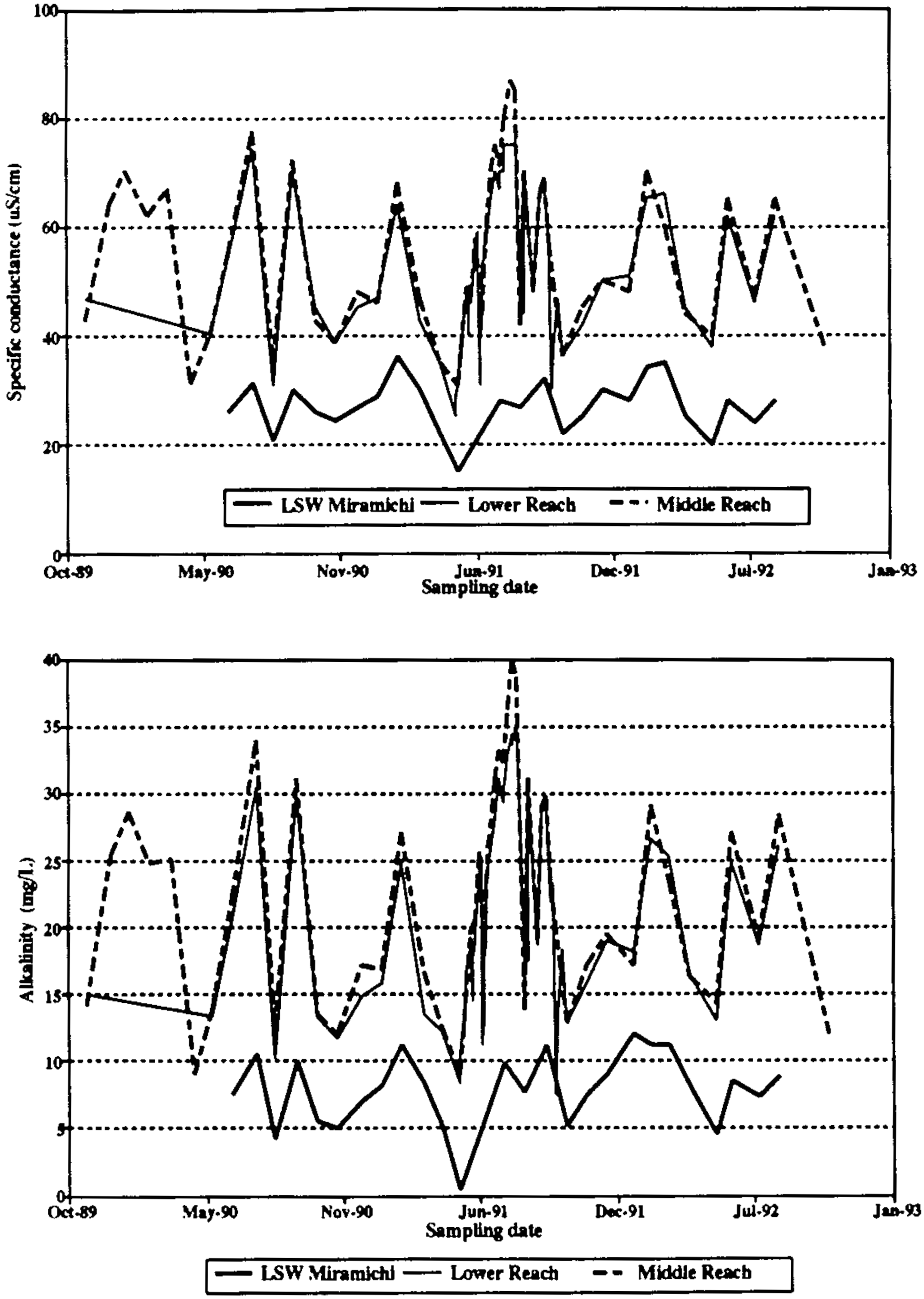

Figure 10. Specific conductance (top panel) and alkalinity (bottom panel) at Catamaran Brook and Little Southwest Miramichi River, 1989 - 1993.

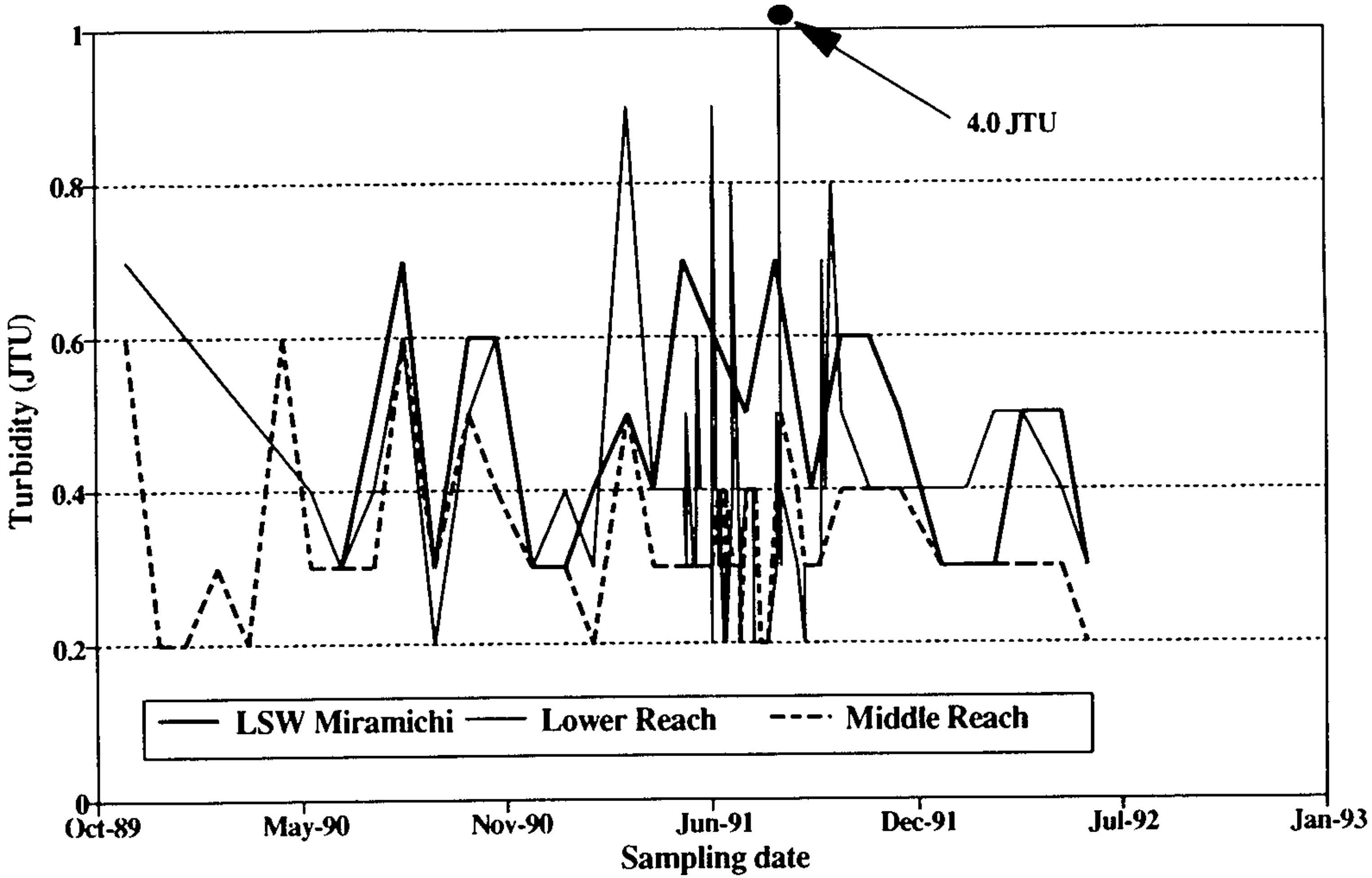

Figure 11. Turbidity at Catamaran Brook and Little Southwest Miramichi River, 1989 - 1992.

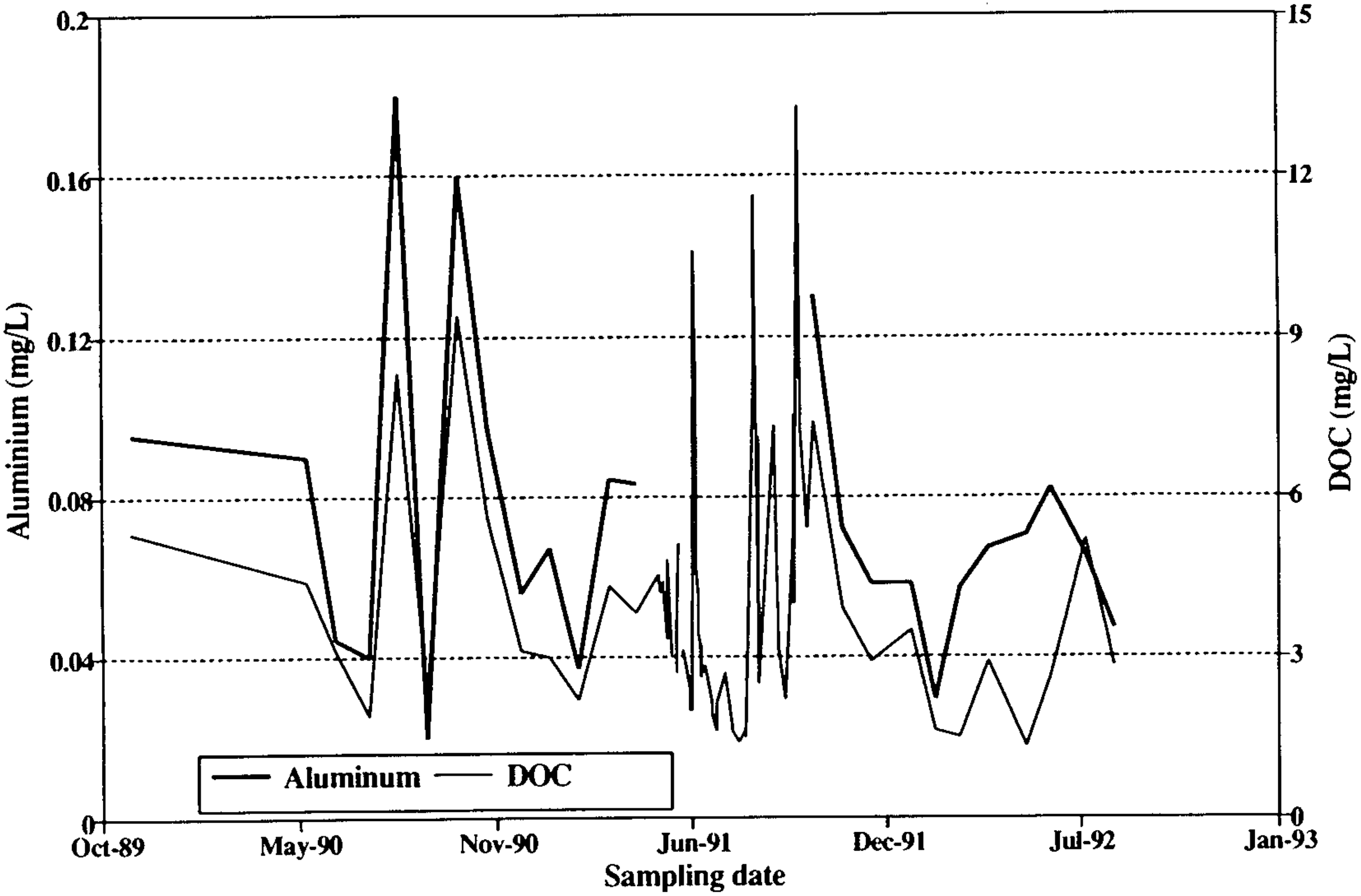

Figure 12. Concentration of aluminium and dissolved organic carbon (DOC) at Catamaran Brook, Lower Reach, 1989 - 1993.

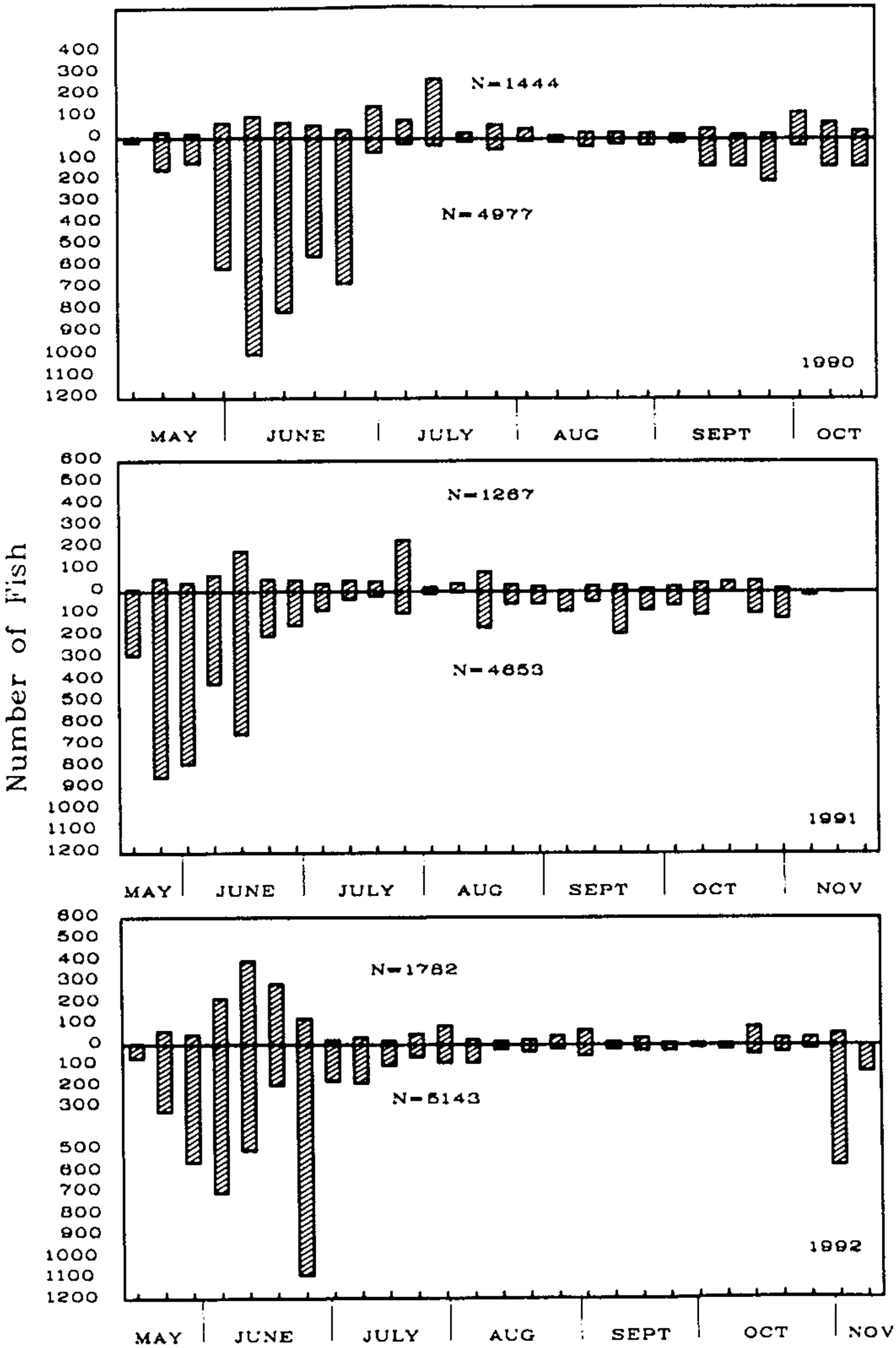

Figure 13. Weekly movements of fish (all species combined) at the counting fence in Catamaran Brook, 1990-1992. Upstream movement is above the horizontal axis; downstream movement is below.

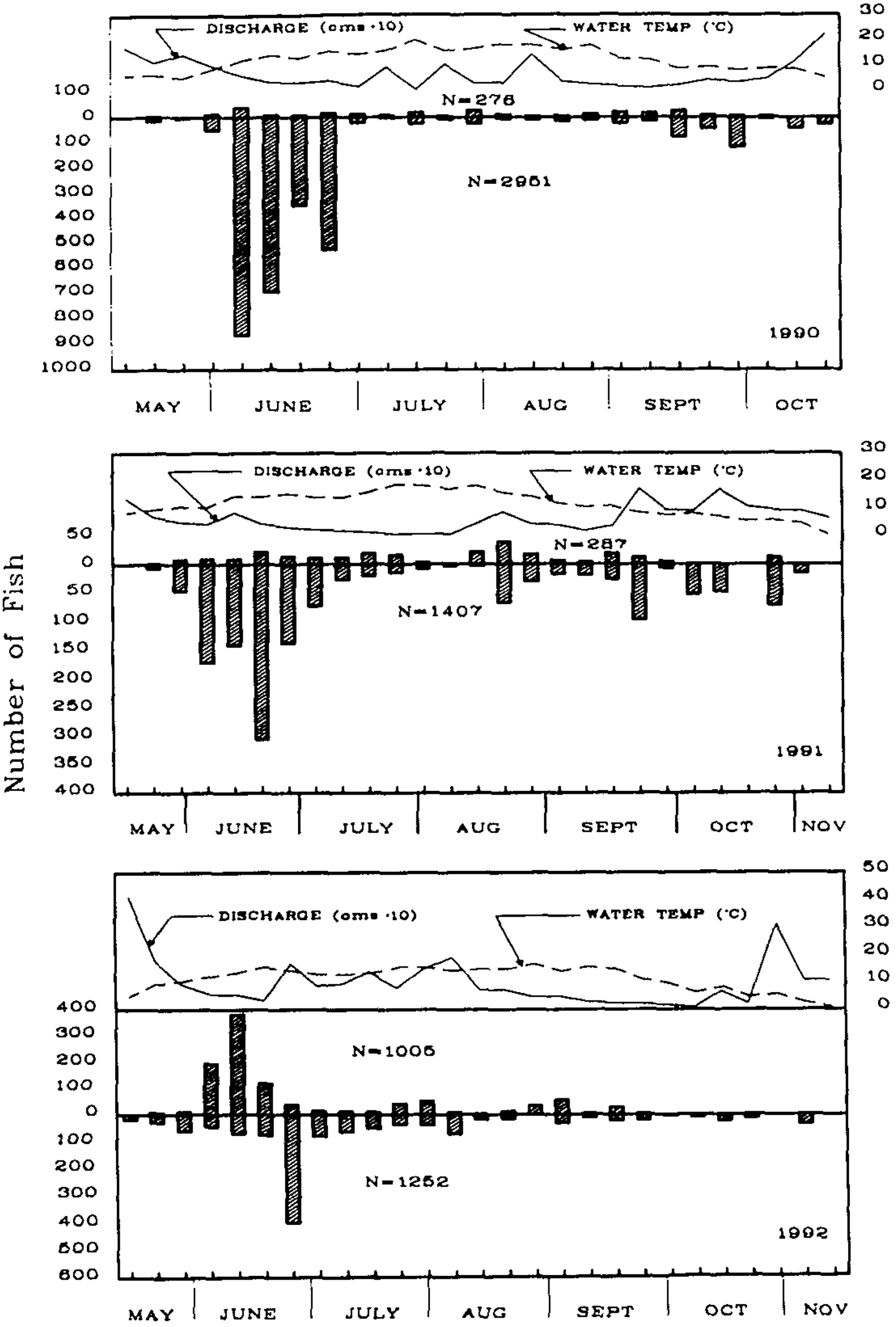

Figure 14 Weekly movements of Cyprinid fishes at the counting fence in Catamaran Brook, 1990–1992. *Upstream movement* is above the horizontal axis; downstream movement is below. Mean, weekly water temperature (°C) and river discharge ($m^3 s^{-1} \cdot 10$) are also plotted for comparison with movements.

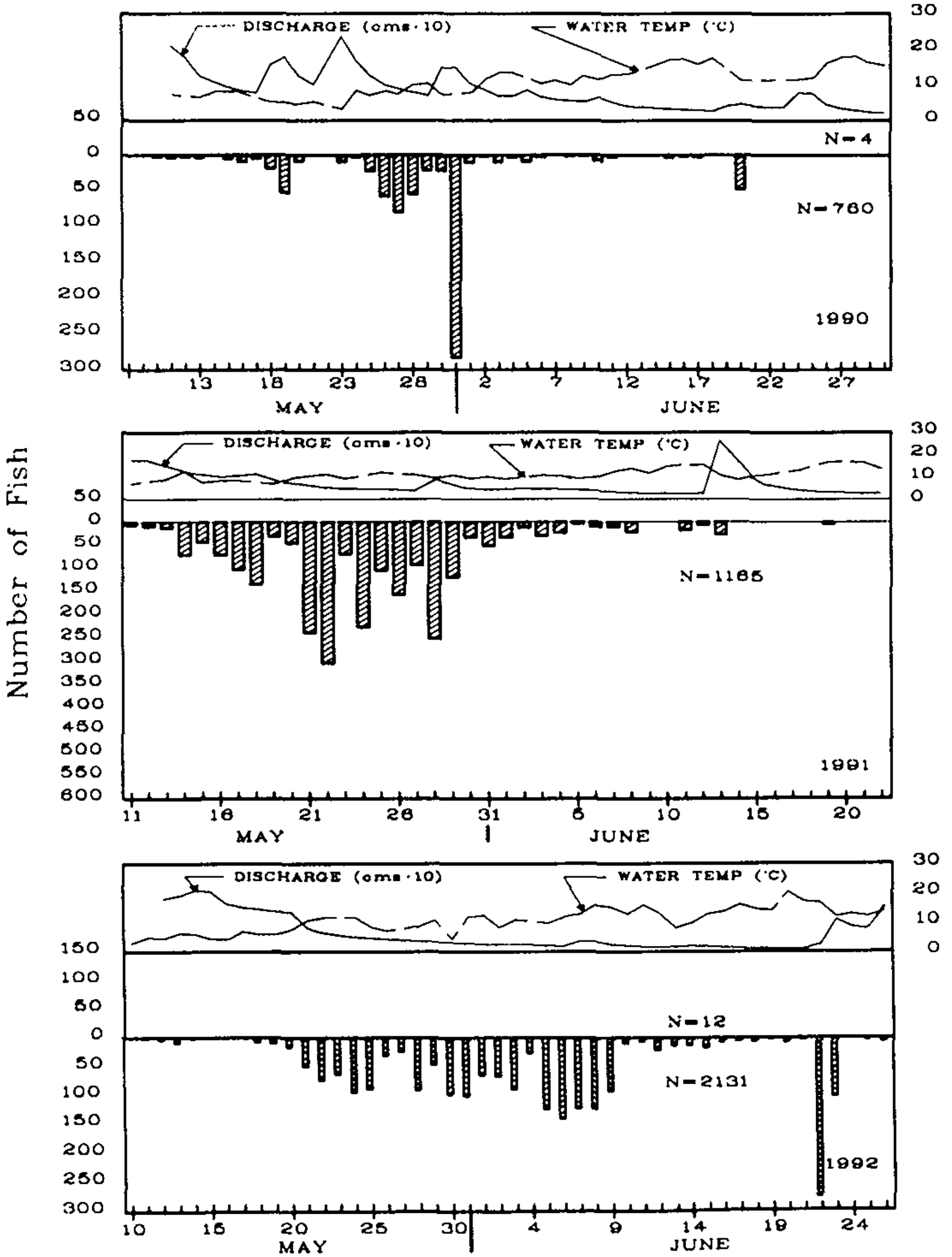

Figure 15. Daily movements of Atlantic salmon smolts at the counting fence at Catamaran Brook, 1990–1992. Upstream movement is above the horizontal axis; downstream movement is below. Mean, daily water temperature (°C) and river discharge ($m^3 \cdot s^{-1} \cdot 10$) are also plotted for comparison with *movements*.

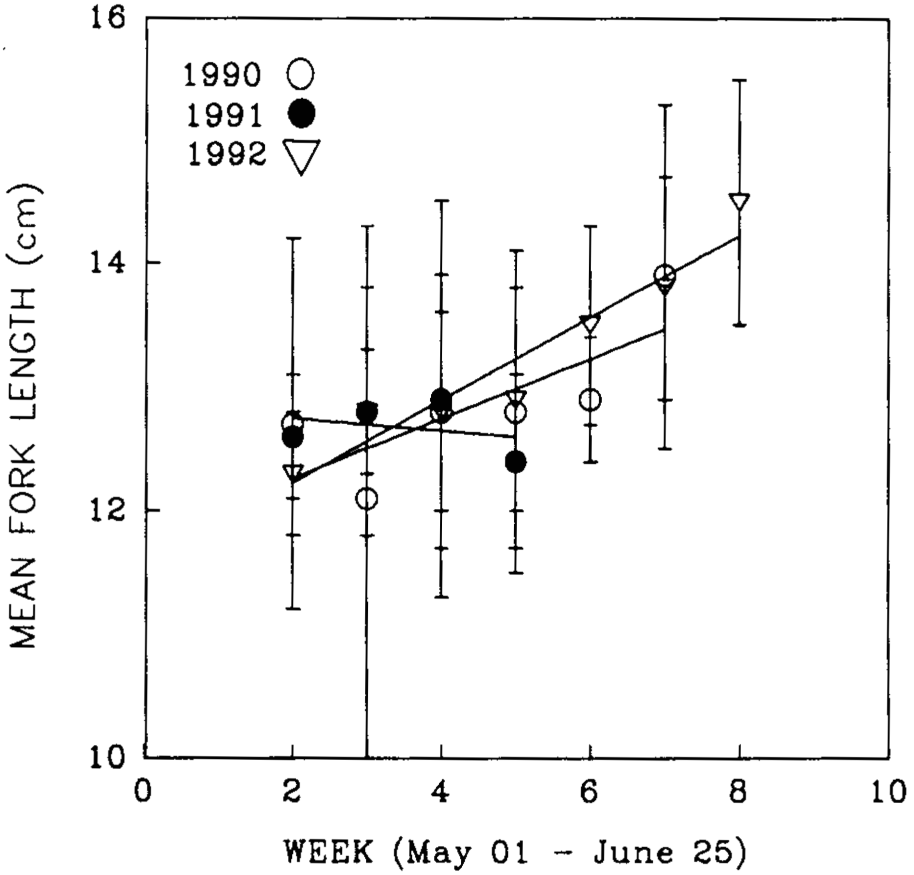

Figure 16. Change in mean fork length (± 1 s.d.) of Atlantic salmon smolts during the spring emigration from Catamaran Brook, 1990-1992.

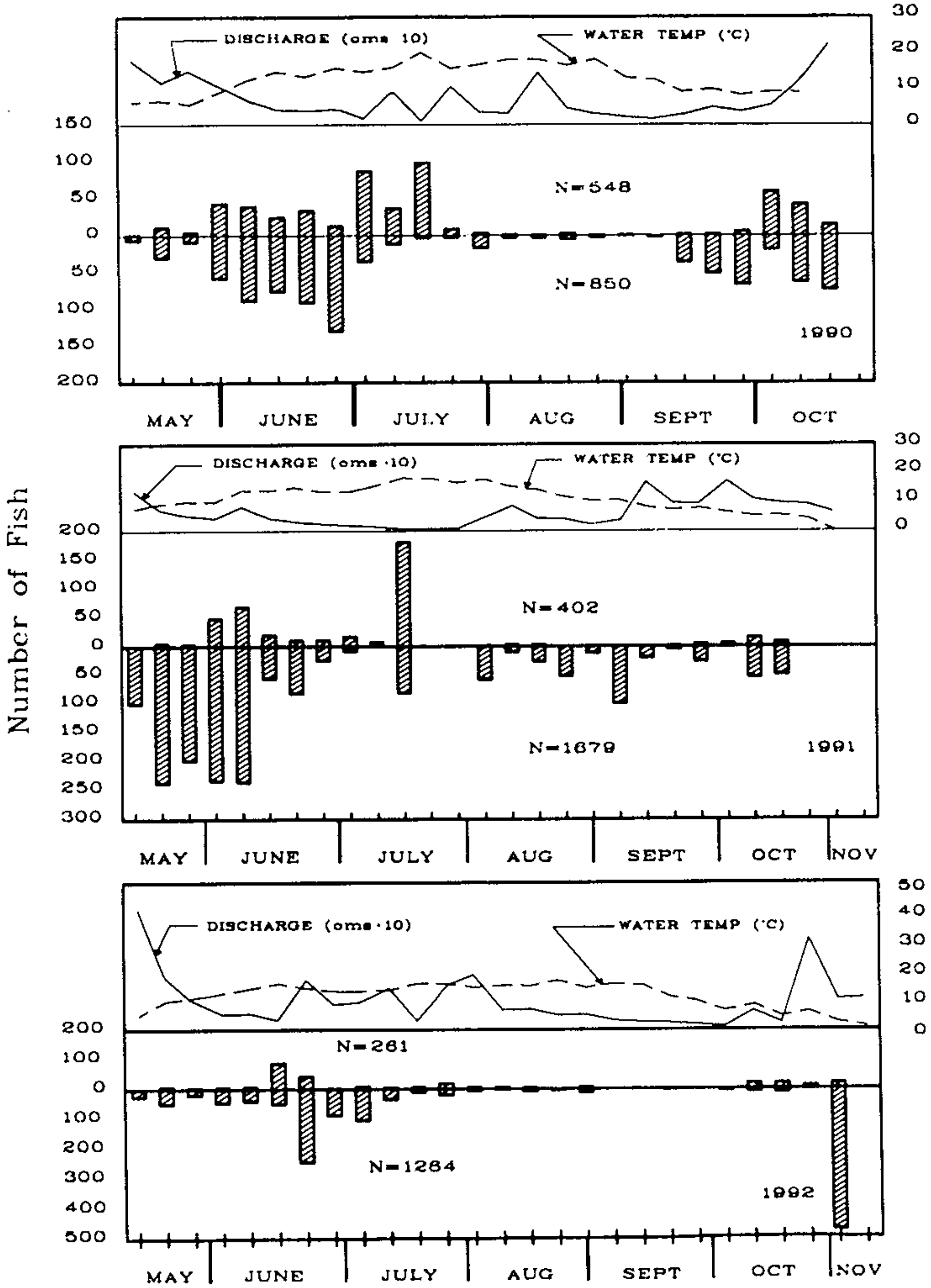

Figure 17. Weekly movements of Atlantic salmon parr at the counting fence in Catamaran Brook, 1990–1992. Upstream movement is above the horizontal axis, downstream movement is below Mean, weekly water temperature (°C) and river discharge ($m^3 \cdot s^{-1} \cdot 10$) are also plotted for comparison with movements.

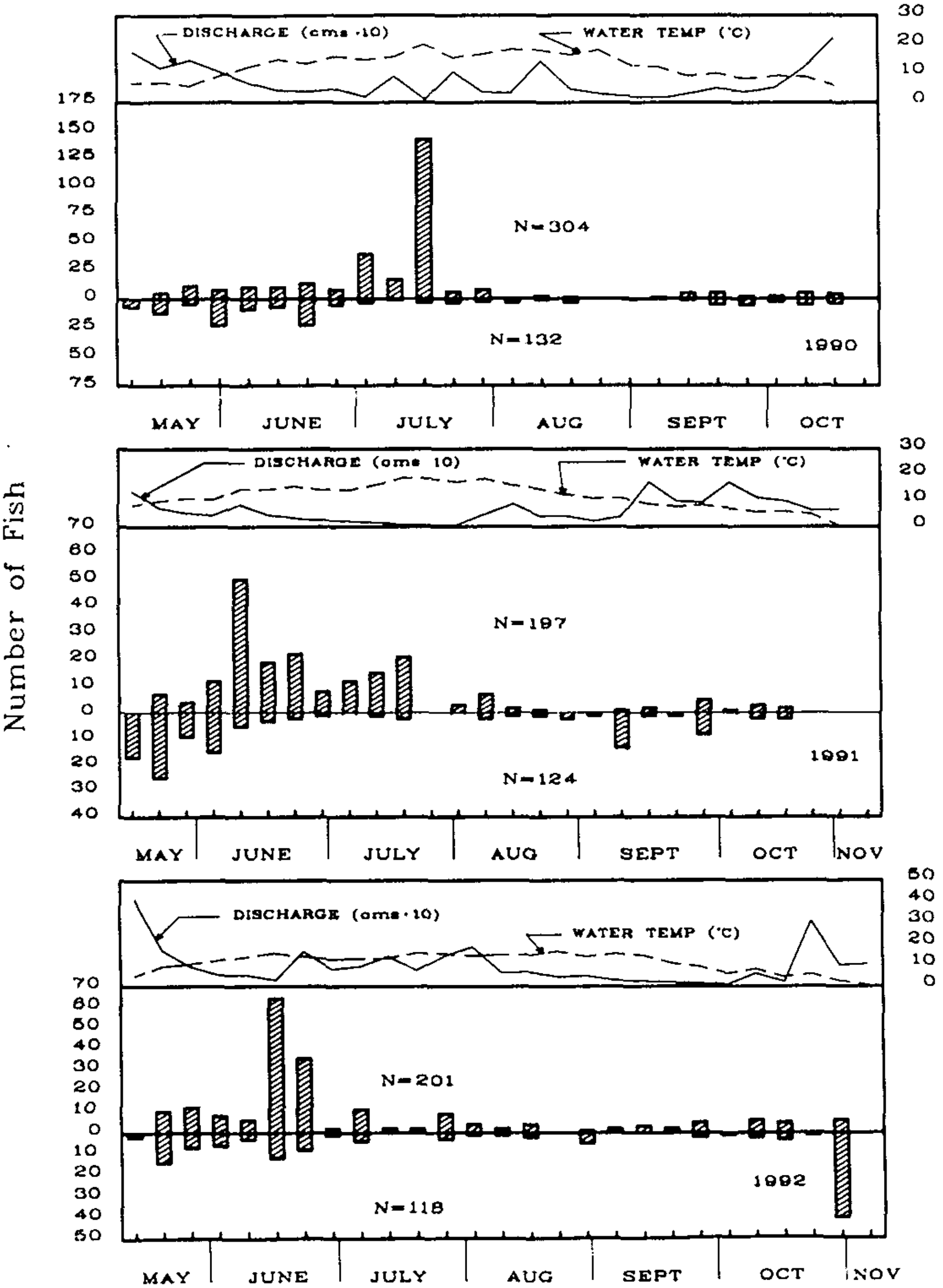

Figure 18. Weekly movements of brook trout at the counting fence in Catamaran Brook, 1990–1992. Upstream movement is above the horizontal axis; downstream movement is below. Mean, weekly water temperature (°C) and river discharge ($m^3 \cdot s^{-1} \cdot 10$) are also plotted for comparison with movements.

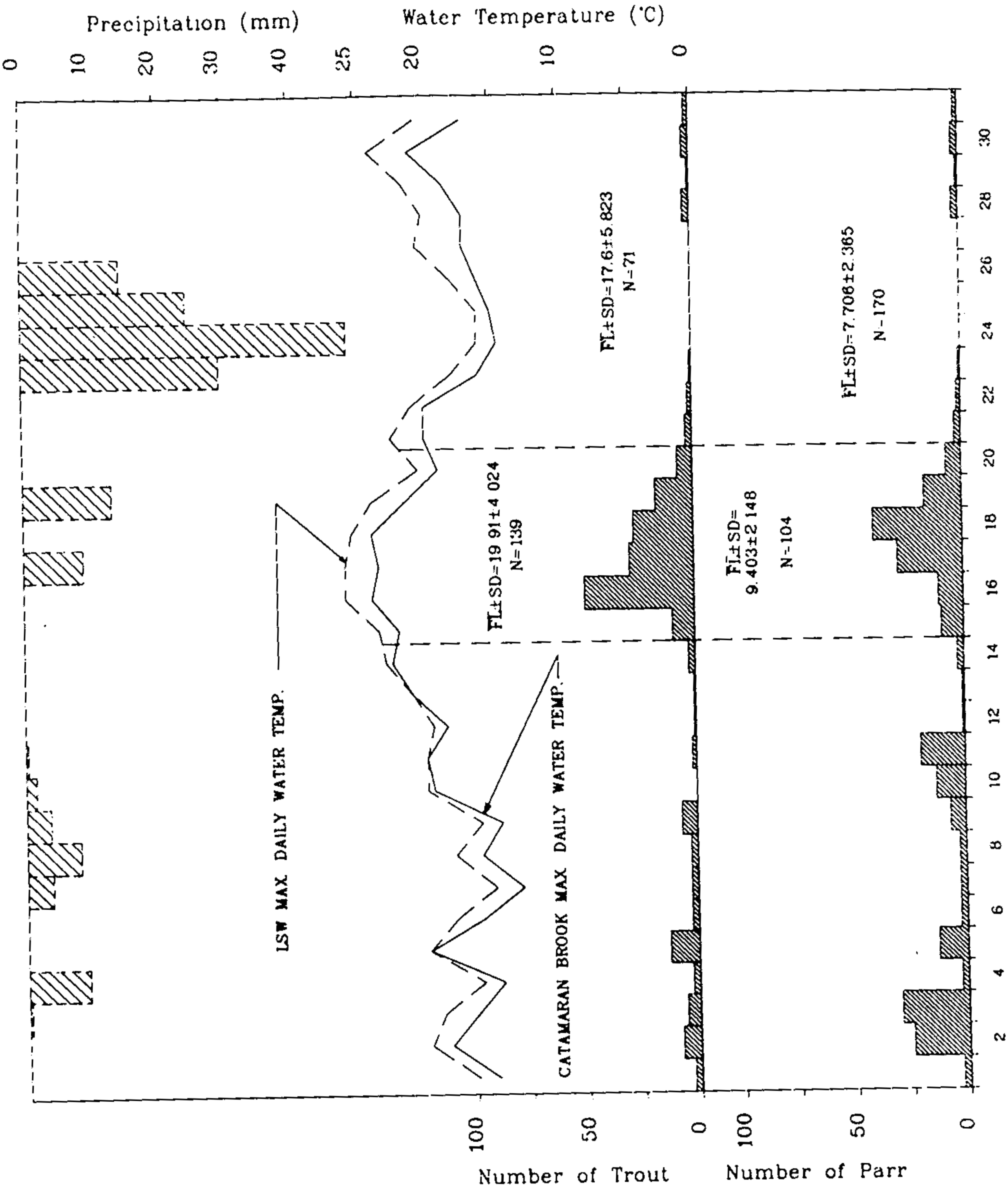

Figure 19. Daily, upstream movements of brook trout and Atlantic salmon parr in relation to high water temperatures measured in the Little Southwest Miramichi River (dashed line) and in Catamaran Brook (solid line) during the month of July in 1990. Movement was enumerated at the counting fence; fork length (FL) and sample size (N) were measured during, and outside, the period of temperature stress; hatched bars (top) represent daily rainfall totals.

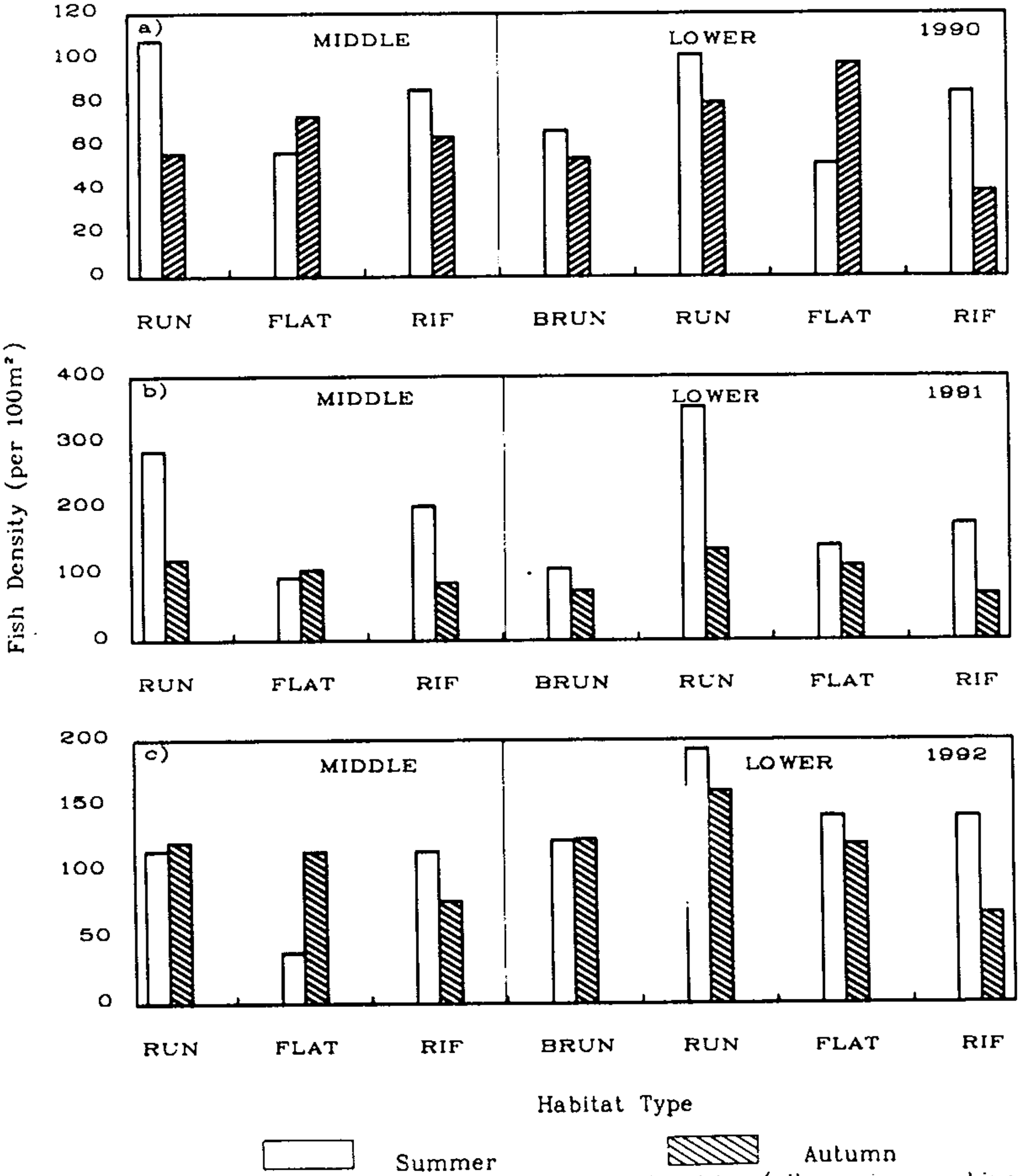

Figure 20. Seasonal comparisons of mean fish densities (all species combined, per $100m^2$) in different habitat-types in the Middle and Lower Reaches of Catamaran Brook, 1990-1992. Densities are the average of two replicates per habitat-type.

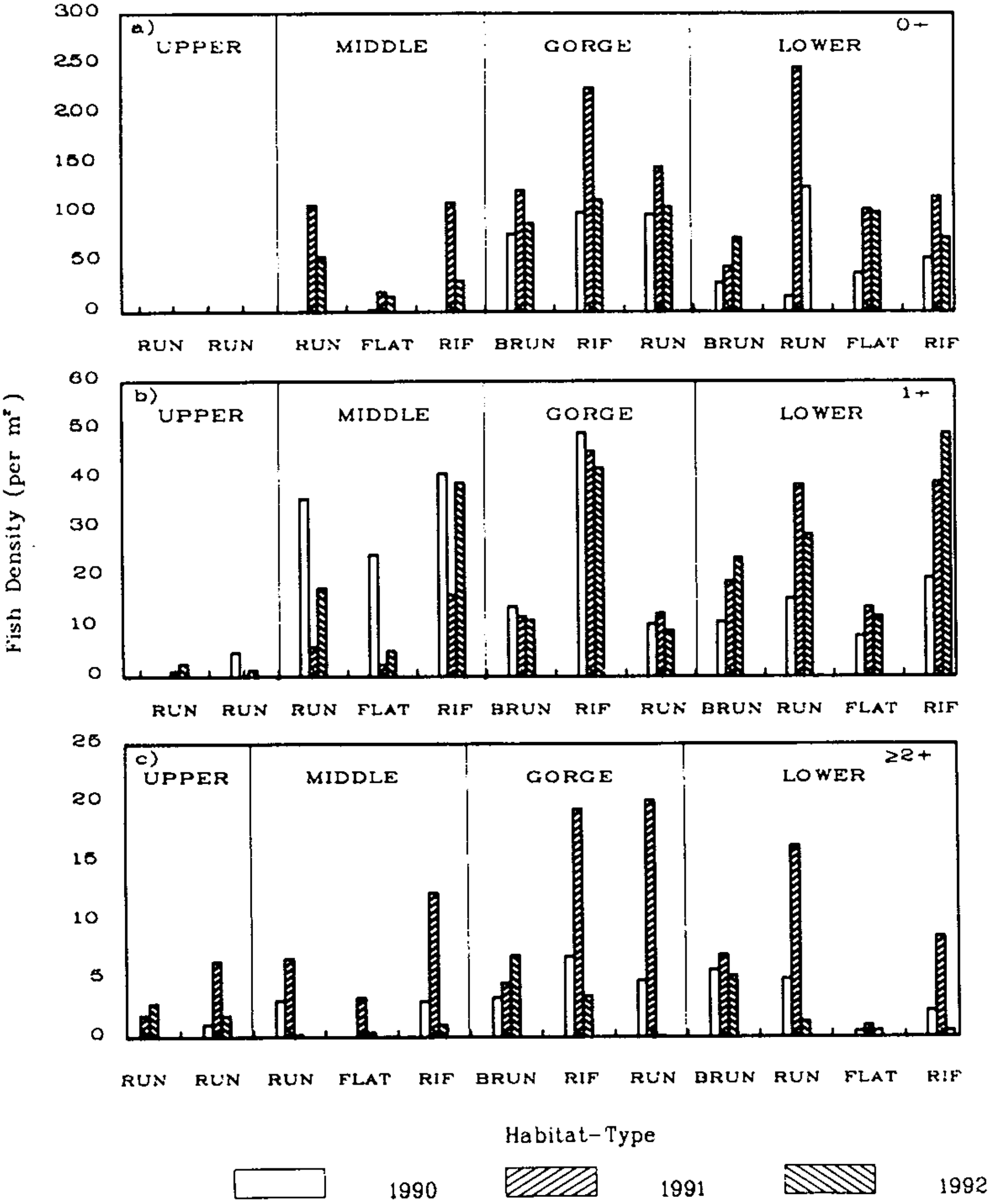

Figure 21. Annual comparisons (1990–1992) of mean density of young-of-the-year (a, top panel), 1+ (b, middle), and ≥2+ juvenile Atlantic salmon (c, bottom) as determined during summer (July) in different habitat-types and study reaches in Catamaran Brook.

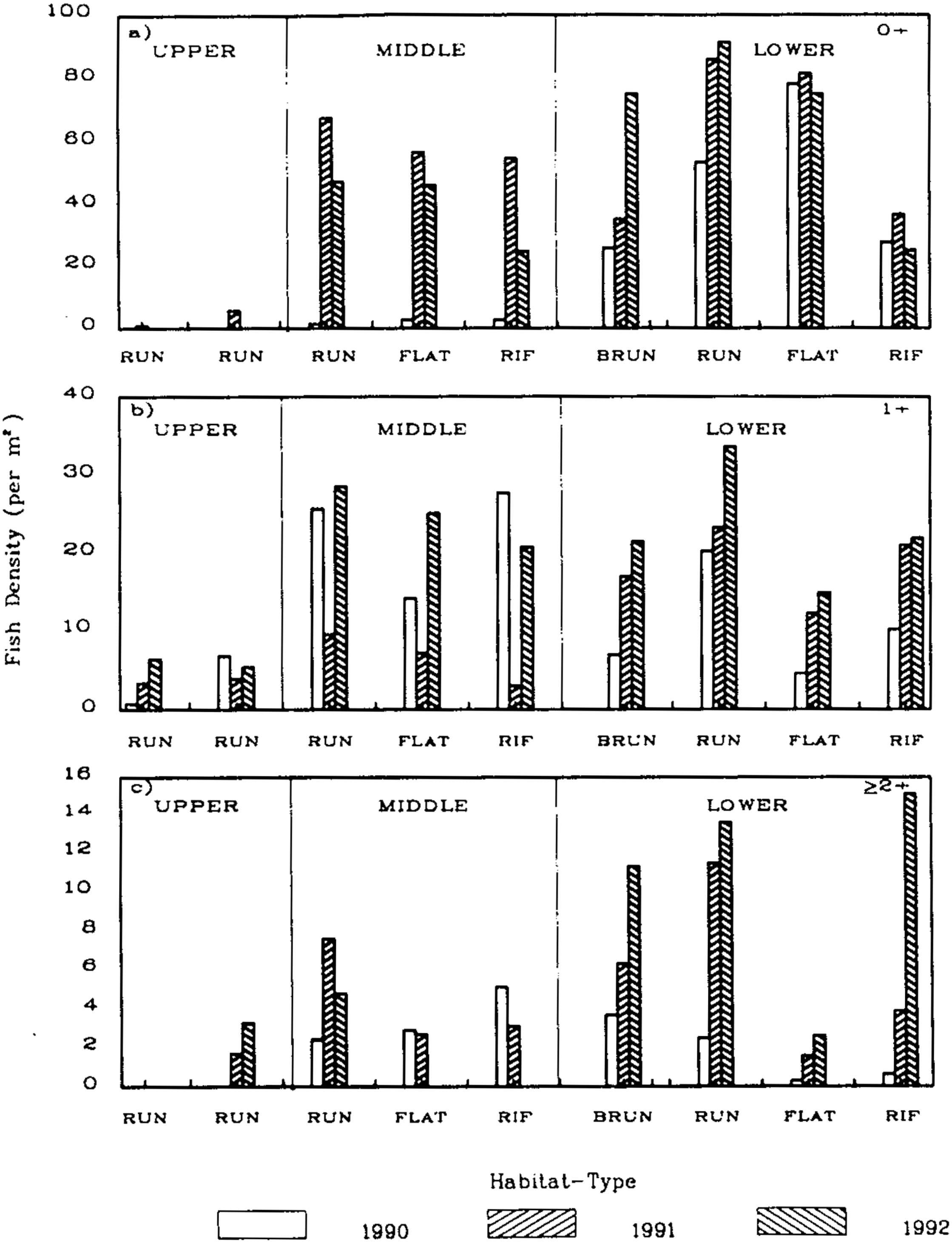

Figure 22. Annual comparisons (1990-1992) of mean density of young-of-the-year (a, top panel), 1+ (b, middle), and ≥2+ juvenile Atlantic salmon (c, bottom), as determined during autumn (November) in different habitat-types and study reaches in Catamaran Brook.

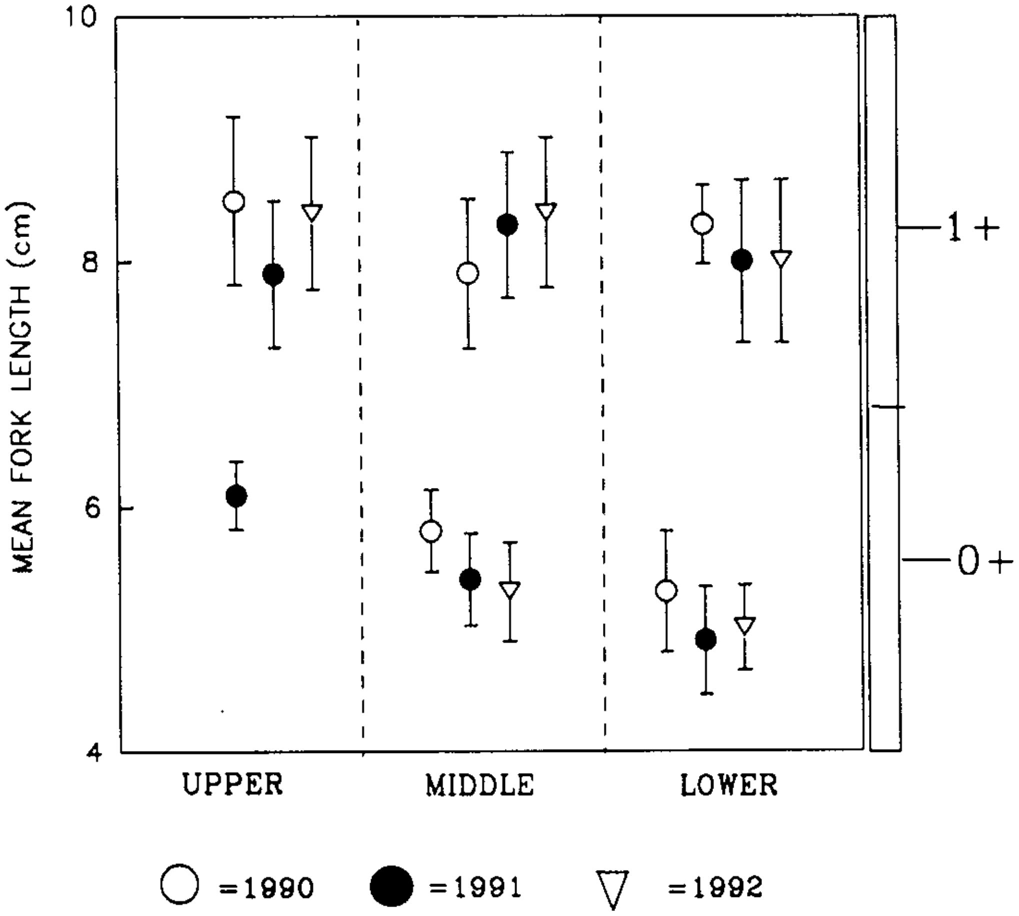

Figure 23. Mean size-at-age for young-of-the-year (0+) and age 1+ Atlantic salmon, at the end of the growing season (November) in three study reaches of Catamaran Brook, 1990-1992. Vertical bars represent ± 1 s.d.

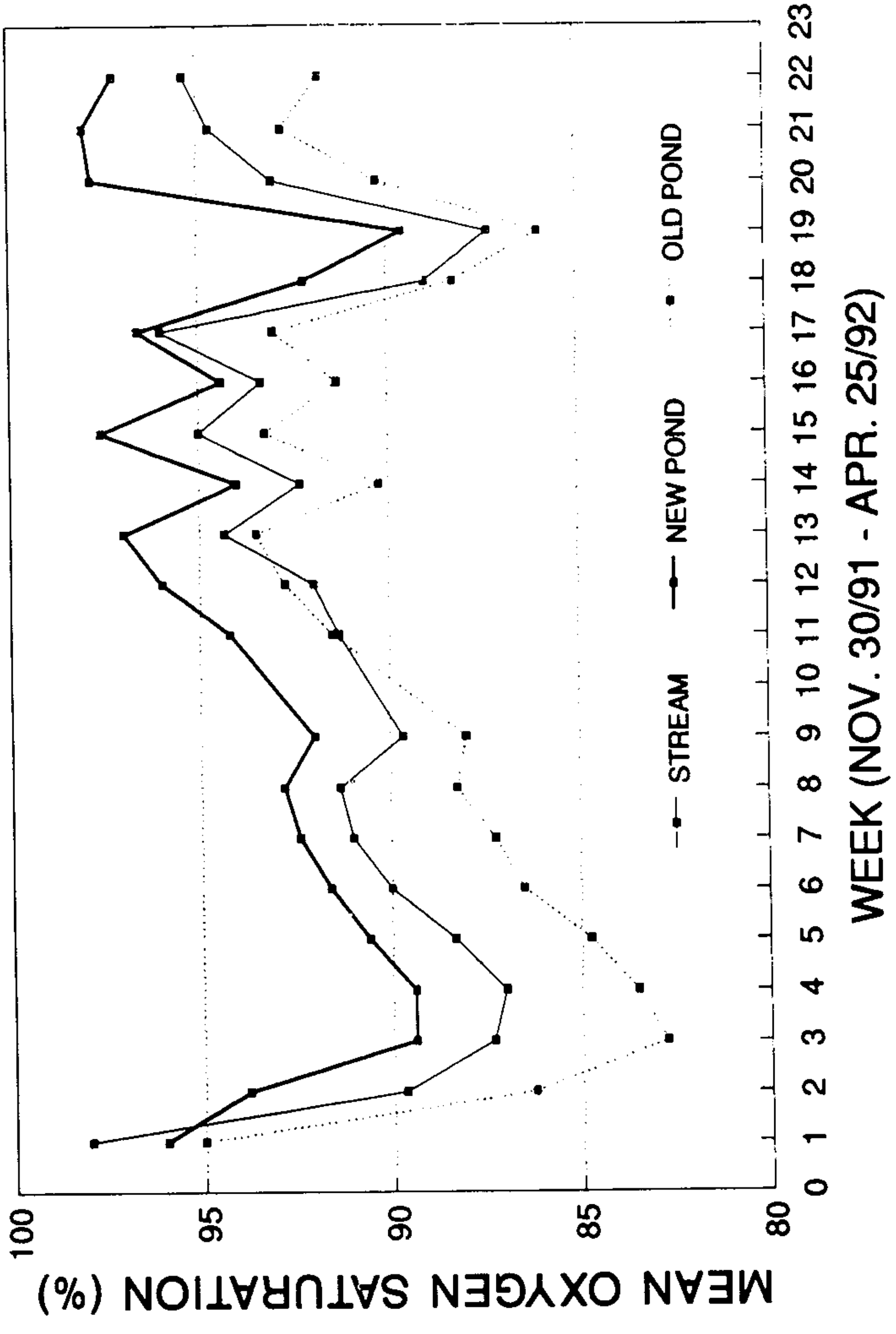

Figure 24. Weekly changes in percent mean dissolved oxygen concentration measured at three locations in Catamaran Brook during the winter of 1991-1992.

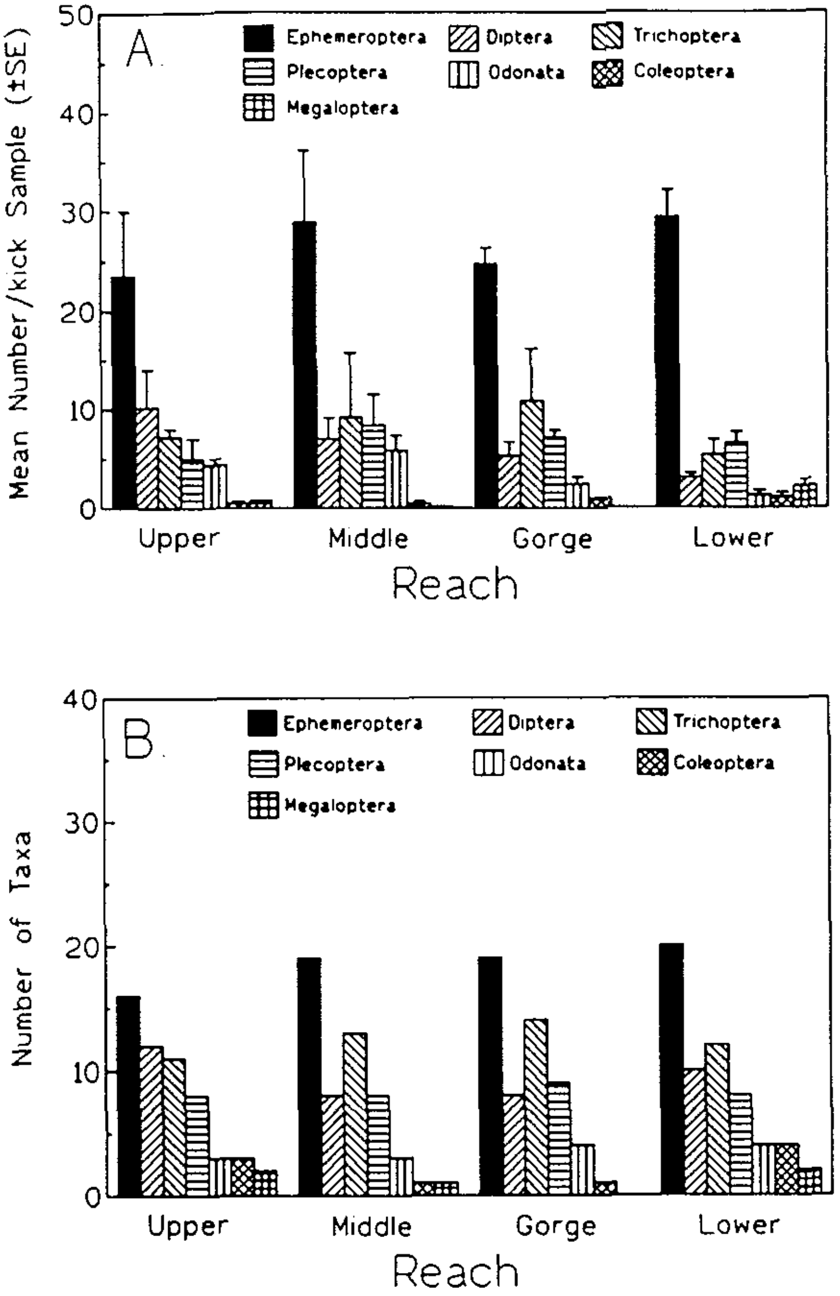

Figure 25. Abundance and diversity of aquatic invertebrates in the four study reaches of Catamaran Brook, N.B., during summer 1990. A. Abundance (mean number/kick sample, averaged over 3 sample dates and 2-4 sites. B. Insect Taxa Richness (total number of genera found in each order, except Chironomdae (Diptera) which were identified to family).

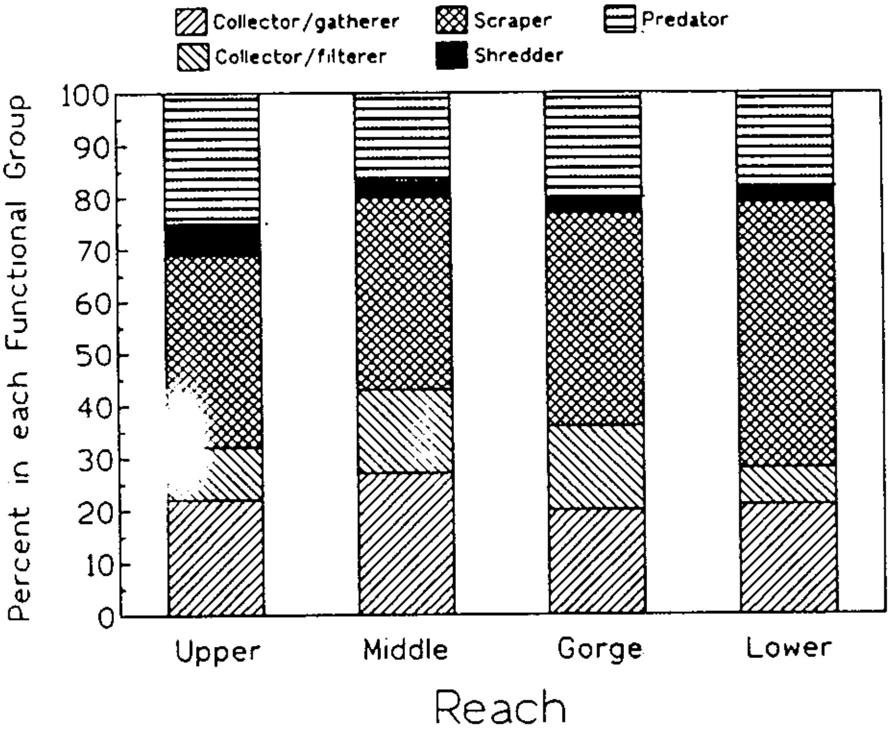

Figure 26. Relative abundance (percent) of invertebrates in each functional feeding group in each study reach, Catamaran Brook, N.B., summer 1990.

APPENDIX I

Participating Agencies and Groups

The following is a list of those groups which have been, or continue to be, involved in the Catamaran Brook Habitat Research Project, in some manner.

(i) Government and Industry

Department of Fisheries and Oceans
  Gulf Region, Moncton, New Brunswick
  Sea Lamprey Unit, Sault Ste. Marie, Ontario

Environment Canada
  Atmospheric Environment Service, Moncton, N.B.
  Water Resources Directorate, Moncton, N.B.
  Water Resources Directorate, Fredericton, N.B.

N.B. Department of Natural Resources and Energy
  Regional Office, Newcastle, N.B.
  Ranger Station, McGraw Brook, N.B.

N.B. Department of the Environment, Fredericton, N.B.

Miramichi Pulp and Paper, Inc.
  Woodlands Division, Newcastle, N.B.

(ii) University / College

Université de Moncton
  École de Génie, Moncton, N.B.

Mount Allison University
  Department of Biology, Sackville, N.B.

University of New Brunswick
  Departments of Biology and Civil Engineering, Fredericton, N.B.

University of Prince Edward Island
  Department of Biology, Charlottetown, P.E.I.

Concordia University
  Department of Biology, Montréal, P.Q.

University of Waterloo
  Department of Biology, Waterloo, Ont.

Holland College
  Renewable Resource Management, Summerside, P.E.I.

(iii) Private Organizations

New Brunswick Wildlife Federation, Fredericton, N.B.

New Brunswick Salmon Council, Doaktown, N.B.

Miramichi Salmon Association, Boiestown, N.B.

Atlantic Salmon Federation, Chamcook, N.B.

Appendix II(a): Site Specific Fish Population Estimates and Densities From Seasonal Electrofishing Surveys in 1990, as Derived From the Removal Method, (Zippin 1956).

Summer						
Reach	**Site Name**	**Area(m2)**	**Total Fish**	**Population Estimate**	**% Pop. Captured**	**Density (per 100m2)**
Upper	UER1	56	35	41.01	85.3	72.96
Upper	UER2	54	32	34.85	91.8	64.54
Upper	UOR1	73	32	40.47	79.1	55.08
Upper	UOR2	46	9	9.22	97.6	20.21
Middle	MR1	59	49	60.83	80.6	103.76
Middle	MR2	82	87	91.98	94.6	111.78
Middle	MF1	116	40	45.85	87.2	39.40
Middle	MF2	116	71	86.14	82.4	74.55
Middle	MRI1	58	37	42.16	87.8	72.68
Middle	MRI2	102	70	100.74	69.5	99.25
Gorge	GBR1	112	114	144.05	79.1	128.56
Gorge	GBR2	140	105	136.34	77	97.73
Gorge	GRI1	83	130	161.54	80.5	194.91
Gorge	GRI2	59	48	51.21	93.7	87.47
Gorge	GR1	101	76	96.62	78.7	95.90
Gorge	GR2	67	69	114.13	60.5	169.84
Lower	LBR1	77	48	105.87	45.3	137.73
Lower	LBR2	49	43	47.71	90.1	96.86
Lower	LR1	128	44	55.04	79.9	43.01
Lower	LR2	90	66	143.22	46.1	159.76
Lower	LF1	235	82	100.95	81.2	42.96
Lower	LF2	192	85	116.36	73	60.49
Lower	LRI1	86	64	79.77	80.2	92.83
Lower	LRI2	99	65	76.17	85.3	76.90
Autumn						
Upper	UER1	69	15	18.95	79.1	27.45
Upper	UER2	68	16	27.83	57.5	40.85
Upper	UOR1	72	10	10.43	95.8	14.48
Upper	UOR2	54	11	32.66	33.7	60.54
Middle	MR1	81	33	37.85	87.2	46.73
Middle	MR2	84	32	55.67	57.5	66.14
Middle	MF1	140	59	92.8	63.6	66.11
Middle	MF2	127	91	103.11	88.3	81.06
Middle	MRI1	67	53	55.97	94.7	84.09
Middle	MRI2	108	47	48.25	97.4	44.68
Lower	LBR1	99	51	73.74	69.2	74.62
Lower	LBR2	67	22	22.31	98.6	33.51
Lower	LR1	125	102	132.56	76.9	106.08
Lower	LR2	124	62	66.43	93.3	53.72
Lower	LF1	167	108	178.19	60.6	106.65
Lower	LF2	167	102	147.48	69.2	88.08
Lower	LRI1	78	32	34.3	93.3	43.98
Lower	LRI2	119	38	39.94	95.2	33.67

Appendix II(b): Site Specific Fish Population Estimates and Densities From Seasonal Electrofishing Surveys in 1991, as Derived From the Removal Method, (Zippin 1956).

			Summer			
Reach	Site Name	Area(m2)	Total Fish	Population Estimate	%Pop. Captured	Density (per 100m2)
Upper	UER1	54	58	58.55	99.1	108.42
Upper	UER2	63	57	59.21	96.3	93.99
Upper	UOR1	69	27	27.85	96.9	40.36
Upper	UOR2	40	14	16.32	85.8	40.81
Middle	MR1	65	92	149.65	61.5	230.23
Middle	MR2	53	148	178.04	83.1	342.39
Middle	MF1	63	44	73.02	60.3	115.91
Middle	MF2	103	65	73.54	88.4	71.40
Middle	MRI1	53	115	126.48	90.9	238 64
Middle	MRI2	95	147	157.21	93.5	165.48
Gorge	GBR1	76	72	73.67	97.7	96.94
Gorge	GBR2	112	250	264.39	94.6	236.06
Gorge	GRI1	79	149	169.53	87.9	214.61
Gorge	GRI2	49	155	176.64	87.7	360.50
Gorge	GR1	102	170	177.98	95.5	174.49
Gorge	GR2	53	90	105.50	85.3	199.06
Lower	LBR1	80	97	103.10	94.1	128.87
Lower	LBR2	83	66	70.27	93.9	84.66
Lower	LR1	79	286	298.92	95.7	378.38
Lower	LR2	78	241	256.19	94.1	328.44
Lower	LF2	197	258	279.49	92.3	141.87
Lower	LF3	111	125	153.69	81.3	138.46
Lower	LRI1	89	151	165.88	91.0	186.38
Lower	LRI2	88	132	141.91	93.0	161.27
			Autumn			
Upper	UER1	62	30	30.92	83.5	57.93
Upper	UER2	61	29	44.16	65.7	72.39
Upper	UOR1	67	15	18.44	81.3	27.53
Upper	UOR2	53	7	10.15	69	19.15
Middle	MR1	79	107	115.38	92.7	146.05
Middle	MR2	110	102	104.06	98	94.60
Middle	MF1	157	100	122.19	81.8	77.83
Middle	MF2	134	176	178.28	98.7	133.04
Middle	MRI1	76	58	58.99	98.3	77.62
Middle	MRI2	107	100	100.40	99.6	93.83
Lower	LBR1	99	93	97.68	95.2	98.66
Lower	LBR2	78	35	36.89	94.9	47.29
Lower	LR1	115	192	196.36	97.8	170.75
Lower	LR2	120	110	119.22	92.3	99.35
Lower	LF2	199	298	305.82	97.4	153.68
Lower	LF3	144	91	97.15	93.7	67.47
Lower	LRI1	90	57	58.03	98.2	64.47
Lower	LRI2	115	80	81.29	98 4	71.31

Appendix II(c): Site Specific Fish Population Estimates and Densities From Seasonal Electrofishing Surveys in 1992, as Derived From the Removal Method, (Zippin 1956).

Summer						
Reach	**Site Name**	**Area(m2)**	**Total Fish**	**Population Estimate**	**%Pop. Captured**	**Density (per 100m2)**
Upper	UERU1	56	29	39.76	72.9	71.13
Upper	UERU2	74	38	39.94	95.2	53.75
Upper	UORU1	92	14	19.05	73.5	20.62
Upper	UORU2	56	9	15.15	59.4	27.01
Middle	MRU1	88	76	84.51	89.9	96.47
Middle	MRU2	96	126	128.00	98.4	133.89
Middle	MF1	129	17	23.77	71.6	18.37
Middle	MF2	124	71	72.76	82.5	58.58
Middle	MRI1	71	87	88.25	98.6	124.64
Middle	MRI2	115	116	119.71	96.9	104.55
Gorge	GBRU1	126	143	149.84	95.4	118.92
Gorge	GBRU2	137	180	184.96	97.3	134.54
Gorge	GRI1	95	194	203.37	95.4	214.85
Gorge	GRI2	69	87	88.57	98.2	129.04
Gorge	GRU1	134	225	231.56	97.2	172.55
Gorge	GRU2	213	147	158.28	92.9	74.20
Lower	LBRU1	87	105	112.44	93.4	128.80
Lower	LBRU2	79	88	92.10	95.6	116.58
Lower	LRU1	97	197	205.08	96.1	211.64
Lower	LRU2	129	194	223.94	86.6	173.59
Lower	LF2	200	348	360.67	96.5	180.03
Lower	LF3	118	112	120.31	93.1	102.08
Lower	LRI1	100	113	116.57	96.9	117.16
Lower	LRI2	111	170	181.40	93.7	163.43

Autumn						
Upper	UERU1	66	50	51.57	97	78.62
Upper	UERU2	27	26	26.73	97.3	98.99
Upper	UORU1	74	40	42.56	94	57.28
Upper	UORU2	47	34	37.69	90.2	80.03
Middle	MRU1	73	103	110.27	93.4	151.88
Middle	MRU2	78	67	70.34	95.3	90.17
Middle	MF1	138	113	123.39	91.6	89.41
Middle	MF2	84	104	112.13	92.8	133.49
Middle	MRI1	67	54	55.58	97.1	83.34
Middle	MRI2	100	66	71.33	92.5	71.12
Middle	MP1	88	87	93.9	92.6	106.59
Middle	MP2	75	85	96.62	88	128.49
Lower	LBRU1	85	103	104.73	98.3	123.50
Lower	LBRU2					
Lower	LRU1	89	136	142.83	95.2	159.94
Lower	LRU2					
Lower	LF2	192	228	229.42	99.4	119.61
Lower	LF3					
Lower	LRI1	92	61	62.25	98	67.73
Lower	LRI2					

Appendix III: Mean Fork Length ± SD of Juvenile Atlantic Salmon Measured During Autumn Electrofishing Surveys (1990-1992) in Different Reaches and Habitat-Types in Catamaran Brook. Values in parentheses refer to sample size.

		Age Class								
		0^+			1^+			2^+		
Reach	**Habitat**	**1990**	**1991**	**1992**	**1990**	**1991**	**1992**	**1990**	**1991**	**1992**
Upper	**Run**	0	6.12±0.28 (9)	0	8.53±0.69 (9)	7.87±1.10 (3)	8.41±0.64 (11)	0	11.2±0.57 (2)	11.50±1.35 (3)
Middle	**Run**	5.60±0.57 (2)	5.46±0.34 (121)	5.32±0.44 (69)	8.04±0.73 (35)	8.23±0.75 (15)	8.60±0.61 (40)	11.50±0.78 (3)	11.43±0.75 (12)	10.46±0.60 (7)
Middle	**Riffle**	5.73±0.15 (4)	5.32±0.38 (103)	5.42±0.33 (40)	7.84±0.53 (44)	8.33±0.38 (6)	8.29±0.70 (32)	11.36±1.26 (8)	11.24±0.69 (5)	0
Middle	**Flat**	6.00±0.34 (5)	5.33±0.41 (154)	5.30±0.43 (88)	8.00±0.59 (36)	8.41±0.54 (20)	8.22±0.47 (50)	10.36±0.49 (7)	10.73±0.84 (7)	0
Middle	**Pool****	-	-	5.39±0.40 (76)	-	-	8.45±0.66 (46)	-	-	10.45±1.00 (6)
Lower	**Bedrock Run**	5.45±0.50 (50)	4.93±0.54 (60)	*4.95±0.33 (63)	8.49±0.53 (11)	8.07±0.67 (30)	*7.86±0.70 (17)	11.36±0.75 (5)	11.09±1.14 (9)	*10.88±0.89 (10)
Lower	**Run**	5.25±0.55 (106)	4.87±0.42 (196)	*4.98±0.36 (79)	8.34±0.55 (19)	7.97±0.66 (51)	*8.09±0.66 (29)	11.00±0.76 (6)	11.92±0.89 (25)	*11.40±0.68 (12)
Lower	**Riffle**	5.44±0.41 (50)	4.96±0.40 (74)	*4.97±0.29 (23)	8.39±0.58 (16)	7.81±0.71 (43)	*8.06±0.70 (20)	11.80 (1)	11.70±0.84 (7)	*11.02±0.60 (13)
Lower	**Flat**	5.23±0.47 (141)	4.85±0.45 (291)	*4.94±0.37 (145)	8.12±0.62 (15)	8.10±0.61 (42)	*7.79±0.63 (27)	10.70 (1)	11.00±0.92 (5)	*10.92±0.79 (5)

**Only one of two replicate sites surveyed.*

** Pools were surveyed in 1992 only.

APPENDIX IV

PUBLICATIONS OF THE CATAMARAN BROOK HABITAT RESEARCH PROJECT

1. Cunjak, R.A., D. Caissie, and N. El-Jabi. 1990. The Catamaran Brook habitat research project: description and general design of study. Can. Tech. Rep. Fish. Aquat. Sci. No 1751. 14p.

2. Cunjak, R.A. and R.G. Randall. 1992. Instream movements and population dynamics of young Atlantic salmon during winter and early spring. *In* R.J. Gibson and R.E. Cutting [ed.]. Production of juvenile Atlantic salmon, Salmo salar, in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118 (in press).

3. Caissie, D., N. El-Jabi, R.A. Cunjak, and G. Bourgeois. 1992. Étude hydro-biologique du bassin Catamaran (N.-B.). Proceedings, Can. Hydrol. Symp. No.19-1992, Winnipeg, Man., June 15-17, 1992: 407-422.

4. Cunjak, R.A. 1992. The Catamaran Brook project: a working example of integrated resource management. Proceedings, Integr. Res. Manage. Sem., Fredericton, N.B., April 7-8, 1992. Forestry Can.- Maritimes Region.

5. This publicaton.

6. MacQuarrie, K. and A. MacLean. 1993. The Catamaran Brook groundwater study: methodology and initiation of data collection. UNB Groundwater Studies Group. Report for Forestry Canada - Maritimes Region.