THERMAL ECOLOGY OF BROOK TROUT (*SALVELINUS FONTINALIS*) AND ATLANTIC SALMON (*SALMO SALAR*) IN IMPOUNDED STREAMS: BEHAVIOURAL RESPONSES AND POPULATION IMPACTS

by

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Abstract

Thermal effects on brook trout, Salvelinus fontinalis, and Atlantic salmon, Salmo salar, were examined in warm (Midgell River) and cold (Valleyfield River) water systems in eastern Prince Edward Island in 1994 and 1995. Salmonid population characteristics were examined through snorkelling, electrofishing, netting, and trapping.

Water temperature reached a maximum of 30°C in the Midgell River and a maximum of 23°C in the Valleyfield River. Midgell River brook trout used cool water refugia created by groundwater springs when daily mean temperatures in the main river exceeded 19.2°C and when daily maximum temperatures exceeded 21.6°C. Juvenile Atlantic salmon remained in the open river during warm water periods. Brook trout migration upstream in the Midgell River decreased when mean daily water temperatures reached 19.6°C. Angling activity decreased during warm periods in the Midgell River. The number of brook trout with predator marks (scars and abrasions) was higher in the Midgell River than in the Valleyfield River, and increased during warm periods when trout were using crowded cold water refugia. Predation in springs could be an important factor limiting brook trout production in a warm water system. Growth rate of young-of-the-year brook trout from May to September was 0.38 $cm\text{-}mo^{-1}$ in 1994 and 0.14 $cm\text{-}mo^{-1}$ in 1995 in the Midgell River and was 0.83 $cm\text{-}mo^{-1}$ in 1994 and 0.77 $cm\text{-}mo^{-1}$ in 1995 in the Valleyfield River. Slow growth of young-of-the-year brook trout in the Midgell River was associated with the duration of the thermal restriction of habitat to cold water refugia.

The Midgell River population was estimated as 3,505 (95% c.i.:2,174 - 5,967) brook trout (408 km^{-1} of stream), and the Valleyfield River population was estimated as 41,237 (95% c.i.: 34,094 - 49,884) brook trout (3,586 km^{-1} of stream length). Differences in brook trout population size observed in the Midgell River and Valleyfield River were significantly related to differences in the thermal conditions of the systems.

INTRODUCTION

Brook trout, Salvelinus fontinalis Mitchill, 1815, and Atlantic salmon, Salmo salar Linnaeus, 1758 (Osteichthyes:Salmonidae), prefer cool water temperatures (Scott and Scott 1988). Brook trout are the most important sport fish on Prince Edward Island and are found in all Prince Edward Island watersheds. Atlantic salmon, primarily of hatchery origin, are also found in some of Prince Edward Island's larger river systems. Brook trout die when water temperatures exceed about 26°C (Coutant 1977). Atlantic salmon have a higher thermal tolerance and are able to withstand temperatures up to 29°C (Coutant 1977). However, trout and salmon are rarely found in watercourses where temperatures surpass 25°C (Grande and Andersen 1991). Water temperatures above 22°C were observed to be the most important factor limiting brook trout production in several Ontario streams (Barton et al. 1985).

Prince Edward Island has over 800 artificial impoundments, most of which have mean depths less than 2 m. Prince Edward Island impoundments (typical size 2 - 50 ha) tend to be larger in low-gradient watersheds, and such impoundments are particularly susceptible to solar warming because of shallow depths and long water residency times. Impoundments on high gradient streams are warmed less because of smaller surfaces and shorter water residencies. Beaver, Castor canadensis, populations tend to concentrate in low lying regions of Prince Edward Island, further increasing impounded areas of thermally susceptible watercourses.

In recent years, the potential effects of impoundment-induced water heating on sport fishes have elicited widespread concern among Prince Edward Island anglers. Guignion et al. (1990) reported water temperatures up to the mid 20s°C at impoundment outlets, and Thompson et al. (1990) found that the maximum water temperature increase between the inlet and outlet of six impoundments ranged from 4.5°C - 13.0°C during a relatively dry summer. The Canadian Council for Resource and Environment Ministers guidelines state that a watercourse alteration should not result in a thermal disturbance which would impact resident aquatic life, and recommend that salmonid waters not exceed 20°C - 21°C (Environment Canada 1994b).

A common response of poikilotherms to unfavourable environmental conditions, such as unsuitably high water temperatures, is behavioural adjustments (Coutant 1987). Impoundment-induced temperature increases may not be a problem for salmonids if safe alternative habitat is available. Approximately 70% of the flow in Prince Edward Island streams originates from groundwater (Francis 1989). Groundwater seeps or springs provide water at a temperature of ~7°C year-round and may function as thermal refugia for salmonids avoiding elevated water temperatures. The abundance of groundwater seeps and springs in Prince Edward Island watercourses may offset impoundment warming by acting as cold water refugia for salmonids.

Within their tolerated temperature range, salmonid growth increases with rising temperature, and artificial heat input from industrial sources has been found to increase salmonid growth rates (Huner and Lindqvist 1986, Morrison 1989). Thus, warming of water in impoundments, if not excessive, could benefit salmonid production by enhancing growth of fish.

High water temperatures may also impact recreational fisheries by reducing success of anglers. Due to the apparent suppressed feeding rate of rainbow trout, Oncorhynchus mykiss, and brown trout, Salmo trutta, at temperatures above 19°C, catch rates by anglers have been shown to decline (Taylor 1978, McMichael and Kaya 1991).

The overall effect of impoundment-induced water temperature elevation on salmonid fishes has not been systematically investigated, despite the ubiquity of artificial impoundments within their range. This study focuses on the effects of impoundment-induced heating on salmonid population size, growth, annual mortality, and behaviour by comparing two stream systems with different thermal environments. I attempt to answer five main questions: i) at what river temperatures do salmonids enter cool water refugia; ii) is timing of upstream migration altered by warm water temperature; iii) do human exploitation and predation increase when fish are confined to cool water refugia; iv) is growth of young of the year (YOY) and year old (1+) salmonids affected by confinement to cool water refugia during warm periods and; v) what are the overall impacts of behavioural responses to warm water temperature on salmonid production?

METHODS

Study Area

This study was conducted in two stream systems in eastern Prince Edward Island. The Midgell River, including MacDonald's Pond, was the warm water study site, and the Valleyfield River, including Maritime Electric Pond, was the cold water site. The Midgell River flows north into St. Peters Bay, an arm of the Gulf of St. Lawrence. The Valleyfield River flows east into Cardigan Bay, an arm of the Northumberland Strait.

The Midgell River has an approximate drainage area of 67 km^2. The topography of the Midgell drainage is low-lying with a mean gradient of about 0.2% from the headwaters to the head-of-tide. Watershed composition is 69% forest, 24% cleared land, 5% marsh, 1% estuary, and 1% ponds (Anon. 1990b). The surface area of the 5.5 km stream length between MacDonald's Pond and the head-of-tide was 36,652 m^2 in August 1995. MacDonald's Pond, the main impoundment on the Midgell, floods 125,980 m^2 above a dam operated by the Prince Edward Island Fish and Wildlife Division and Ducks Unlimited Canada (ASE Consultants 1997). MacDonald's is regarded as a warm pond; outlet water temperatures were 26°C in August 1988 and water had cooled by only 1°C one kilometre downstream (Anon. 1988). Dissolved oxygen levels decreased to levels considered unsuitable for salmonids in MacDonald's Pond in 1994 (ASE Consultants 1997). The upper reaches of the Midgell River are influenced by beaver activity, which has resulted in numerous small impoundments (Figures 1 and 2; PEI Department of Technology and Environment 1994 and 1995). A smaller Ducks Unlimited impoundment, McCarrick's Pond, is located 7.5 km upstream from MacDonald's Pond. In the fall of 1993, 20,000 young of the year (YOY) Atlantic salmon were stocked close to the head-of-tide and in 1995, 9,400 age 1+ salmon parr were stocked immediately downstream of MacDonald's Pond (Appendix 1).

The Valleyfield River is located in southeastern Prince Edward Island. The watershed area is approximately 88.3 km^2. An estimated 41% of this area has been cleared for agricultural production (Anon. 1990a). The 11.5 km stream length study site of the Valleyfield River has a mean gradient of about 0.5 % and a surface area of 130,764 m^2. The Maritime Electric Pond covers approximately 27,140 m^2 (ASE Consultants 1997), and is located 2 km above tidal influence. A smaller impoundment, Egolf's Pond, is located about 6 km further upstream from Maritime Electric Pond (Figure 3). Surface temperature in both ponds remained below 20°C throughout the summer of 1990 (Thompson 1991). Dissolved oxygen levels remain at levels suitable for salmonids in the Maritime Electric impoundment (ASE Consultants 1997).

The Valleyfield River watershed contains numerous unsurfaced roads and has on-going tree harvesting operations, which have contributed to the siltation of important spawning and rearing areas (Anon. 1990b). Fish trapping in 1990 on the Maritime Electric Pond and Egolf's Pond showed an upstream migration of 1,488 and 846 brook trout, respectively (Thompson 1991). Totals of 20,000 YOY salmon, 8,000 1+ parr, 5,900 1+ smolts, and 2,000 2+ smolts were stocked in the Valleyfield

River in 1994. Totals of 11,600 1+ parr, 6,200 1+ smolts, 1,300 2+ parr, and 3,900 2+ smolts were stocked in the Valleyfield River in 1995 (Appendix 1).

Temperature

Thermal surveys were conducted in both study streams during the summers of 1994 and 1995. In both systems, Hobo™ and Sealog™ data loggers were deployed upstream, downstream, and within study impoundments to record water temperature every hour throughout the June-August (12 week) study periods of 1994 and 1995 (Figures 1-4). Loggers were located at three depths within impoundments in order to detect thermal stratification. Impoundment data loggers were deployed 0.5 m below the water surface, 0.5 m above the substrate, and at the mid-point of the water column. Temperature loggers were deployed at different times, which left 3 - 6 week gaps in the 12 week data set. For each site with missing data, a regression equation was developed that related the temperature at that site to the temperature at other sites during periods when full temperature records were available. These regression equations were used to estimate temperatures for sites with incomplete logger records.

Temperature surveys were also conducted in impoundments from a boat using a hand-held thermometer and in free flowing regions by walking downstream. The spring body (main region of groundwater influence), and thermal plume (total stream length of groundwater influence), were defined by a -2°C differential from the main river temperature. The spring bodies of study sites, Springs 1-3 in the Midgell River and Springs 1- 2 in the Valleyfield River, were measured in a 1 m grid to determine surface area and volume.

Total lengths of thermal plumes of all Midgell River springs were measured to provide a maximum indicator of groundwater influence on the system in relation to the total stream length. Springs were categorized as seeps or tributaries according to their origin. Spring seeps originated from the stream substrate. Spring tributaries originated from a site adjacent to the main watercourse and entered the stream through a channel in the bank. Pond surveys involved the use of a weighted thermal probe. The hand-held thermometer was towed slowly along the substrate of the pond's channel and in areas which were visually assessed to be potential areas of groundwater influence. The lack of emergent vegetation was used as an indicator of the pond channel and potential sites of spring water influence in shallow water.

Growth of brook trout

The relationship of growth rates to thermal environment was investigated by comparing scale-based growth estimates and fork lengths sampled from young-of-the-year (YOY), age 1+, and age 2+ brook trout from the two systems on 14 May, 24-28 July, and 5 September, 1995. Ages of brook trout are provided in months using a zero point of 1 April, the estimated date of juvenile emergence. Overlap of the age 1+ and the age 2+ cohort was apparent from scale sample periods. The overlap proportion of age 1+ trout was counted from the lower end of the overlap range to estimate the division from the age 2+ cohort. The age 1+ and age 2+ fork length divisions from each scale sample date were used to estimate fork length divisions in adjacent electrofisher and fyke net sampling periods between April and October in 1994 and 1995.

Regression analysis of age 1+ fork lengths on time from scale sample periods provided a linear equation that was used to define the change in the upper fork length of the 1+ age cohorts for sampling periods between April and October in 1994 and 1995. Mean fork lengths at age were calculated for each sampling period. Regression analysis of fork lengths from scale samples was used to estimate growth of age 1+ in 1995, and from fork length frequency analysis and scale samples to estimate growth of age 0+ in 1994 and 1995.

<u>Growth of Atlantic salmon</u>

Growth of YOY Atlantic salmon in the Midgell was estimated from size changes in age cohorts over the 1994 and 1995 field season. Sampling in the Valleyfield River produced too few YOY Atlantic salmon to estimate growth rates. Growth rates were not estimated for salmon greater than age YOY in either system because wild and hatchery parr could not be reliably distinguished due to incomplete fin clipping of hatchery fish.

Mortality rate

Annual mortality rates were calculated using the following equation:

$$A = 1 - (N_{t+1} / N_t)$$

where A = mortality rate, N_t = number of fish at age t, and N_{t+1} = number of fish at age t + 1 year (Ricker 1975). The low number of age 2+ trout sampled for ageing did not allow for the complete delineation of the age 2+ fork length cohort from older year classes; however, cohort analysis indicated that most of the fish older than the age 1+ sampled were probably age 2+. All trout above the upper end of the age 1+ cohort were assumed to be age 2+ in the mortality rate estimates. In the Midgell, the age structure of older than YOY salmon was not defined and could not be effectively estimated; therefore, mortality rates were not estimated. Young of the year brook trout were not counted in the Valleyfield River sites in 1995; therefore, YOY mortality rates could not be estimated for this time.

Trends in angling activity

In 1995, tag returns from anglers were used to estimate trends of fishing activity from May to 15 September in the Midgell River and from June to 15 September in the Valleyfield River. Signs were placed at conspicuous locations in each watercourse to increase return rates from anglers.

Electrofishing and snorkelling

Electrofishing was utilized in both study streams to measure fish densities, track movements, capture trout for marking, and collect samples for growth analysis. A Smith-Root backpack electrofisher was used to sample salmonids in riverine habitats. Fork lengths of salmonids were measured to the nearest millimetre. Wild salmon parr were distinguished from hatchery salmon parr by the presence of an adipose fin. In 1995, most captured brook trout over 12 cm were anaesthetized with benzocaine and marked with individually numbered Floy™ fingerling tags and released. Densities of salmonids were estimated by two electrofishing methods. The open method involved one electrofishing sweep without barrier nets. The closed method involved multiple sweeps within barrier nets to obtain a population estimate using the calculation described by Zippin (1958).

Density estimates for older than YOY salmonids were calculated from open electrofishing sites using the catchability estimate from closed sites. The catchability is the number of salmonids captured in the first sweep as a proportion of the population estimate (see Jones and Stockwell 1995). Open electrofishing was used at all sites except three sites in the last sampling period in 1994, when the closed method was used. At sites where closed electrofishing was conducted, the catchability measured at that site was used to estimate populations at dates when the open method was employed. At sites where closed electrofishing was not conducted, the mean electrofishing catchability from closed sites was used to estimate populations. The following tests were used to compare densities of salmonids over time and between systems : ANOVA, T-test, Mann-Whitney rank sum test, and Kruskall-Wallis ANOVA on ranks.

Snorkelling surveys were conducted to increase sampling frequency without increasing stress associated with electrofishing on salmonids. Snorkelling surveys were conducted using one or two persons. In the one person method, surveys involved swimming upstream in a zigzag manner while counting year class and species of salmonid. One pass was made through the site and an attempt was made to visually assess the entire area of the site. The two person method involved the division of the river into parallel halves. Each individual counted fish on his or her side of the river while moving upstream. In both methods, snorkellers attempted to swim around the location of observed fish in order to minimize disturbance. In July 1994, snorkelling surveys were conducted at four of the five electrofishing sites in the Midgell River.

In 1994, five 30 m stream length sites (Native, Old Mill, Artties, Upper Fence, and Elm Road) were electrofished in the Midgell River (Figure 1, Table 1). Open surveys were conducted twice during the summer (June and July). The closed method was used during the last sampling period in late August 1994 at the Old Mill Site and the Native Site in the Midgell River.

In 1995, four Midgell sites ranging in length from 80 to 130 m were electrofished using the open method (Upper Native, Old Mill, Corner Pool, Elm Road); (Figure 2, Table 1). The open method was also used at the head-of-tide spring four times from July to September to tag trout and increase recapture samples.

In June and July of 1994, four 30 m Valleyfield River sites were electrofished using the open method; one was located on a major branch (Egolf's) and three were located on the main stem (Phantom Lane, Upper Phantom Lane, and MacRae's;

Figure 3). In August, the closed electrofishing method and the two person snorkelling method were used at the Phantom Lane Site. All brook trout and Atlantic salmon captured by electrofishing were catagorized as YOY or older than YOY and most were measured to the nearest millimetre. In 1995, four sites 60 m - 130 m were electrofished (Heatherdale, Mermey's 1, Mermey's 2, Brooklyn) on two of the major branches of the Valleyfield River (Table 1, Figure 4). Site location was shifted from the main stem of the Valleyfield River in order to assess sites of similar size to those in the Midgell River. Brook trout aged one year and older were measured during sampling in the Valleyfield River electrofishing sites, while YOY were sampled incidentally. The majority of age 1+ trout captured were tagged. Additional electrofishing sites including 200m downstream form Egolf's Pond, 700m downstream from Egolf's Pond, MacRae's, 200m downstream from Brooklyn Pond, Maritime Electric Pond Headwater, and Phantom Lane were established to tag trout. Valleyfield YOY brook trout sampled by electrofishing were used to develop age cohort data, but not to reflect abundance. All year classes of juvenile Atlantic salmon were sampled.

Survey transects were established upstream, downstream, and in the springs to assess salmonid use of spring habitat. Brook trout and Atlantic salmon were classified as "out-of-spring" and "in-spring". Out-of-spring fish were those observed in a 40 m transect upstream and downstream from the spring site. In-spring fish were those observed at the spring site or in areas where water temperature was more than 2°C cooler than the main river temperature.

Assessment of spring habitat use was undertaken by electrofishing and snorkelling. Electrofishing in small in-spring habitat was conducted by repeated sweeps until no further fish could be found. The open method of electrofishing was used for 'hot-in-spring' transects. Snorkelling surveys were used to increase sampling frequency.

In 1994, four springs in the Midgell River were monitored for all year classes of salmonids. At three sites (Springs 1-3), springs were monitored from July to September. In Spring 3, electrofishing (open method) and snorkelling were impractical because of the large number of fish. Hence populations at this site were estimated by mark-recapture. At the fourth site (Small Spring), electrofishing was conducted once in July.

In 1995, Springs 1-3 on the Midgell River were surveyed using snorkelling every 2-3 weeks and electrofishing every two months from May to September. The Small Spring was snorkelled and electrofished in July.

In 1995, spring habitat use was assessed by electrofishing in two springs upstream from the Maritime Electric Pond, Valleyfield River.

To examine thermal avoidance in the Midgell River, the number of trout in each spring was plotted against the daily mean and daily maximum water temperatures of the adjacent river. The avoidance temperature was defined as the lowest temperature at which the presence of intermediate to high numbers of brook trout occurred in springs. Mann-Whitney rank sum tests were used to test differences in numbers above and below avoidance temperatures. In 1994, observations in Spring 3 were conducted at temperatures when high numbers of brook trout were present, therefore the lowest temperature at surveying provided the best estimate of avoidance temperature.

Habitat surveys

Habitat surveys of 1994 sites were conducted on three of the four electrofishing sites in the Valleyfield River and two of the five electrofishing sites in the Midgell River. Two cross-stream transects were established at each site. Three depths and stream width were recorded from each transect. Surface area and volume were calculated for each site.

In August 1995, habitat surveys of electrofishing sites and spring study sites were conducted in the Valleyfield and Midgell Rivers. Cross-stream transects were established at 20 m intervals along the site. Habitat characteristics, including site length, depth, stream width, and current velocity were recorded every metre along the transect. Surface area (m^2) and water volume (m^3) were calculated for each site.

In 1995, densities of salmonids older than YOY captured in each electrofishing site were expressed as fish 30 m^{-1} of stream length and as fish m^{-2}. Habitat data were not collected for all 1994 sites; therefore, densities in that year were expressed as number of older than YOY salmonids 30 m^{-1} of stream length.

Population distributional changes were monitored by comparing salmonids 30m^{-1} stream length electrofished in different sampling periods within each system. In 1995, density m^{-2} in each system was compared for similar sampling periods.

Description of fyke nets and catch per unit effort

Fyke nets were used to capture brook trout for a mark and recapture experiment and monitoring spring usage in impoundments. Salmonids captured were counted, measured, marked with Floy™ fingerling tags, and released. Fyke nets used were of two sizes. Large fyke nets had 30 m - 50 m leads, 10 m wings, and were 1 m deep. The fyke net itself was composed of five square frames, the first being 1.2 m^2, and the four on the tail 0.80 m^2, leading to a bag at the tail end. Small fyke nets had 1 m - 2 m leads and a depth of 0.5 m, leading to a series of 6 circular hoops and a bag at the tail. Mesh size for all nets was 1 cm^2. One "double net" was used, which consisted of two small fyke nets joined by a 2 m lead. The double net was used in the first sampling period on both systems and was counted as two small nets in the calculation of catch net-day^{-1}.

The catch per unit effort (CPUE) of brook trout and Atlantic salmon was calculated as captures net-day^{-1}. The CPUE was compared for fyke nets of the same size and was used to reflect changes in salmonid densities in pond habitats outside and inside springs. The CPUE was used to compare study ponds. Statistical analysis of CPUE involved the following tests: Kruskall-Wallis, Kruskall-Wallis analysis of variance (ANOVA) on ranks (Dunn's method), ANOVA, and Mann-Whitney rank sum.

Fyke netting in MacDonald's Pond

Fyke nets were set in six regions of MacDonald's Pond in order to sample the pond's major habitats (Figure 5). Four springs were assessed with fyke nets (Headwater Spring, Spring 3, Small Spring, and New Spring). Fyke nets were first set in 24 April and 1 May and pulled 13-19 May before the water warmed, when salmonids were presumed to be widely distributed in the ponds. Eight weeks after the first marking period, fyke nets were reset to obtain recaptures and detect distribution shifts. In late July to mid August, when brook trout migrate to areas of spring influence in the Midgell River, fyke nets were utilized to capture individuals for mark and recapture experiments. In July-August, water in springs was warmer at the surface than at the bottom. Ice was used to cool the surface water used in fish holding containers close to the bottom temperature of the springs to reduce thermal stress during processing and marking. The Headwater Spring was assessed during the three sampling periods. Three smaller springs (Small Spring, Spring 3, and New Spring) located upstream from the Headwater Spring were assessed for the July-August sampling period. After water temperatures cooled in the stream during September and October, fyke nets were reset to recover marked fish.

Sampling methods for salmonids in MacDonald's Pond differed between 1994 and 1995. Electrofishing was used in 1994, and fyke netting and electrofishing were used in 1995. Method selectivity of one year class over another would impact estimates of population parameters. Selectivity was estimated by calculating the proportions of 1+ trout in each capture sample for fyke netting and electrofishing samples in Spring 3 where both methods were used during July and August 1995.

Fyke netting in Maritime Electric Pond

Small fyke nets were set in Maritime Electric Pond during periods in late June to early July, August and late September to mid October to capture trout for the mark and recapture experiment and to detect distribution shifts of the population. During the first marking period, fyke nets were set outside direct spring influence. In August, fyke nets were set in a headwater spring and outside spring influence (Figure 6). Spring usage was estimated by comparing CPUE for areas outside spring influence and inside spring usage. In September and October, fyke nets were set outside spring influence.

Fish counting fences and fishway traps

Three two-way fish counting traps were operated in each river system (Figures 1-6; Appendix 2). Fish traps were positioned to monitor movement into and out of the ponds and to and from salt water. All salmonids were counted and fork lengths of most salmonids were measured to the nearest millimetre. Most brook trout over 12 cm were tagged and released.

The fishway at MacDonald's Pond is of a pool-and-weir design. The fishway trap was constructed by dividing a fishway cell into two compartments by a 1 cm^2 mesh screen supported by a wooden frame. The trap was covered by a plywood board, which was secured with a padlock. The same design was used for Egolf's Pond fishway.

The fishway of the Maritime Electric Pond is of a vertical slot design. The fishway trap was constructed by blocking off the upstream sluiceway with a 1 cm^2 screen to prevent migration beyond that point. Trout migrating upstream were restricted to the cell downstream from the screen and fish migrating downstream were restricted to the fishway cell upstream from the screen. The trap was secured with a screen cover and a padlock. Salmonids within study impoundments could avoid fishway traps by migrating downstream over the bypass, thus circumventing the traps.

Fish counting fences were constructed with conduit and steel supports of similar design described by Anderson and MacDonald (1978). Fences were placed from bank to bank and angled to funnel migrating fish into traps. Traps used at the headwaters of the Maritime Electric Pond, and at the Midgell River head-of-tide, had a steel frame with 1 cm^2 mesh screen. The trap at the headwaters of MacDonald's Pond had a wire frame with 1 cm^2 mesh screen. Traps were secured with a cover and a padlock.

Marking mortality

The effect of tagging on brook trout mortality was estimated as follows: one hundred brook trout were electrofished and an additional one hundred were trapped and taken to the Cardigan Salmonid Enhancement Centre. Fifty fish from each group were tagged and measured, with the remainder acting as controls. These fish were kept in a 2 m diameter circular tank where mortality was monitored for five weeks. The percent mortality was used to estimate the number of tagged fish available for recapture. Proportions were compared with a z-test (SigmaStat 2.0 1995).

Predation

Injuries and abrasions on salmonids older than YOY were recorded as predator marks. Changes in proportions of salmonids bearing marks were tracked over time and location. Tags could potentially make trout more visible and, therefore, increase removal of marked fish through predation, thus biasing population estimates. Preferential predation of marked fish was tested by comparing proportions of recaptures with predator marks with proportions of first time captures with predator marks in a z-test (SigmaStat 2.0 1995).

Population estimates

The adjusted Peterson method was used to estimate brook trout populations:

$$N=(M+1)(C+1)/(R+1)$$

where N = population size, M = number of marked fish, C = number of fish captured, and R = number of fish recaptured (Ricker 1975).

Four mark and recapture population estimates were conducted in Spring 3 in the headwaters of MacDonald's Pond in 1994. Trout electrofished from this spring were marked by an adipose fin clip and released. A seine net, 3 m wide and 1 m tall with a 0.5 cm^2 mesh, was used during two recaptures.

During the 1995 recapture period, tag loss was indicated by the presence of tag scarred trout in the recapture sample. Tag loss was due to migration of the tag wire through the soft tissue anterior to the dorsal fin. After 1 July, tags were tied through the cartilage at the anterior end of the dorsal fin and secured to the first dorsal ray. Population estimates were calculated for the marking periods after 1 July.

In 1995, population estimation by the mark-and-recapture method was expanded to include pond and riverine habitats on both systems. In the Midgell River, populations were estimated in MacDonald's Pond and in the 5.5 km section of stream between the pond and the estuary. In MacDonald's Pond, six population estimates were calculated from the 10 July to 15 August fyke net sampling period, and one population estimate was calculated from 11 September to 11 October fyke sampling period. In riverine habitat, two population estimates were calculated from electrofishing in the Head-of-Tide Spring. In the fall of 1995, the 5.5 km section downstream from MacDonald's Pond was electrofished twice in a gentle zigzag pattern and three population estimates were calculated. The gentle zigzag method involved electrofishing while walking upstream, moving in a zigzag manner from bank to bank.

The Valleyfield River population estimates were for combined pond and riverine habitat. The Maritime Electric Pond, the area downstream from the pond, the upstream region from the pond to Egolf's Pond, and from MacRae's Bridge to Brooklyn Pond was treated as one 11.5 km section. This section was electrofished using the gentle zigzag method from the head of tide upstream until the entire riverine study area was sampled. The high number of recaptures from electrofishing recapture in the fall allowed for the breakdown of mark and recapture estimates to marking site. From the electrofishing recapture, population estimates were calculated for marking sites which include Maritime Electric fishway trap, Maritime Electric headwater fence, fyke net sites, electrofishing sites, and all sites combined.

Fyke netting in the Maritime Electric Pond from 30 September to 14 October provided additional recapture samples.

Population estimates for Atlantic salmon and brook trout were also calculated by extrapolating estimated numbers per stream length at electrofishing sites to the total stream length of 5.5 km in the lower Midgell River and 11.5 km in the Valleyfield River. Statistical analyses were conducted using Sigma-plot, Sigma-stat, and Excel software programs.

RESULTS

Temperature

Regressions of thermograph data used to estimate gaps in water temperature records yielded r^2 values ranging from 0.629 - 0.995 (Appendix 3). Prolonged periods of stressful water temperature for brook trout and Atlantic salmon were present at all main river and pond sites in the Midgell River, while main river temperatures in the Valleyfield River remained in a range considered conducive to salmonid production (Figures 7 - 11). Springs remained much cooler than the main river and ponds in both systems (Figures 7, 8 and 11).

Water temperatures in MacDonald's Pond, Midgell River, peaked at 30.0°C in July 1994 and 29.6°C in August 1995 (Table 2). Mean monthly temperatures in the Midgell were approximately 1°C cooler in 1995 than in 1994 (Table 2). In MacDonald's Pond, temperatures increased between inflow and surface/outflow by about 2.0°C in 1994 and 1.3°C in 1995. In 1994, water exiting MacDonald's Pond cooled by approximately 1.9°C, 1.5km downstream, and by 4.1°C, 5.5 km downstream, based on mean monthly temperature. In 1995, water exiting MacDonald's Pond cooled by 0.7°C, 1.5km downstream. MacDonald's Pond was thermally stratified, with monthly mean temperatures at the pond bottom about 1.9°C cooler than surface/outflow temperature in 1994 and about 1.5°C cooler in 1995.

The warmest Valleyfield River temperature was 23.3°C, recorded from Egolf's Pond outflow in 1995 (Table 2). Maximum temperature for other thermograph sites remained below 21.8°C in 1994 and 20.0°C in 1995. Mean monthly temperature recorded at the Maritime Electric Pond outflow was approximately 0.7°C warmer than inflow water temperatures.

Thermal surveys in the 3.1 km section between the MacDonald's Pond headwater fence and MacDonald's Pond outflow indicated that springs influenced water temperature in 3.2% of the watercourse length, and the largest spring (Headwater Spring) was located 100m upstream from the inflow of the pond (Table 3). Because of the large size of MacDonald's Pond, some small springs may have escaped detection. Downstream from MacDonald's Pond outflow to the head of tide, maximum estimated spring influence was approximately 4.3% of stream length, most of which was from the Head-of-Tide Spring entering the system approximately 150 m upstream from tidal influence (Table 3). The plume from the Head-of-Tide Spring extends beyond the head of tide and cools tidal areas of the lower river.

Spring usage

Snorkelling and electrofishing results indicate that brook trout used cold water refugia when the main stream temperature warmed during June - August in the Midgell River system (Tables 4 - 7, Figures 12 - 14).

Atlantic salmon parr were not observed in spring habitats in densities that would indicate they were moving into them to seek cool refugia (Tables 4 - 7).

The avoidance temperature was estimated as the lowest river temperature at which intermediate to high numbers of brook trout were present in spring habitat. In 1994 and 1995, brook trout abundance in Springs 1 and 2 was similar and avoidance temperature was assessed by pooling data from two years for each spring. The avoidance temperature in Spring 1 was 19.7°C for the mean daily temperature and 21.7°C for the daily maximum temperature (Figure 15, Man-Whitney rank sum, $P < 0.05$). The avoidance temperature for Spring 2 was 19.7°C for the mean daily temperature and 22.4°C for the daily maximum temperature (Figure 15, Man-Whitney rank sum, $P < 0.05$). Brook trout abundance in Spring 3 was dramatically different between years and avoidance temperatures were determined separately for each year. In 1994, Spring 3 avoidance temperatures were 17.7°C for the daily mean and 21°C for the daily maximum (Figure 16). In 1995, Spring 3 avoidance temperatures were 20.4°C and 23.2°C for the daily mean and daily maximum, respectively (Figure 16, Man-Whitney rank sum , $P < 0.05$). From snorkelling and electrofishing observations in springs, the mean of the daily mean avoidance temperatures was 19.2°C (17.7°C - 20.4°C), and the mean of the maximum daily avoidance temperatures was 21.6°C (21°C -23.2°C).

Brook trout were observed in the outside transects of Springs 1 and 2 at temperatures above the estimated avoidance temperatures. The highest number of brook trout (17) observed in the transect outside Spring 2 occurred when the daily maximum temperature was 23.2°C. Observations of salmonids in the outside transect of Spring 3 and Small Spring were not possible due to greater than 1m depth and poor visibility. The outside transect of Spring 3 and Small Spring was located in the main channel of the inflow section to MacDonald's Pond.

Fyke net captures indicated that brook trout were widely distributed in MacDonald's Pond during the April-May sampling period (Figure 17). In July and August, when temperatures warmed, 98% (256) of brook trout captures occurred in spring habitat. When temperatures cooled in the September-October sampling period, 21 trout were captured at spring influence sites and 21 were captured outside spring influence (Figure 17). Brook trout CPUE in fyke nets in MacDonald's Pond over the three sampling periods reflected the change in distribution toward areas which were thermally influenced by springs during warm periods of the summer.

In Region 6 of MacDonald's Pond, small fyke nets were used. In the Headwater Spring, mean catch day-net^{-1} was 0 in May, 3.2 in July, and 0.6 in September-October sampling periods (Table 8). The difference in catch day-net^{-1} of the Headwater Spring was significant between the sampling period of May and July-August and the period of May and September-October (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P < 0.05$), but was not significant between the sampling periods of July-August and September-October (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P > 0.05$). In July-August, fyke net CPUE was significantly higher in the Headwater Spring than in sites outside spring influence (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P < 0.05$). Small nets were used in Region 5, and the April - May mean CPUE was 0.4 (Table 8). In April and May, Headwater Spring fyke net CPUE was significantly lower than that of nets set in Region 5 (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P<0.05$). For the September-October sampling period, Headwater Spring CPUE was significantly higher than in Region 2 (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P < 0.05$), but not significantly higher in other sites (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P > 0.05$). Fyke net CPUE of the New Spring site was not significantly different from other sites (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P > 0.05$).

Two other springs (Small Spring and Spring 3) in MacDonald's Pond were fished with fyke nets during the July and September-October sampling periods (Table 8). Small Spring mean CPUE was 1.5 in July - August and 0.1 in September-October sampling periods, a significant difference between sampling periods (Mann-Whitney rank sum, $P < 0.05$). Spring 3 mean CPUE's of 0.6 in July - August and 0.2 in September-October were not significantly different (Mann-Whitney rank sum, $P > 0.05$). When compared to sites outside spring influence for the July-August sampling period, fyke net CPUE was significantly higher in Spring 3 and Small Spring (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P < 0.05$). For the September-October sampling period, Spring 3 and Small Spring CPUE's were not significantly different compared to all other sites (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P > 0.05$).

In sites outside spring influence in MacDonald's Pond, two fyke net sizes were used. The mean of large fyke net CPUE's ranged from 0 to 1.0 in April-May, 0 to 0.2 in July-August, and 0 in September-October sampling periods (Table 8). Mean small net CPUE was 0.43 in April-May, ranged from 0 to 0.1 in July-August, and ranged from 0 - 0.2 for the September-October sampling period (Table 8).

Large fyke net CPUE was significantly higher in Region 4 in the April-May sampling period than in September-October (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P < 0.05$), but was not significantly different than in the July - August sampling periods (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P > 0.05$). No significant difference in large net CPUE was observed in Region 1 over sampling periods (Kruskall-Wallis, $P > 0.05$). Region 2 and 3 small net CPUE was not significantly different during the July-August and September-October sampling periods (Mann-Whitney rank sum, $P > 0.05$).

Electrofishing captures of brook trout and Atlantic salmon in two Valleyfield River springs did not indicate an attraction to spring habitat for either species (Tables 9 and 10). Fyke netting in the Maritime Electric Pond captured 23 brook trout out of spring influence during the June-July sampling period; 37 brook trout out of spring influence and 14 brook trout in spring influence during the August sampling period; and 68 brook trout out of spring influence during the September-October sampling period (Figure 18, Table 11). Fyke net catch per unit effort of brook trout in the Valleyfield River did not differ significantly over the sampling periods (ANOVA, $P > 0.05$), suggesting that brook trout were neither attracted to nor avoided spring habitat in the Maritime Electric Pond during the August sampling period. Juvenile salmon CPUE for sites outside spring influence in the June-July and August sampling periods was significantly higher than juvenile salmon CPUE in spring habitat in August (Mann-Whitney rank sum, $P < 0.05$).

A total of 22 salmon parr were captured by fyke net in the Maritime Electric Pond. Three adult Atlantic salmon were captured in September in the Maritime Electric Pond (Figure 18).

Brook trout catch net - day^{-1} in the Valleyfield River was significantly higher than in the Midgell River during all three sampling periods in areas outside springs (Mann-Whitney rank sum, $P < 0.05$). In August in the Valleyfield River and in July-August in Midgell River, brook trout catch net-day^{-1} in spring habitat did not differ significantly (Mann-Whitney rank sum, $P > 0.05$).

Age structure, growth, and mortality

In the Midgell River, fork lengths of age 1+ fish ranged from 7.2 - 14.5 cm on 14 May, 9.5 - 15.1 cm on 24 July, and 9.3 - 17.6 cm on 5 September (Table 12). Overlap of age 1+ and age 2+ fork lengths occurred on 14 May and 5 September (Table 13). Growth of Midgell River age 1+ brook trout from scale analysis can be described by the equation $y = 0.81x - 1.47$, $r^2 = 0.374$, $P<0.001$, where y = fork length (cm) and x = age (14.0 - 17.5 months). The equation was used to estimate cohort divisions of YOY, age 1+, and older than 1+ in fork length distributions for each sample period in 1994 and 1995 (Figures 19 - 24, Appendices 4 - 6). Fork length of YOY brook trout was less than 6.3 cm in May-June, 8.0 cm in July-August, and 9.0 cm in September-October (Table 14). Seasonal growth of YOY brook trout from age 2.0 - 5.5 months was 0.38 cm month^{-1} in 1994 and 0.14 cm month^{-1} in 1995 (Table 15, Figure 28). Seasonal growth of age 1+ brook trout from 14.0 - 17.5 months was 0.81 cm month^{-1} in 1995 (Table 15,

Figure 28). Brook trout growth rate between YOY (4 months) and age 1+ (16 months) was 5.6 cm yr^{-1} in the Midgell River (Table 15, Figure 29).

Capture method selectivity for age 1+ and age 2+ brook trout was compared in Spring 3 where both electrofishing and fyke netting were conducted in 1995. Brook trout aged 1+ constituted 69% of electrofishing captures and 58% of fyke net captures indicating a slight selectivity for older year classes by fyke nets compared to electrofishing; however, this difference was not significant (z-test, $P > 0.05$).

Valleyfield River fork lengths of aged 1+ trout were 7.4 - 16.6 cm on 14 May, 10.4 - 15.8 cm on 28 July, and 9.6 - 17.2 cm on 5 September (Table 12). Overlap of age 1+ and age 2+ cohorts occurred in all three scale sampling periods (Table 13). Valleyfield River scale samples gave a growth rate equation of $y = 0.50x + 4.19$, $r^2 = 0.124$, $P<0.001$, where y = fork length (cm) and x = age (14.0 - 17.5 months). The equation was used to estimate cohort divisions of YOY, age 1+, and older than 1+ for each sample period (Figure 25 - 27, Appendices 7 and 8). Valleyfield River YOY brook trout fork lengths ranges were less than 7.4 cm in May-June, 9.0 cm in July-August, and 9.5 cm in September (Table 14). Seasonal YOY growth from 2.0 - 5.5 months in the Valleyfield was 0.83 cm $month^{-1}$ in 1994 and 0.77 cm $month^{-1}$ in 1995 (Figure 28). Growth of age 1+ trout from 14.0 to 17.5 months was 0.50 cm $month^{-1}$ in 1995 (Table 15, Figure 28). Annual growth from YOY (4 months) to age 1+ (16 months) was 6.0 cm-$year^{-1}$ in the Valleyfield River (Table 15, Figure 29).

Mortality rates were estimated for both systems from fork length frequency analysis. Estimated annual mortality rates for YOY brook trout in the Midgell River ranged from 0.22 - 0.37 in 1994 and 0.26 - 0.31 in 1995 (Table 16). Annual mortality estimates for age 1+ trout captured in riverine habitat ranged from 0.35 - 0.57 in 1994 and 0.40 - 0.86 in 1995 in the Midgell River. Mortality estimates for age 1+ brook trout in MacDonald's Pond were dramatically different during the two field seasons. In 1994, age 1+ mortality estimates were 0.64 in July and 0.80 in August sampling periods. In 1995, age 1+ mortality estimates could not be effectively estimated due to the large number of age 2+ brook trout. The change in the age structure of the population suggests that brook trout recruitment to the 1+ year class in MacDonald's Pond and the age 1+ brook trout population size was higher in 1994 compared to 1995 in the Midgell River.

The Valleyfield River annual mortality estimate of YOY brook trout was 0.10 - 0.65 in 1994. Mortality of 1+ fish in riverine habitat was 0.80 - 0.93 in 1994 and 0.79 - 0.88 in 1995. In the Maritime Electric Pond, the annual mortality estimate for age 1+ brook trout was 0.10 for the June and July sampling period and was 0.11 for the September and October sampling period (Table 16).

In the Midgell River, fork lengths of juvenile Atlantic salmon captured from electrofishing sites ranged from 4 cm to 18 cm (Figures 30 - 33, Appendices 9 - 12). Juvenile Atlantic salmon were categorized on the basis of fork length frequencies into age groups. The YOY age cohort contained those salmon with fork lengths less than 6.0 cm in May - June, less than 7.0 in July, and less than 8.0 cm in August-

September sampling period (Table 17). The majority of salmon parr captured in the Midgell River were of hatchery origin. The percentage of hatchery salmon parr among the total parr catch in the Midgell River was 70% in 1994 and 74% in 1995 (Tables 18 and 19). Scale analysis was not conducted on wild salmon parr; therefore, growth rates of salmon older than YOY was not calculated. Growth rates for YOY Atlantic salmon were 0.48 cm $month^{-1}$ in 1994 and 0.47 cm $month^{-1}$ in 1995 (Figure 34).

Valleyfield River YOY Atlantic salmon were distinguished by fork lengths less than 6.0 cm in May - June, less than 7.0 in July, and less than 8.0 cm in August - October sampling periods (Figures 35 - 37, Appendices 13 and 14). Three YOY salmon were captured in 1994 and one YOY salmon was captured in 1995. The low number (4) of YOY salmon captured in the Valleyfield River did not allow for growth estimates. Distinction between wild parr and hatchery parr was through the presence or absence of an adipose fin. No fish of hatchery origin were captured in 1994; 74% were of hatchery origin in 1995 (Tables 20 and 21). However, identification of fish by using an adipose fin clip in the Valleyfield River was problematic. Electrofishing results from the Egolf's Site in the Valleyfield River demonstrated that not all juvenile Atlantic salmon were clipped prior to stocking. This area downstream of Egolf's Pond was stocked with salmon prior to electrofishing in August. Of the 117 parr captured, 93 were adipose fin clipped. Of the 24 parr with no clips, 71% had eroded pectoral fins. Salmon parr with fin erosion are usually of hatchery origin. As a result, growth and mortality rates were not estimated for Valleyfield River Atlantic salmon parr. The absence of YOY Atlantic salmon indicates that natural production on the Valleyfield River is low. It is not known if stocking of salmon parr without adipose fin clips occurred on the Midgell River.

Electrofishing

In the Midgell River during 1994, catchability of salmonids with one sweep electrofishing using barrier nets was 0.87 at the Old Mill Site and 0.54 at the Native Site. The site specific catchability was used to estimate older than YOY salmonids at the Old Mill Site and Native Site, while the mean catchability of 0.71 (Table 22), was used to estimate older than YOY salmonids in other open sites in 1994 and 1995.

The seasonal change in the number of brook trout captured in the Midgell River electrofishing sites suggests that the presence was influenced by warm water temperature in summer. The number of brook trout declined when water temperatures exceeded 19.0°C at electrofishing sites. In 1994, brook trout were 1.4 to 18.2 fish $30m^{-1}$ in June, 0 in July, and 0 to 2 fish $30m^{-1}$ in August (Table 23, Figure 38). The decline of brook trout $30m^{-1}$ was significant between June and July sampling periods (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P < 0.05$), but not significant in the August sampling period compared to other periods (Kruskall-Wallis ANOVA on ranks, Dunn's method, $P > 0.05$). In 1995, brook trout were 0.4 to 8.3 fish $30m^{-1}$ in May, 0 to 4.5 fish $30m^{-1}$ in July, and 0 to 7 fish $30m^{-1}$ in September

(Table 24, Figure 38). In June, brook trout were captured in all electrofishing sites. In July and September, brook trout were not captured in two of the four sites; however, no significant change in brook trout $30m^{-1}$ was detected (ANOVA, $P > 0.05$). Atlantic salmon parr did not show similar distribution shifts as brook trout over the sampling periods (Tables 23 and 24, Figure 39). No significant difference in Atlantic salmon parr $30m^{-1}$ was detected through either field season (ANOVA, $P > 0.05$).

The electrofishing catchability estimate for the Phantom Lane site was 0.53 of the population of trout older than YOY, and was used to estimate population of salmonids older than YOY at electrofishing sites in the Valleyfield River.

Electrofishing of brook trout and Atlantic salmon parr did not indicate seasonal distribution shifts in the Valleyfield River (Tables 25 and 26, Figures 40 - 41). In 1994, brook trout numbered 11 to 59 fish-$30m^{-1}$ in June, and 6 to 36 fish-$30m^{-1}$ in July (Table 25, Figure 40); the difference between sampling periods was not statistically significant (T-test, $P > 0.05$). In 1995, brook trout numbered 31 to 138 fish-$30m^{-1}$ in June, 34 to 137 fish-$30m^{-1}$ in August, and 42 to 95 fish-$30m^{-1}$ in September (Table 26, Figure 40); no significant difference among the three sampling periods was detected (ANOVA, $P > 0.05$). Densities of Atlantic salmon parr did not show changes over the three sampling periods in 1994 and 1995 (Tables 25 and 26, Figure 41). No significant difference was detected for salmon parr $30m^{-1}$ in the June and July sampling periods in 1994 (T-test, $P > 0.05$). In 1995, no significant difference was detected in salmon parr $30m^{-1}$ over the three sampling periods (ANOVA, P > 0.05).

In 1995, Midgell River brook trout densities in electrofishing sites were 0.002 to 0.041 m^{-2} in May, 0 to 0.02 m^{-2} in July, and 0 to 0.035 m^{-2} in electrofishing sites in September. In 1995, Valleyfield River brook trout densities in electrofishing sites were 0.11 to 0.53 m^{-2} in June, 0.13 to 0.54 m^{-2} in August, and 0.15 to 0.41 m^{-2} in September. Brook trout-m^{-2} at electrofishing sites were significantly higher in the Valleyfield River than in the Midgell River during all sampling periods (Mann-Whitney rank sum, P < 0.05). In 1995, Atlantic salmon parr-m^{-2} were not significantly different between systems (Kruskall-Wallis ANOVA on ranks, P > 0.05).

Salmonid Movements

In 1994, fish trapping in the Midgell River indicated that salmonid movement was minimal during periods when water temperature warmed in June, July, and August. The Native fence located close to the head of tide captured 143 trout migrating upstream and 1,036 trout migrating downstream (Figure 42). Two major peaks in downstream brook trout movement occurred, one during the first three weeks of May when water temperatures were cool, and the second during July when daily mean water temperature exceeded 19.5°C. The majority of upstream movement occurred between 5 June - 10 July when mean daily water temperature ranged from 10.0°C - 19.6°C. Following cessation of upstream movement on July 11, mean daily water temperatures ranged from 18.0°C - 23.8°C. No brook trout were captured in MacDonald's Pond fishway from 16 June to 7 September. One brook trout was captured migrating upstream at the fish counting fence operated at the head of MacDonald's Pond from 16 June - 26 August. Eight salmon parr migrating upstream were captured in MacDonald's Pond fishway trap during September (Figure 43).

Thirty-three brook trout were captured and tagged at the Native fence in the Midgell River from 2-4 May and 26-29 May, 1995, thirty-two of which were moving downstream (Figure 44). After May, the Native fence was operated during daylight hours only and salmonid capture was minimal. During 25-27 June, the Native fence was operated for three consecutive nights. During this time, a total of 70 brook trout were captured moving downstream when water temperatures ranged from 19.9°C - 24.9°C, and the mean water temperature for the two day period was 21.9°C.

During 1995, 49 brook trout were captured migrating upstream from MacDonald's fishway trap in the Midgell River (Figure 45). The upstream migrant component of MacDonald's Pond was composed of two groups. A total of 23 brook trout were captured moving into the pond from 15 May to 24 June. The run started when water temperature was approximately 13°C. The run continued through early June and ceased on 24 June when the mean daily water temperature was 21.2°C. Upstream movement resumed in October and November when water temperature decreased. One brook trout was captured moving downstream and one salmon parr was captured moving upstream in June (Figures 45 and 46).

In 1995, 14 brook trout were captured at the fish counting fence in the headwaters of MacDonald's Pond (Figure 47). Four were captured moving downstream and 10 were captured moving upstream. Most (67%) movement occurred in early June. Upstream movement peaked between 24 June and 2 July when mean daily water temperatures ranged 18.2°C - 21.0°C. The following week of 3 July - 12 July mean daily water temperatures were higher than 21.0°C.

Trapping results indicated much greater upstream movements in the Valleyfield River than in the Midgell River. In 1994 and 1995 respectively, 1,495 and 1,142 brook trout were captured in the upstream trap at Maritime Electric Pond (Figures 48 and 49). Upstream brook trout movement on the Valleyfield system began in early June, continued through July, and declined during August. The majority of upstream captures occurred in July when water temperatures ranged from 11.7°C to 19.5°C.

In 1995, 15 juvenile Atlantic salmon were captured moving upstream and five were captured moving downstream at the Maritime Electric fishway trap (Figure 50). Thirty-two adult salmon were captured at the Maritime Electric Fishway, ranging in fork length from 49 cm - 60 cm (Figure 51).

The Maritime Electric Pond headwater counting facility produced incomplete capture of salmonids moving through this site. On several occasions, undermining of the fence and the main box trap occurred. As a result, this facility was treated as a partial counting fence. In 1994, a total of 332 brook trout were captured migrating upstream and in 1995, totals of 104 brook trout migrating upstream and 95 migrating downstream were captured (Figures 52 and 53). In 1995, the majority of the downstream movement occurred in early June, while the majority of upstream moving trout were captured in mid June and July. Forty-two Atlantic salmon smolts were captured moving downstream in June, and 6 salmon parr were captured moving upstream (Figure 54). Eleven adult salmon were captured ranging in fork length from 49 cm - 60 cm (Figure 55).

A total of 240 brook trout were captured moving upstream at Egolf's Pond fishway trap from 1 July to 30 October 1995 (Figure 56). Capture of downstream moving salmonids was minimal and was comprised of 3 trout in early July. A large proportion (46%) of upstream migrating trout were captured in October. A total of 24 salmon parr were captured moving upstream (Figure 57).

Marking mortality

Mortality in the electrofishing group and in the trapping group was 2%. Mortality in the electrofishing and tagging group was 4%, and in the trapping and tagging group was 2% (Table 27). No significant difference in mortality was observed between groups (z-test, $P > 0.05$).

Predator marks

Scars, abrasions, and external injuries on brook trout and Atlantic salmon were recorded as predator marks and monitored through both field seasons in Midgell and Valleyfield rivers. Most predator markings on salmonids were V-shaped or U-shaped and were presumed to originate from attacks by belted kingfishers, Megaceryle alcyon, great blue herons, Ardea herodias, American bitterns, Botaurus lentiginosus, cormorants, Phalacrocorax auritus, American eels, Anguilla rostrata, salmon, or trout.

In the Midgell River, the proportion of trout with predator marks was highest in July and August when brook trout were at high densities in springs (Table 28). In riverine habitat, the proportion of predator marks in Spring 2 were 0 on 16 July and 0.33 on 25 August. In Spring 3 of MacDonald's Pond, the proportions of brook trout with predator marks was 0.06 on 9 July and 0.21 in 25 August. No predator marks were observed on Atlantic salmon parr in 1994.

In 1995, in Spring 2 the proportion of predator marks on brook trout was 0.00 on 11 June and 0.15 on 30 July (Table 29). In Spring 3, the proportion of brook trout with predator marks increased from 0.00 on 10 July to 0.20 on 2 August. The total proportion of Atlantic salmon parr with predator marks was 0.01 in 1995.

The greatest observed proportion of brook trout with predator marks in Valleyfield riverine sites was 0.06 on 30 July 1994 and 0.08 on 6 June 1995 (Tables 30 and 31). No predator marks were observed on Atlantic salmon parr in 1994 and 1995.

The proportion of predator marks on salmon and trout was pooled according to sampling periods and systems (Table 32). Proportions of predator marks on trout were significantly higher in the Midgell River than in the Valleyfield River during the July-August sampling period in 1994 and 1995 (Z-test, $P < 0.05$). There was no significant difference between systems at any other time in 1994 or 1995 (Z-test, $P > 0.05$). Predation as a possible source of tag loss was not considered to significantly impact mark and recapture population estimates because the frequency of predator marks on previously tagged trout was not significantly higher than on first time captures (Z-test, $P > 0.05$).

Trends in angling activity

A total of 18 tag returns were reported by anglers in the Midgell River in 1995, all from MacDonald's Pond (Appendix 15). During the first marking stage, from 24 April to 9 July, reported angler captures were 10.1% of marked fish. For the period 10 July to 15 September, the rate of capture was 3.3% of tagged brook trout. The timing of tag returns suggested that fishing pressure was greatest during May, decreased in June and July, and increased in August and September (Figure 58). In 1996, 3 tags were reported from anglers. One was captured in the Midgell River estuary and two were captured in the Morell River estuary river system close to the head of tide. The Morell River is a neighbouring river system to the Midgell River.

Calculated tag returns by Valleyfield River anglers were approximately 4.6% of brook trout tagged at the Maritime Electric fishway trap (Appendix 16). The timing of tag returns in the Valleyfield River indicated a constant fishing pressure from July to September (Figure 58). No tags were in place to assess the spring fishery in the Valleyfield River.

Population estimates

Populations were estimated by applying the number of salmonids electrofished per stream length to the total length of stream (Midgell: 5.5 km between MacDonald's Pond and head of tide; Valleyfield: 11.5 km between Egolf's

Pond and the head of tide and Brooklyn Pond and MacRae's Bridge). The catchability correction factor was used to estimate densities from open electrofinshing sites. The sites located outside the mark and recapture regions in the headwaters of the Midgell River (Elm Road) and the Valleyfield River (Brooklyn) were not used in population estimates.

Midgell River population estimates for brook trout age 1+ and older from electrofishing sites downstream from MacDonald's Pond were 517 in June, 0 in July, and 183 in September, 1994; and 333 in May, 71 in July, and 48 in September, 1995 (Tables 33 and 34). Juvenile Atlantic salmon parr estimates ranged from 1,897 - 2,237 in 1994 and 761 - 1,561 in 1995 (Tables 33 and 34).

During the recapture period (October-November), the 5.5 km section downstream from MacDonald's Pond was electrofished twice and yielded a total of 11 recaptures, one of which was marked in MacDonald's Pond. Population estimates for this region were 1,231(95% c.i.: 639 - 2,590) on 18-20 October, 1,969 (95% c.i.: 803 - 4,922) on 22-23 November , and 1,595 (95% c.i.: 904 - 3,078) for the total (Table 35). The Head-of-Tide Spring trout population estimates were 1,364 (95% c.i.: 557 - 3,411) on 30 August and 1,875 (95% c.i.: 765 - 4,688) on 1 September (Table 35). In 1994, mark and recapture in Spring 3 located in the headwaters of MacDonald's Pond gave four estimates : 363 (95% c.i.: 229 - 605) on 9 July, 949 (95% c.i.: 493 - 1,997) on 15 July, 600 (95% c.i.: 372 - 1,022) on 21 July, and 764 (95% c.i.: 594 - 983) on 25 August (Table 36). In 1995, direct electrofishing at this site resulted in the capture of 14 trout on 15

July, 6 trout on 24 July, and 15 trout on 2 August. The change in the number of brook trout inhabiting Spring 3 from 1994 and 1995 may be the result of a change in population number and age structure in MacDonald's Pond. The majority of brook trout sampled in MacDonald's Pond in 1994 were age 1+. In 1995, most brook trout sampled from MacDonald's Pond were age 2+.

During July-August 1995, brook trout capture in MacDonald's Pond springs was high. This period was broken down into five mark and recapture periods. Five estimates from the July-August period ranged from 558 (95% c.i.: 228 - 1,394) - 3,329 (95% c.i.: 1,653 - 7,282) brook trout (Table 35). The brook trout population from the September-October recapture was 1,779 (95% c.i.: 794 - 4,449) (Table 35). A total population estimate for the Midgell River from the final recapture period was 3,505 (95% c.i.: 2,174 - 5,967) brook trout (408 km^{-1} of stream).

Brook trout populations estimated from Valleyfield River electrofishing sites in 1994 were 14,490 in June, 7,472 in July, and 61,333 in August; and in 1995 were 30,213 in June, 32,140 in August, and 26,282 in September (Tables 37 and 38). Salmon parr estimates ranged from 181 - 9,781 during 1994, and from 154 - 694 during 1995 (Tables 37 and 38).

A total of 2,083 brook trout was tagged and available for recapture on the Valleyfield River. In the electrofishing recapture sweep, 3,824 greater than age YOY trout were captured and of these 160 were recaptures. From the site of marking population estimates were 41,237 (95% c.i.: 34,094 - 49,884) for electrofishing, 66,898 (95% c.i.: 50,901 - 88,119) for the Maritime Electric fishway, 32,513 (95% c.i.: 13,270 - 81,281) for Maritime Electric Pond fyke nets, and 37,613 (95% c.i.: 17,770 -72,332) for Maritime Electric Pond headwater fish counting fence (Table 39). The mark and recapture estimate from all sites was 49,392 (95% c.i.: 42,229 - 57,624) brook trout (4,295 km^{-1} of stream) (Table 39). The estimate from the electrofishing sites is probably the best estimate for the Valleyfield River because it incorporates a high number of marked fish and the age class in the marking sample is 1+, representative of the majority of the markable trout population in the Valleyfield River

A total of 6 brook trout were recaptured in the Maritime Electric Pond by fyke nets in the September - October sampling period and gave a population estimate of 20,840 (95% c.i.: 10,346 - 39,110) for the Valleyfield River (Table 40).

DISCUSSION

Temperature

Water temperatures in the Midgell River system increased to levels (daily mean >19.2 °C) considered unsuitable for brook trout production in both 1994 and 1995. The maximum temperatures recorded in the Midgell in 1994 and 1995 were approximately 4°C higher than those recorded during 1986 by Thompson et al. (1990). The elevated temperatures in MacDonald's Pond were due primarily to upstream conditions, rather than to solar heating within the pond. Along the 7.5 km section between MacDonald's Pond and McCarrick's Pond, beavers have constructed many small impoundments, which slow water flow and increase the surface area of the stream. From 3.1 to 6.6 km upstream from MacDonald's Pond, the Midgell River lacks streamside canopy due to an old impoundment, now de-watered. Beaver dams and the removal of canopy have been shown to raise temperatures to levels detrimental to salmonids (Burns 1972, Avery 1992). MacDonald's Pond did increase temperatures slightly and prolonged the duration and extent of high temperatures downstream from the pond outflow. Water temperature in the Valleyfield River remained cool and at levels considered to be favourable for brook trout production during both field seasons. Water temperatures below 21°C exiting the Maritime Electric Pond are comparable to temperatures previously recorded at this site by Wildlife Habitat Canada (Thompson 1991). Gradient and stream side cover are probably the principal factors regulating water temperature in both systems.

Behaviour

Changes in fyke net CPUE in sites in MacDonald's Pond indicated a movement of trout into pond springs when water temperatures warmed in July and August. In most cases, CPUE in areas outside spring influence did not suggest a decrease in brook trout numbers during the July-August sampling period. This may relate to the duration of sampling in regions outside spring habitat and the use of fyke nets of different sizes, thus reducing comparability of results. The low density of trout present in MacDonald's Pond may also pose difficulties in assessing trout movement from the main pond area outside spring influence. Seasonal distributions in high density populations could be easier to detect, however, because of the large number of fish involved. The variability of brook trout CPUE from fyke nets did not allow for an estimate of avoidance temperatures in the same way as did snorkelling and electrofishing observations in springs. This is probably due to methodology: fyke net capture is related to movement and not necessarily to number of fish present. Fluctuation in capture of brook trout in fyke nets during warm periods may be due to brook trout leaving the springs to feed and returning to springs in search of cool water, which may not be reflective of preferred temperatures.

The use of cold water refugia by salmonids has been previously reported (Elson 1942; Huntsman 1942; Fry 1951; Gibson 1966; Kaya et al. 1977; Nielsen et al. 1994). The location of brook trout in the Midgell River system appears to be strongly influenced by water temperature. Brook trout were observed in cool water refugia during warm periods in the summer when daily mean stream temperatures exceeded 19.2°C and maximum temperatures exceeded 21.6°C. This observation is in agreement with a number of other studies (Smith and Saunders 1958; Gibson 1966; Henderson 1963). Brook trout are seldom found where water temperatures exceed 20°C if cooler habitat is available (Fry 1951; Smith and Saunders 1958; Henderson 1963). Rainbow trout have similarly been observed to move into deep areas of pools where water temperatures were on average 3.5°C cooler than surface water temperatures, which ranged from 26°C - 29°C. Rainbows did not use these thermal refuges when water temperatures were less than 22°C (Nielsen et al. 1994).

In my study, brook trout were observed by snorkelling, electrofishing, and fyke netting in areas outside direct spring influence, which suggests that brook trout continue to forage in the main river even at temperatures that normally trigger movement to thermal refugia. In a laboratory study, it was shown that yellow perch, Perca flavescens, would make short excursions into areas of inhospitable thermal conditions in order to feed (Thorp 1994). Although the primary factor regulating spring usage by brook trout is undoubtedly warm temperature, it is probably not the only one. The interaction of abiotic and biotic factors of the spring, including water depth, cover, water velocity, dissolved oxygen content, food availability, and competition within and amongst species, could have an impact on the carrying capacity of the cold water refugia. In my study, a greater proportion of older and larger brook trout were located in pond springs, than in shallow river springs which were predominately inhabited by YOY and yearling brook trout.

Temperature also influenced migration behaviour of brook trout on the Midgell River. Upstream migration decreased when the daily temperatures reached 19.6°C (mean) and 22°C (maximum). In late June, the Midgell River fish counting fence at the head of tide was operated over a three night period, and 70 brook trout were counted moving downstream either to the large spring at the head of tide or into estuarine waters. This exodus to cool downstream waters is probably a means of avoiding unfavourable conditions. Burton and Odum (1945) associated a daylight temperature of 19°C with limited brook trout dispersal; above 19°C, brook trout sought cooler waters. Movement of brook trout into cool tributaries (12°C -15°C) of Lake Ainslie, Nova Scotia, occurred when lake temperatures exceeded 21°C (Elson 1942). When water temperatures of the Little Southwest Miramichi surpassed 22°C, brook trout moved into Catamaran Brook, a tributary which remained about 2°C - 3°C cooler than the main river (Cunjak et al. 1993). Movement of salmonids from MacDonald's Pond into upstream waters during warm water periods did not occur and is thought to be due mainly to the lack of upstream cold water refuges available (water flowing into the pond was only slightly cooler than water exiting the pond).

Crowding into small refugia can cause a break-down of territory defence (Coutant 1987). The high densities of fish in thermal refugia may create potential problems affecting survival. Predator marks or beak marks on fish have been used as indicators of predation by cormorants (Davies et al. 1995), herons (Cass 1990), kingfishers (White 1936), and murres, Uria sp. (Hislop and MacDonald 1989). Avian predators including great blue herons, kingfishers, and bitterns were observed in or close to the Midgell River springs during warm water sampling periods. Frequency of occurrence of predator marks on brook trout at high densities in the Midgell River springs was higher than for brook trout in the Valleyfield River. This is probably an indication of a greater incidence of attempted predation on brook trout concentrated in cool water refugia in the Midgell River. Thorp (1994) reported that large numbers of trout physiologically restricted to cold water were more vulnerable to predators. During warm water conditions, the flow in a tributary had ceased, leaving many small pools from which escape from predators was greatly reduced (Thorp 1994). Low water temperatures in springs could further increase the chance of predation. Spontaneous activity of brook trout is maximized at approximately 14°C - 16°C (Graham 1949), and oxygen uptake for physical activity is maximized at 16°C (Fisher and Sullivan 1958). Spring water temperatures of 7°C could slow reaction time of brook trout to predators, particularly to endothermic predators.

Another important limiting agent of the brook trout population could be the predatory nature of salmonids. Kennedy and Strange (1986), while working on Atlantic salmon and brown trout, found that water depth was the major variable which defined yearling and fry habitat and concluded that fry which move into deeper regions run a high risk of predation by older salmonids. Alexander (1979) estimated that the most important predator of YOY brown trout and brook trout was older year classes of brown trout. In the Midgell River, warm water temperatures cause a territoriality breakdown as trout move into springs. The trout age structure of riverine springs indicated that both fry and yearling trout inhabit spring refugia at high numbers, making fry very susceptible to intra-specific predation. Predation on fry may be the most important factor limiting recruitment into the next year class in the Midgell River. Another predator of salmonids which was captured in both systems was the American eel. The overall effect of predation as a limiting factor for Midgell River Brook trout cannot be fully understood from my study. The apparent high predator pressure on brook trout in the Midgell River system may be associated with differences in predator populations in both systems. Apparent increased predation could be an important reason for the low brook trout population found in the Midgell River.

Atlantic salmon were not observed to be attracted to spring habitat during warm periods. Atlantic salmon parr were observed in transects outside of spring influence when water temperatures were highest. Huntsman (1942) recorded deaths of adult salmon at temperatures close to 30°C, as well as the use of cooler water in tributaries by parr during warm periods. Riverine water temperatures in the Midgell system remained slightly below 30°C, and a behavioural response of Atlantic salmon parr to use study springs was not apparent. The upper lethal temperature for Atlantic salmon is close to 29°C, approximately 3°C higher than the upper lethal temperature for brook trout (Grande and Andersen 1991).

The absence of parr in spring water suggests that brook trout and salmon behave quite differently in warm water conditions. Brook trout respond to warm temperatures considerably below their lethal limit, whereas salmon parr apparently do not seek thermal refugia even when temperatures approach lethal levels. This result differed from Gibson (1966) who observed salmon parr moving into spring seeps (~17°C) when water temperature rose above 22°C. The lack of spring usage by salmon parr in the Midgell River could be due to springs remaining at ~7°C. Springs may be used by salmon and trout at high water temperatures; however, springs are more critical to the survival of brook trout than Atlantic salmon at high water temperatures (Fry 1951). This behavioural characteristic and higher temperature tolerance probably allows salmon parr to remain distributed throughout the river system during warm periods and may provide juvenile salmon with a competitive advantage over brook trout in warm water systems. Water temperature is considered to be a factor effecting interspecific competition and dominance in salmonids (De Staso and Rahel 1994).

Growth

Water temperature has a major influence on growth of brook trout (Leach 1924; Myers 1946; Baldwin 1956; Davis 1956; Haskell et al. 1956; Patrick and Graf 1962; McCormick et al. 1972). Leach (1924) reported that a temperature range of 7°C - 18°C was most appropriate for growth of brook trout. Davis (1956) suggested that the range was closer to 13°C - 16°C for optimal brook trout growth. Haskel et al. (1956) demonstrated increased brook trout growth rates with increased temperatures, which ranged from 8°C -11°C. When brook trout were held at four different temperatures (9°C, 13°C, 17°C, and 21°C), growth and prey conversion efficiency was best at 13°C, with metabolic expenditure greatest at 17°C and 21°C (Baldwin 1956). McCormick et al. (1972) held brook trout from the alevin to fry stages at six different temperatures regimes (7.1°C, 9.8°C, 12.4°C, 15.4°C, 17.9°C, and 19.5°C) and reported maximum biomass gain at temperatures of 12.4°C and 15.4°C, as well as increased mortality at temperatures of 17.9°C and 19.5°C.

Young of the year brook trout sampled between May and September in 1994 and 1995 grew faster in the Valleyfield River than in the Midgell River. Slow growth of YOY trout in the Midgell River was probably due to the thermal restriction of fish to the space limited cold water refugia . However, 14 month old trout were similar in size in the two systems, indicating a faster growth in the Midgell from age 6 months to age 14 months. This may be related to the low densities and reduced competition in the Midgell River, factors which favour growing conditions and reflect the potential of the Midgell River as a trout habitat in the absence of thermal restriction. As well, water temperature in the Midgell River during the spring and fall seasons may be more favourable to growth than the cold temperatures in the Valleyfield River.

The presence and use of cold water refugia in the Midgell River appears to reduce the effect of above optimal temperatures on growth of 1+ brook trout. In fact, growth of 1+ trout was greater in the Midgell River and in the Valleyfield River. Brook trout older than YOY may be better able to cope with thermal restriction in springs. This may be due to mobility and feeding. Yearling brook trout can move more efficiently than YOY trout due to their larger size. As well, by sharing spring habitat with YOY trout, they are provided with a food source without leaving the spring.

Annual mortality rate of salmonids has been associated with a number of variables, including density-dependence (Mortensen 1977), predation and competition (Kennedy and Strange 1986), and water temperature (Kaya 1978). The difference in number and age class of trout captured in Spring 3 and Small Spring in 1994 and 1995 in the Midgell River could reflect a substantial difference in recruitment of YOY trout into the 1+ age class. The greatest impact of thermal restriction may be on YOY brook trout. Predation and reduced growth in springs would be related to the duration spent in springs or how warm or cool temperatures are in the summer. The mean monthly air temperature recorded in Charlottetown, Prince Edward Island, was about 4°C cooler in July 1993 than in July 1994 (Environment Canada 1993 and 1994a). This suggests that YOY brook trout likely spent less time in springs in 1993 than in 1994. A briefer period of spring confinement would lead to a higher survival rate, and could explain the abundance of 1+ trout in MacDonald's Pond in 1994. Annual mortality rates and changes in strength of a year class size suggests that the Midgell River brook trout population could be related to changes in annual environmental conditions effecting the degree of density dependence in cold water refugia. Proper definition of factors controlling recruitment of 1+ brook trout would require a longer term than that incorporated in this study.

High mortality is often associated with density-dependence and the territorial behaviour of salmonids (Miller 1958; Le Cren 1973). Heavy annual mortality rates of 0.80 and 0.93 on the Valleyfield River suggest that the population is controlled by density dependent factors. High exploitation and anadromy could be another reason for high mortality rate of 1+ brook trout in the Valleyfield River. Exploitation can result in removal of older year classes from a population (Bennet 1970); thus 1+ mortality estimates based on proportions of older year classes under heavy exploitation pressure may lead to high mortality estimates for 1+ brook trout. Anadromy associated with age 2+ and older trout may also positively bias annual mortality rates as older year classes migrate to salt water habitat.

Trends in angling activity

Tag returns from anglers could indicate that fishing activity on the Midgell River declined during warm periods of the summer relative to concurrent fishing pressure on the Valleyfield River. McMichael and Kaya (1991) reported higher angling activity and catch of brown trout and rainbow trout when water temperatures were below 19°C. Very few anglers were observed utilizing MacDonald's Pond between late June and mid-August. This change in angling effort could be the result of diminished feeding rates or altered distribution of brook trout during warm periods as brook trout move into a greatly reduced areas of the pond where spring refugia are located. Coutant (1987) suggests that fish using space-limited thermal refugia are susceptible to angling. The potential of increased exploitation in pond springs appears to be high; however, very few anglers appear to be taking advantage of this opportunity. Only one party of anglers was observed to frequent MacDonald's Pond during warm periods (pers. observ.). Most angling activity during warm periods occurred in Region 6 of MacDonald's Pond in sites close to spring influence (pers. observ.). During warm summer months, the value of the Midgell River to the local recreational brook trout fishery appears to be minimal.

Smith and Saunders (1963) reported that angling success rates increased after pond creation in the Wilmot River, Prince Edward Island. They credited this change to the ability of impoundments to hold up trout during their downstream descent to estuarine waters in the spring of the year, as well as to the function of impoundments as holding areas for trout returning to the system in the summer. The maximum bi-monthly mean surface water temperature recorded in Wilmot Pond remained below 20°C (Smith and Saunders 1963).

Angling activity based on tag returns on the Valleyfield River appears to remain relatively high in July, August, and September. The majority of tags returned by anglers were initially applied at the Maritime Electric trap and are considered to be from fish of anadromous origin. Previous studies have indicated that the Valleyfield River and neighbouring Montague River are of significant importance to Prince Edward Island's recreational fishery (Cairns 1996).

Population

Factors which can impact brook trout productivity in stream systems are substrate, cover, temperature, and flow rates (Wesche 1985). Water temperature has been shown to be the main factor limiting the geographic distribution of brook trout (McCrimmon and Campbell 1969), and the chief factor which differentiates non-trout streams from trout streams (Barton et al. 1985). Weekly water temperatures over 22°C limited brook trout production in streams of southern Ontario (Barton et al. 1985). Daily maximum water temperature profiles recorded over the course of this study demonstrate that Midgell River water exceeded 22°C for prolonged periods in 1994 and 1995. The significant impact of temperature on trout populations has prompted several studies which have evaluated long-term impacts on brook trout habitat by climatic warming (Meisner 1990). Meisner (1990) estimated that an increase in ambient air temperature would result in a significant loss of brook trout habitat in southern Ontario streams. Population estimates of 3,505 (95% c.i.:2,174 - 5,967) brook trout (408 km^{-1} of stream length) in the Midgell River and 41,237 (95% c.i.: 34,094 - 49,884) brook trout (3,586 km^{-1} of stream length) in the Valleyfield River demonstrate a marked difference in population size in a warm water versus a cold water system.

Conclusion

This study indicates that even during warm water periods (>19.2°C) juvenile Atlantic salmon parr remained in the open river. Most brook trout took refuge in springs during warm water periods. Predation in springs could be an important factor limiting the brook trout population size in a warm water system. Human exploitation did not increase in springs during warm water periods. The brook trout population was approximately an order of magnitude greater in a cold water system than in a warm water system of similar size. Growth of YOY brook trout in Midgell River appears to be influenced by the confinement of fish to space limited cool water refugia. The presence of springs does not neutralize the impact of warm water temperature on a brook trout population in a warm water system. This study should act as the impetus for further investigation into other environmental parameters, predator-prey interactions, and ecological impacts of warm water on brook trout production on Prince Edward Island.

LITERATURE CITED

Alexander, G.R. 1979. Predators of fish in cold water streams. pp. 153 - 170. In Predator-prey systems in fisheries management. H. Clippers ed. Sport Fishing Institute Pub. Washington D.C.

Anderson, T.C. and B.P. MacDonald. 1978. A portable weir for counting migrating fishes in rivers. Fish. Marine Serv. Tech. Rep. 733:13p.

Anon. 1988. P.E.I. Water temperature study. Unpubl. report for the 1988 field season, Ducks Unlimited Canada.

Anon. 1990a. Montague-Valleyfield Rivers Complex watershed activities. The Canada-Prince Edward Island Water Management Agreement, Surface Water Program. Unpubl. report, Environment Canada, Inland Water Directorate and P.E.I. Department of Environment, Fish and Wildlife Branch. 27 p.

Anon. 1990b. St. Peter's Bay Complex watershed activities. The Canada-Prince Edward Island Water Management Agreement, Surface Water Program. Unpubl. report, Environment Canada, Inland Water Directorate and P.E.I. Department of the Environment, Fish and Wildlife Branch. 29 p.

ASE Consultants Inc. 1997. Impact of impoundments and their suitability for resident and anadromous fish species on Prince Edward Island. Unpublished report 154p.

Avery, E.L. 1992. Effects of removing beaver dam upon a northern Wisconsin brook trout stream. Wisconsin Department of Natural Resources, Bureau of Research, Fish Research Section, Study 406, Madison. 8p.

Baldwin, N.W. 1956. Food consumption and growth of brook trout at different temperatures. Trans. Am. Fish. Soc. 86:323-328.

Barton, D.R., W.D. Taylor, and R.M. Beitte. 1985. Dimensions of riparian buffer strips required to maintain trout habitat in southern Ontario streams. N. Am. J. Fish. Manage. 5:364-378.

Bennet, G.W. 1970. Management of lakes and ponds. 2nd ed. Litton Educational Publishing, Ltd. 375 p.

Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Trans. Am. Fish. Soc. 101:1 - 17.

Burton, G.W. and E.P. Odum. 1945. The distribution of stream fish in the vicinity of Mountain Lake, Virginia. Ecology 26:182-194.

Cairns, D.K. 1996. Effort, harvest, and expenditures of trout and salmon anglers on Prince Edward Island in 1994, from a mail-out survey. Man. Rep. Can. Fish. Aquat. Sci. no. 2367

Cass, D.N. 1990. 'Beak prints' held war against aerial invaders. Fish Farmer 13: 46-47.

Coutant, C.C. 1977. Compilation of temperature preference data. J. Fish. Res. Bd. Can. 34:583-770.

Coutant, C.C. 1987. Thermal preference: when does an asset become a liability? Environ. Biol. Fishes. 18:161-172.

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). Tech. Rep. Can. Fish. Aquat. Sci. 1914.

Davies J.M., M.J. Feltham, and M.V. Walsingham. 1995. Management and Ecological note on fish wounding by cormorants, *Phalacrocorax carbo* L. Fish. Manage. Ecology. 2:321- 324.

Davis, H.S. 1956. Culture and diseases of game fishes. 2nd. ed. University of California Press, Berkeley and Los Angeles, Calif. 332 pp.

De Staso, J. and F.J. Rahel. 1994. Influence of water temperature between juvenile Colorado River cutthroat trout and brook trout in a laboratory stream. Trans. Am. Fish. Soc. 123:289-297.

Elson, P.F. 1942. Effect of temperature on activity of *Salvelinus fontinalis*. J. Fish. Res. Bd. Can. 5:461-470.

Environment Canada. 1993. Climatic perspectives: a weekly review of Canadian climate and water. 15:27-31.

Environment Canada. 1994a. Climatic perspectives: a weekly review of Canadian climate and water. 16:27-31.

Environment Canada. 1994b. Canadian Council of Resources and Environmental Ministers.

Fisher, K.C. and C.M. Sullivan. 1958. The effect of temperature on the spontaneous activity of speckled trout before and after lesions of the brain. Can. J. Zool. 36:49-63.

Francis, R.M. 1989. Hydrogeology of the Winter River basin, Prince Edward Island. Prince Edward Island Department of Environment. Unpublished report.

Fry, F.E.J. 1951. Some environmental factors influencing relations of speckled trout (*Salvelinus fontinalis*). Proc. N.E. Atlantic Fisheries Conf. 1:1-29.

Gibson, R.J. 1966. Some factors influencing the distributions of brook trout and young Atlantic salmon. J. Fish. Res. Bd. Can. 23:1,977-1,980.

Graham, J.M. 1949. Some effects of temperature and oxygen pressure on the metabolism and activity of speckled trout, *Salvelinus fontinalis*. Can. J. Res. 27:270-288.

Grande, M. and S. Andersen. 1991. Critical thermal maxima for young salmonids. J. Freshw. Ecol. 6:275-279.

Guignion, D.L., T.D. Dupuis, and R.E. MacFarlane. 1990. Factors influencing water temperature and the possible impacts of high water temperatures on salmonids in the Morell River, Prince Edward Island. Unpubl. report, Biology Department, University of P.E.I. 36 p.

Haskell, D. C., L.E. Wolf, and L. Bouchard. 1956. The effect of temperature on the growth of brook trout. N.Y. Fish and Game. J. 3:108-113.

Henderson, N.E. 1963. Influence of light and temperature on the reproductive cycle of the eastern brook trout, *Salvelinus fontinalis* (Mitchill). J. Fish. Res. Bd. Can. 20:859-897.

Hislop, J.R.G. and W.S. MacDonald. 1989. Damage to fish by seabirds in the Moray Firth. Scottish Birds. 15: 151-155.

Huner, J.V. and O.V. Lindqvist. 1986. Nuclear power plant heat for culturing Atlantic salmon smolts. Aquacult. Mag. 12:22-24.

Huntsman, A.G. 1942. Death of salmon and trout with high temperature. J. Fish Res. Bd. Can. 5:485-501.

Jones, M.L. and J.D. Stockwell. 1995. A rapid assessment procedure for the enumeration of salmonine population in streams. N. Am. J. Fish. Manage. 15: 551-562.

Kaya, C.M. 1978. Thermal resistance of rainbow trout from a permanently heated stream, and two hatchery strains. Prog. Fish. Cult. 39:138-142.

Kaya, C. M., L.R. Kaeding, and D.E. Burkhalter. 1977. Use of coldwater refuge by rainbow and brown trout in a geothermally heated stream. Prog. Fish. Cult. 39:37-39.

Kennedy, G.J. and C.D. Strange. 1986. The effects of intra- and inter-specific competition on the distribution of stocked juvenile Atlantic salmon, *Salmo salar* L., in relation to depth and stream gradient in an upland trout, *Salmo trutta* L., stream. J. Fish. Biol. 29:199-214.

Leach, G.C. 1924. Artificial propagation of brook trout and rainbow trout with notes on three other species. Rep. U.S. Comm. Fish. for 1923, App. 6, Doc. 955:1-74.

Le Cren, E.D. 1973. The population dynamics of young trout (*Salmo trutta*) in relation to density and territorial behaviour. Rapp. P.-v. Reun. Cons. int. Explor. Mer.164:241-246.

McCormick, J.H., K.E.F. Hokenson, and B.R. Jones. 1972. Effects of temperature on growth and survival of young brook trout, *Salvelinus fontinalis*. J. Fish. Res. Bd. Can. 29 :1,107-1,112.

McCrimmon, H.R. and J.S. Campbell. 1969. World distribution of brook trout, *Salvelinus fontinalis*. J. Fish. Res. Bd. Can. 26:1,699-1,725.

McMichael, G.A. and C.M. Kaya. 1991. Relations among stream temperature, angling success for rainbow trout and brown trout, and fisherman satisfaction. N. Am. J. Fish. Manage. 11:190-199.

Meisner, J.D. 1990. Potential loss of thermal habitat for brook trout, due to climatic warming, in two southern Ontario streams. Effects of climate change on fish Trans. Am. Fish. Soc. 119:282-291.

Miller, R.B. 1958. The role of competition and the mortality of hatchery trout. J. Fish. Res. Bd. Can. 15:27-45.

Morrison, B.R.S. 1989. The growth of juvenile Atlantic salmon, *Salmo salar* L., and brown trout, *Salmo trutta* L., in a Scottish river system subject to cooling-water discharge. J. Fish. Biol. 35:539-556.

Mortensen, E. 1977. Density-dependent mortality of trout fry (*Salmo trutta* L.) and its relationship to the management of small streams. J. Fish. Biol. 11:613-617.

Myers, C. 1946. Trout foods. Some observations on trout food during their first twelve months. Salmon Trout Mag. 118:212-218.

Nielsen, J.L., T.E. Lisle, and V. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Trans. Am. Fish Soc. 123:613-625.

Patrick, N.D. and P. Graf. 1962. The effect of temperature on artificial culture of aurora trout. Can. Fish. Cult. 30:49-55.

Prince Edward Island Department of Technology and Environment. 1994 and 1995. Beaver survey data. P O Box 2000. Charlottetown P.E.I. C1A 7N8. Unpublished data.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191:382 p.

Scott, W.B. and M.G.Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219:731 p.

Sigma Stat for Windows version 2.0. 1992-1995 ©. Jandel Corporation.

Smith, M.W. and J.W. Saunders. 1958. Movements of brook trout, *Salvelinus fontinalis* (Mitchill), between and within fresh and salt water. J. Fish. Res. Bd. Can. 15:1,403-1,449.

Smith, M.W. and J.W. Saunders. 1963. Influence of pond formation on brook trout movements and angling success. J. Fish. Res. Bd. Can. 20:327-345.

Taylor, A.H. 1978. An analysis of the trout fishing at Eye Brook - an eutrophic reservoir. J. Anim. Ecol. 47:407-423.

Thompson, B. 1991. Fishway trapping statistics for Knox's Dam (Montague River); Maritime Electric Dam and Egolf's Dam (Valleyfield River) for 1987-1990). Unpublished report. Prince Edward Island Department of Technology and Environment. P O Box 2000. Charlottetown P.E.I. C1A 7N8.

Thompson, B.F., D.I. Bray, and K. McAloney. 1990. Effects of Prince Edward Island waterfowl impoundments on water temperature. Can. Wat. Res. J. 15:217-230.

Thorp, J.E. 1994. Salmonid flexibility: responses to environmental extremes Trans. Am. Fish. Soc. 123:606-612.

Wesche, T.A. 1985. Stream channel modifications and reclamation structures to enhance fish habitat. In The Restoration of Rivers and Streams: Theories and Experience. Ed. by J.A. Gore. Boston:Butterworth Publ. pp. 103-165.

White, H.C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. J. Biol. Bd. Can. 2 : 299 - 309.

Zippin, C. 1958. The removal method of population estimation. J. Wildl. Manage. 22: 83-91.

Table 1. Electrofishing site parameters, Midgell River and Valleyfield River, 1994 - 1995.

Year	River	Site	Date	Length (m)	Mean width (m)	Area (m^2)	Mean depth (m)	Vol (m^3)	Velocity ($m\text{-}sec^{-1}$)
1994	Valleyfield	Upper Phantom	1-Jan	30	12.8	383	0.38	146	ns
		MacRae's	1-Jan	30	10.8	323	0.37	118	ns
		Egolf's	1-Jan	30	9.0	270	0.11	30	ns
1995		Heatherdale	16-Aug	130	9.1	1189	0.30	360	0.48
		Mermey's 1	17-Aug	92	7.3	675	0.23	160	0.47
		Mermey's 2	17-Aug	60	8.7	524	0.18	109	0.43
		Brooklyn	18-Aug	106	6.2	659	0.20	130	0.40
		S 2 outside transect	16-Aug	40	9.4	375	0.27	131	0.48
		S 2 inside transect	16-Aug	8	4.2	33	0.09	3	ns
		S 1 inside transect	16-Aug	4	2.9	12	0.16	1	ns
1994	Midgell	Native	2-Jan	30	10.8	323	ns	ns	ns
		Old Mill	2-Jan	30	6.0	180	ns	ns	ns
1995		Upper Native	5-Aug	130	6.3	815	0.22	176	0.45
		Old Mill	5-Aug	102	6.2	636	0.21	137	0.48
		Corner Pool	5-Aug	94	7.5	705	0.19	127	0.39
		Elm Road	5-Aug	80	6.7	539	0.31	163	ns
		S 1 outside transect	29-Aug	80	7.6	605	0.23	132	ns
		S 1 inside transect	29-Aug	33	4.7	155	0.18	24	ns
		S 2 outside transect	29-Aug	80	5.6	448	0.19	88	ns
		S 2 inside transect	29-Aug	4	7.3	26	0.19	4	ns
		S 3	Aug	10	8.3	83	0.48	40	ns

S = spring
ns = not sampled

Table 2. Monthly mean and maximum water temperatures at Midgell River and Valleyfield River thermograph sites, 1994 - 1995.

			June 8 - 30		July		August	
River	Year	Site	Mean	Max	Mean	Max	Mean	Max
Midgell	1994	Elm Road	17.5	27.7	21.2	27.5	18.8	26.9
		M Pond inflow	18.5	26.3	23.0	28.6	20.4	27.5
		S 3	-	-	6.2	9.2	6.6	10.6
		M Pond middle	20.3	24.2	23.5	26.0	21.5	26.3
		M Pond bottom	20.0	23.4	22.6	25.7	21.1	26.2
		M Pond surface	21.5	27.4	25.0	30.0	22.8	29.2
		Artties	19.9	25.8	23.6	27.8	21.3	27.4
		Old Mill	19.4	26.4	23.4	29.8	20.9	28.3
		S 2 pool	-	-	15.2	22.6	14.9	21.6
		S 2 inflow	-	-	8.5	11.7	8.0	12.9
		Native fence	17.2	24.1	21.1	26.9	18.6	25.3
	1995	MacCarrick's Pond	19.5	26.5	22.5	27.6	19.8	27.1
		Elm Road	17.3	25.3	20.2	26.5	17.8	27.1
		M Pond inflow	17.6	25.1	21.4	26.5	19.4	27.3
		M Pond bottom	18.2	21.6	20.5	22.4	19.1	22.9
		M Pond surface	18.9	26.5	22.9	28.4	20.5	29.6
		Old Mill	18.2	24.9	22.2	27.5	19.8	28.6
Valleyfield	1994	ME Pond inflow	14.0	19.9	16.5	20.2	14.9	19.8
		ME Pond surface	14.7	19.2	17.6	21.7	15.8	20.4
		ME Pond bottom	13.2	16.4	15.8	19.1	14.3	17.8
		ME Pond middle	13.6	16.4	16.4	20.6	14.8	19.6
		ME Pond outflow	14.6	19.7	17.2	21.0	15.7	20.5
	1995	Egolf's Pond outflow	15.5	21.6	17.8	22.9	16.7	23.3
		S	6.2	9.7	6.0	6.2	6.1	6.4
		MacRae's Bridge	13.6	18.3	15.5	19.1	14.1	18.9
		ME Pond inflow	13.3	18.2	15.3	19.0	13.9	18.8
		ME Pond outflow	13.9	18.3	16.0	19.5	14.6	19.9

M Pond = MacDonald's Pond
ME Pond = Maritime Electric Pond
S = Spring

Table 3. Maximum spring influence measured as meters of stream length, Midgell River, 1994 - 1995.

Area surveyed: MacDonald's Pond headwater fish counting fence to MacDonald's Pond outflow.
Distance surveyed : 3100 m
Distance of spring influence on main channel 99.4
Proportion of spring influence as a total stream length: 0.032

Meters	Spring name	Spring type	Thermal influence as length of river (m)
400	Spring a	trib	1
494	Spring b	trib	1
515	Spring c	seep	1
839	Small Spring	seep	2
1225	Spring 3	trib	3
1460	New Spring	seep	7
1666	Headwater Spring	seep	86
3100	Pond outflow		

Area surveyed: MacDonald's Pond outflow to head of tide.
Distance : 5500 m
Distance of spring influence on main channel 185
Proportion of spring influence as a total stream length: 0.043

Meters	Spring name	Spring type	Thermal influence as length of river (m)
480	Spring d	trib	1
1230	Spring e	trib	0
1320	Old Mill	trib	1
1650	Spring f	seep	1
1860	Spring 2	trib	2
2160	Spring 1	trib	80
3000	Spring g	trib	1
5350	Head of Tide Spring	trib	150
5500	Head of tide		

Table 4. Snorkelling counts and electrofishing counts of salmonids at Spring 1, Midgell River, 1994 - 1995.

			Trout in spring			Trout out of spring			Salmon in spring			Salmon out of spring			Temperature °C			
Year	Method	Date	Total	YOY	>YOY	Total	YOY	>YOY	Total	YOY	Parr	Total	YOY	Parr	Spring TOS	River Mean DOS	River Max DOS	# snork [a]
1994	sn	29-Jul	163	142	21	0	0	0	0	0	0	27	1	26	8	25.4	27.2	1
	sn	1-Aug	95	86	9	1	0	1	0	0	0	32	4	28	10.5	25.2	28.3	1
	sn	4-Aug	101	84	17	0	0	0	0	0	0	32	8	24	8.5	24.1	27.0	2
	sn	9-Aug	160	143	17	0	0	0	3	2	1	50	3	47	8	21.3	24.1	1
	sn	23-Aug	61	50	11	1	0	1	0	0	0	29	2	27	9	19.7	21.7	2
	sn	5-Sep	9	6	3	21	20	1	0	0	0	12	7	5	9	14.7	15.6	1
	ef	5-Sep	23	15	8	ns	ns	ns	1	1	0	ns	ns	ns	9	14.7	15.6	
1995	sn	25-May	6	6	0	1	0	1	0	0	0	5	0	5	10	13.6	16.1	1
	sn	5-Jun	3	3	0	6	4	2	0	0	0	7	0	7	8	16.2	18.1	1
	ef	11-Jun	0	0	0	3	1	2	0	0	0	7	0	7	7.3	16.9	18.3	
	sn	24-Jun	59	52	7	9	5	4	0	0	0	6	0	6	8.8	20.5	23.2	
	sn	5-Jul	112	104	8	1	0	1	0	0	0	7	0	7	7.5	22.4	24.2	1
	sn	15-Jul	267	225	42	0	0	0	0	0	0	10	4	6	7.8	23.2	25.7	1
	ef	30-Jul	97	38	59	5	0	5	10	3	7	16	3	13	8	23.3	26.5	1
	sn	6-Aug	86	73	13	2	0	2	3	1	2	7	0	7	10.4	20.7	22.4	
	sn	13-Aug	102	75	27	1	0	1	0	0	0	7	0	7	7.9	22.7	23.6	1
	sn	20-Aug	24	22	2	0	0	0	2	1	1	3	2	1	8.4	19.7	23.2	1
	sn	29-Aug	6	5	1	3	2	1	0	0	0	4	0	4	7.1	14.9	18.1	1
	ef	11-Sep	27	19	8	8	1	7	7	3	4	14	2	12	10	12.5	13.5	1

[a] number of snorkellers conducting outside spring transect

sn = snorkelling

ef = electrofishing

ns = not sampled

YOY = Young of the year

TOS = time of sampling from hand held thermometer

DOS = 24 hour period the day of sampling from adjacent data logger

Table 5. Snorkelling counts and electrofishing counts of salmonids at Spring 2, Midgell River, 1994 - 1995.

			Trout in spring			Trout out of spring			Salmon in spring			Salmon out of spring			Temperature °C			
Year	Method	Date	Total	YOY	>YOY	Total	YOY	>YOY	Total	YOY	Parr	Total	YOY	Parr	Spring TOS	River Mean DOS	River Max DOS	# snork [a]
1994	ef	16-Jul	38	9	29	ns	ns	ns	ns	ns	ns	ns	ns	ns	9.8	21.8	22.9	
	sn	23-Jul	64	33	31	0	0	0	0	0	0	14	7	7	ns	25.2	27.6	1
	sn	27-Jul	47	27	20	0	0	0	0	0	0	6	1	5	14	25.0	26.5	1
	sn	29-Jul	52	29	23	0	0	0	0	0	0	9	5	4	ns	25.4	27.2	
	sn	4-Aug	56	34	22	0	0	0	0	0	0	9	3	6	18	24.1	27.0	2
	sn	10-Aug	57	30	27	0	0	0	0	0	0	6	4	2	16.5	20.9	23.4	1
	ef	22-Aug	12	ns	12	ns	ns	ns	ns	ns	ns	ns	ns	ns	10.1	21.1	22.4	
	sn	5-Sep	7	5	2	2	1	1	1	1	0	0	0	0	10	14.7	15.6	1
	ef	5-Sep	5	3	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	10	14.7	15.6	
1995	sn	25-May	0	0	0	2	1	1	0	0	0	5	0	5	12	13.6	16.1	1
	sn	5-Jun	0	0	0	5	3	2	0	0	0	5	0	5	10	16.2	18.1	1
	ef	11-Jun	0	0	0	4	1	3	0	0	0	2	0	2	ns	16.9	18.3	
	sn	24-Jun	30	30	0	17	10	7	0	0	0	14	0	14	9.8	20.5	23.2	1
	sn	5-Jul	20	18	2	2	1	1	0	0	0	10	1	9	10	22.4	24.2	1
	sn	15-Jul	46	45	1	2	2	0	0	0	0	13	3	10	14	23.2	25.7	1
	sn	30-Jul	46	30	16	2	2	0	0	0	0	13	5	8	13	23.3	26.5	1
	ef	30-Jul	40	28	12	9	8	1	0	0	0	14	8	6	14	23.3	26.5	
	sn	6-Aug	36	29	7	6	5	1	0	0	0	14	3	11	14	20.7	22.4	1
	sn	13-Aug	44	32	12	2	2	0	0	0	0	10	2	8	14	22.7	23.6	1
	sn	20-Aug	29	13	16	0	0	0	0	0	0	2	1	1	10.1	19.7	23.2	1
	sn	29-Aug	8	5	3	2	0	2	0	0	0	7	2	5	12	14.9	18.1	1
	sn	11-Sep	0	0	0	2	0	2	0	0	0	7	2	5	8	12.5	13.5	1
	ef	11-Sep	2	1	1	6	3	3	0	0	0	12	4	8	10	12.5	13.5	

[a] number of snorkellers conducting outside spring transect
sn = snorkelling
ef = electrofishing
ns = not sampled
YOY = Young of the year
TOS = time of sampling from hand held thermometer
DOS = 24 hour period the day of sampling from adjacent data logger

Table 6. Snorkelling counts, electrofishing counts, and seining counts of salmonids at Spring 3, Midgell River, 1994-1995.

			Trout in spring			Trout out of spring			Salmon in spring			Salmon out of spring			Temperature °C			
Year	Method	Date	Total	YOY	>YOY	Total	YOY	>YOY	Total	YOY	Parr	Total	YOY	Parr	Spring TOS	River Mean DOS	River Max DOS	# snork [a]
1994	ef	8-Jul	54[b]	3	51	ns	ns	ns	0	0	0	ns	ns	ns	ns	19.9	21.0	ns
	ef	9-Jul	245[b]	21	224	ns	ns	ns	0	0	0	ns	ns	ns	ns	19.4	22.8	ns
	seine	15-Jul	27[b]	1	26	ns	ns	ns	0	0	0	ns	ns	ns	ns	22.4	26.3	ns
	seine	21-Jul	32[b]	2	30	ns	ns	ns	0	0	0	ns	ns	ns	ns	23.7	27.7	ns
	ef	25-Aug	154[b]	7	147	ns	ns	ns	0	0	0	ns	ns	ns	9.3	17.7	21.0	ns
1995	sn	25-May	4	4	0	ns	ns	ns	0	0	0	ns	ns	ns	ns	13.6	16.1	ns
	ef	6-Jun	0	0	0	ns	ns	ns	0	0	0	ns	ns	ns	10	16.4	19.3	ns
	ef	11-Jun	0	0	0	ns	ns	ns	0	0	0	ns	ns	ns	6.1	16.9	18.3	ns
	sn	24-Jun	14	4	10	ns	ns	ns	0	0	0	ns	ns	ns	ns	20.5	23.2	ns
	sn	5-Jul	20	4	16	ns	ns	ns	0	0	0	ns	ns	ns	7.5	22.4	24.2	ns
	ef	10-Jul	11	0	11	ns	ns	ns	0	0	0	ns	ns	ns	7	23.0	24.2	ns
	sn	15-Jul	14	2	12	ns	ns	ns	0	0	0	ns	ns	ns	7	23.2	25.7	ns
	ef	24-Jul	6	0	6	ns	ns	ns	0	0	0	ns	ns	ns	ns	22.7	24.5	ns
	ef	2-Aug	15	0	15	ns	ns	ns	0	0	0	ns	ns	ns	7	22.4	23.6	ns
	sn	2-Aug	34	20	14	ns	ns	ns	0	0	0	ns	ns	ns	ns	22.4	23.6	ns
	sn	12-Aug	28	15	13	ns	ns	ns	0	0	0	ns	ns	ns	7.4	23.7	26.5	ns
	sn	20-Aug	2	1	1	ns	ns	ns	0	0	0	ns	ns	ns	7.4	19.7	23.2	ns
	sn	29-Aug	4	4	0	ns	ns	ns	0	0	0	ns	ns	ns	6.8	14.9	18.1	ns
	ef	12-Sep	3	2	1	ns	ns	ns	0	0	0	ns	ns	ns	ns	12.2	13.2	ns

[a] number of snorkellers conducting outside spring transect
[b] represents number captured in mark and recapture estimate and not number of trout present in spring
sn = snorkelling
ef = electrofishing
ns = not sampled
TOS = time of sampling from hand held thermometer
DOS = 24 hour period the day of sampling from adjacent data logger

Table 7. Snorkelling counts and electrofishing counts of salmonids at Small Spring, Midgell River, 1994 - 1995.

			Trout in spring			Trout out of spring			Salmon in spring			Salmon out of spring			Temperature °C			
Year	Method	Date	Total	YOY	>YOY	Total	YOY	>YOY	Total	YOY	Parr	Total	YOY	Parr	Spring TOS	River Mean DOS	River Max DOS	# snork [a]
1994	ef	8-Jul	84	0	84	ns	ns	ns	0	0	0	ns	ns	ns	ns	19.9	21	ns
1995	sn	5-Jul	29	0	29	ns	ns	ns	0	0	0	ns	ns	ns	ns	22.4	24.2	ns
1995	ef	24-Jul	1	0	1	ns	ns	ns	0	0	0	ns	ns	ns	ns	25.0	28.7	ns

[a] number of snorkellers conducting outside spring transect

sn = snorkelling

ef = electrofishing

ns = not sampled

TOS = time of sampling from hand held thermometer

DOS = 24 hour period the day of sampling from adjacent data logger

Table 8. Salmonid catches in fyke nets, MacDonald's Pond, Midgell River, 1995.

Date	Region	Site	Species	Net size	Days	# captured	Catch fyke net-day^{-1} Mean	SD	Range	Temperature °C Mean DOS
Spring sampling period										
28-April - 19-May	1	outside S	bt	lg	22	7	0.32	0.84	0 - 3.0	8.2
24-April - 19-May	2	outside S	bt	lg	26	15	0.58	0.98	0 - 4.0	7.7
24-April - 19-May	3	outside S	bt	lg	26	12	0.46	1.30	0 - 6.0	7.7
28-April - 19-May	4	outside S	bt	lg	22	22	1.00	1.34	0 - 4.0	8.2
28-April - 19-May	4	outside S	A s parr	lg	22	1	0.05	0.21	0 - 1.0	8.2
29-April - 19-May	5	outside S	bt	sm	22	21	0.43	0.48	0 - 1.7	8.2
1-May - 13-May	6	Headwater S	bt	sm	12	0	0	0	0	7.8
1-May - 19-May	6	outside S	bt	lg	6	0	0	0	0	7.8
1-May - 19-May	6	outside S	A s parr	lg.	6	1	0.17	0.41	0 - 1.0	7.8
Summer sampling period										
10-Jul - 2-Aug	1	outside S	bt	lg	24	0	0	0	0	23.5
3-Aug - 15-Aug	2	outside S	bt	sm	14	0	0	0	0	20.8
3-Aug - 15-Aug	3	outside S	bt	sm	14	0	0	0	0	20.8
3-Aug - 15-Aug	4	outside S	bt	lg	14	3	0.23	0.56	0 - 1.5	20.8
10-Jul - 15-Aug	6	Headwater S	bt	sm	37	204	3.17	6.03	0 - 26	22.6
10-Jul - 2-Aug	6	S 3	bt	sm	24	14	0.60	0.95	0 - 4.0	23.5
10-Jul - 2-Aug	6	Small S	bt	sm	24	35	1.46	1.91	0 - 7.0	23.5
28-Jul - 2-Aug	6	New S	bt	sm	6	2	0.33	0.82	0 - 2.0	24.7
10-Jul - 24-Jul	6	outside S	bt	sm	14	1	0.07	0.27	0 - 1.0	22.8
Fall sampling period										
11-Sep - 24-Sep	1	outside S	bt	lg	14	0	0	0	0	16.9
11-Sep - 24-Sep	2	outside S	bt	sm	14	0	0	0	0	16.9
11-Sep - 24-Sep	3	outside S	bt	sm	14	1	0.06	0.13	0 - 0.3	16.9
11-Sep - 4-Oct	4	outside S	bt	lg	24	0	0	0	0	16.7
11-Sep - 5-Oct	6	Headwater S	bt	sm	25	18	0.61	0.83	0 - 3.0	16.7
11-Sep - 15-Sep	6	S 3	bt	sm	5	1	0.20	0.45	0 - 1.0	18.0
11-Sep - 24-Sep	6	Small S	bt	sm	14	2	0.14	0.23	0 - 0.5	16.9
11-Sep - 12-Oct	6	outside S	bt	sm	21	21	0.23	0.53	0 - 2.7	16.1

bt= brook trout, A s parr= Atlantic salmon parr, S= Spring,
DOS= 24 hour period the day of sampling from adjacent data logger,

Table 9. Electrofishing counts of salmonids at Spring 1, Valleyfield River, 1995.

	Trout in spring			Trout out of spring			Salmon in spring			Salmon out of spring			Temperature °C		
													Spring	River	River
Date	Total	YOY	>YOY	Total	YOY	>YOY	Total	YOY	Parr	Total	YOY	Parr	TOS	Mean DOS	Max DOS
7-Jun	1	0	1	72	ns	72	0	0	0	2	0	2	6.6	12.5	14.8
18-Aug	2	2	0	95	16	79	0	0	0	3	0	3	6.6	16.6	18.3
13-Sep	1	1	0	148	52	96	0	0	0	4	0	4	7	12.5	14

ns = not sampled

TOS = time of sampling from hand held thermometer

DOS = 24 hour period the day of sampling from adjacent data logger

Table 10. Electrofisher counts of salmonids at Spring 2, Valleyfield River, 1995.

	Trout in spring			Trout out of spring			Salmon in spring			Salmon out of spring			Temperature °C		
													Spring	River	River
Date	Total	YOY	>YOY	Total	YOY	>YOY	Total	YOY	Parr	Total	YOY	Parr	TOS	Mean DOS	Max DOS
7-Jun	1	0	1	24	ns	24	0	0	0	2	0	2	6.6	12.5	14.8
8-Aug	0	0	0	27	0	27	0	0	0	3	0	3	6.6	14.6	16.6
13-Sep	6	6	0	51	12	39	0	0	0	1	0	1	7	12.5	14

ns = not sampled

TOS = time of sampling from hand held thermometer

DOS = 24 hour period the day of sampling from adjacent data logger

Table 11. Salmonid catches in fyke nets, Maritime Electric Pond, Valleyfield River,1995.

			Net		#	Catch fyke net-day -1			Temperature °C
Date	Site	Species	size	Days	captured	Mean	SD	Range	Mean DOS
Spring sampling period									
27-Jun - 4 - Jul	outside S	bt	sm	8	23	0.96	0.53	0 - 2.0	13.5
27-Jun - 4 - Jul	outside S	A s parr	sm	8	9	0.39	0.27	0 - 0.7	13.5
Summer sampling period									
12-Aug - 19-Aug	outside S	bt	sm	8	37	2.49	1.82	0 - 4.3	15.1
12-Aug - 19-Aug	outside S	A s parr	sm	8	8	0.27	0.17	0.2 - 0.7	15.1
12-Aug - 19-Aug	Headwater S	bt	sm	8	14	1.61	1.32	0.5 - 3.3	15.1
12-Aug - 19-Aug	Headwater S	A s parr	sm	8	1	0.04	0.05	0 - 0.1	15.1
Fall sampling period									
30-Sep - 14-Oct	outside S	bt	sm	15	68	2.06	2.08	0 - 5.2	7.9
30-Sep - 14-Oct	outside S	A s parr	sm	15	4	0.13	0.13	0 - 0.3	7.9
30-Sep - 14-Oct	outside S	A s adult	sm	15	3	0.13	0.22	0 - 0.5	7.9

bt = brook trout

A s parr = Atlantic salmon parr

A s adult = Atlantic salmon adult

DOS = 24 hour period the day of sampling from adjacent data logger

Table 12. Length at estimated age for brook trout of the Midgell River and Valleyfield River, 1995.

System	Age (months)	Fork length (cm)			
		Mean	SD	N	Range
Midgell	1.5	5.4	0.39	5	5.2 - 6.0
	3.9	5.5	0.60	9	4.8 - 6.5
	13.5	9.6	1.96	40	7.2 - 14.5
	15.9	11.8	1.66	11	9.5 - 15.1
	17.2	12.3	1.88	26	9.3 - 17.6
	25.5	18.0	3.57	3	13.9 - 20.6
	27.9	21.1	3.42	11	15.1 - 26.4
	29.2	16.6	0.85	2	16.2 - 17.2
Valleyfield	1.5	4.7	0.89	8	3.9 - 6.9
	5.2	6.7	0.91	30	4.5 - 8.6
	13.5	10.8	2.32	51	7.4 - 16.6
	15.8	13.0	1.34	34	10.4 - 15.8
	17.2	12.3	2.00	40	9.6 - 17.2
	25.5	16.3	1.88	14	14.2 - 21.1
	27.8	16.1	0.70	3	15.4 - 16.8
	29.2	17.5	1.51	6	15.5 - 19.7

Table 13. Proportion of brook trout age 2+ with fork lengths within the age 1+ cohort for each scale sample period, Midgell River and Valleyfield River, 1995.

River	Date	Fork length (cm)			
			Overlap		
		Age 1+	Age 2+	N	Prop age 2+
Midgell	14-May	7.2 - 14.5	13.9 - 14.5	4	0.50
	28-Jul	9.5 - 15.1	-	0	0
	5-Sep	9.3 - 17.6	16.0 - 17.6	3	0.66
Valleyfield	14-May	7.4 - 16.6	14.2 - 16.6	17	0.69
	24-Jul	10.4 - 15.8	15.4 - 15.8	4	0.75
	5-Sep	9.6 - 17.2	15.5 - 17.2	6	0.50

Table 14. Fork lengths (cm) and age (months) of brook trout, Midgell River and Valleyfield River, 1994 - 1995.

						Fork length (cm)			
Year	System	Habitat	Dates inclusive	Method	Age (months)	Mean	SD	N	Range
1994	Midgell	Pond	8-Jul - 21-Jul	ef & sein	3.5	6.2	1.07	21	4.7 - 8.0
1994	Midgell	Pond	8-Jul - 21-Jul	ef & sein	15.5	11.5	1.77	309	8.5 - 15.4
1994	Midgell	Pond	8-Jul - 21-Jul	ef & sein	>26.5	17.5	1.84	110	15.5 - 24.0
1994	Midgell	Pond	25-Aug	ef	4.8	5.6	0.42	10	5.0 - 6.2
1994	Midgell	Pond	25-Aug	ef	16.8	13.1	1.92	120	9.2 - 16.7
1994	Midgell	Pond	25-Aug	ef	>27.8	19.0	2.00	24	16.7 - 25.3
1994	Midgell	River	9-Jun - 13-Jun	ef	2.4	5.0	0.62	27	3.5 - 5.8
1994	Midgell	River	9-Jun - 13-Jun	ef	14.4	11.3	1.68	17	8.2 - 14.0
1994	Midgell	River	9-Jun - 13-Jun	ef	>26	17.5	2.54	10	14.7 - 21.9
1994	Midgell	River	17-Jul - 31-Jul	ef	3.8	5.7	0.41	10	4.9 - 6.2
1994	Midgell	River	17-Jul - 31-Jul	ef	15.8	14.6	1.06	17	12.8 - 16.3
1994	Midgell	River	17-Jul - 31-Jul	ef	>26.8	20.3	2.24	11	16.5 - 25.0
1994	Midgell	River	31-Aug - 5-Sep	ef	5.1	6.3	0.49	9	5.6 - 7.1
1994	Midgell	River	31-Aug - 5-Sep	ef	17.1	14.0	0.62	7	13.2 - 15.0
1994	Midgell	River	31-Aug - 5-Sep	ef	>28.1	20.7	3.20	3	17.0 - 22.6
1995	Midgell	Pond	24-Apr - 19-May	fn	13.2	11.1	1.73	5	9.0 - 13.0
1995	Midgell	Pond	24-Apr - 19-May	fn	>24.2	22.6	4.25	72	15.2 - 36.0
1995	Midgell	Pond	10-Jul - 15-Aug	fn	15.9	13.3	1.49	38	10.7 - 15.5
1995	Midgell	Pond	10-Jul - 15-Aug	fn	>26.9	22.4	3.63	168	15.7 - 36.0
1995	Midgell	Pond	11-Sep - 12-Oct	fn	17.9	13.7	1.80	9	11.2 - 17.2
1995	Midgell	Pond	11-Sep - 12-Oct	fn	>28.9	24.0	5.28	29	17.2 - 36.0
1995	Midgell	River	22-May - 11- Jun	ef	2.1	5.3	1.34	2	4.3 - 6.2
1995	Midgell	River	22-May - 11- Jun	ef	14.1	10.8	1.46	28	8.0 - 14.0
1995	Midgell	River	22-May - 11- Jun	ef	>25.1	15.5	1.34	4	14.0 - 17.2
1995	Midgell	River	29-Jul - 1-Aug	ef	4	6.2	0.59	82	4.8 - 7.4
1995	Midgell	River	29-Jul - 1-Aug	ef	16	12.6	1.39	61	8.9 - 14.9
1995	Midgell	River	29-Jul - 1-Aug	ef	>26	20.0	4.05	21	15.2 - 29.5
1995	Midgell	River	5-Sep - 12-Sep	ef	5.3	6.2	0.97	32	4.3 - 7.7
1995	Midgell	River	5-Sep - 12-Sep	ef	17.3	12.5	1.65	22	9.8 - 16.0
1995	Midgell	River	5-Sep - 12-Sep	ef	>28.3	18.1	2.73	7	16.0 - 23.3
1995	Midgell	River	28-Jul	ef	3.9	6.0	0.53	26	5.1 - 7.1
1995	Midgell	River	28-Jul	ef	15.9	12.6	1.59	22	10.0 - 15.6
1995	Midgell	River	28-Jul	ef	>26.9	19.0	1.86	8	15.8 - 21.8
1995	Midgell	River	3-Aug	ef	4.1	6.3	0.62	16	4.9 - 7.7
1995	Midgell	River	3-Aug	ef	16.1	12.8	1.64	58	9.5 - 15.5
1995	Midgell	River	3-Aug	ef	>27.1	20.8	4.05	27	15.8 - 32.1
1995	Midgell	River	1-Sep	ef	17	14.1	1.30	30	10.4 - 16.2
1995	Midgell	River	1-Sep	ef	>28	25.0	8.38	18	16.2 - 42.7
1995	Midgell	River	30-Aug	ef	17	13.2	1.91	34	9.8 - 16.2
1995	Midgell	River	30-Aug	ef	>28	20.5	5.64	16	16.3 - 34.0
1994	Valleyfield	River	15-Jun - 24-Jun	ef	2.6	5.1	0.77	109	2.9 - 7.3
1994	Valleyfield	River	15-Jun - 24-Jun	ef	14.6	11.3	1.23	74	9.0 - 15.3
1994	Valleyfield	River	15-Jun - 24-Jun	ef	>25.6	16.6	1.24	5	15.3 - 18.3
1994	Valleyfield	River	20-Jul - 30-Jul	ef	3.8	6.4	0.89	116	4.3 - 8.1
1994	Valleyfield	River	20-Jul - 30-Jul	ef	15.8	12.4	1.47	41	9.8 - 15.3
1994	Valleyfield	River	20-Jul - 30-Jul	ef	>26.8	18.4	2.98	8	15.4 - 25.7
1994	Valleyfield	River	17-Sep	ef	5.6	7.7	0.93	160	5.0 - 9.4
1994	Valleyfield	River	17-Sep	ef	17.6	13.0	1.60	144	9.5 - 16.5
1994	Valleyfield	River	17-Sep	ef	>29	17.9	1.12	15	16.6 - 20.1
1995	Valleyfield	Pond	27-Jun - 4-Jul	fn	15	13.9	0.62	10	13.0 - 14.8
1995	Valleyfield	Pond	27-Jun - 4-Jul	fn	>26	18.6	3.42	9	15.2 - 24.5
1995	Valleyfield	Pond	12-Aug - 19-Aug	fn	16.5	13.5	1.72	11	11.0 - 15.6
1995	Valleyfield	Pond	12-Aug - 19-Aug	fn	>27.5	19.7	3.35	38	16.2 - 30.0
1995	Valleyfield	Pond	30-Sep - 14-Oct	fn	18.2	13.9	1.78	36	9.8 - 16.6
1995	Valleyfield	Pond	30-Sep - 14-Oct	fn	>29.2	21.4	4.99	32	17.0 - 40.0
1995	Valleyfield	River	7-Jun - 20-Jun	ef	2.5	5.0	0.81	14	3.9 - 5.6
1995	Valleyfield	River	7-Jun - 20-Jun	ef	14.5	11.8	1.77	689	7.0 - 15.5
1995	Valleyfield	River	7-Jun - 20-Jun	ef	>25.5	17.3	1.70	123	15.5 - 23.0
1995	Valleyfield	River	8-Aug - 19-Aug	ef	4.5	6.5	0.94	248	4.3 - 9.0
1995	Valleyfield	River	8-Aug - 19-Aug	ef	16.5	12.5	1.61	586	9.0 - 15.6
1995	Valleyfield	River	8-Aug - 19-Aug	ef	>27.5	17.6	1.91	124	15.7 - 25.3
1995	Valleyfield	River	13-Sep - 15-Sep	ef	5.5	7.3	1.12	346	4.0 - 9.4
1995	Valleyfield	River	13-Sep - 15-Sep	ef	17.5	12.7	1.75	527	9.5 - 16.5
1995	Valleyfield	River	13-Sep - 15-Sep	ef	>28.5	18.3	1.85	62	16.5 - 26.0

ef = electrofishing, sein = sein netting, fn = fyke netting.

Table 15. Growth rates for brook trout, Midgell River and Valleyfield River, 1994 - 1995.

System	Species	Year (s)	Age (months)	Equation	r^2	N	P value	(cm - mo^{-1})	(cm - yr^{-1})
Midgell	bt	1994	2.0 - 5.5	y = 0.38x + 4.21	0.297	77	<0.001	0.38	
Midgell	bt	1995	2.0 - 5.5	y = 0.14x + 5.60	0.011	172	0.118	0.14	
Midgell	bt	1995	14.0 - 17.5	y = 0.81x - 1.47	0.374	77	<0.001	0.81	
Midgell	bt	1994-95	4.0 - 16.0	y = 0.46x + 3.84	0.795	154	<0.001		5.60
Midgell	A s	1994	2.0 - 5.5	y = 0.48x + 1.13	0.868	12	0.003	0.48	
Midgell	A s	1995	2.0 - 5.5	y = 0.47x + 3.62	0.122	36	<0.001	0.47	
Valleyfield	bt	1994	2.0 - 5.5	y = 0.83x + 3.11	0.604	385	<0.001	0.83	
Valleyfield	bt	1995	2.0 - 5.5	y = 0.77x + 3.05	0.229	608	<0.001	0.77	
Valleyfield	bt	1995	14.0 - 17.5	y = 0.50x + 4.19	0.124	125	<0.001	0.50	
Valleyfield	bt	1994-95	4.0 - 16.0	y = 0.50x + 4.46	0.777	510	<0.001		5.96

bt = brook trout

A s = Atlantic salmon YOY

sc = scale

fl = fork length

fn = fyke net

ef = electrofishing

Table 16. Annual mortality rates of brook trout, Midgell River and Valleyfield River, 1994 - 1995.

Year	System	Habitat	Dates inclusive	Method	Age (months)	N	YOY mortality rate	1+ mortality rate
1994	Midgell	Pond	8-Jul - 21-Jul	ef & sein	3.5	21		
1994	Midgell	Pond	8-Jul - 21-Jul	ef & sein	15.5	309		0.64
1994	Midgell	Pond	8-Jul - 21-Jul	ef & sein	>26.5	110		
1994	Midgell	Pond	25-Aug	ef	4.8	10		
1994	Midgell	Pond	25-Aug	ef	16.8	120		0.80
1994	Midgell	Pond	25-Aug	ef	>27.8	24		
1994	Midgell	River	9-Jun - 13-Jun	ef	2.4	27	0.37	
1994	Midgell	River	9-Jun - 13-Jun	ef	14.4	17		0.41
1994	Midgell	River	9-Jun - 13-Jun	ef	>26	10		
1994	Midgell	River	17-Jul - 31-Jul	ef	3.8	10		
1994	Midgell	River	17-Jul - 31-Jul	ef	15.8	17		0.35
1994	Midgell	River	17-Jul - 31-Jul	ef	>26.8	11		
1994	Midgell	River	31-Aug - 5-Sep	ef	5.1	9	0.22	
1994	Midgell	River	31-Aug - 5-Sep	ef	17.1	7		0.57
1994	Midgell	River	31-Aug - 5-Sep	ef	>28.1	3		
1995	Midgell	Pond	24-Apr - 19-May	fn	13.2	5		
1995	Midgell	Pond	24-Apr - 19-May	fn	>24.2	72		
1995	Midgell	Pond	10-Jul - 15-Aug	fn	15.9	38		
1995	Midgell	Pond	10-Jul - 15-Aug	fn	>26.9	168		
1995	Midgell	Pond	11-Sep - 12-Oct	fn	17.9	9		
1995	Midgell	Pond	11-Sep - 12-Oct	fn	>28.9	29		
1995	Midgell	River	22-May - 11- Jun	ef	2.1	2		
1995	Midgell	River	22-May - 11- Jun	ef	14.1	28		0.86
1995	Midgell	River	22-May - 11- Jun	ef	>25.1	4		
1995	Midgell	River	29-Jul - 1-Aug	ef	4	82	0.26	
1995	Midgell	River	29-Jul - 1-Aug	ef	16	61		0.66
1995	Midgell	River	29-Jul - 1-Aug	ef	>26	21		
1995	Midgell	River	5-Sep - 12-Sep	ef	5.3	32	0.31	
1995	Midgell	River	5-Sep - 12-Sep	ef	17.3	22		0.68
1995	Midgell	River	5-Sep - 12-Sep	ef	>28.3	7		
1995	Midgell	River	28-Jul	ef	3.9	26		
1995	Midgell	River	28-Jul	ef	15.9	22		0.64
1995	Midgell	River	28-Jul	ef	>26.9	8		
1995	Midgell	River	3-Aug	ef	4.1	16		
1995	Midgell	River	3-Aug	ef	16.1	58		0.53
1995	Midgell	River	3-Aug	ef	>27.1	27		
1995	Midgell	River	1-Sep	ef	17	30		0.40
1995	Midgell	River	1-Sep	ef	>28	18		
1995	Midgell	River	30-Aug	ef	17	34		0.53
1995	Midgell	River	30-Aug	ef	>28	16		
1994	Valleyfield	River	15-Jun - 24-Jun	ef	2.6	109	0.32	
1994	Valleyfield	River	15-Jun - 24-Jun	ef	14.6	74		0.93
1994	Valleyfield	River	15-Jun - 24-Jun	ef	>25.6	5		
1994	Valleyfield	River	20-Jul - 30-Jul	ef	3.8	116	0.65	
1994	Valleyfield	River	20-Jul - 30-Jul	ef	15.8	41		0.80
1994	Valleyfield	River	20-Jul - 30-Jul	ef	>26.8	8		
1994	Valleyfield	River	17-Sep	ef	5.6	160	0.10	
1994	Valleyfield	River	17-Sep	ef	17.6	144		0.90
1994	Valleyfield	River	17-Sep	ef	>29	15		
1995	Valleyfield	Pond	27-Jun - 4-Jul	fn	15	10		0.10
1995	Valleyfield	Pond	27-Jun - 4-Jul	fn	>26	9		
1995	Valleyfield	Pond	12-Aug - 19-Aug	fn	16.5	11		
1995	Valleyfield	Pond	12-Aug - 19-Aug	fn	>27.5	38		
1995	Valleyfield	Pond	30-Sep - 14-Oct	fn	18.2	36		0.11
1995	Valleyfield	Pond	30-Sep - 14-Oct	fn	>29.2	32		
1995	Valleyfield	River	7-Jun - 20-Jun	ef	2.5	14		
1995	Valleyfield	River	7-Jun - 20-Jun	ef	14.5	689		0.82
1995	Valleyfield	River	7-Jun - 20-Jun	ef	>25.5	123		
1995	Valleyfield	River	8-Aug - 19-Aug	ef	4.5	248		
1995	Valleyfield	River	8-Aug - 19-Aug	ef	16.5	588		0.79
1995	Valleyfield	River	8-Aug - 19-Aug	ef	>27.5	124		
1995	Valleyfield	River	13-Sep - 15-Sep	ef	5.5	346		
1995	Valleyfield	River	13-Sep - 15-Sep	ef	17.5	527		0.88
1995	Valleyfield	River	13-Sep - 15-Sep	ef	>28.5	62		

ef = electrofishing, sein = sein netting, fn = fyke netting.

Table 17. Fork lengths (cm) and age (months) of juvenile Atlantic salmon, Midgell River and Valleyfield River, 1994 - 1995.

							Fork length (cm)			
Year	System	Habitat	Dates inclusive	Method	Hatchery	Age (months)	Mean	SD	N	Range
1994	Midgell	River	9-Jun - 13-Jun	ef	wild	>13.4	11.4	1.58	7	9.3 - 14.2
1994	Midgell	River	9-Jun - 13-Jun	ef	hatchery	>13.4	9.9	0.89	29	8.5 - 11.7
1994	Midgell	River	17-Jul - 31-Jul	ef	wild	3.8	4.8	0.41	10	4.0 - 5.3
1994	Midgell	River	17-Jul - 31-Jul	ef	wild	>14.8	9.8	1.66	4	8.0 - 11.3
1994	Midgell	River	17-Jul - 31-Jul	ef	hatchery	>14.8	10.4	0.84	20	8.8 - 12.2
1994	Midgell	River	31-Aug - 5-Sep	ef	wild	5.1	6.3	2.05	2	5.5 - 7.0
1994	Midgell	River	31-Aug - 5-Sep	ef	wild	>16.1	11.4	1.53	10	8.4 - 15.1
1994	Midgell	River	31-Aug - 5-Sep	ef	hatchery	>16.1	11.0	0.52	12	10.1 - 11.9
1994	Valleyfield	River	20-Jul - 30-Jul	ef	wild	3.8	3.9	0.07	2	3.8 - 3.9
1994	Valleyfield	River	20-Jul - 30-Jul	ef	unk	>14.8	12.6	0.83	34	11.1 - 14.4
1994	Valleyfield	River	17-Sep	ef	unk	>16.6	14.7	-	1	-
1994	Valleyfield	River	15-Jun - 24-Jun	ef	unk	>13.6	11.6	1.17	151	9.8 - 15.2
1995	Midgell	River	22-May - 11- Jun	ef	wild	>13.1	9.3	1.75	28	6.8 - 13.2
1995	Midgell	River	22-May - 11- Jun	ef	hatchery	>13.1	9.0	0.52	10	8.0 - 9.7
1995	Midgell	River	22-May - 11- Jun	ef	unk	>13.1	10.5	4.17	2	7.5 - 13.4
1995	Midgell	River	29-Jul - 1-Aug	ef	wild	4	5.1	0.29	20	4.5 - 5.6
1995	Midgell	River	29-Jul - 1-Aug	ef	wild	>15	10.9	1.48	32	9.0 - 15.0
1995	Midgell	River	29-Jul - 1-Aug	ef	hatchery	>15	11.2	1.42	25	9.5 - 15.2
1995	Midgell	River	29-Jul - 1-Aug	ef	unk	>15	11.5	2.44	8	10.0 - 15.1
1995	Midgell	River	11-Sep - 12-Sep	ef	wild	5.3	6.1	0.76	11	4.8 - 7.3
1995	Midgell	River	11-Sep - 12-Sep	ef	wild	>16.3	11.9	1.59	36	9.2 - 14.5
1995	Midgell	River	11-Sep - 12-Sep	ef	hatchery	>16.3	11.5	1.63	30	7.3 - 16.7
1995	Midgell	River	11-Sep - 12-Sep	ef	unk	>16.3	11.3	1.79	20	7.0 - 14.7
1995	Midgell	River	28-Jul	ef	hatchery	>14.9	10.5	0.67	14	9.4 - 11.5
1995	Midgell	River	28-Jul	ef	wild	>14.9	10.6	-	1	-
1995	Midgell	River	3-Aug	ef	wild	4.1	5.9	0.79	8	5.1 - 7.7
1995	Midgell	River	3-Aug	ef	wild	>15.1	10.2	-	1	-
1995	Midgell	River	3-Aug	ef	hatchery	>15.1	10.2	0.93	111	7.4 - 14.6
1995	Midgell	River	1-Sep	ef	hatchery	>16	10.8	0.61	24	9.7 - 12.2
1995	Midgell	River	1-Sep	ef	unk	>16	11.6	2.25	3	10.2 - 14.2
1995	Midgell	River	30-Aug	ef	hatchery	>16	10.8	1.21	84	6.6 - 15.6
1995	Midgell	River	30-Aug	ef	wild	>16	11.7	1.11	4	10.5 - 13.0
1995	Valleyfield	Pond	27-Jun - 4-Jul	fn	unk	>14	14.7	1.00	12	13.4 - 16.5
1995	Valleyfield	Pond	12-Aug - 19-Aug	fn	unk	>15.5	16.8	0.50	7	15.8 - 17.3
1995	Valleyfield	Pond	30-Sep - 14-Oct	fn	unk	>17.2	16.8	0.87	3	15.5 - 17.5
1995	Valleyfield	River	7-Jun - 20-Jun	ef	unk	>13.5	11.2	1.17	27	9.0 - 13.2
1995	Valleyfield	River	8-Aug - 19-Aug	ef	wild	4.5	6.6	-	1	-
1995	Valleyfield	River	8-Aug - 19-Aug	ef	unk	>15.5	13.4	1.60	133	10.7 - 16.5
1995	Valleyfield	River	13-Sep - 15-Sep	ef	unk	>16.5	13.3	1.92	10	8.5 - 15.5

Table 18. Salmon parr with adipose fin clips captured by electrofishing in riverine sites, Midgell River, 1994.

Date	Site	Total	Clipped	Unclipped	Unknown	Proportion Clipped
9-Jun	Native	4	4	0	0	1.00
13-Jun	Old Mill	14	10	4	0	0.71
9-Jun	Artties	8	8	0	0	1.00
12-Jun	Upper fence	9	6	3	0	0.67
11-Jun	Elm Road	1	1	0	0	1.00
17-Jul	Native	7	6	1	0	0.86
17-Jul	Old Mill	9	8	1	0	0.89
17-Jul	Artties	6	5	1	0	0.83
31-Jul	Upper fence	1	0	1	0	0.00
31-Jul	Elm Road	1	1	0	0	1.00
31-Aug	Native	16	5	9	2	0.36
31-Aug	Old Mill	6	3	3	0	0.50
5-Sep	S 1	2	0	1	1	0.00
Total		84	57	24	3	0.70

S = spring
ns = not sampled

Table 19. Salmon parr with adipose fin clips, Midgell River, 1995.

Date	Habitat	Site	Method	Total	Clipped	Unclipped	Unknown	Proportion Clipped
22-May	River	Upper Native	ef	7	3	4	0	0.43
22-May		Old Mill	ef	9	2	7	1	0.22
23-May		Comer Pool	ef	16	0	15	1	0.00
11-Jun		S 1	ef	6	2	3	1	0.40
11-Jun		S 2	ef	2	2	0	0	1.00
30-Jul		Upper Native	ef	9	6	1	1	0.86
29-Jul		Old Mill	ef	11	10	6	0	0.63
29-Jul		Comer Pool	ef	21	4	16	0	0.20
30-Jul		S 1	ef	13	2	6	9	0.25
30-Jul		S 2	ef	6	3	3	1	0.50
28-Jul		Head of tide S	ef	18	14	1	4	0.93
3-Aug		Head of tide S	ef	111	111	1	0	0.99
30-Aug		Head of tide S	ef	91	84	4	3	0.95
1-Sep		Head of tide S	ef	27	24	3	3	0.89
12-Sep		Upper Native	ef	38	23	17	0	0.58
11-Sep		Old Mill	ef	6	6	6	0	0.50
11-Sep		Comer Pool	ef	23	1	13	0	0.07
11-Sep		S 1	ef	12	0	0	12	-
11-Sep		S 2	ef	8	0	0	8	-
Apr-May	Pond	R 4	fn	1	0	1	0	0.00
Apr-May		R 6	fn	1	1	0	0	1.00
	Total			436	298	107	44	0.74

ef = electrofishing
fn = fyke net
ns = not sampled
S= spring
R = region

Table 20. Salmon parr with adipose fin clips captured by electrofishing in riverine sites, Valleyfield River, 1994.

Date	Site	Total	Clipped	Unclipped	Unknown	Proportion Clipped
24-Jun	Egolf's	34	0	34	0	0
17-Jun	MacRae's	18	0	18	0	0
15-Jun	Upper Phantom	2	0	2	0	0
30-Jul	Egolf's	23	0	23	0	0
30-Jul	MacRae's	10	0	10	0	0
17-Sep	Phantom Lane	1	0	0	1	ns
Total		88	0	87	1	0

Table 21. Salmon parr with adipose fin clips, Valleyfield River, 1995.

Date	Habitat	Site	Method	Total	Clipped	Unclipped	Unknown	Proportion Clipped
7-Jun	River	Heatherdale (S 1)	ef	2	0	2	0	0.00
7-Jun		S 2	ef	2	0	0	2	-
6-Jun		Mermey's 2	ef	2	0	0	2	-
20-Jun		200m dwn B Pd	ef	7	0	0	7	-
6-Jun		200m dwn E Pond	ef	1	0	0	1	-
7-Jun		Phantom Lane	ef	4	4	0	0	1.00
20-Jun		200m dwn B Pd	ef	7	0	0	7	-
19-Jun		MacRae's	ef	6	5	1	0	0.83
18-Aug		Heatherdale (S 1)	ef	3	0	3	0	0.00
17-Aug		Mermeys 1	ef	1	1	0	0	1.00
21-Jun		700m dwn E Pd	ef	5	0	5	0	0.00
5-Aug		700m dwn E Pd	ef	3	0	2	1	0.00
19-Aug		Mermey's 2	ef	1	0	0	1	-
8-Aug		S 2	ef	3	1	2	0	0.33
8-Aug		200m dwn E Pd	ef	117	93	24	0	0.79
9-Aug		ME Pond headwater	ef	4	0	3	1	0.00
13-Sep		Heatherdale (S 1)	ef	4	4	0	0	1.00
14-Sep		Mermey's 2	ef	3	3	0	0	1.00
13-Sep		S 2	ef	1	0	1	0	0.00
14-Sep		Mermey's 1	ef	2	2	0	0	1.00
15-Sep		ME Pond headwater	ef	7	1	3	3	0.25
Jun-Jul	Pond	outside S	fn	9	9	0	0	1.00
Jul-Aug		outside S	fn	8	5	0	3	1.00
Jul-Aug		inside S	fn	1	0	0	1	-
Sep-Oct		outside S	fn	4	0	0	4	-
	Total			207	128	46	33	0.74

ef = electrofishing
fn = fyke net

Table 22. Results of electrofishing within barrier nets for salmonids older than YOY from three electrofishing sites, 1994.

River	Site	Date	1st sweep	2nd sweep	3rd sweep	4th sweep	Population	SE (P)	Catchability [a]
Valleyfield	Phantom Lane	17-Sep	88	37	22	-	165	0.06	0.53
Midgell	Old mill	31-Aug	5	1	0	-	6	0.13	0.87
Midgell	Native	31-Aug	10	4	4	0	19	0.19	0.54
Mean Midgell									0.71

[a] catchability = (number of salmonids captured in first sweep / population estimate)

Table 23. Snorkelling observations and electrofishing captures, Midgell River, 1994.

			Trout				Salmon				Temperature °C		
						>YOY[a]				>YOY[a]			
Date	Site	Method	Total	YOY	>YOY	$30m^{-1}$	Total	YOY	Parr	$30m^{-1}$	Mean DOS	Max DOS	# snork[a]
9-Jun	Native	ef	2	1	1	1.4	4	0	4	5.6	11.5	13.9	
13-Jun	Old Mill	ef	12	10	2	2.8	14	0	14	19.7	17.1	17.3	
9-Jun	Arties	ef	3	0	3	4.2	8	0	8	11.3	13.2	13.7	
12-Jun	Upper fence	ef	21	8	13	18.2	9	0	8	12.7	16.9	20.3	
11-Jun	Elm Road	ef	16	8	8	11.2	1	0	1	1.4	14.5	19.3	
17-Jul	Native	ef	0	0	0	0	7	0	7	9.9	19.7	23.2	
27-Jul	Native	sn	0	0	0	na	9	0	9	na	22.9	24.0	2
17-Jul	Old Mill	ef	0	0	0	0	11	2	9	12.7	22.1	26.4	
27-Jul	Old Mill	sn	0	0	0	na	32	2	30	na	25.0	26.5	2
17-Jul	Arties	ef	0	0	0	0	14	8	6	8.4	22.1	26.4	
31-Jul	Upper fence	ef	0	0	0	0	1	0	1	1.4	24.3	27.1	
5-Aug	Upper fence	sn	0	0	0	na	0	0	0	na	24.5	26.9	2
31-Jul	Elm Road	ef	2	2	0	0	1	0	1	1.4	22.4	26.1	
31-Aug	Native[c]	ef	2	0	2	2	16	0	16	16	15.5	16.6	
31-Aug	Native	sn	0	0	0	na	0	0	0	na	15.5	16.6	1
31-Aug	Old Mill[c]	ef	0	0	0	0	8	2	6	6	18.1	19.8	
31-Aug	Old Mill	sn	0	0	0	na	4	0	4	na	18.1	19.8	1

[a] catchability correction factor used to estimate populations
[b] number of snorkellers conducting survey
[c] closed electrofishing method
ef = electrofishing
sn = snorkelling
DOS = 24 hour period the day of sampling from adjacent data logger
na = not available

Table 24. Electrofishing captures, Midgell River, 1995.

		Trout					Salmon					Temperature °C	
					>YOY [a]					>YOY [a]			
Date	Site	Total	YOY	>YOY	$30m^{-1}$	m^{-2}	Total	YOY	Parr	$30m^{-1}$	m^{-2}	Mean DOS	Max DOS
22-May	Upper Native	2	1	1	0.4	0.002	7	0	7	2.7	0.015	13.0	15.4
22-May	Old Mill	12	10	8	4.0	0.021	9	0	9	4.5	0.024	13.0	15.4
23-May	Corner Pool	5	0	5	2.7	0.012	16	0	16	8.7	0.039	13.0	15.4
28-May	Elm Road	13	0	13	8.3	0.041	0	0	0	0	0	12.4	18.0
1-Aug	Upper Native	2	2	0	0	0	10	1	9	3.5	0.019	23.8	28.6
29-Jul	Old Mill	3	0	3	1.5	0.008	21	5	16	8.0	0.035	22.8	25.5
29-Jul	Corner Pool	1	1	0	0	0	21	0	21	11.4	0.051	22.8	25.5
29-Jul	Elm Road	11	4	7	4.5	0.022	0	0	0	0	0	20.7	23.7
28-Jul	Head of Tide S	80	55	25	na	na	18	ns	18	na	na	23.7	27.5
3-Aug	Head of Tide S	100	13	87	na	na	123	8	112	na	na	20.1	24.2
30-Aug	Head of Tide S	50	ns	50	na	na	91	ns	91	na	na	16.1	17.5
1-Sep	Head of Tide S	48	ns	48	na	na	27	ns	27	na	na	11.5	12.4
12-Sep	Upper Native	0	0	0	0	0	46	6	40	15.6	0.084	12.2	13.2
11-Sep	Old Mill	2	0	2	1.0	0.005	12	0	12	6.0	0.032	12.5	13.5
11-Sep	Corner Pool	1	1	0	0	0	14	0	14	7.0	0.033	12.5	13.5
14-Sep	Elm Road	17	6	11	7.0	0.035	0	0	0	0	0	17.2	18.8

[a] catchability correction factor used to estimate populations

DOS = 24 hour period the day of sampling from adjacent data logger

ns = not sampled

na = not available

S = spring

Table 25. Snorkelling observations and electrofishing captures, Valleyfield River, 1994.

Date	Site	Method	Trout Total	Trout YOY	Trout >YOY	Trout >YOY [a] 30m^{-1}	Salmon Total	Salmon YOY	Salmon Parr	Salmon >YOY [a] 30m^{-1}	Temperature °C Mean DOS	Temperature °C Max DOS	# snork [b]
24-Jun	Egolf's	ef	14	8	6	11	34	0	34	64	13.0	15.7	
17-Jun	MacRae's	ef	69	44	25	47	18	0	18	34	14.8	18.8	
15-Jun	Upper Phantom	ef	43	25	18	34	3	1	2	4	14.8	18.8	
15-Jun	Phantom Lane	ef	62	31	31	59	1	1	0	0	14.8	18.8	
30-Jul	Egolf's	ef	4	1	3	6	23	0	23	43	17.3	18.8	
30-Jul	MacRae's	ef	70	41	19	36	10	0	10	19	17.3	18.8	
20-Jul	Upper Phantom	ef	31	27	4	8	2	2	0	0	16.3	18.3	
20-Jul	Phantom Lane	ef	60	45	15	28	0	0	0	0	16.3	18.3	
11-Aug	Phantom Lane	sn	295	190	105	na	0	0	0	na	15.3	16.6	2
11-Aug	Upper Phantom	sn	207	87	120	na	6	0	6	na	15.3	16.6	2
11-Aug	MacRae's	sn	158	110	48	na	13	0	13	na	14.6	16.3	2
11-Aug	Egolf's	sn	1	1	0	na	7	0	7	na	14.6	16.3	2
1-Sep	Phantom Lane	sn	263	185	78	na	0	0	0	na	13.5	14.2	2
17-Sep	Phantom Lane [c]	ef	319	172	147	165	1	0	1	2	16.6	16.6	
17-Sep	Phantom Lane	sn	294	229	65	na	0	0	0	na	16.5	17.5	2

[a] catchability correction factor used to estimate populations
[b] number of snorkellers conducting survey
[c] closed electrofishing method
ef = electrofishing
sn = snorkelling
DOS = 24 hour period the day of sampling from adjacent data logger
na = not available

Table 26. Electrofishing captures, Valleyfield River, 1995.

Date	Site	Trout Total	Trout YOY	Trout >YOY	Trout >YOY[a] 30m^{-1}	Trout >YOY[a] m^{-2}	Salmon Total	Salmon YOY	Salmon Parr	Salmon >YOY[a] 30m^{-1}	Salmon >YOY[a] m^{-2}	Temperature °C Mean DOS	Temperature °C Max DOS
6-Jun	200m dwn E Pd	44	2	42	na	na	1	0	1	na	na	13.4	17.1
7-Jun	Phantom Lane	41	2	39	na	na	4	0	4	na	na	12.3	14.7
7-Jun	Heatherdale	72	ns	72	31	0.11	2	0	2	1	0.003	12.5	14.8
17-Jun	Mermey's 1	174	2	174	107	0.49	0	0	0	0	0	12.4	13.2
6-Jun	Mermey's 2	146	ns	146	138	0.53	2	0	2	2	0.006	11.6	14.4
20-Jun	Brooklyn	137	ns	137	73	0.39	0	0	0	0	0	14.9	16.6
20-Jun	200m dwn B Pd	65	ns	65	na	na	7	0	7	na	na	13.6	16.2
19-Jun	MacRae's	66	ns	66	na	na	6	0	6	na	na	15.2	17.3
19-Jun	ME Pond headwater	28	ns	28	na	na	0	0	0	na	na	15.0	17.0
21-Jun	700m dwn E Pd	27	ns	27	na	na	5	0	5	na	na	15.6	19.0
5-Aug	700m dwn E Pd	83	16	67	na	na	3	0	3	na	na	18.1	19.3
8-Aug	200m dwn E Pd	22	18	4	na	na	117	0	117	na	na	17.1	20.2
9-Aug	ME Pond headwater	118	43	75	na	na	5	1	4	na	na	15.3	17.4
18-Aug	Heatherdale	95	16	79	34	0.13	3	0	3	1	0.004	14.1	15.4
17-Aug	Mermey's 1	264	71	193	119	0.54	1	0	1	1	0.003	16.2	17.3
19-Aug	Mermey's 2	185	40	145	137	0.52	1	0	1	1	0.003	13.0	15.0
18-Aug	Brooklyn	169	38	131	70	0.38	0	0	0	0	0	14.1	15.4
13-Sep	Heatherdale	148	52	96	42	0.15	4	0	4	2	0.006	12.5	14.0
14-Sep	Mermey's 1	229	84	145	89	0.41	2	0	2	1	0.005	14.0	14.6
14-Sep	Mermey's 2	159	59	100	95	0.36	3	0	3	3	0.010	14.0	14.6
15-Sep	Brooklyn	213	89	124	66	0.36	0	0	0	0	0	12.8	14.2
15-Sep	ME Pond headwater	147	75	72	na	na	7	0	7	na	na	12.6	14.1

[a] catchability correction factor used to estimate populations

DOS = 24 hour period the day of sampling from adjacent data logger

ns = not sampled

na = not available

S = spring

E Pd = E'golf's Pond

B Pd = Brooklyn Pond

Table 27. Mortality study of brook trout captured in the Valleyfield River, October-November, 1995.

Method	Number	Number of deaths	Prop of total
Electrofishing	50	1	0.02
Electrofishing and tagging	50	2	0.04
Fish trap	50	1	0.02
Trapping and tagging	50	1	0.02

Table 28. Proportion of older than YOY salmonids with predator marks, Midgell River, 1994.

				Trout			Salmon parr		
Date	Habitat	Site	Method	Total	P mrk	Prop	Total	P mrk	Prop
17-Jul	River	Native	ef	0	0	0	7	0	0
17-Jul		Old Mill	ef	0	0	0	9	0	0
17-Jul		Artties	ef	0	0	0	6	0	0
31-Jul		Upper fence	ef	0	0	0	1	0	0
16-Jul		S 2	ef	29	0	0	0	0	0
22-Aug		S 2	ef	12	4	0.33	0	0	0
31-Aug		Native	ef	2	0	0	16	0	0
31-Aug		Old Mill	ef	0	0	0	6	0	0
5-Sep		S 2	ef	2	0	0	0	0	0
5-Sep		S 1	ef	8	1	0.13	0	0	0
8-Jul	Pond	Small S	ef	84	3	0.04	0	0	0
9-Jul		S 3	ef	224	15	0.06	0	0	0
15-Jul		S 3	sein	26	2	0.08	0	0	0
21-Jul		S 3	sein	30	0	0	0	0	0
25-Aug		S 3	ef	147	31	0.21	0	0	0
	Total			564	56	0.10	45	0	0

P mrk = number with predator marks

Prop = proportion of salmonids with predator marks

ef = electrofishing

sn = snorkelling

S = spring

Table 29. Proportions of older than YOY salmonids with predator marks, Midgell River, 1995.

				Trout									Salmon parr		
				Totals			Recapture			1st time capture					
Date	Habitat	Site	Method	Tot	P mrk	Prop	Tot	P mrk	Prop	Tot	P mrk	Prop	Tot	P mrk	Prop
22-May	River	Upper Native	ef	1	0	0	0	0	0	1	0	0	7	0	0
22-May		Old Mill	ef	8	0	0	0	0	0	8	0	0	9	0	0
23-May		Corner Pool	ef	5	0	0	0	0	0	5	0	0	16	0	0
28-May		Elm Road	ef	13	0	0	0	0	0	13	0	0	0	0	0
11-Jun		S 1	ef	3	0	0	0	0	0	3	0	0	5	0	0
11-Jun		S 2	ef	3	0	0	0	0	0	3	0	0	2	0	0
1-Aug		Upper Native	ef	0	0	0	0	0	0	0	0	0	9	0	0
29-Jul		Old Mill	ef	3	0	0	0	0	0	3	0	0	16	0	0
29-Jul		Corner Pool	ef	0	0	0	0	0	0	0	0	0	21	1	0.05
29-Jul		Elm Road	ef	7	0	0	0	0	0	11	0	0	0	0	0
30-Jul		S 1	ef	64	2	0.03	2	1	0.5	62	1	0.02	8	0	0
30-Jul		S 2	ef	13	2	0.15	0	0	0	13	2	0.15	6	0	0
28-Jul		Head of Tide S	ef	25	1	0.04	0	0	0	25	1	0.04	18	0	0
3-Aug		Head of Tide S	ef	87	1	0.01	0	0	0	86	1	0.01	112	0	0
30-Aug		Head of Tide S	ef	50	2	0.04	4	0	0	48	2	0.04	91	0	0
1-Sep		Head of Tide S	ef	48	0	0	3	0	0	45	0	0	27	1	0.04
12-Sep		Upper Native	ef	0	0	0	0	0	0	0	0	0	40	0	0
11-Sep		Old Mill	ef	2	0	0	0	0	0	2	0	0	12	0	0
11-Sep		Corner Pool	ef	0	0	0	0	0	0	0	0	0	14	0	0
14-Sep		Elm Road	ef	11	0	0	0	0	0	11	0	0	0	0	0
11-Sep		S 1	ef	15	0	0	0	0	0	15	0	0	9	0	0
11-Sep		S 2	ef	4	0	0	0	0	0	5	0	0	8	0	0
Apr-May	Pond	R 1	fn	7	0	0	0	0	0	0	0	0	0	0	0
Apr-May		R 2	fn	15	0	0	0	0	0	0	0	0	0	0	0
Apr-May		R 3	fn	12	0	0	0	0	0	0	0	0	0	0	0
Apr-May		R 4	fn	22	0	0	0	0	0	0	0	0	1	0	0
Apr-May		R 5	fn	27	0	0	0	0	0	0	0	0	0	0	0
10-Jul		S 3	ef	11	0	0	0	0	0	11	0	0	0	0	0
Aug		R 4	fn	3	0	0	1	0	0	2	0	0	0	0	0
Jul-Aug		R 6 - out of S	fn	1	0	0	0	0	0	1	0	0	0	0	0
Jul-Aug		Headwater S	fn	204	9	0.04	19	0	0	185	9	0.049	0	0	0
Jul-Aug		S 3	fn	14	2	0.14	3	0	0	11	2	0.182	0	0	0
Jul-Aug		Small S	fn	35	4	0.11	6	0	0	29	4	0.138	0	0	0
Jul-Aug		New S	fn	2	0	0	0	0	0	2	0	0	0	0	0
2-Aug		S 3	ef	15	3	0.20	9	2	0.22	6	1	0.14	0	0	0
12-Sep		S 3	ef	1	1	1	1	1	1	0	0	0	0	0	0
Sep-Oct		Headwater S	fn	18	1	0.06	5	0	0	13	1	0.07	0	0	0
Sep-Oct		S 3	fn	1	0	0	0	0	0	1	0	0	0	0	0
Sep-Oct		Small S	fn	2	0	0	0	0	0	2	0	0	0	0	0
Sep-Oct		R 3	fn	1	0	0	0	0	0	1	0	0	0	0	0
Sep-Oct		R 6 - out of S	fn	21	0	0	3	0	0	18	0	0	0	0	0
	Total			774	28	0.04	56	4	0.07	641	24	0.04	431	2	0.01

Total = number examined for predator marks
P mrk = number with predator marks
Prop = proportion of salmonids with predator marks
ef = electrofishing
fn = fyke netting
S = spring
R = region

Table 30. Proportion of older than YOY salmonids with predator marks, Valleyfield River, 1994.

				Trout			Salmon parr		
Date	Habitat	Site	Method	Tot	P mrk	Prop	Tot	P mrk	Prop
30-Jul	River	Egolf's	ef	3	0	0	23	0	0
30-Jul		MacRae's	ef	19	1	0.06	10	0	0
20-Jul		Upper Phantom	ef	4	0	0	0	0	0
20-Jul		Phantom lane	ef	15	0	0	0	0	0
17-Sep		Phantom lane	ef	147	0	0	1	0	0
	Total			188	1	0.01	34	0	0

Tot = number examined for predator marks

P mrk = number with predator marks

Prop = proportion of salmonids with predator marks

ef = electrofishing

Table 31. Proportion of older than YOY salmonids with predator marks, Valleyfield River, 1995.

				Trout									Salmon parr		
				Totals			Recapture			1st time capture					
Date	Habitat	Site	Method	Tot	P mrk	Prop	Tot	P mrk	Prop	Tot	P mrk	Prop	Tot	P mrk	Prop
7-Jun	River	S 2	ef	24	0	0	0	0	0	24	0	0	2	0	0
6-Jun		200m dwn E Pd	ef	42	3	0.08	0	0	0	42	3	0.08	1	0	0
7-Jun		Phantom Lane	ef	39	0	0	0	0	0	40	0	0	4	0	0
7-Jun		Heatherdale	ef	72	0	0	0	0	0	72	1	0	2	0	0
17-Jun		Mermey's 1	ef	174	1	0.01	0	0	0	174	1	0.01	0	0	0
6-Jun		Mermey's 2	ef	146	1	0.01	0	0	0	146	1	0.01	2	0	0
20-Jun		Brooklyn	ef	137	1	0.01	0	0	0	130	1	0.01	0	0	0
20-Jun		200m dwn B Pd	ef	65	2	0.03	0	0	0	65	0	0	7	0	0
19-Jun		MacRae's	ef	43	0	0	0	0	0	43	0	0	6	0	0
19-Jun		ME Pond hd	ef	28	1	0.04	0	0	0	0	0	0	0	0	0
21-Jun		700m dwn E Pd	ef	27	0	0	0	0	0	31	0	0	5	0	0
5-Aug		700m dwn E Pd	ef	67	0	0	0	0	0	40	0	0	3	0	0
8-Aug		S 2	ef	27	1	0	1	0	0	26	1	0.04	3	0	0
8-Aug		200m dwn E Pd	ef	22	0	0	2	0	0	53	0	0	117	0	0
9-Aug		ME Pond hd	ef	75	0	0	6	0	0	71	0	0	4	0	0
18-Aug		Heatherdale	ef	79	2	0.03	4	0	0	75	2	0.03	3	0	0
17-Aug		Mermey's 1	ef	193	1	0.01	19	0	0	174	1	0.01	1	0	0
19-Aug		Mermey's 2	ef	145	0	0	13	0	0	132	0	0	1	0	0
18-Aug		Brooklyn	ef	131	1	0.01	15	0	0	116	1	0.01	0	0	0
13-Sep		Heatherdale	ef	96	0	0	26	0	0	69	0	0	4	0	0
14-Sep		Mermey's 1	ef	145	4	0.03	64	2	0.03	87	2	0.02	2	0	0
14-Sep		Mermey's 2	ef	100	3	0.02	39	0	0	125	3	0.02	3	0	0
15-Sep		Brooklyn	ef	124	1	0.01	50	1	0.02	74	0	0	0	0	0
13-Sep		S 2	ef	39	0	0	3	0	0	32	0	0	1	0	0
15-Sep		ME Pond hd	ef	72	0	0	7	0	0	65	0	0	7	0	0
Jun-Jul	Pond	outside S	fn	23	0	0	2	0	0	21	0	0	9	0	0
Aug		outside S	fn	37	1	0.03	3	0	0	34	1	0.03	8	0	0
Aug		Headwater S	fn	14	1	0.07	2	0	0	12	1	0.08	1	0	0
Sep-Oct		outside S	fn	68	0	0	12	0	0	36	0	0	4	0	0
	Total			2,254	24	0.01	268	3	0.01	2,009	19	0.01	200	0	0

Tot = number examined for predator marks, P mrk = number with predator marks, Prop = proportion of salmonids with predator marks
ef = electrofishing, fn = fyke netting, S = spring, E Pd = Egolf's Pond, B Pd = Brooklyn Pond

Table 32. Monthly summary of the proportion of older than YOY brook trout with predator marks, Midgell River and Valleyfield River, 1994-95.

River	Year	Habitat	Sample period	Tot	P mrk	Prop
Midgell	1994	River	Jul	43	4	0.09
	1994	River	Sep	8	1	0.13
	1994	Pond	Jul - Aug	532	51	0.10
	1995	River	May - Jun	33	0	0.00
	1995	River	Jul - Aug	251	8	0.03
	1995	River	Sep	80	0	0.00
	1995	Pond	Apr - May	83	0	0.00
	1995	Pond	Jul - Aug	286	18	0.06
	1995	Pond	Sep - Oct	44	2	0.05
Valleyfield	1994	River	Jul	41	1	0.02
	1994	River	Sep	147	0	0.00
	1995	River	Jun	802	9	0.01
	1995	River	Aug	747	5	0.01
	1995	River	Sep	576	8	0.01
	1995	Pond	Jun - Jul	23	0	0.00
	1995	Pond	Aug -Sep	51	2	0.04
	1995	Pond	Sep - Oct	68	0	0.00

Tot = number examined for predator marks
P mrk = number with predator marks
Prop = proportion of salmonids with predator marks

Table 33. Estimated population of older than YOY brook trout and salmon parr for the 5.5 km stream below MacDonalds Pond. Estimates based on extrapolation of electrofishing population estimates from each sampling period, Midgell River, 1994.

		Temperature °C		Trout			Salmon		
Site	Date	Mean DOS	Site length	Tot	Site pop [a]	Total pop [b]	Tot	Site pop [a]	Total pop [b]
Native	9-Jun	14	30	1	1.4		4	5.6	
Old Mill	13-Jun	17	30	2	2.8		14	19.7	
Arttles	9-Jun	14	30	3	4.2	517	8	11.3	2,237
Native	17-Jul	23	30	0	0		7	9.9	
Old Mill	17-Jul	27	30	0	0		9	12.7	
Arttles	17-Jul	26	30	0	0	0	6	8.4	1,897
Native	31-Aug	17	30	2	2		16	16	
Old Mill	31-Aug	20	30	0	0	183	6	6	2,017

Tot = number captured electrofishing

[a] population estimate for $30m^{-1}$ stream from catchability correction factor

[b] population estimate for $5.5\ km^{-1}$ of stream

Table 34. Estimated population of older than YOY brook trout and salmon parr for the 5.5 km stream below MacDonalds Pond. Estimates based on extrapolation of electrofishing population estimates from each sampling period, Midgell River, 1995.

		Temperature °C	Site length	Trout			Salmon		
Site	Date	Mean DOS	(m)	Tot	Site pop [a]	Total pop [b]	Tot	Site pop [a]	Total pop [b]
Upper Native	22-May	15	130	1	1.4		7	9.9	
Old Mill	22-May	15	102	8	11.3		9	12.7	
Comer Pool	23-May	15	94	5	7.1	333	16	22.6	761
Upper Native	1-Aug	24	130	0	0.0		9	12.7	
Old Mill	29-Jul	25	102	3	4.2		16	22.6	
Comer Pool	29-Jul	24	94	0	0.0	71	21	29.6	1,095
Upper Native	12-Sep	13	130	0	0.0		40	56.4	
Old Mill	11-Sep	14	102	2	2.8		12	17.0	
Comer Pool	11-Sep	14	94	0	0.0	48	14	19.7	1,561

Tot = number captured electrofishing

[a] population estimate for electrofishing site stream length from catchability correction factor

[b] population estimate for 5.5 km^{-1} of stream

Table 35. Population estimates for older than YOY brook trout in a) 5.5 km^{-1} stream length downstream from MacDonald's Pond, b) Head of Tide Spring, c) MacDonald's Pond, and total estimate, Midgell River, 1995.

a) 5.5 km section downstream from MacDonald's Pond

Date	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - m^{-2}
Oct. 18-20	178	54	7	1,231 (639 - 2,590)	0.03
Nov. 22-23	178	43	3	1,969 (803 - 4,922)	0.05
Total	178	97	10	1,595 (904 - 3,078)	0.04

b) Head of Tide Spring

Date	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - m^{-2}
30-Aug	106	50	3	1,364 (557 - 3,411)	0.04
1-Sep	149	49	3	1,875 (765 - 4,688)	0.05

c) MacDonald's Pond

Marking period	Capture period	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - m^{-2}
10-Jul - 16-Jul	17Jul - 15-Aug	121	190	6	3,329 (1,653 - 7,282)	0.03
10-Jul - 22-Jul	23 Jul - 15-Aug	153	171	10	2,408 (1,365 - 4,647)	0.02
10-Jul - 27-Jul	28 Jul - 15-Aug	164	81	4	2,706 (1,208 - 6,765)	0.02
10-Jul - 1-Aug	2-Aug - 15-Aug	210	30	3	1,635 (667 - 4,088)	0.01
10-Jul - 7-Aug	8-Aug - 15-Aug	222	9	3	558 (228 - 1,394)	0.004
10-July - 15-Aug	11-Sep - 11-Oct	216	44	4	1,779 (794 - 4,449)	0.01

d) Total population estimate from final recapture

Habitat	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - km^{-1}	Trout - m^{-2}
River	178	97	11[a]			
Pond	216	44	4			
Total	394	141	15	3,505 (2,174 - 5,967)	408	0.02

[a] Includes recapture of brook trout marked in MacDonald's Pond

Table 36. Population estimates for older than YOY brook trout, Spring 3, Midgell River, 1994.

Date	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - m^{-2}
9-Jul	24	246	16	363 (229 - 605)	4.37
15-Jul	270	27	7	949 (493 - 1997)	11.43
21-Jul	290	32	15	600 (372 - 1022)	7.23
25-Aug	290	154	58	764 (594 - 983)	9.20

Table 37. Estimated population of older than YOY brook trout and salmon parr for the 11.5 km of stream. Estimates based on extrapolation of electrofishing population estimates from each sampling period, Valleyfield River, 1994.

		Temperature °C		Trout			Salmon		
Site	Date	Mean DOS	Site length	Tot	Site pop [a]	Total pop [b]	Tot	Site pop [a]	Total pop [b]
Egolf's	24-Jun	13	30	6	11.3		34	64.3	
MacRae's	17-Jun	15	30	25	47.3		18	34.0	
Upper Phantom	15-Jun	15	30	18	34.0		2	3.8	
Phantom lane	15-Jun	15	30	31	58.6	14,490	0	0.0	9,781
Egolf's	30-Jul	17	30	3	5.7		23	43.5	
MacRae's	30-Jul	17	30	19	36.1		10	18.9	
Upper Phantom	20-Jul	16	30	4	7.6		0	0	
Phantom lane	20-Jul	16	30	15	28.5	7,472	0	0	5,977
Phantom lane ***	17-Sep	17	30	147	165	61,333	1	1.9	181

Tot = number captured electrofishing

[a] population estimate for $30m^{-1}$ stream from catchability correction factor

[b] population estimate for 11.5 km^{-1} of stream

Table 38. Estimated population of older than YOY brook trout and salmon parr for the 11.5 km of stream. Estimates based on extrapolation of electrofishing population estimates from each sampling period, Valleyfield River, 1995.

		Temperature °C		Trout			Salmon		
Site	Date	Mean DOS	Site length	Tot	Site pop [a]	Total pop [b]	Tot	Site pop [a]	Total pop [b]
Heatherdale	6-Jun	13	130	72	136.1		2	3.8	
Merney's 1	17-Jun	12	92	174	328.9		0	0.0	
Merney's 2	6-Jun	12	60	146	275.9	30,213	2	3.8	154
Heatherdale	18-Aug	14	130	79	149.3		3	5.7	
Merney's 1	17-Aug	16	92	193	364.8		1	1.9	
Merney's 2	19-Aug	13	60	145	274.1	32,140	1	1.9	385
Heatherdale	13-Sep	13	130	96	181.4		4	7.6	
Merney's 1	14-Sep	14	92	145	274.1		2	3.8	
Merney's 2	14-Sep	14	60	100	189.0	26,282	3	5.7	694

Tot = number captured electrofishing

[a] population estimate for electrofishing site stream length from catchability correction factor

[b] population estimate for 11.5 km^{-1} of stream

Table 39. Population estimates for older than YOY brook trout calculated for marking sites from electrofishing recapture, Valleyfield River, September, 1995.

Site	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - km^{-1}	Trout - m^{-2}
Electrofishing sites	1,131	3,824	104	41,237 (34,094 - 49,884)	3,586	0.32
ME Pond fishway trap	856	3,824	48	66,898 (50,901 - 88,119)	5,817	0.51
ME Pond fyke nets	33	3,824	3	32,513 (13,270 - 81,281)	2,827	0.25
ME headwater fence	58	3,824	5	37,613 (17,770 -72,332)	3,271	0.29
All sites	2,078	3,824	160	49,392 (42,299 - 57,624)	4,295	0.38

Table 40. Population estimate for older than YOY brook trout from fyke net recapture, Valleyfield River, September - October, 1995.

Site	Marked	Captured	Recaptured	Population (c.i.: 95%)	Trout - km^{-1}	Trout - m^{-2}
M E Pond	2,083	69	6	20,840 (10,346 - 39,110)	1,812	0.16

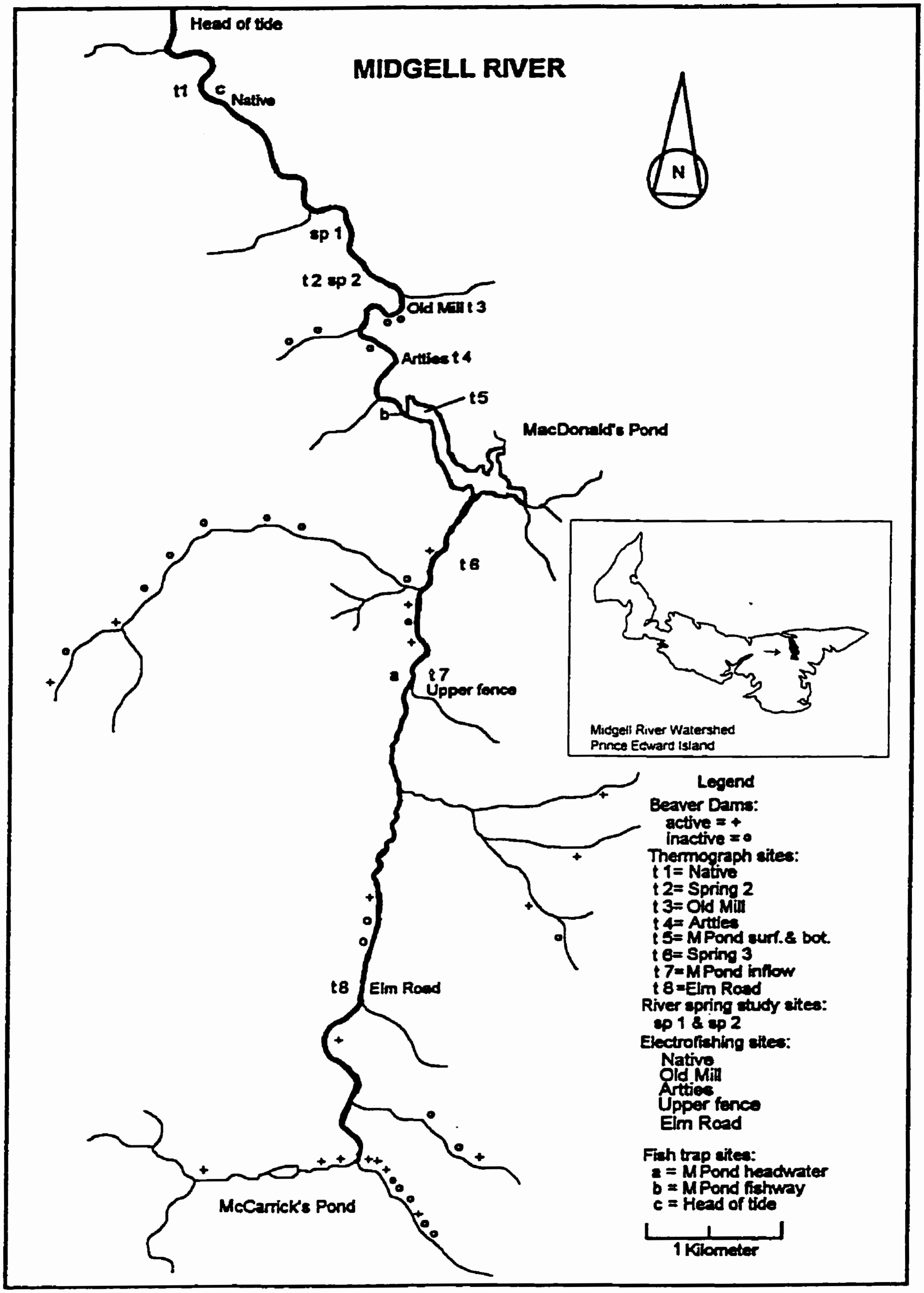


Figure 1. Location of study sites, Midgell River, 1994.

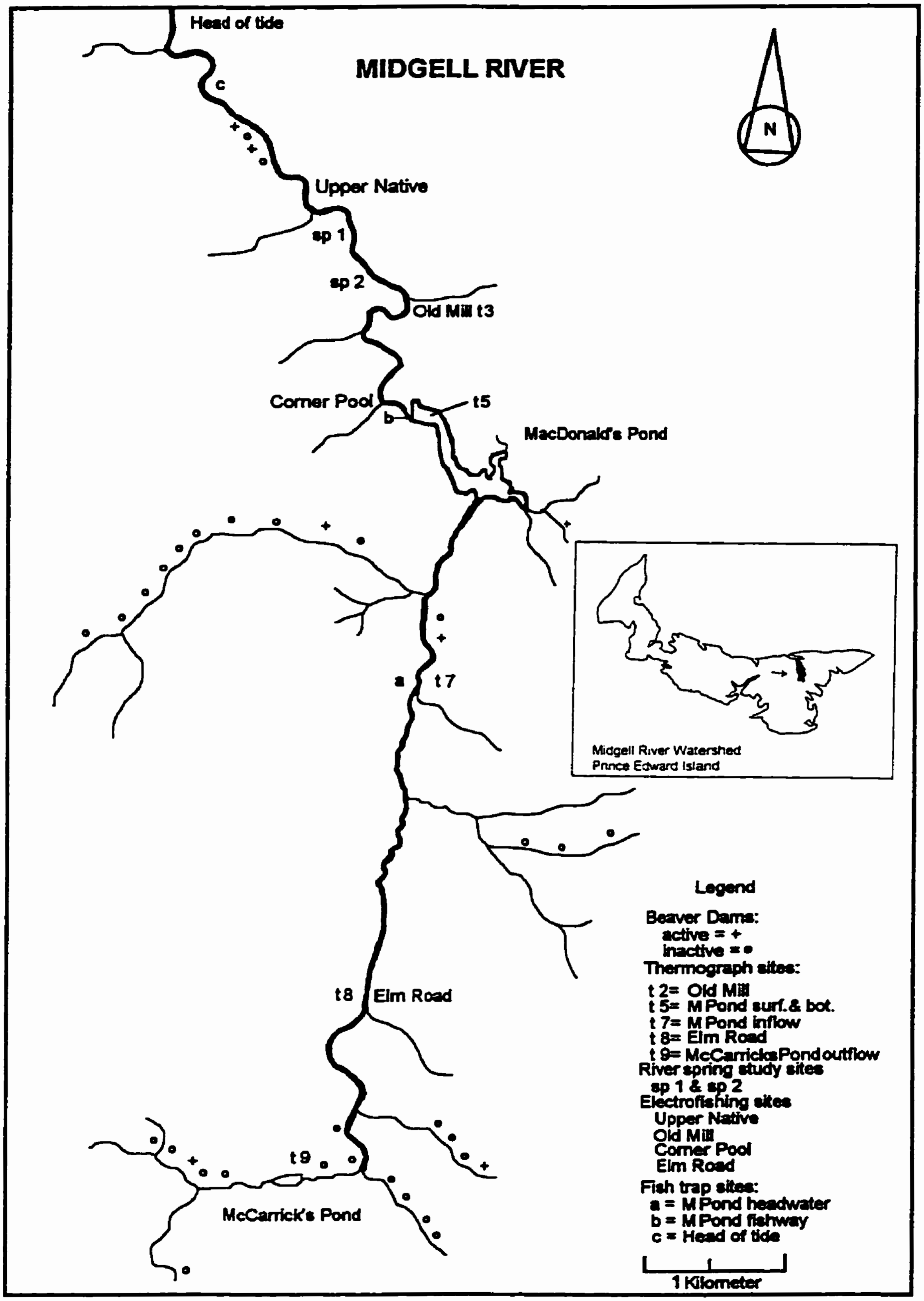


Figure 2. Location of study sites, Midgell River, 1995.

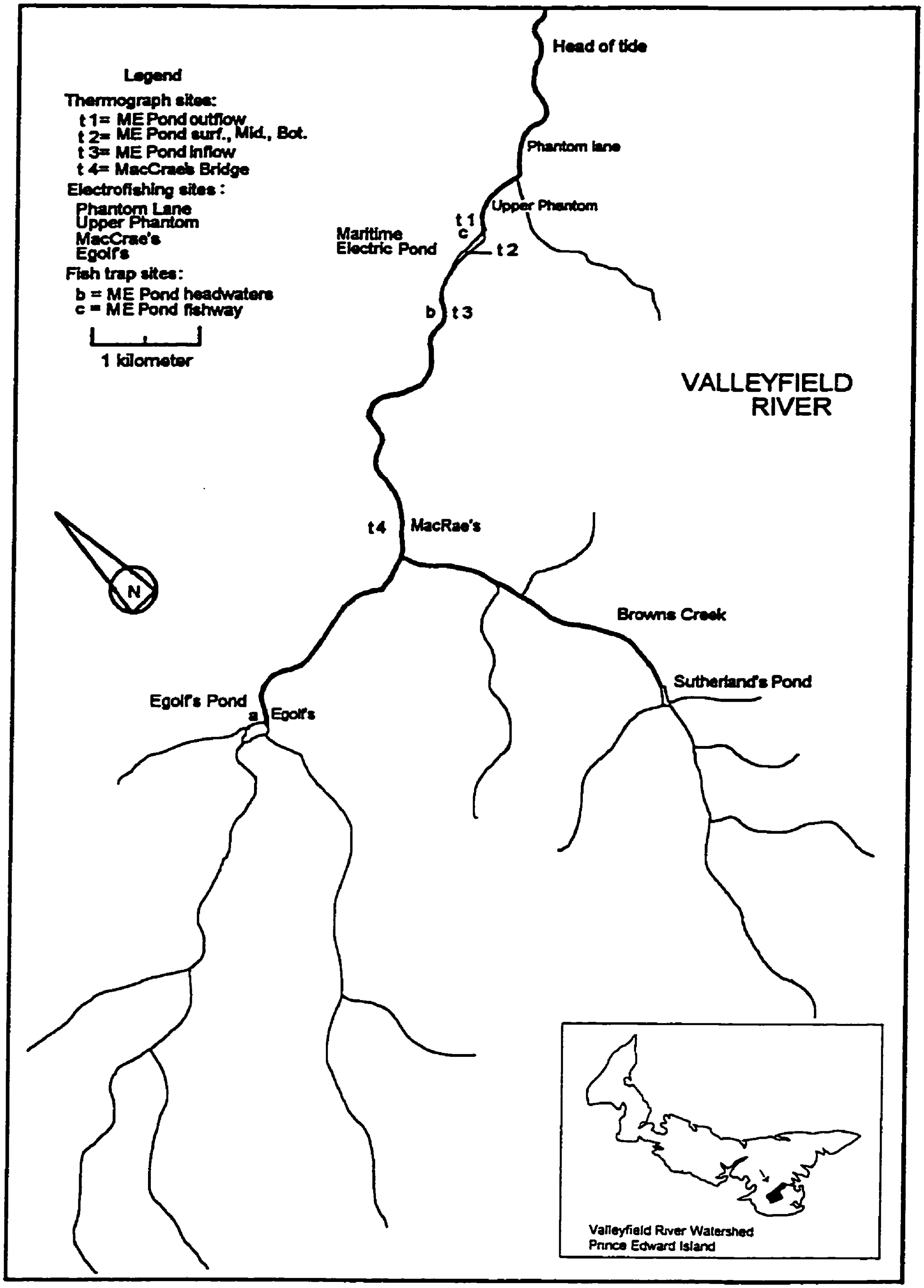


Figure 3. Location of study sites, Valleyfield River, 1994.

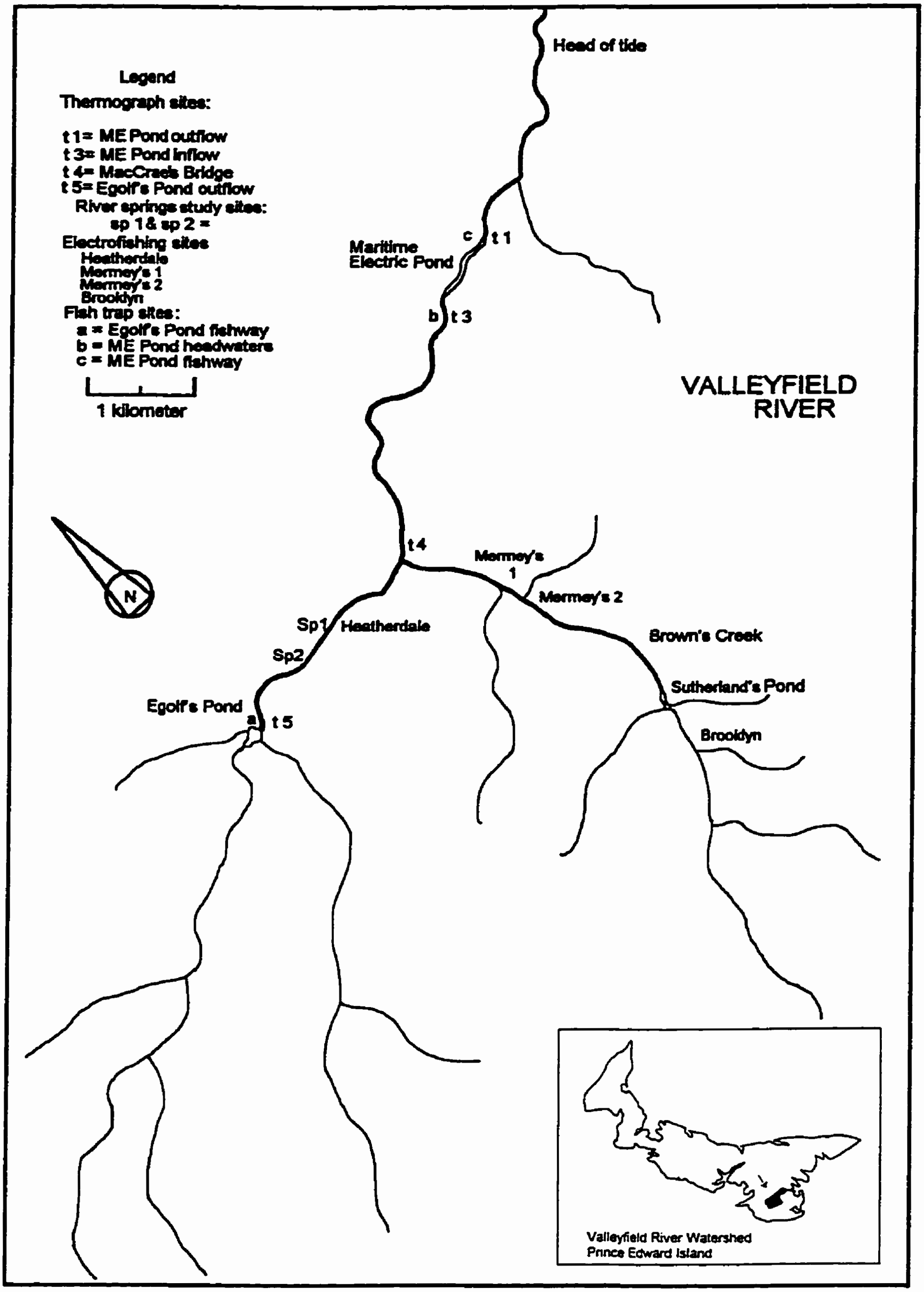


Figure 4. Location of study sites, Valleyfield River, 1995.

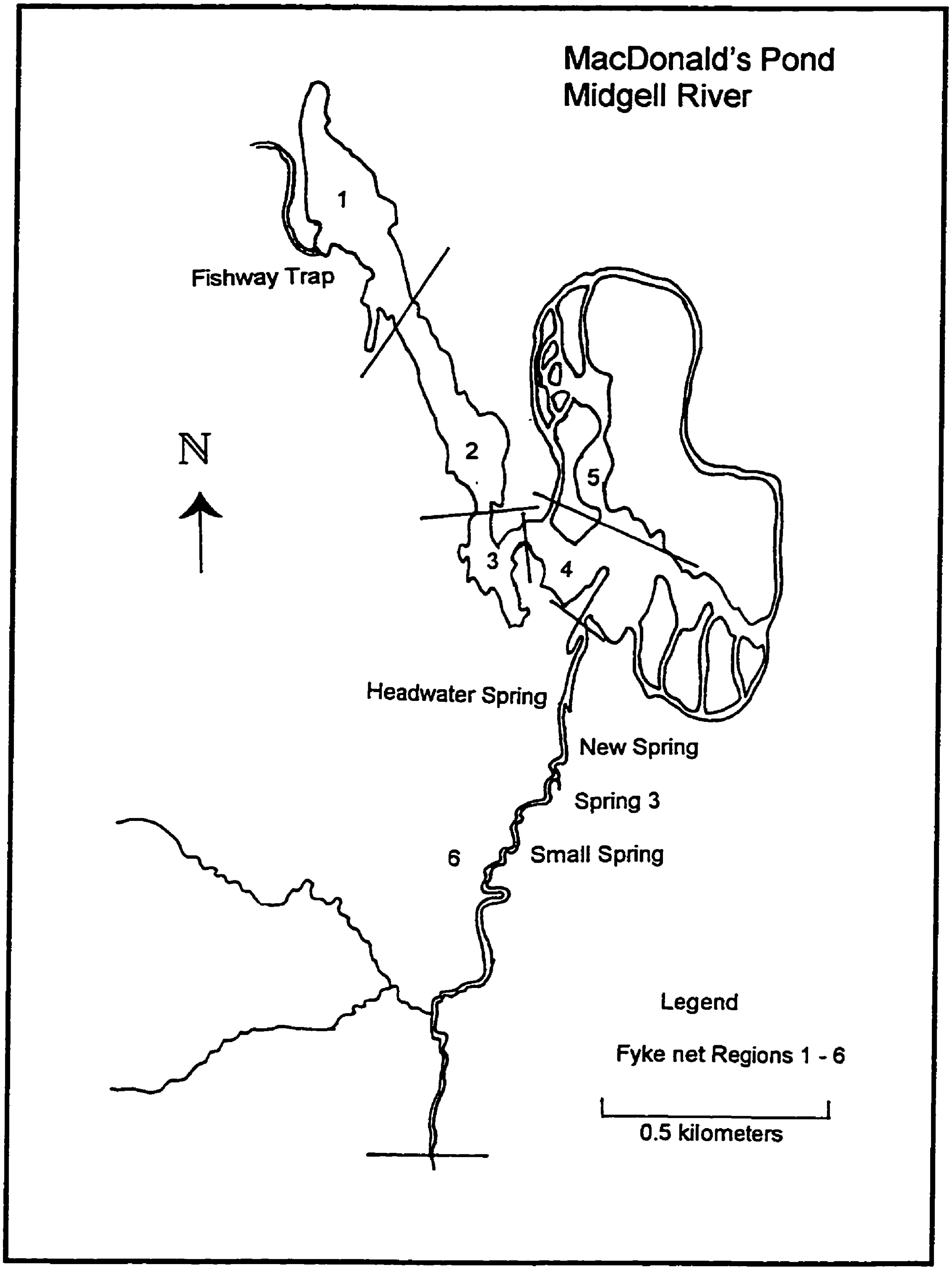


Figure 5. MacDonald's Pond, Midgell River, 1995.

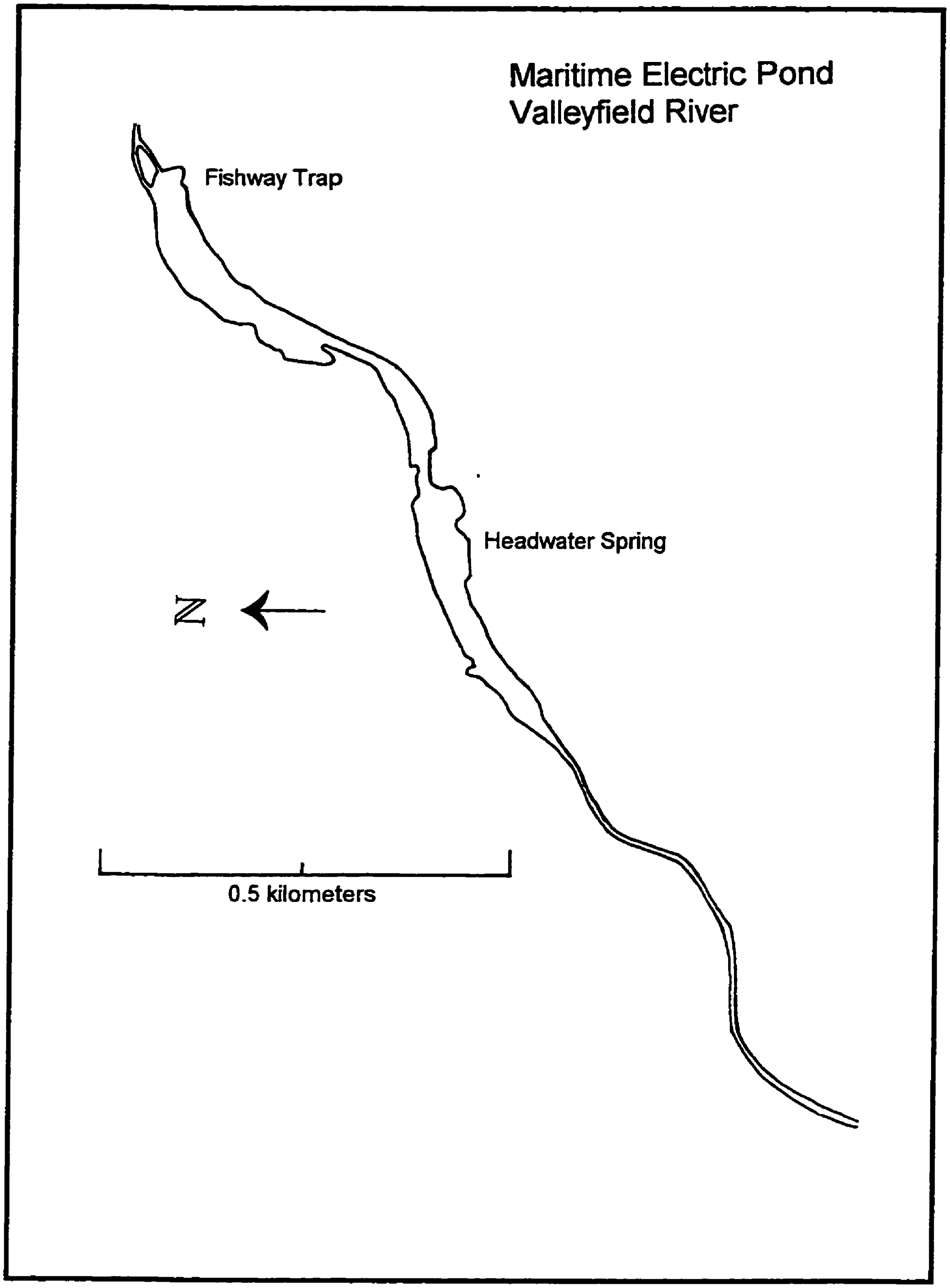


Figure 6. Maritime Electric Pond, Valleyfield River, 1995.

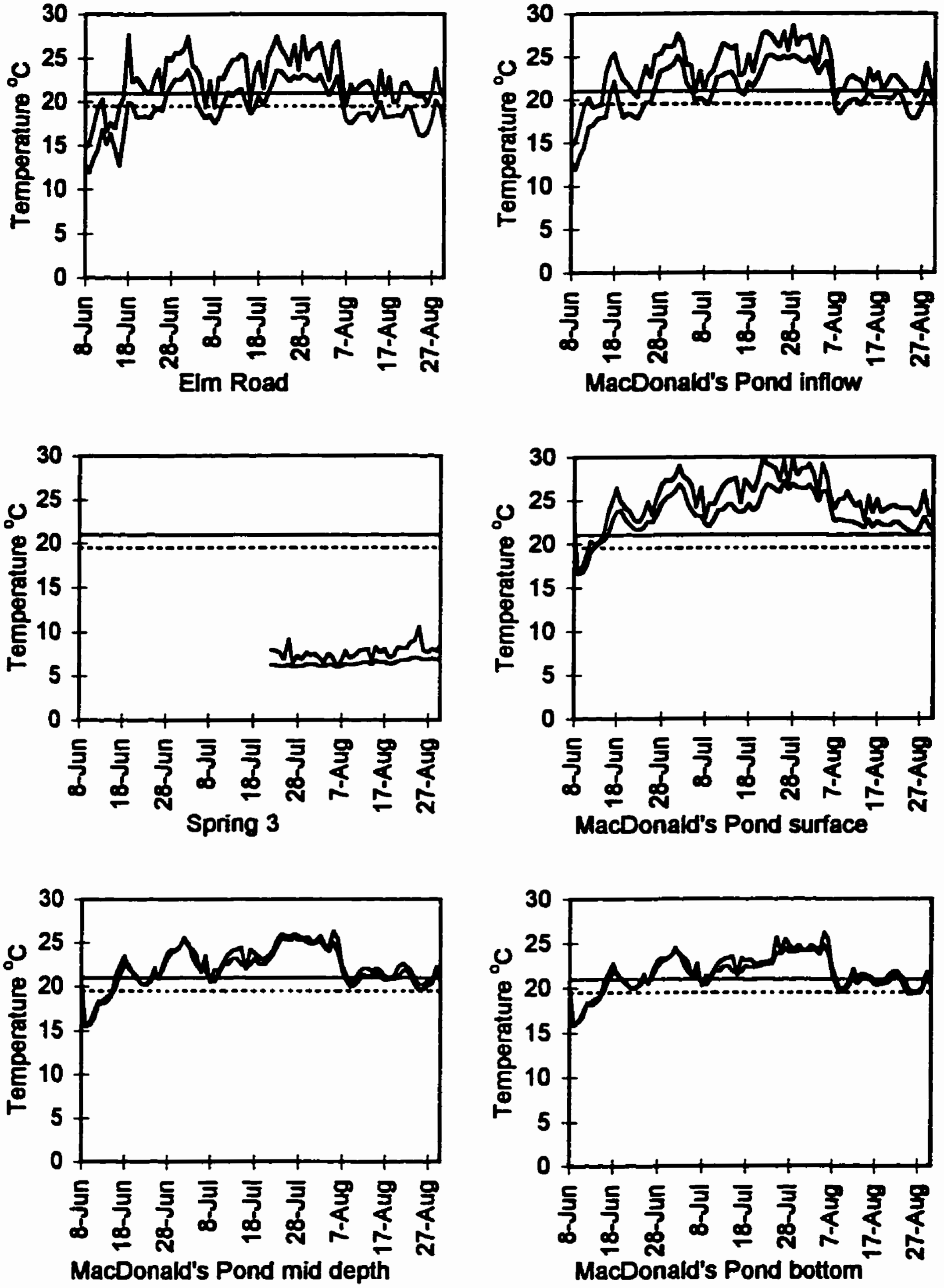


Figure 7. Daily mean and maximum temperatures on the upper Midgell River, 1994. Horizontal lines are maximum (21.6°C) and mean (19.2°C) daily avoidance temperatures for brook trout.

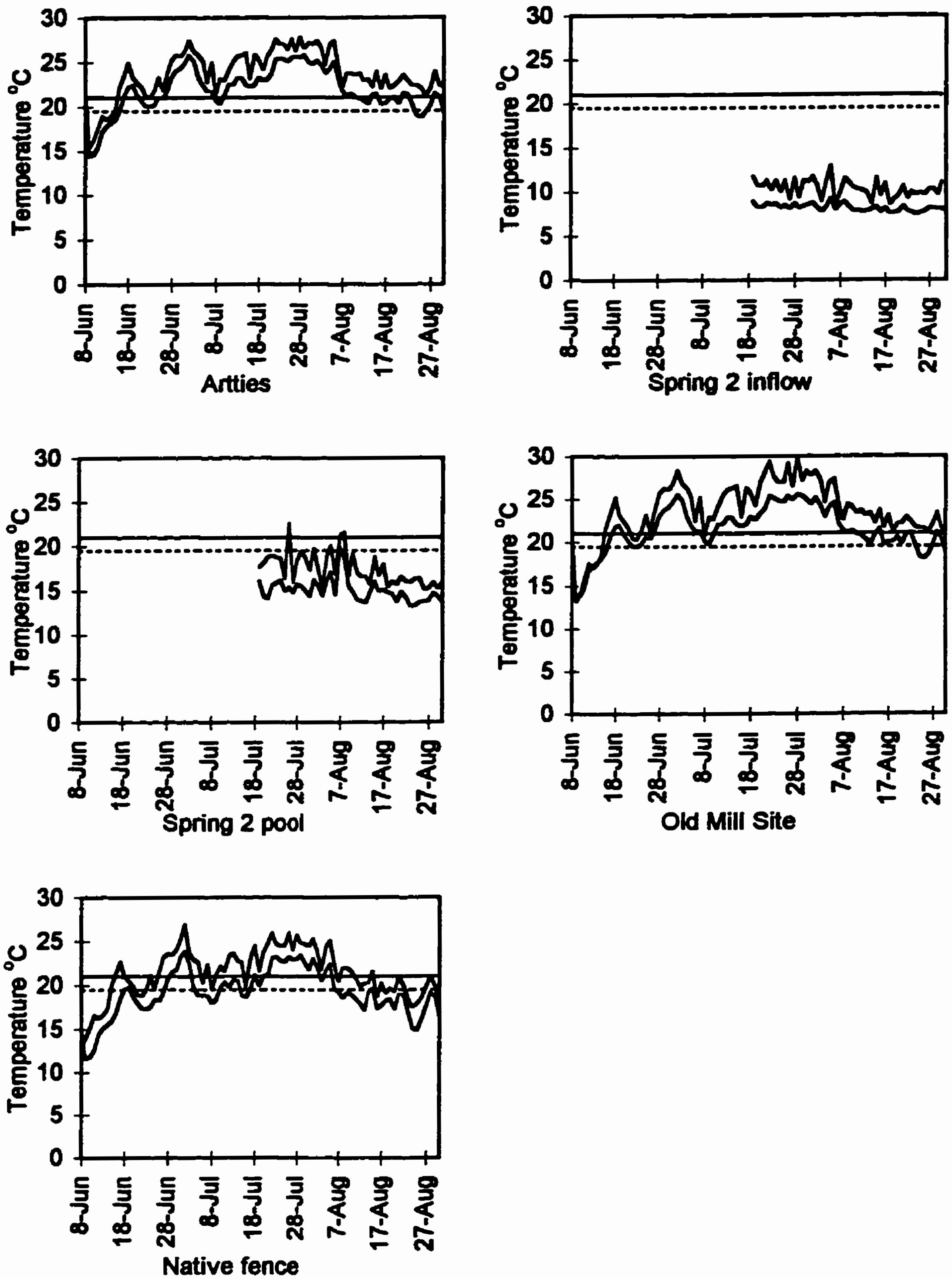


Figure 8. Daily mean and maximum temperatures on the lower Midgell River, 1994. Horizontal lines are maximum (21.6°C) and mean (19.2°C) daily avoidance temperatures for brook trout.

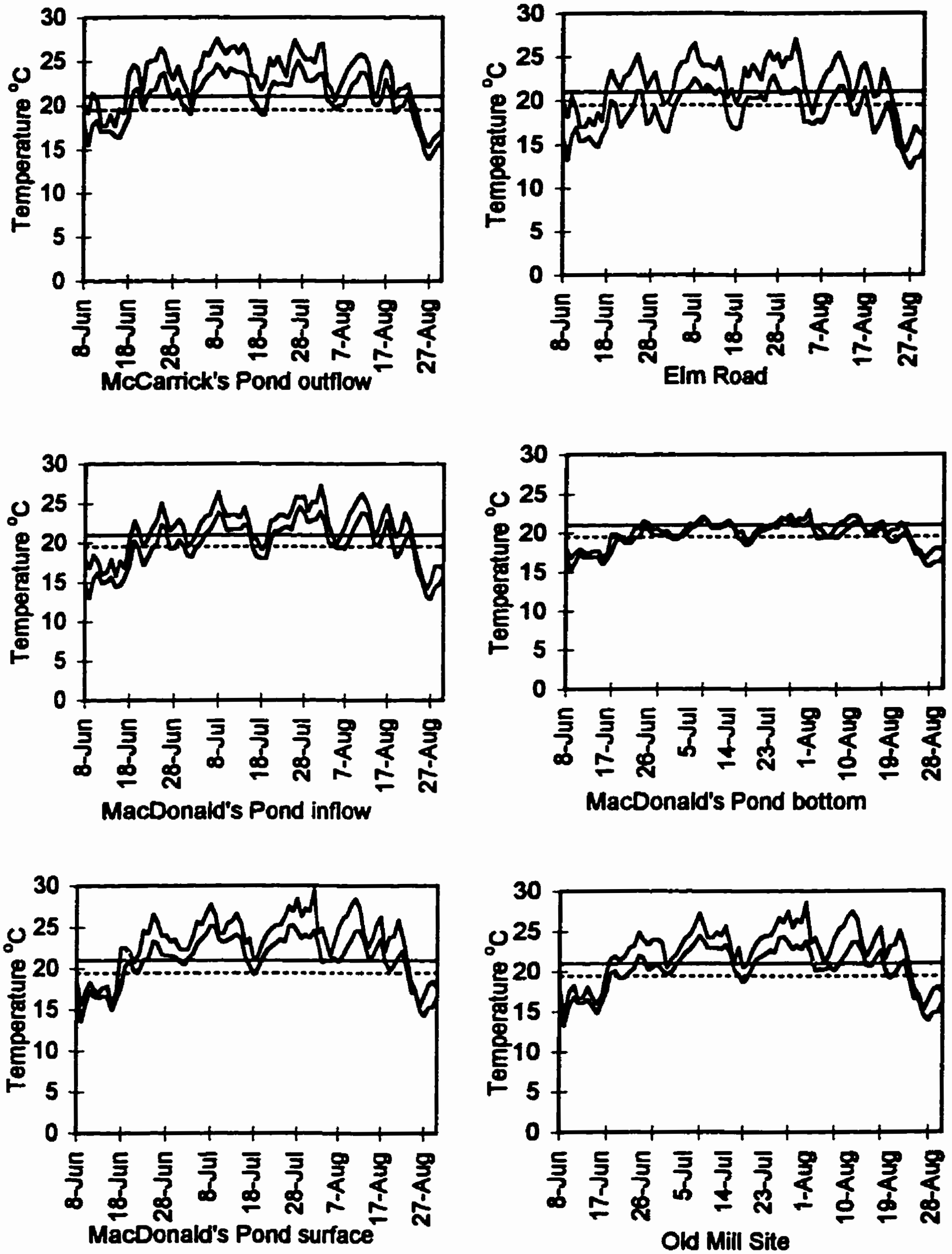


Figure 9. Daily mean and maximum temperatures on the Midgell River, 1995. Horizontal lines are maximum (21.6°C) and mean (19.2°C) daily avoidance temperatures for brook trout.

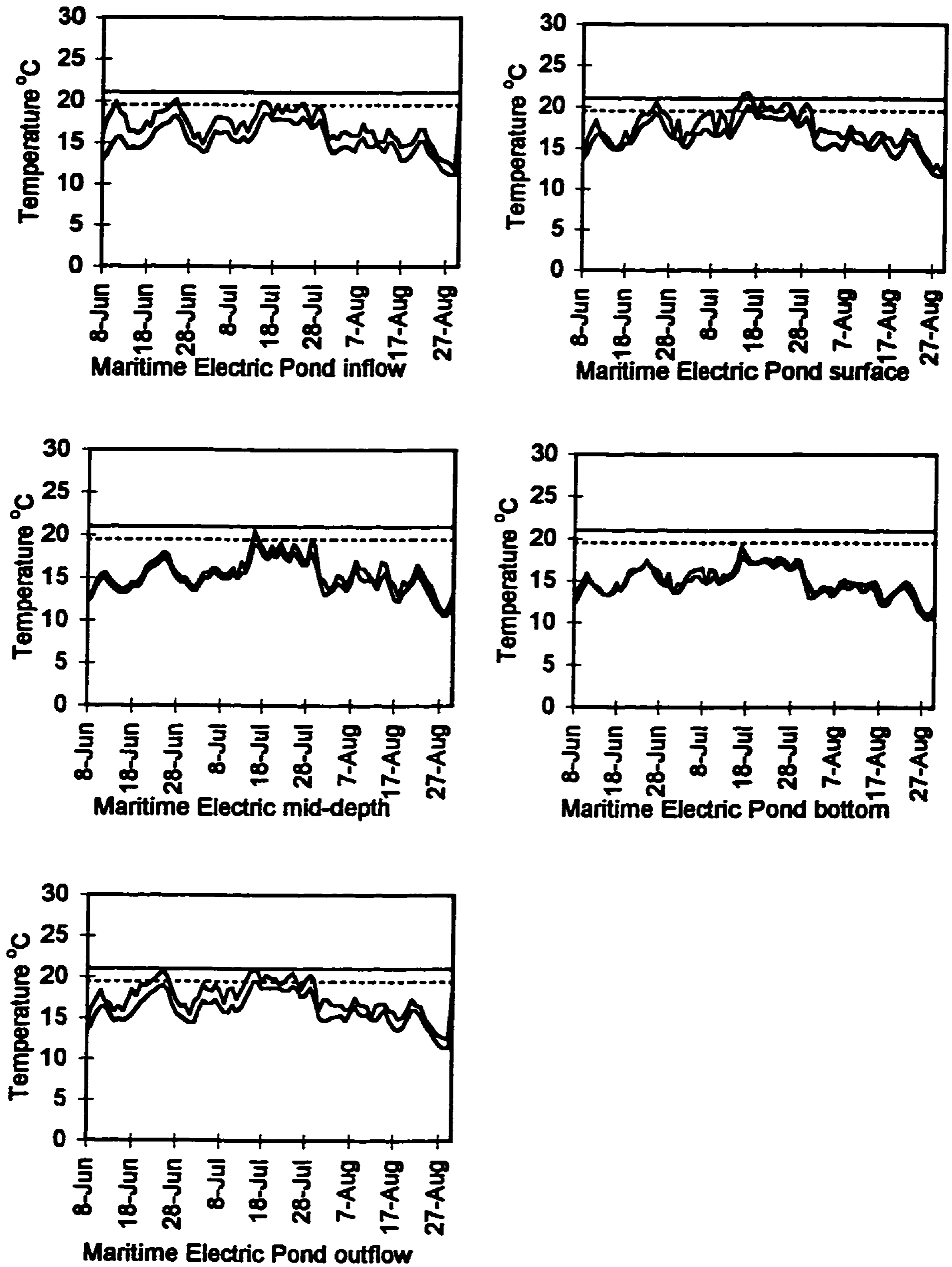


Figure 10. Daily mean and maximum temperatures on the Valleyfield River, 1994. Horizontal lines are maximum (21.6°C) and mean (19.2°C) daily avoidance temperatures for brook trout.

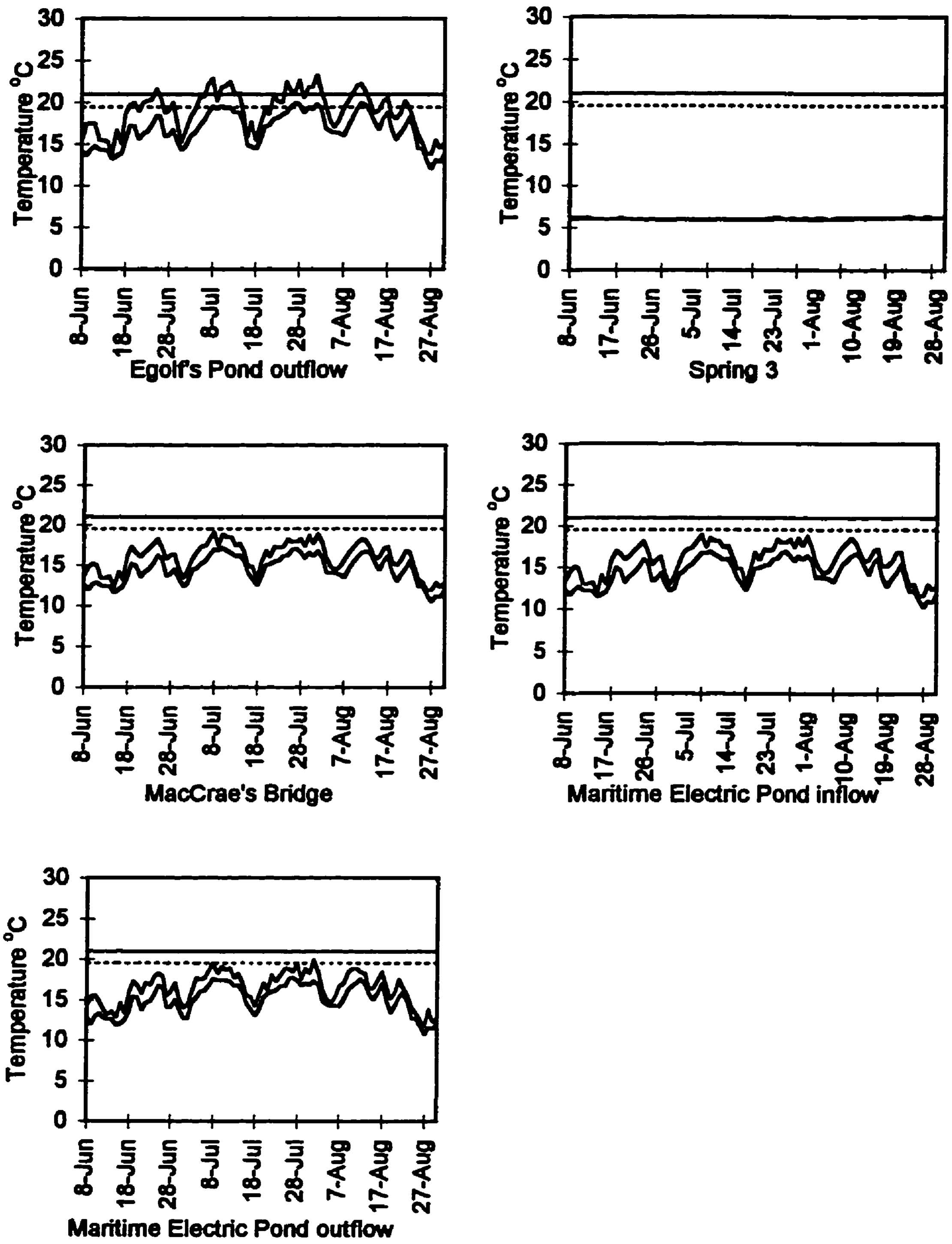


Figure 11. Daily mean and maximum temperatures on the Valleyfield River, 1995. Horizontal lines are maximum (21.6°C) and mean (19.2°C) daily avoidance temperatures for brook trout.

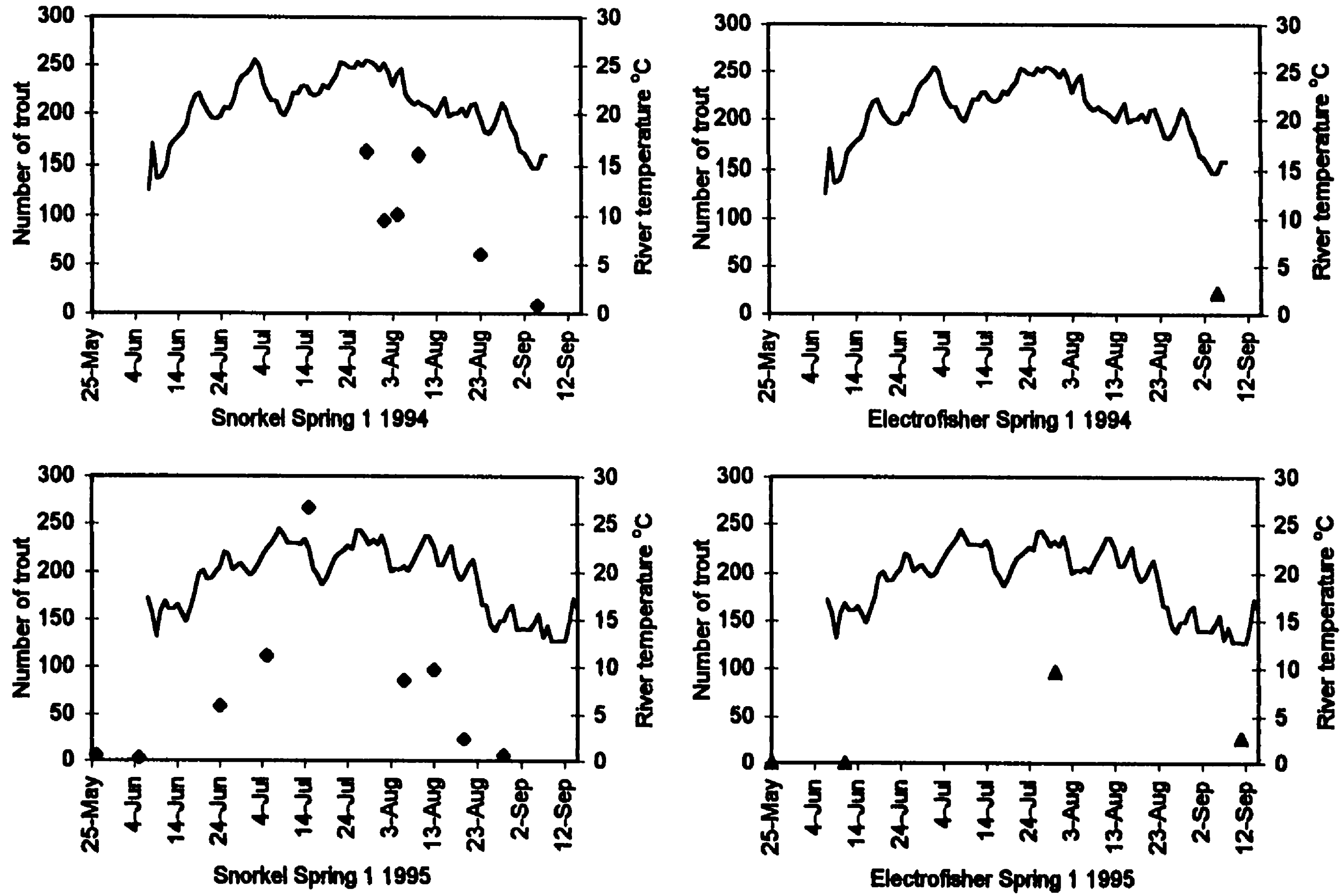


Figure 12. Snorkelling counts and electrofishing counts of brook trout in Spring 1, Midgell River, 1994 - 1995.

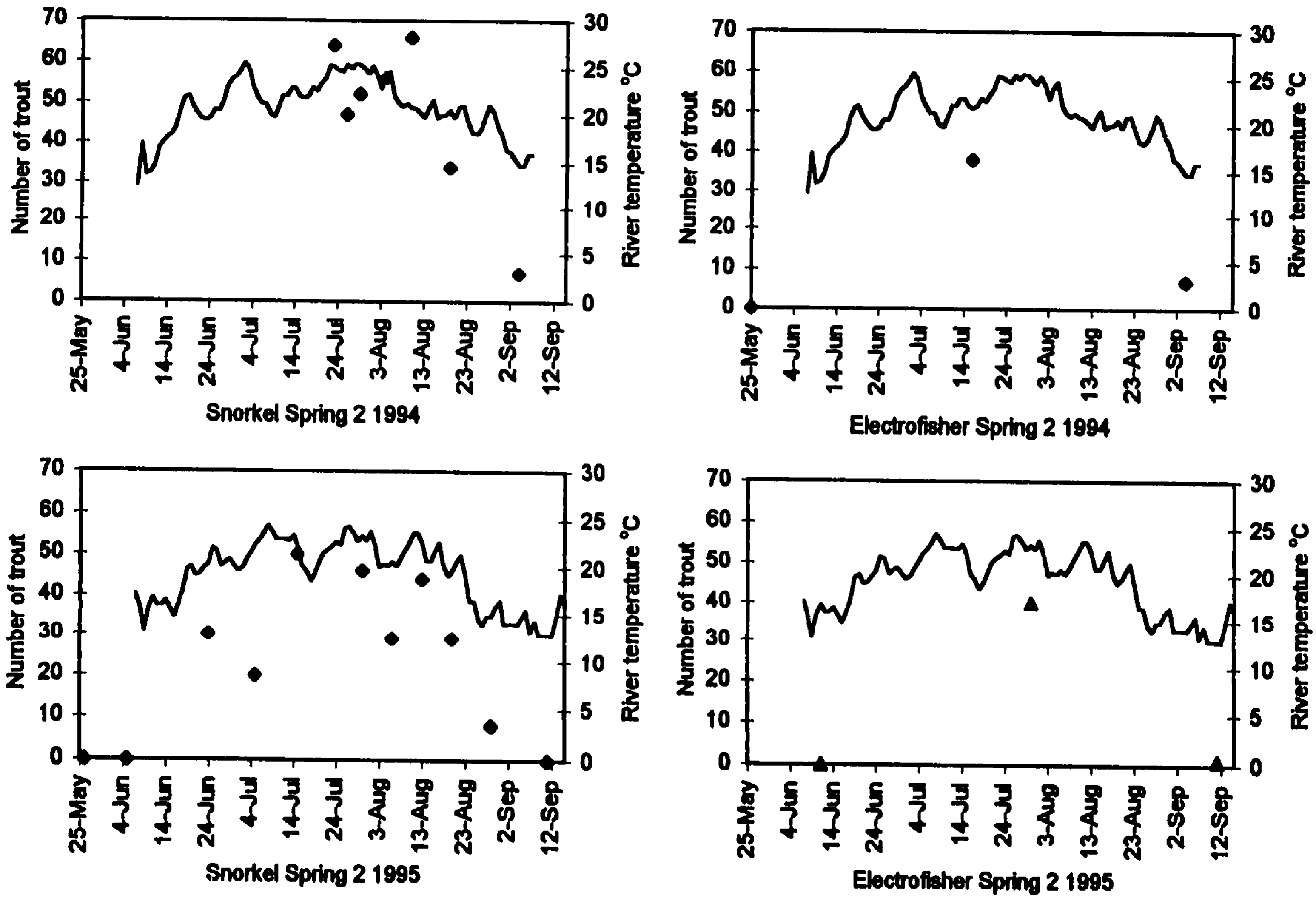


Figure 13. Snorkelling counts and electrofishing counts of brook trout in Spring 2, Midgell River, 1994 - 1995.

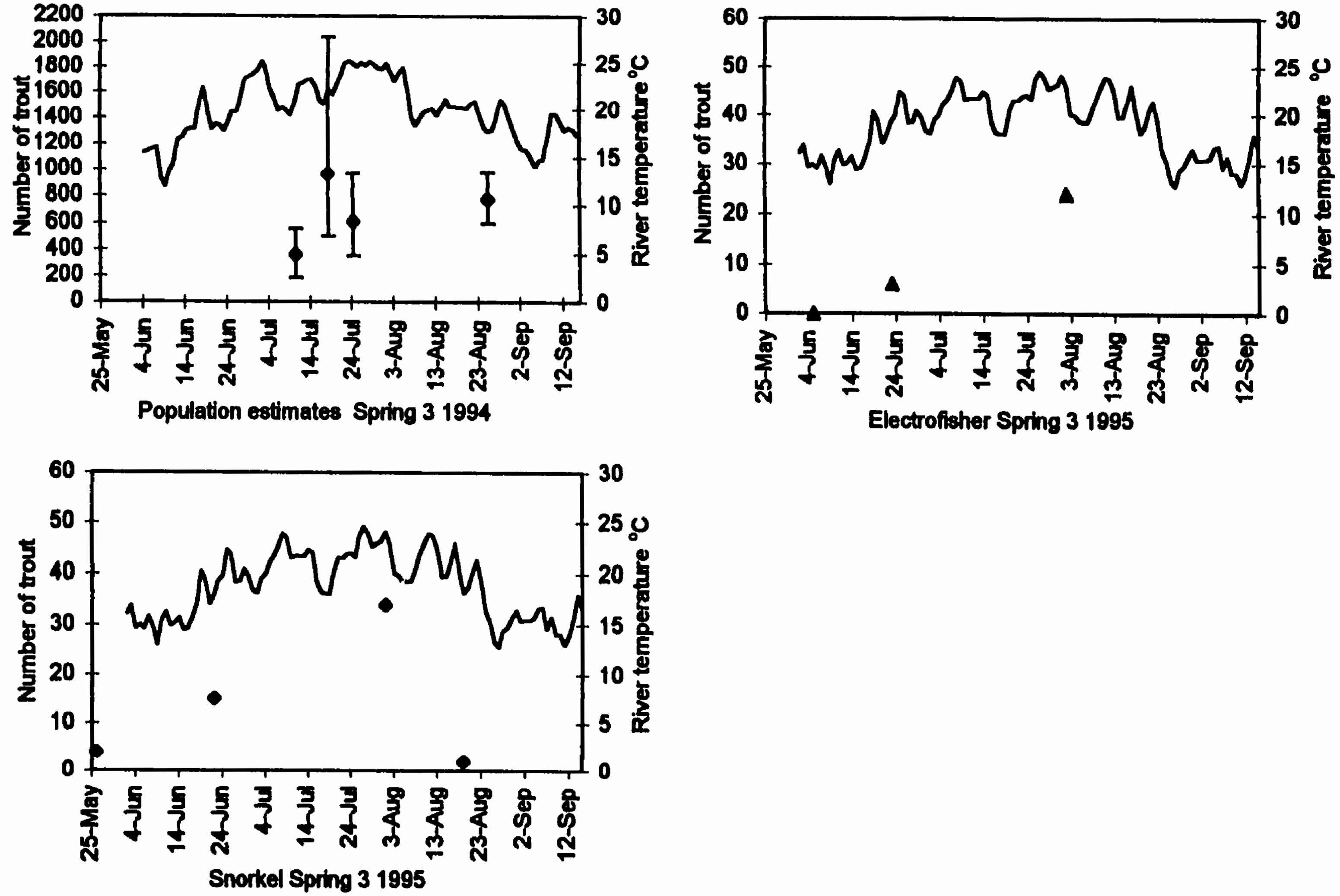


Figure 14. Population estimates and 95% ci's, snorkelling counts, and electrofishing counts of brook trout in Spring 3, Midgell River, 1994 - 1995.

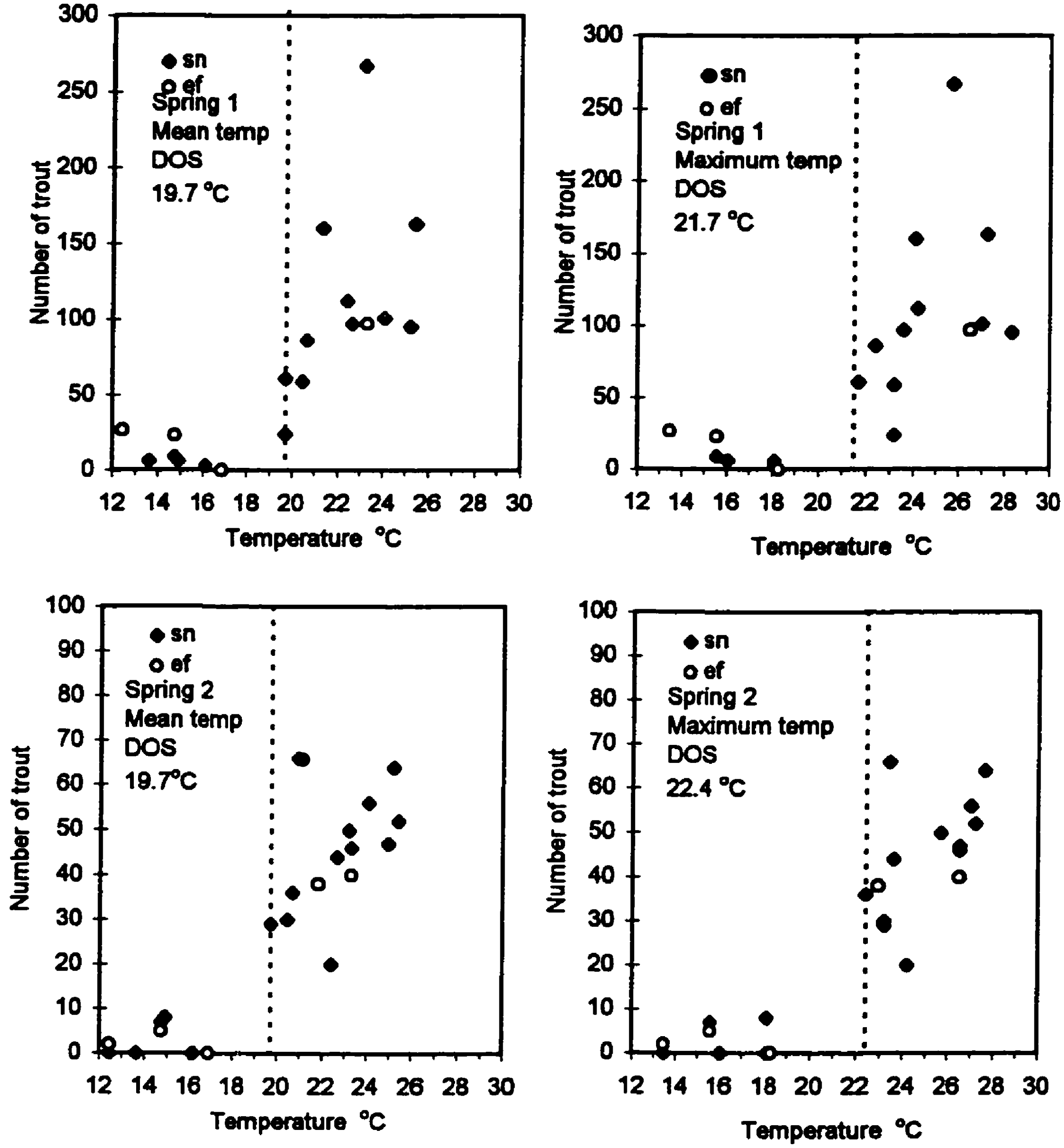


Figure 15. Estimated daily mean and daily maximum avoidance temperature for two springs in Midgell River, 1994-1995. ef = electrofishing capture, sn =snorkelling observation, DOS = day of sampling.

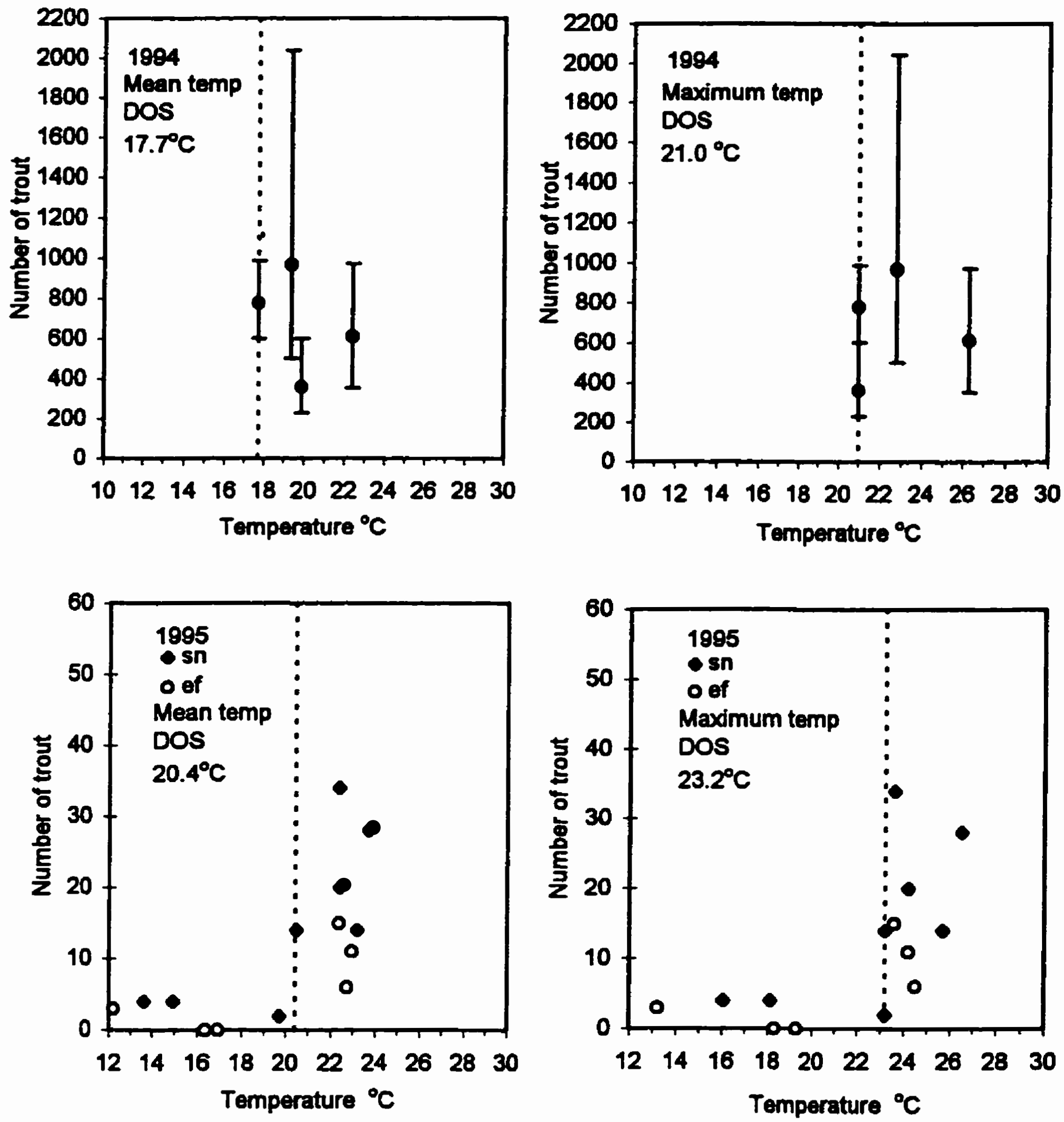


Figure 16. Estimated daily mean and daily maximum avoidance temperature for Spring 3, Midgell River, 1994-1995. ef = electrofishing capture, sn = snorkelling observation, DOS = day of sampling

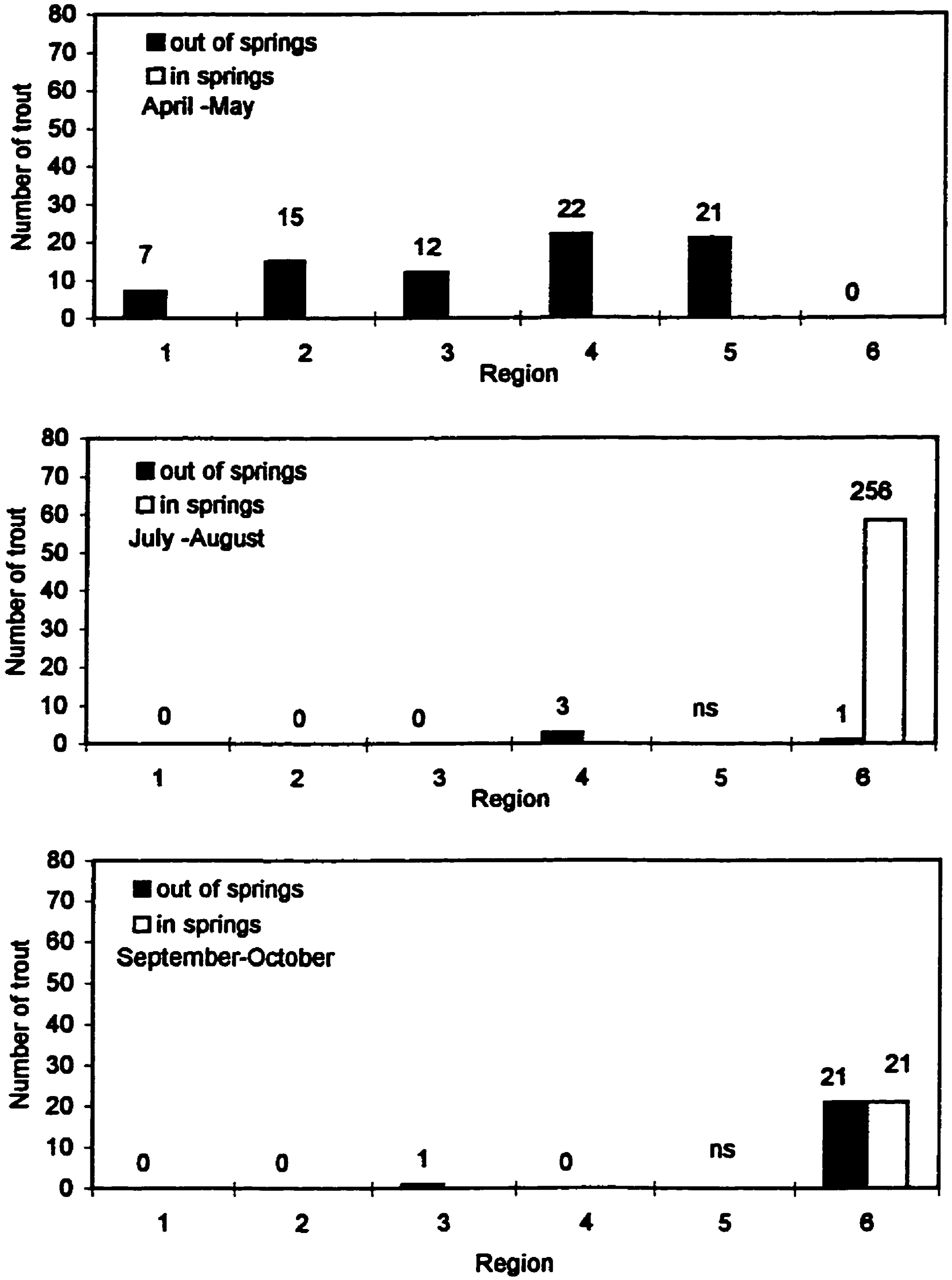


Figure 17. Number of brook trout captured by fyke net region and habitat, MacDonald's Pond, Midgell River, 1995.
ns = not sampled

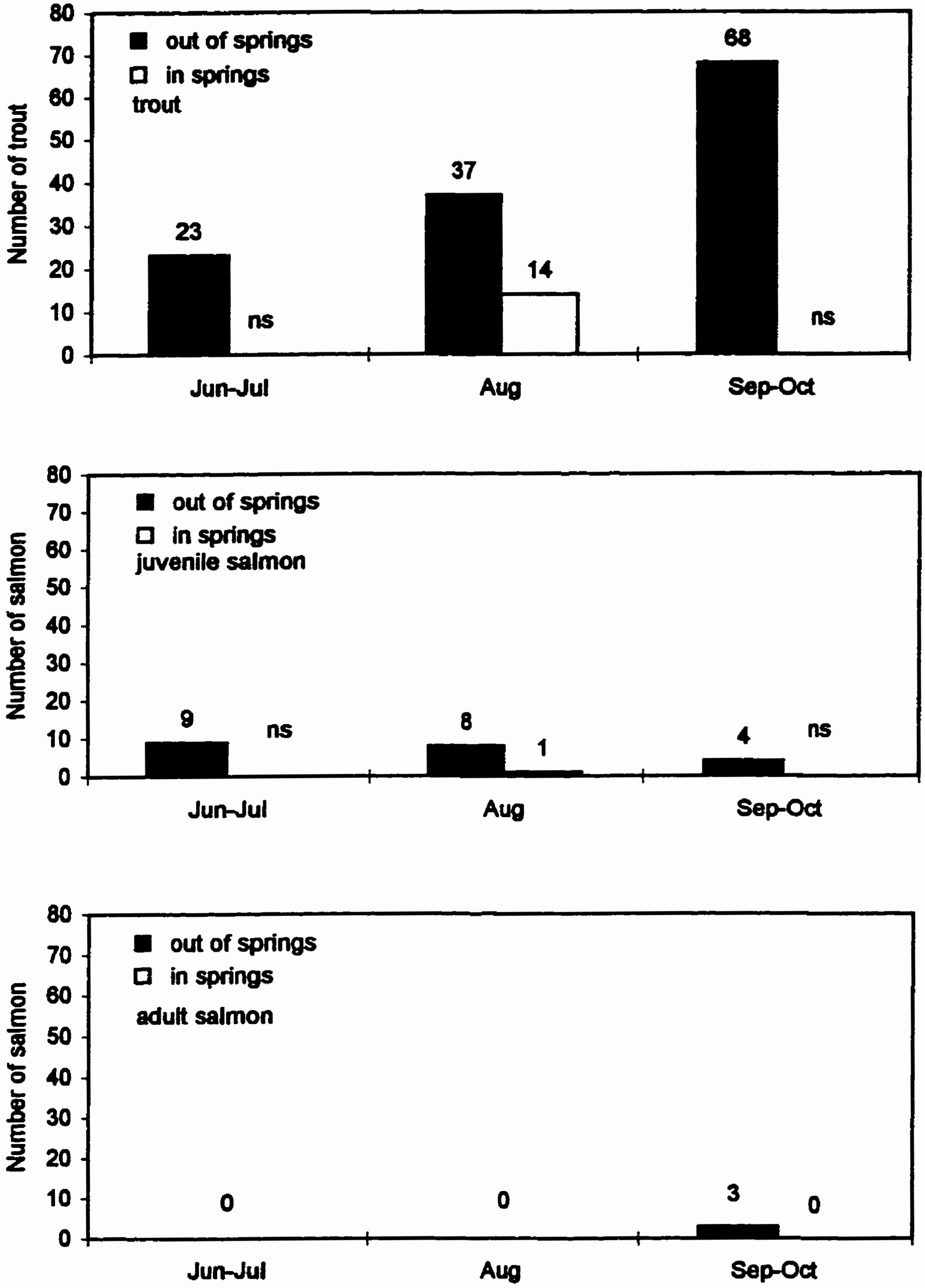


Figure 18. Number of brook trout and Atlantic salmon captured by fyke nets, Maritime Electric Pond, Valleyfield River, 1995.
ns = not sampled

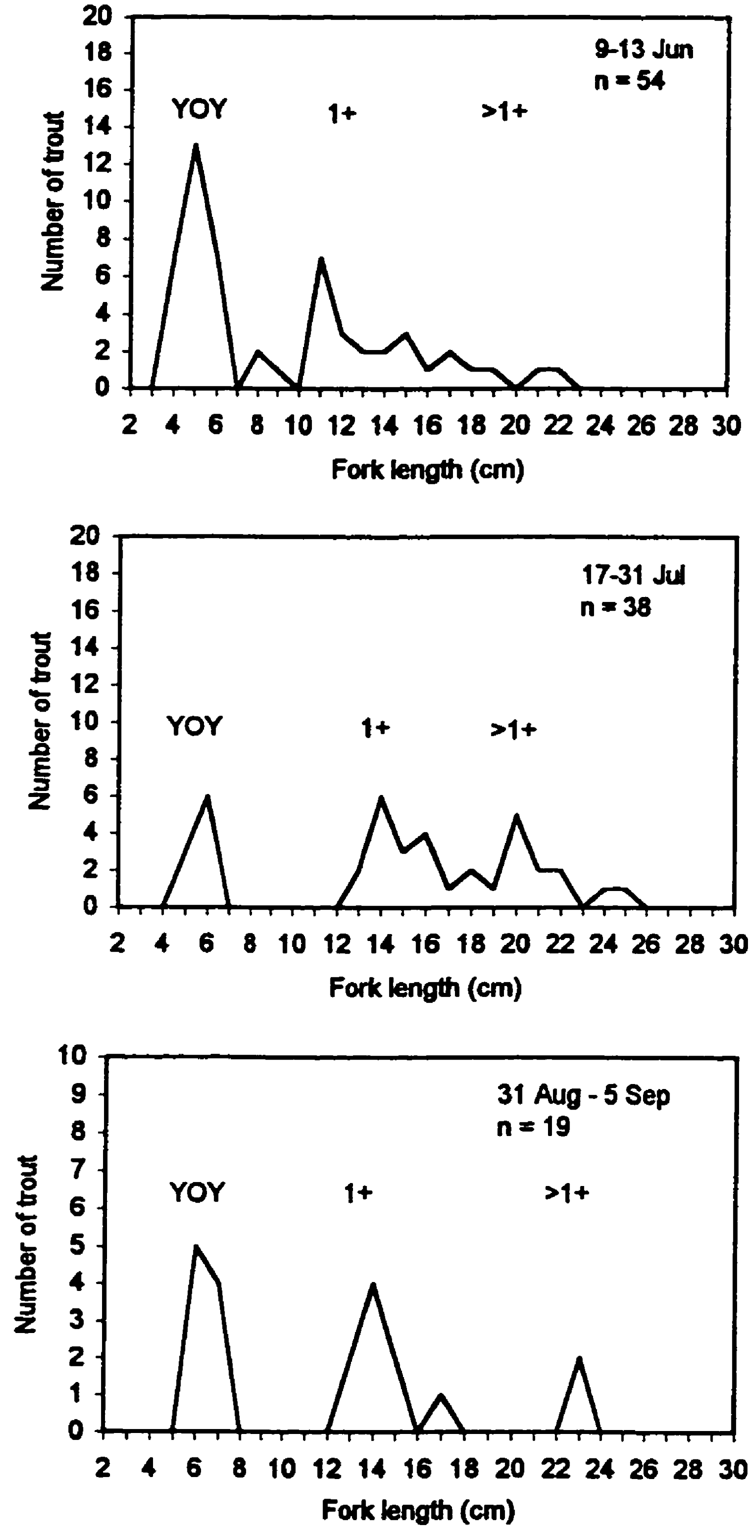
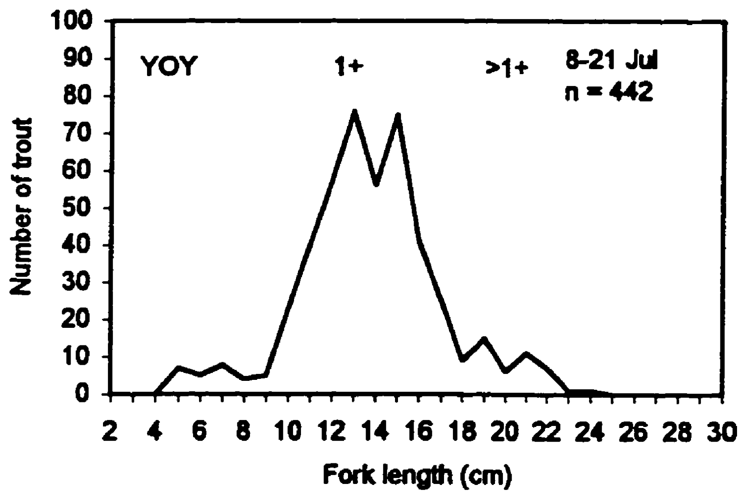


Figure 19. Summary of fork length frequency distributions of brook trout captured in riverine sites in each electrofishing period, Midgell River, 1994.



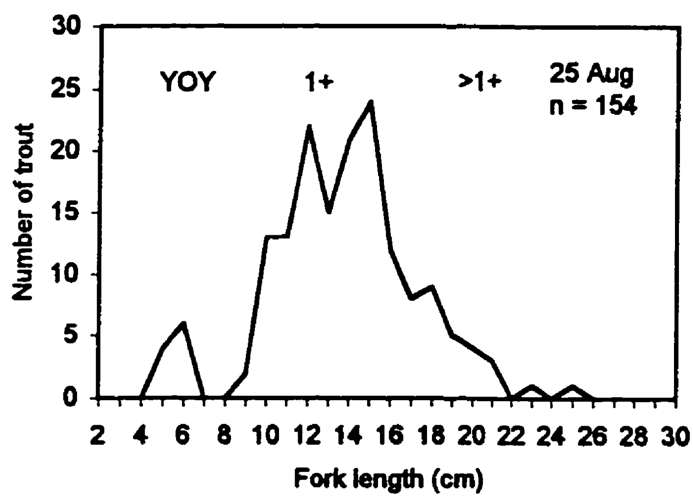


Figure 20. Summary of fork length frequency distributions of brook trout captured in MacDonald's Pond in each electrofishing period, Midgell River, 1994.

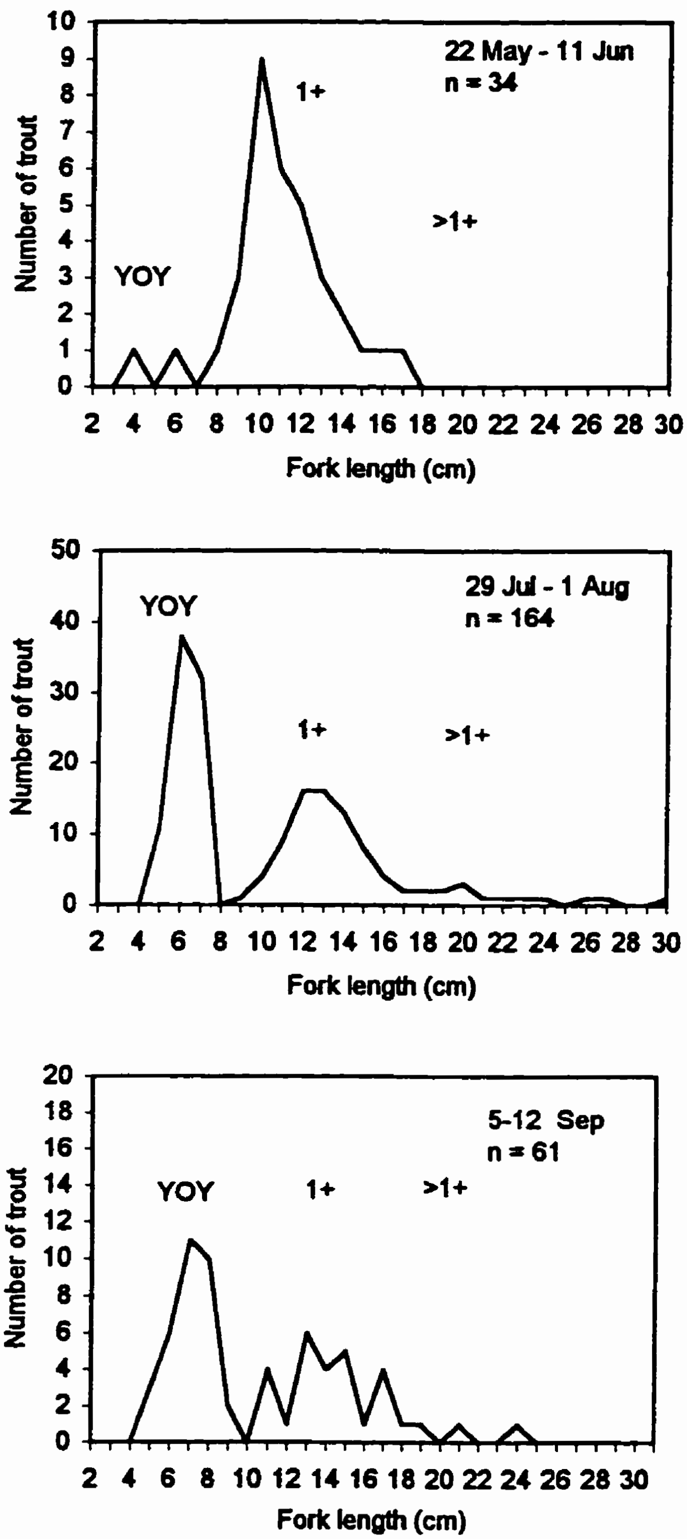


Figure 21. Summary of fork length frequency distributions of brook trout captured in riverine sites in each electrofishing period, Midgell River, 1995.

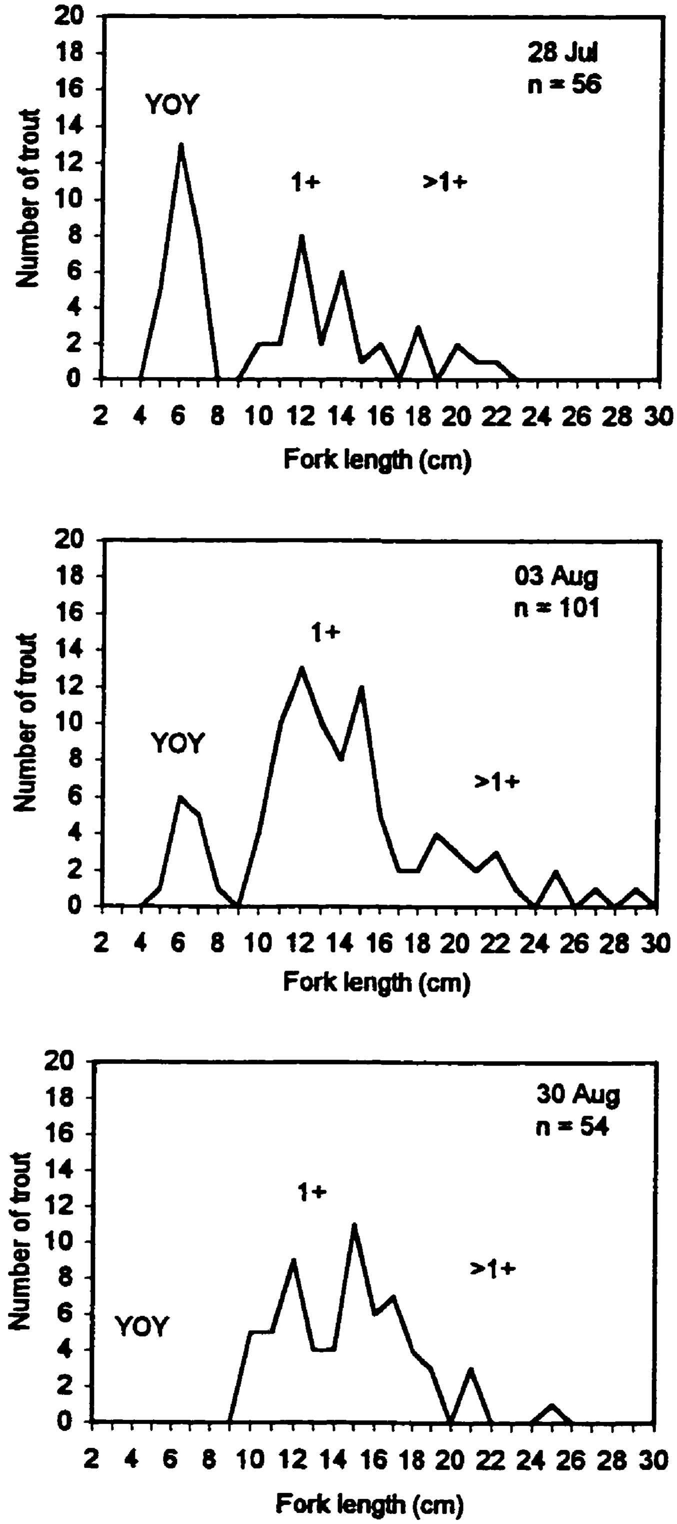


Figure 22. Summary of fork length frequency distributions of brook trout captured in the Head of Tide Spring electrofishing site, Midgell River, 1995.

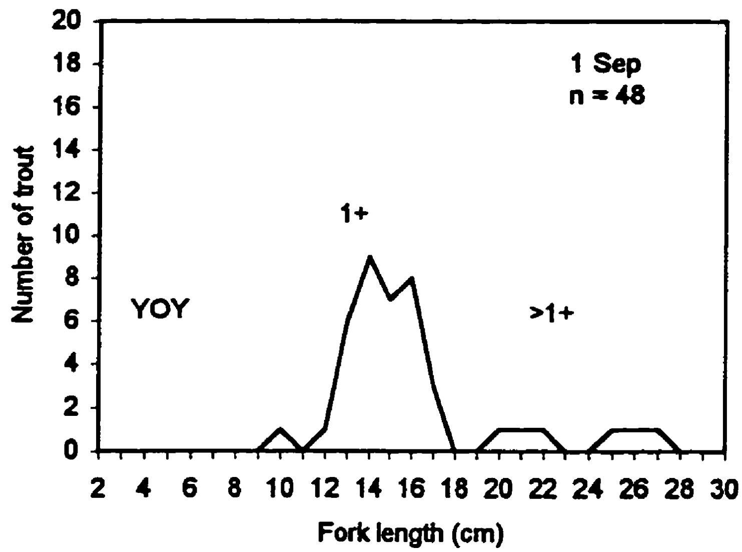


Figure 23. Summary of fork length frequency distributions of brook trout captured in the Head of Tide Spring electrofishing site, Midgell River, 1995.

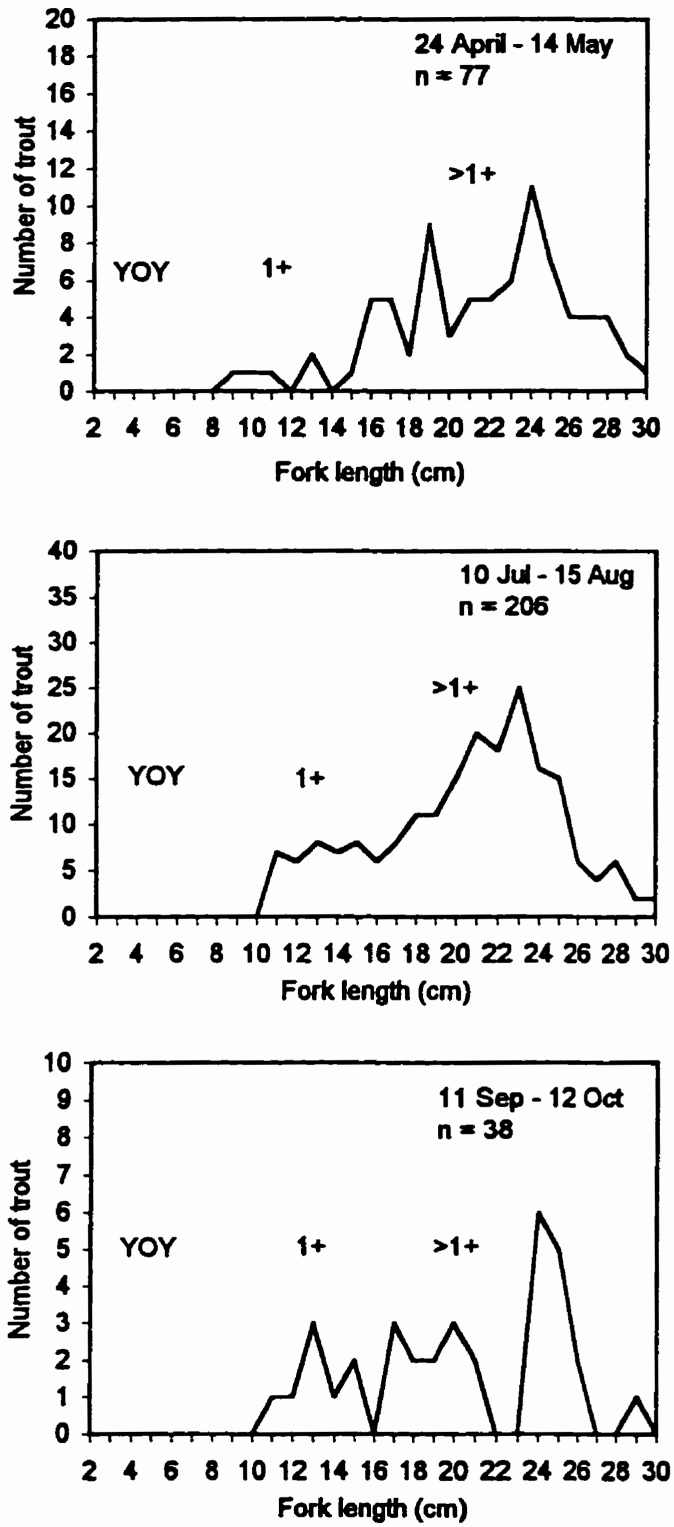


Figure 24. Summary of fork length frequency distributions of brook trout captured in MacDonald's Pond in each fyke netting period, Midgell River, 1995.

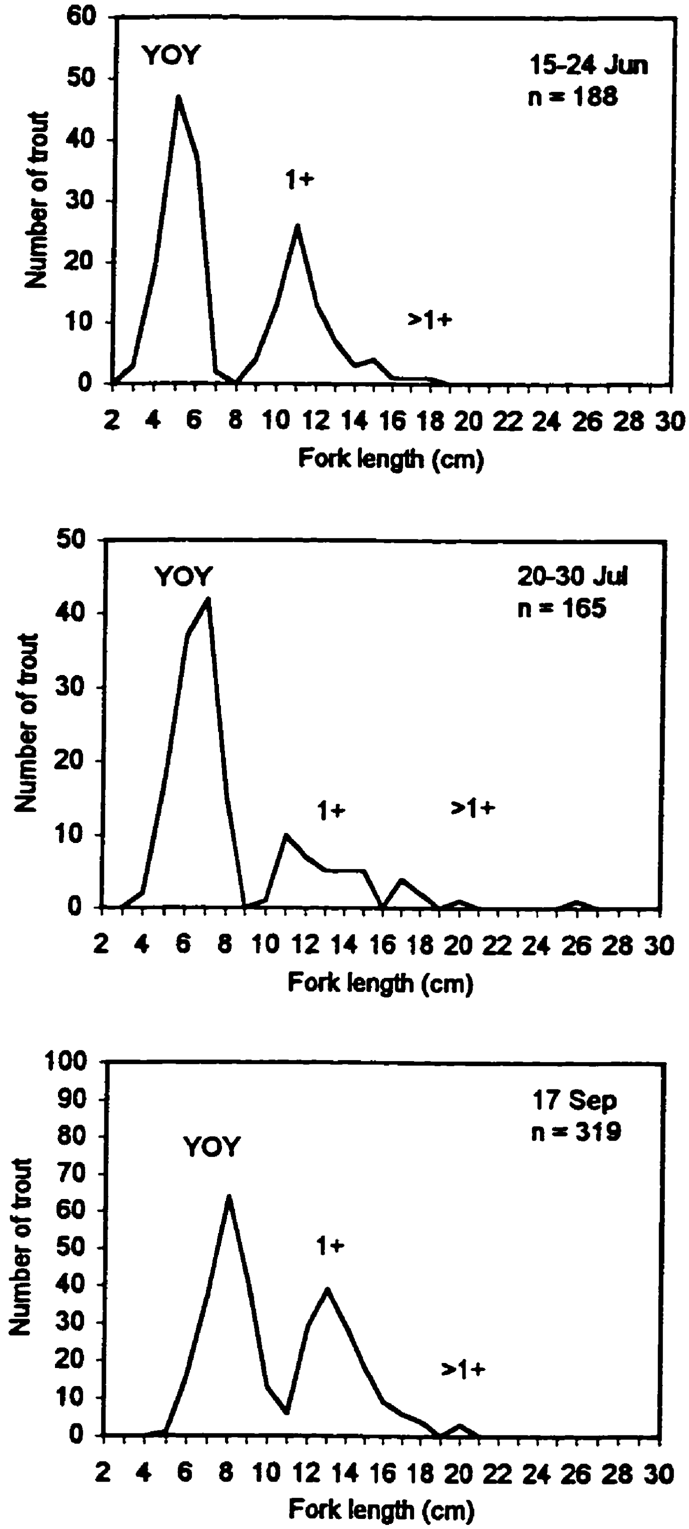


Figure 25. Summary of fork length frequency distributions of brook trout captured in each electrofishing period, Valleyfield River, 1994.

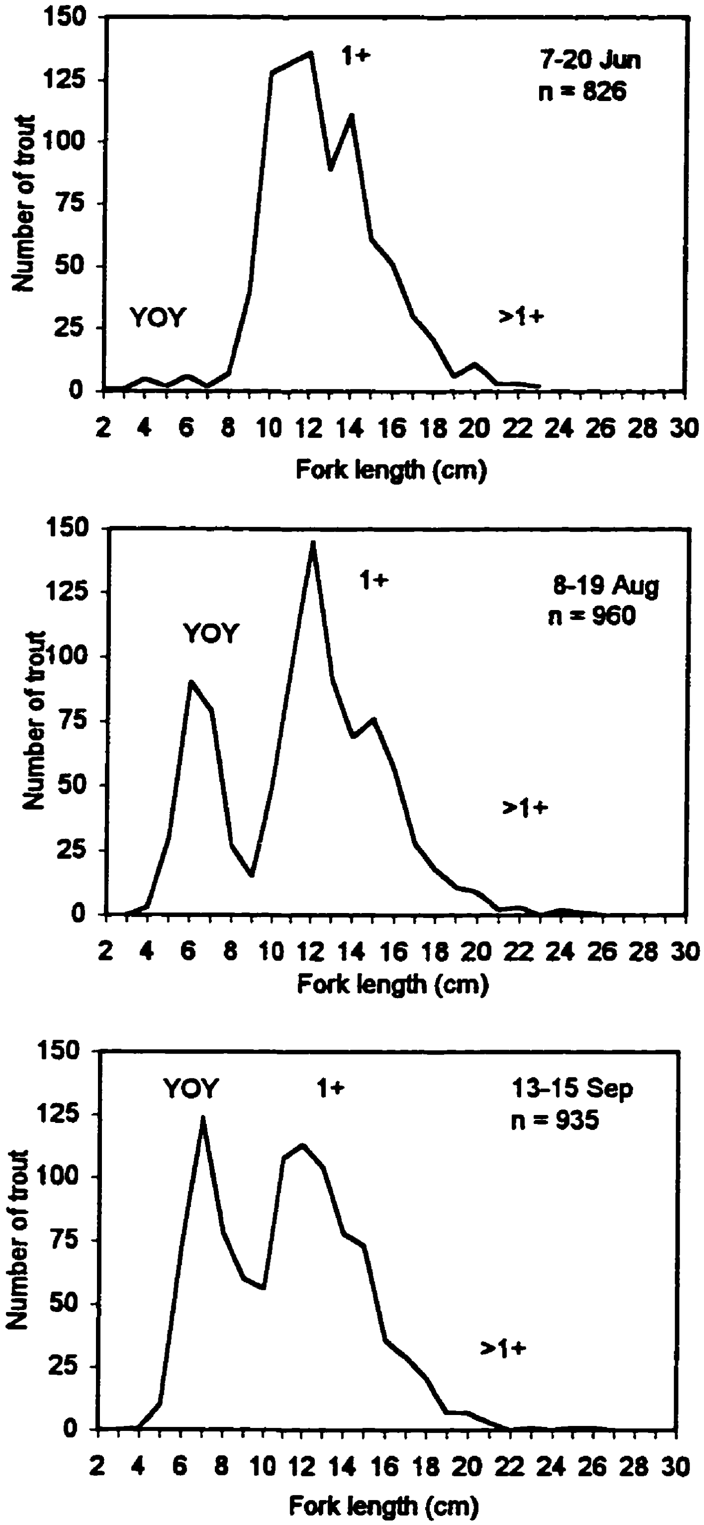


Figure 26. Summary of fork length frequency distributions of brook trout captured in each electrofishing period, Valleyfield River, 1995.

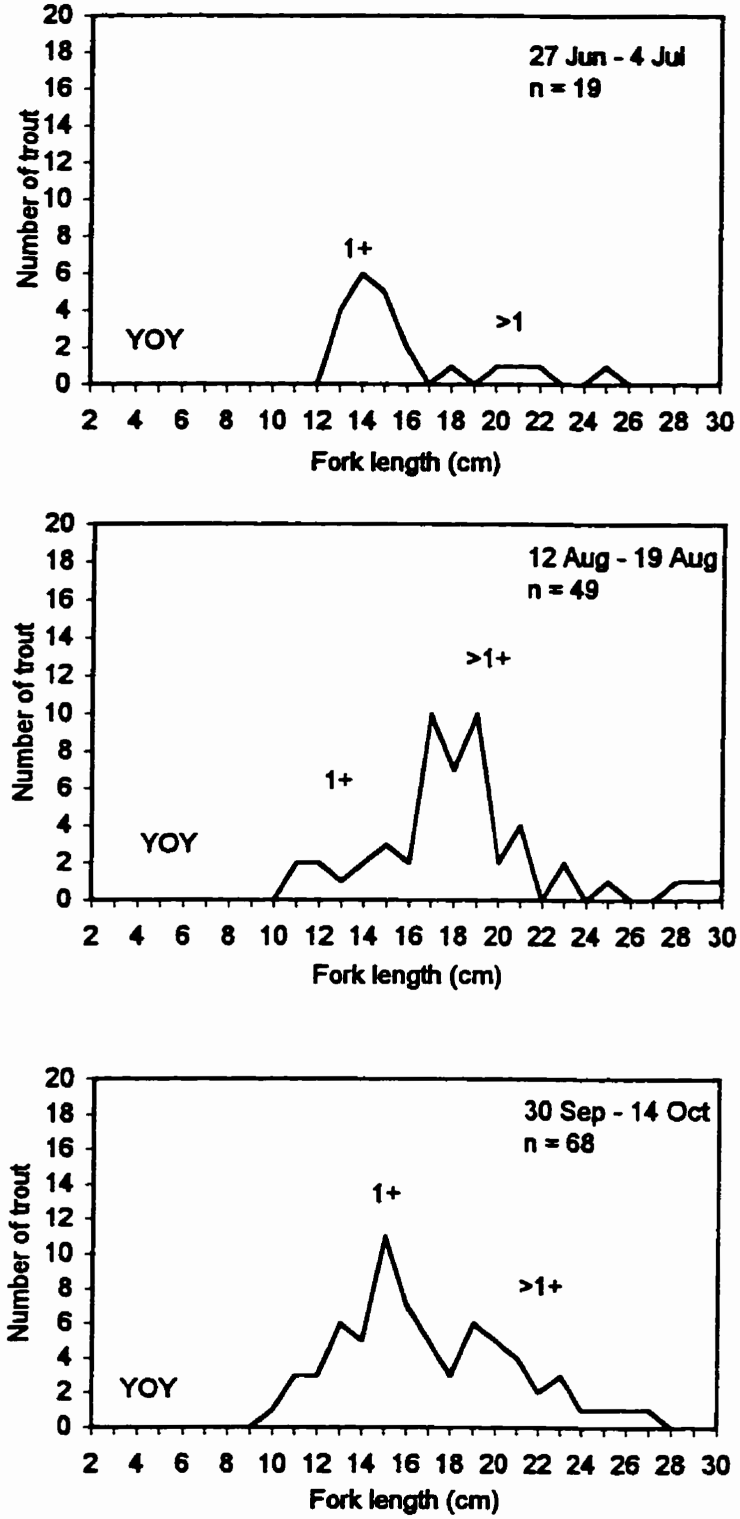


Figure 27. Summary of fork length frequency distributions of brook trout captured in Maritime Electric Pond in each fyke netting period, Valleyfield River, 1995.

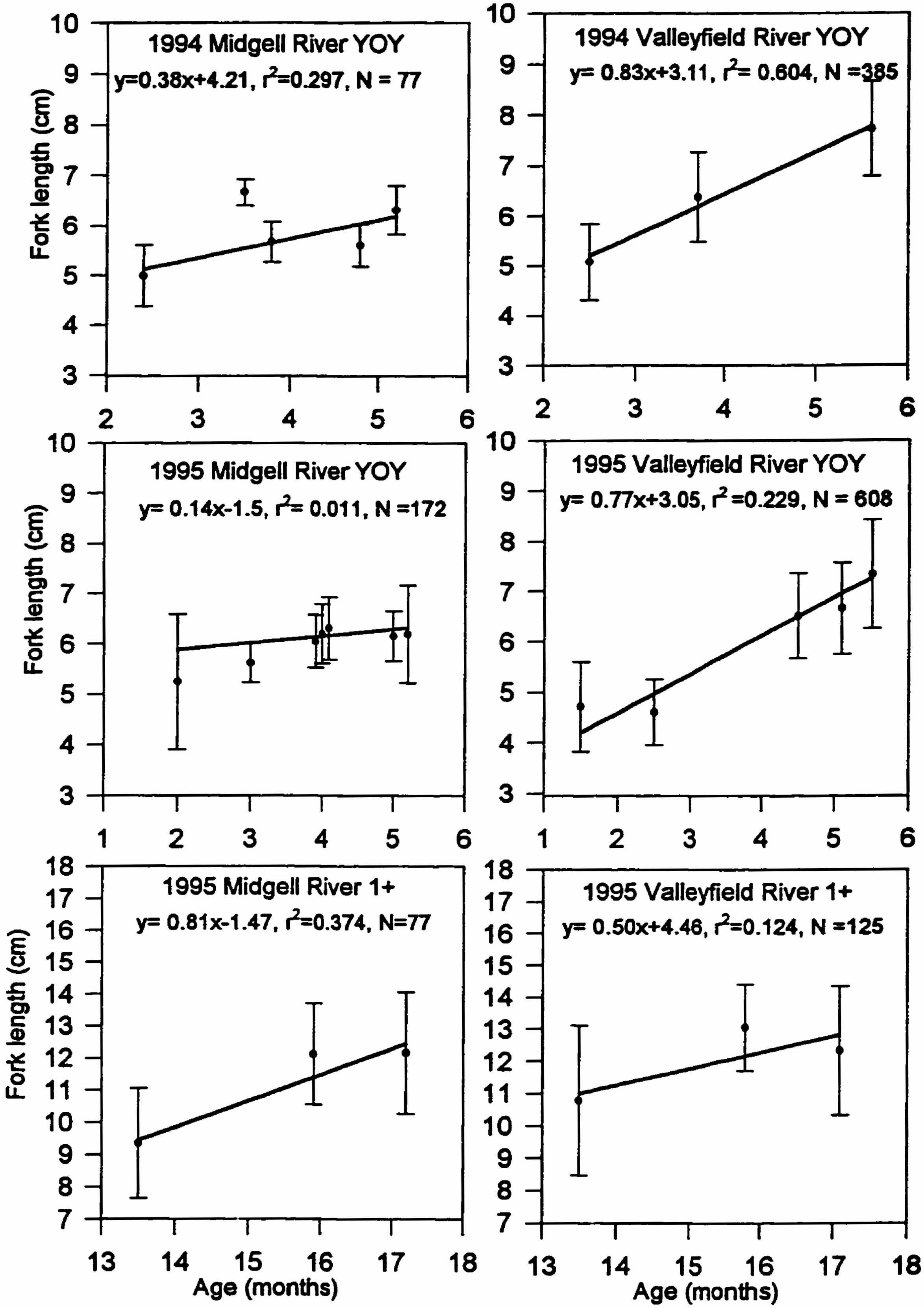


Figure 28. Growth rate of young of the year and yearling brook trout from May to September, Midgell River and Valleyfield River, 1994 - 1995.

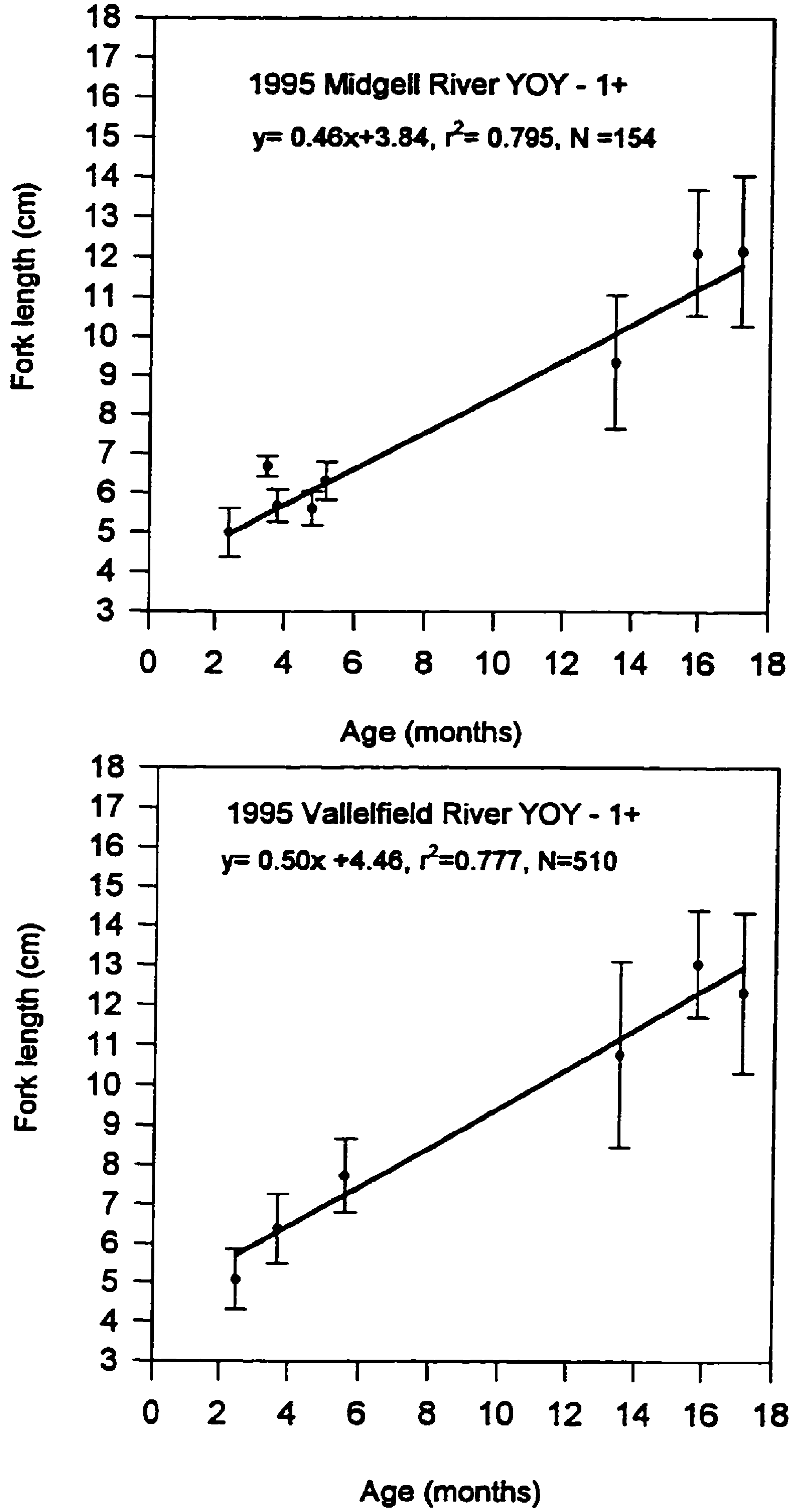


Figure 29. Annual growth of brook trout from 4.0 months to 16.0 months of age, Midgell River and Valleyfield River, 1994 - 1995.

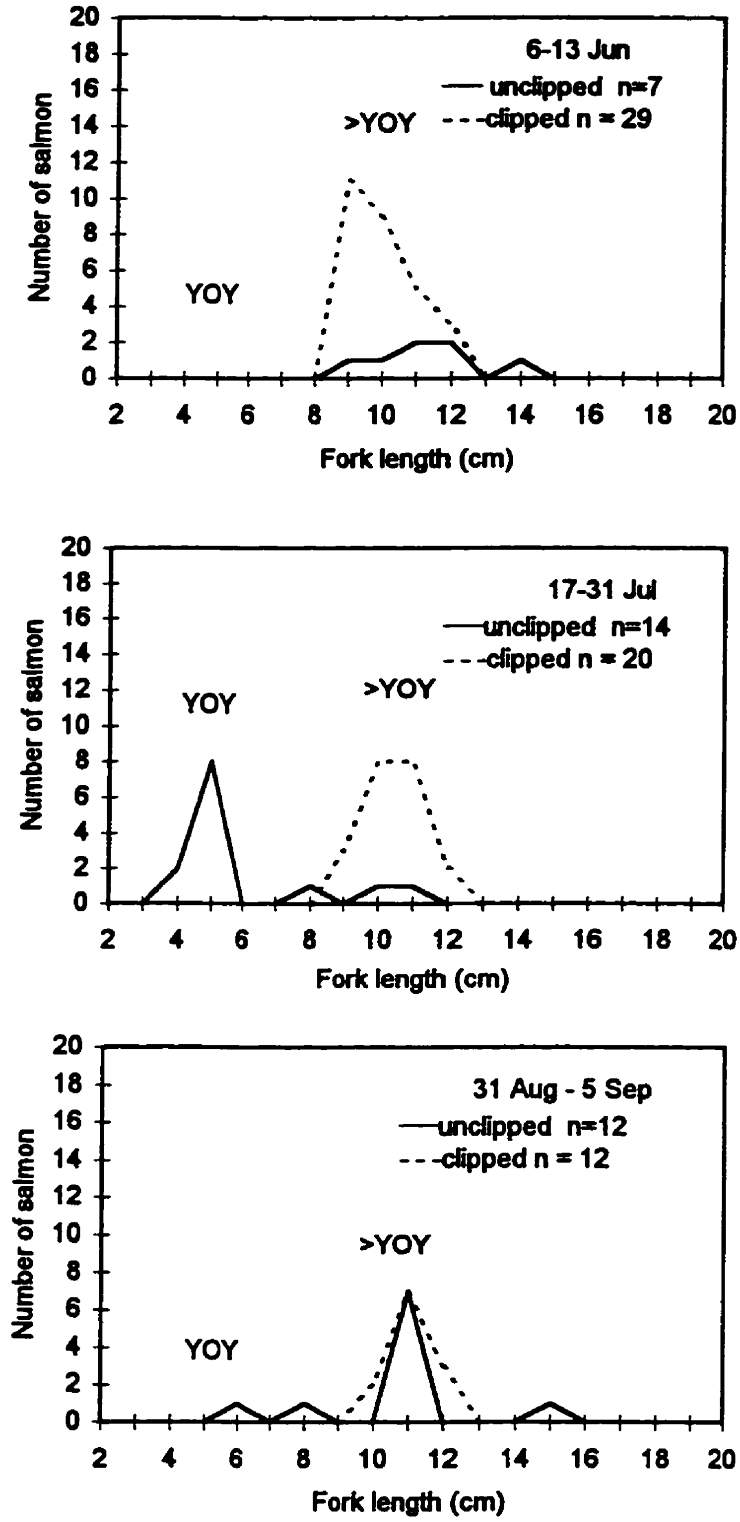


Figure 30. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in riverine sites in each electrofishing period, Midgell River, 1994.

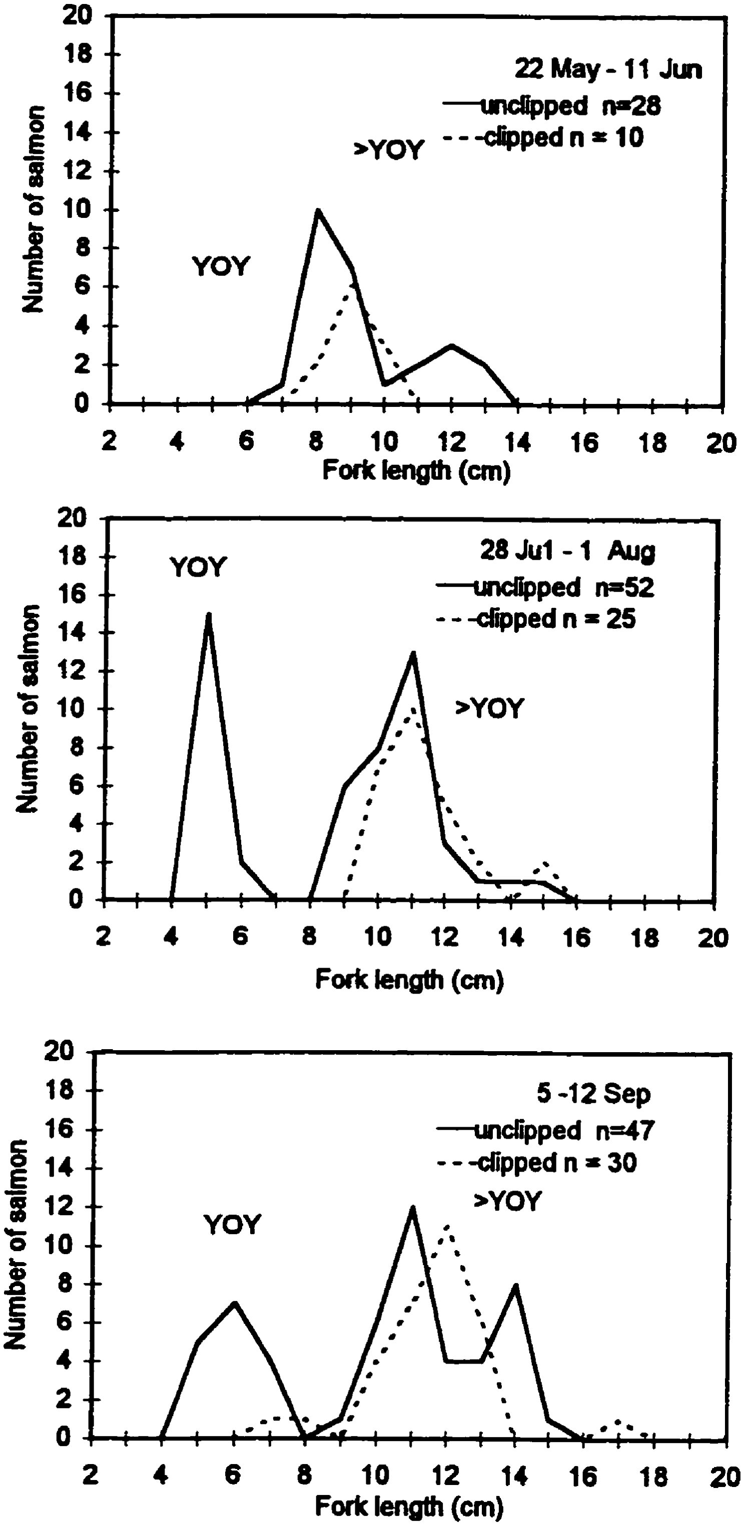
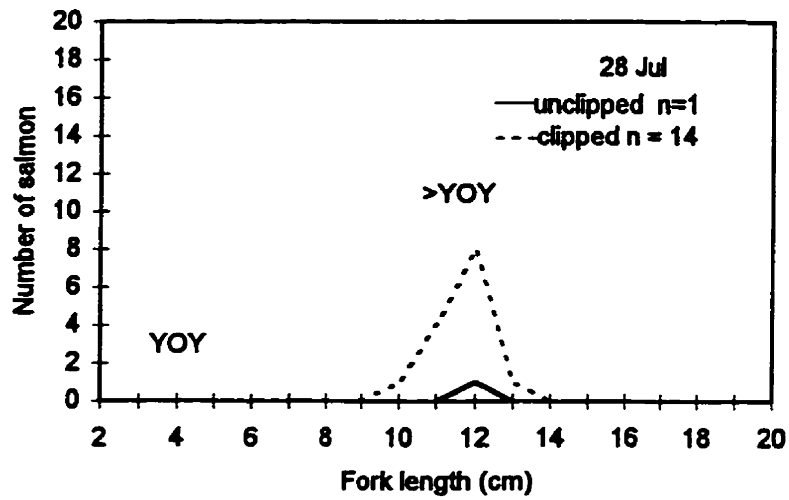
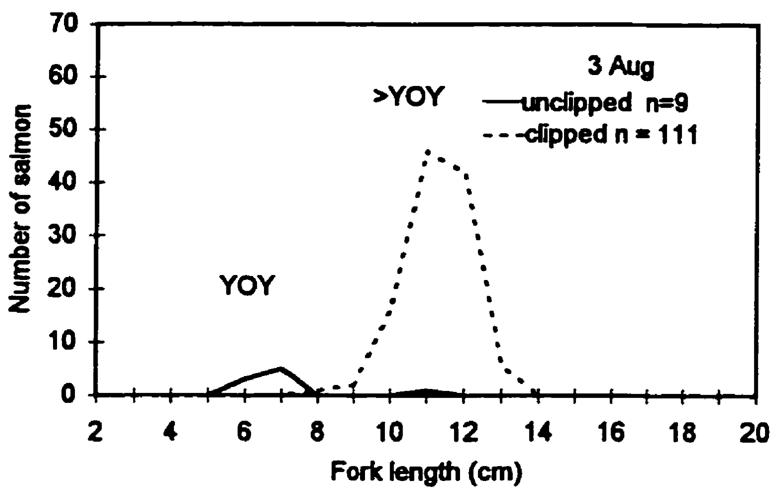


Figure 31. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in riverine sites in each electrofishing period, Midgell River, 1995.





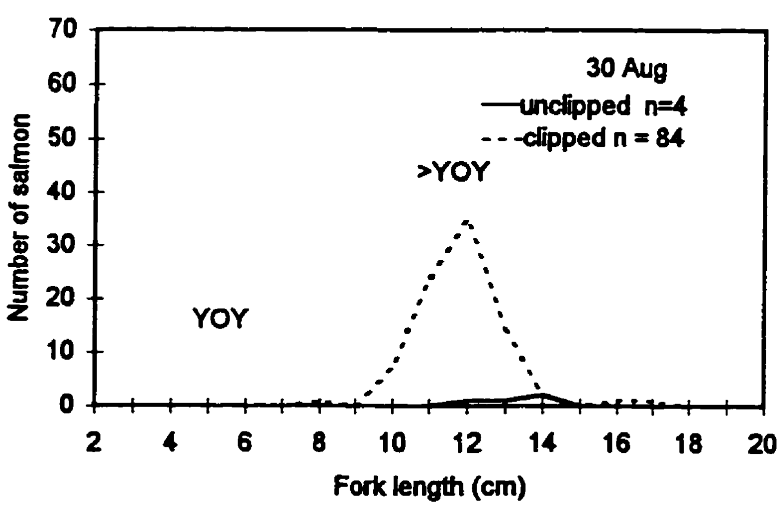


Figure 32. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in the Head of Tide Spring electrofishing site, Midgell River, 1995.

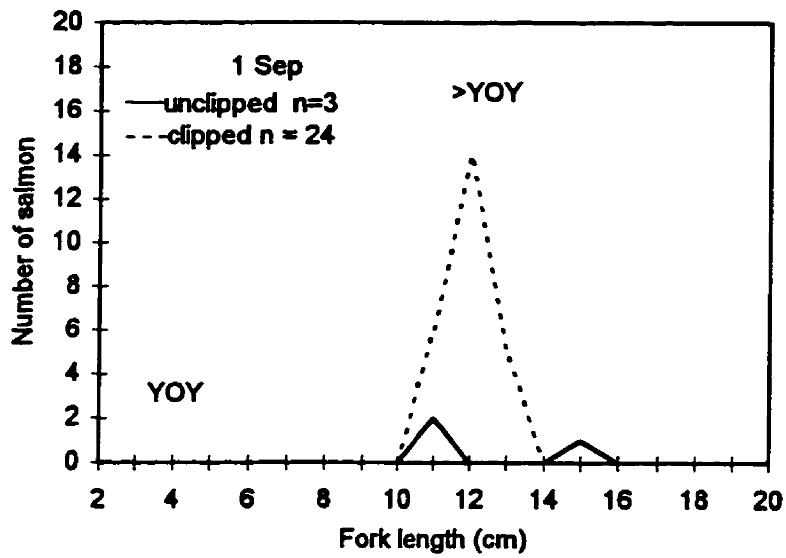


Figure 33. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in the Head of Tide Spring electrofishing site, Midgell River, 1995.

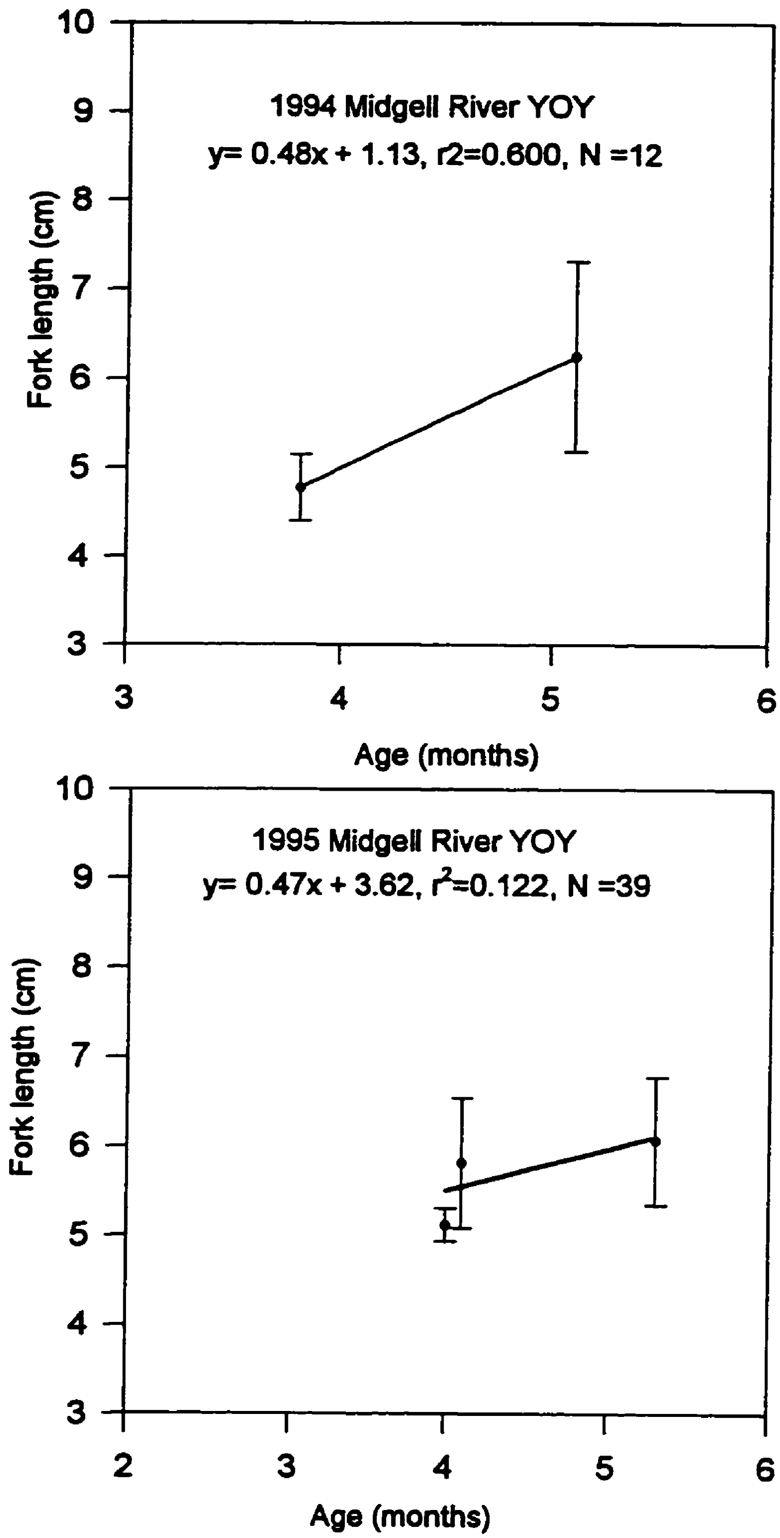


Figure 34. Growth rate of young of the year Atlantic salmon from May to September, Midgell River, 1994 - 1995.

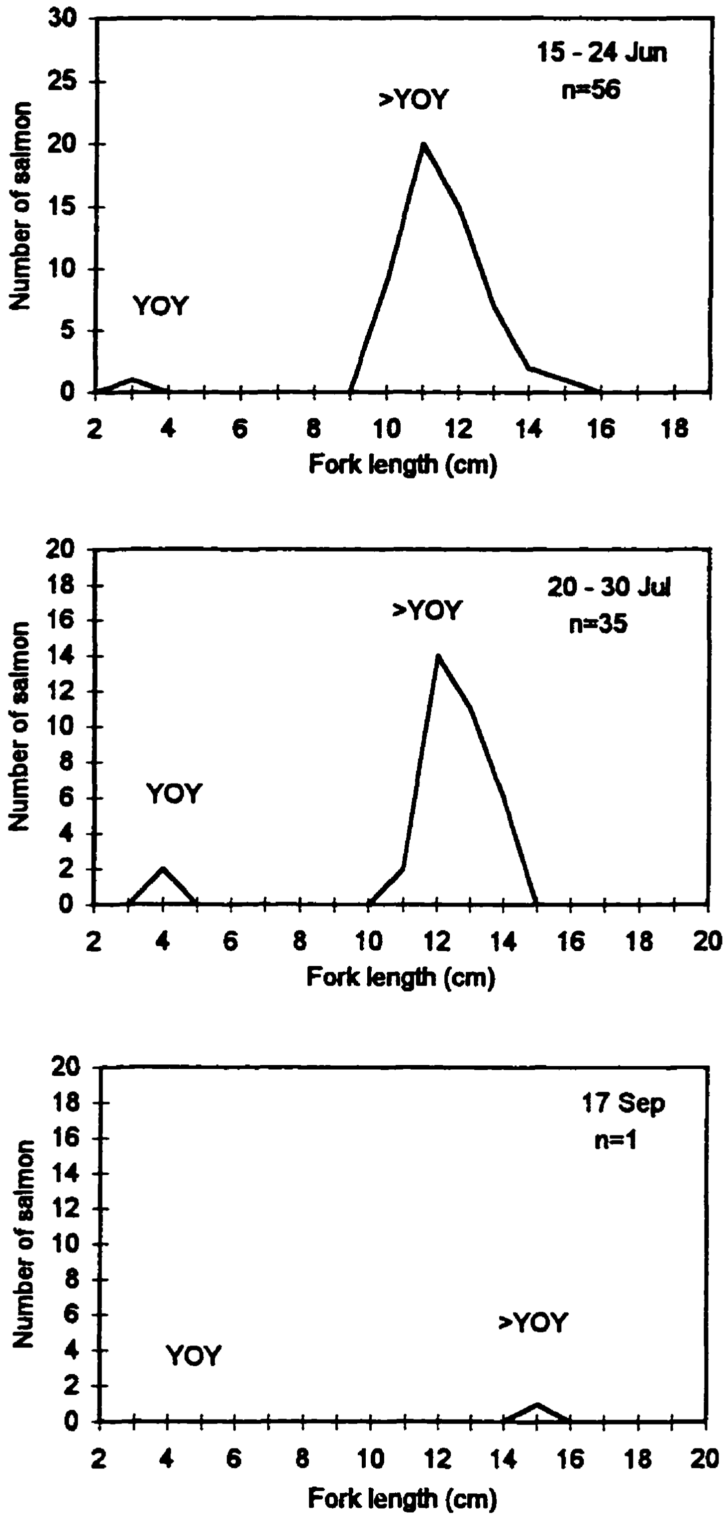


Figure 35. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in each electrofishing period, Valleyfield River, 1994.

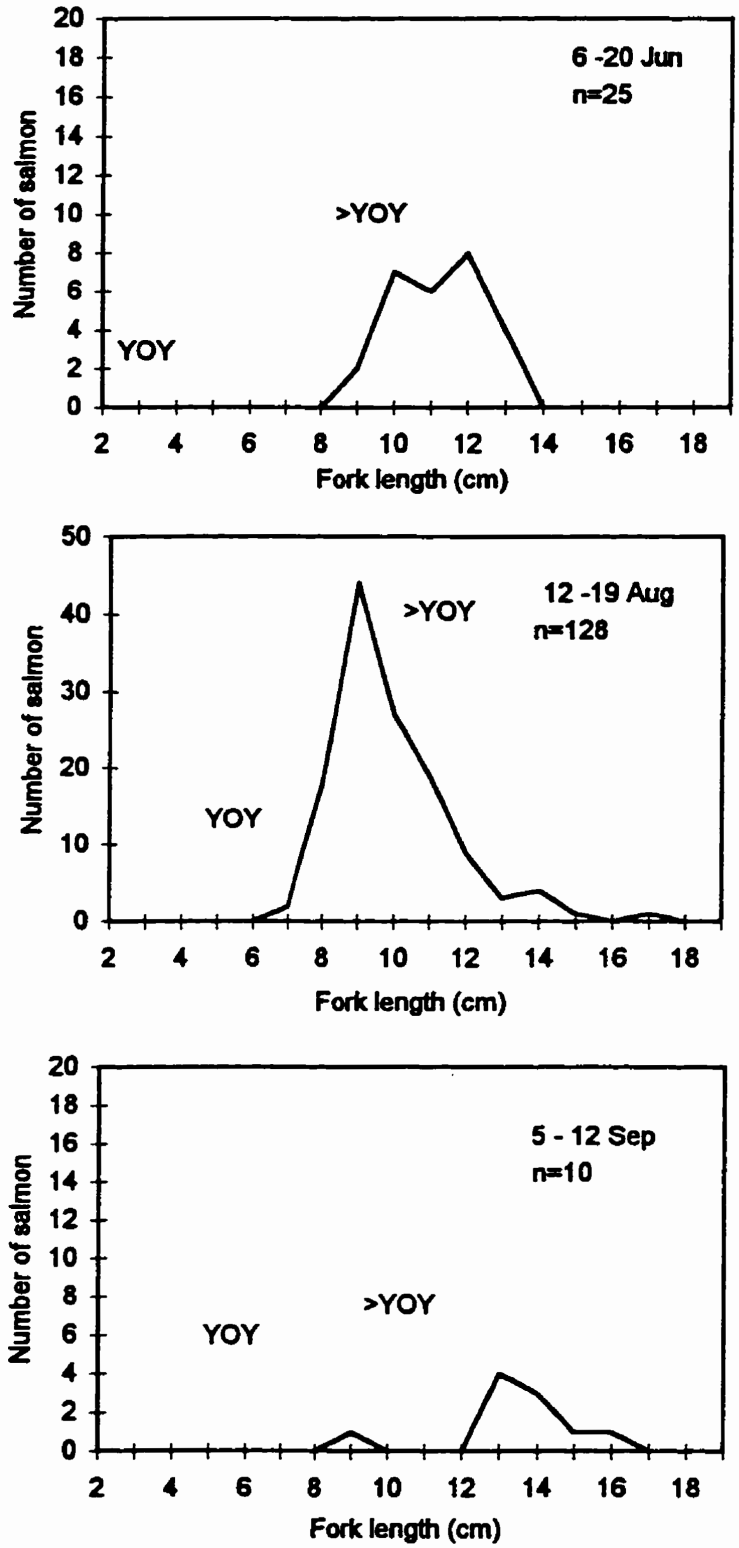


Figure 36. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in each electrofishing period, Valleyfield River, 1995.

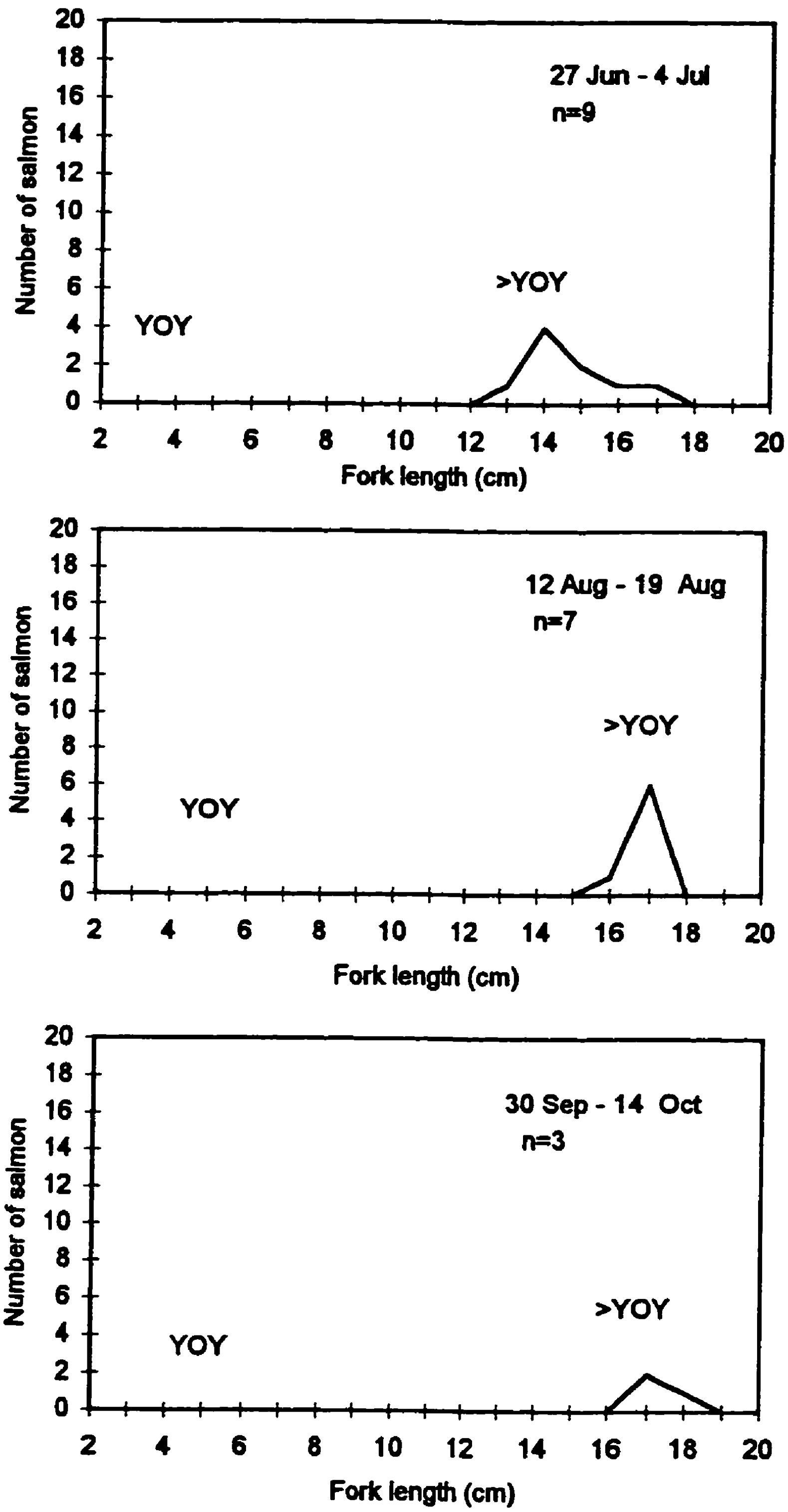


Figure 37. Summary of fork length frequency distributions of juvenile Atlantic salmon captured in Maritime Electric Pond in each fyke netting period, Valleyfield River, 1995.

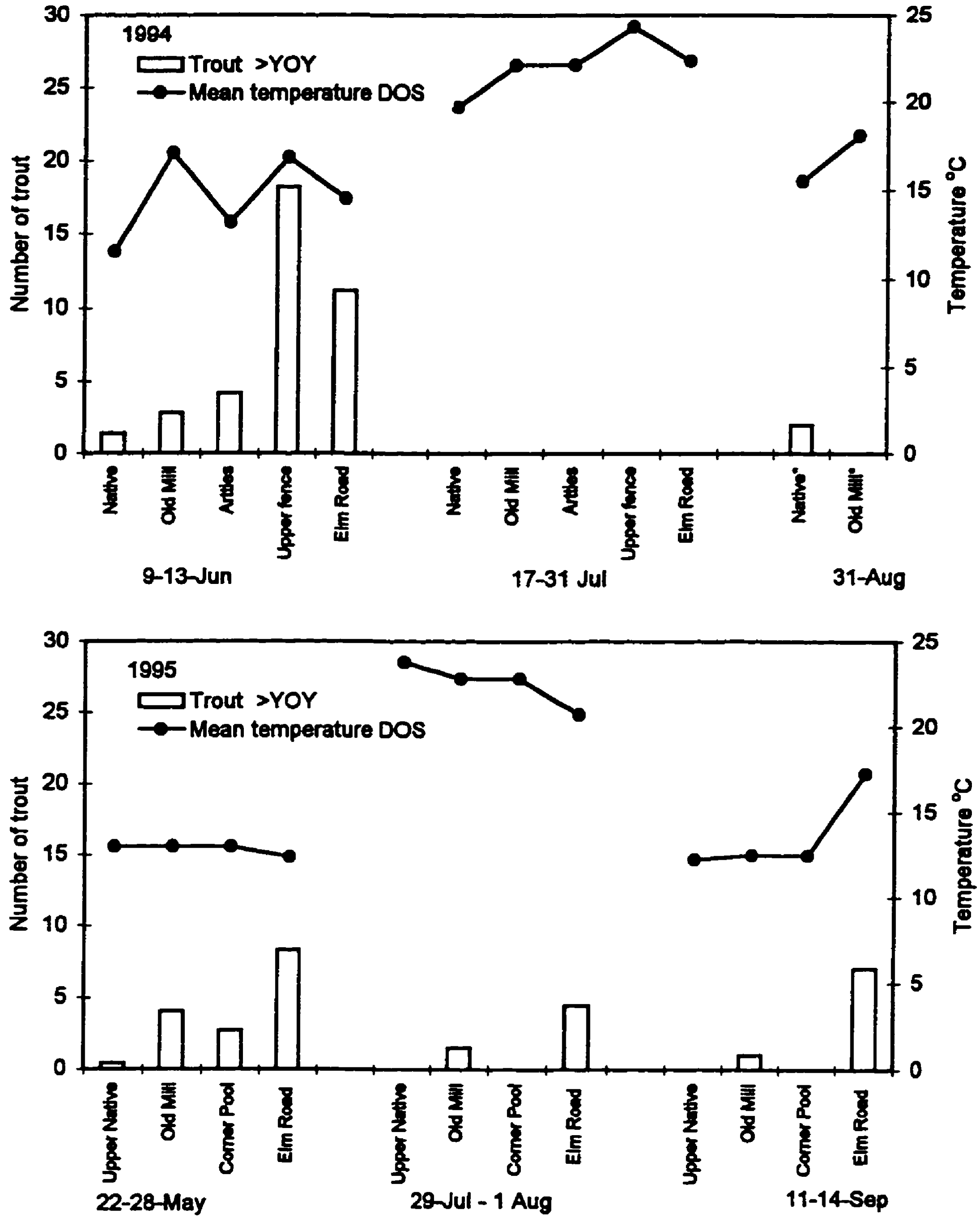


Figure 38. Brook trout captured per $30m^{-1}$ stream length in electrofishing sites, Midgell River, 1994-1995. DOS = day of sampling, *= closed electrofishing method

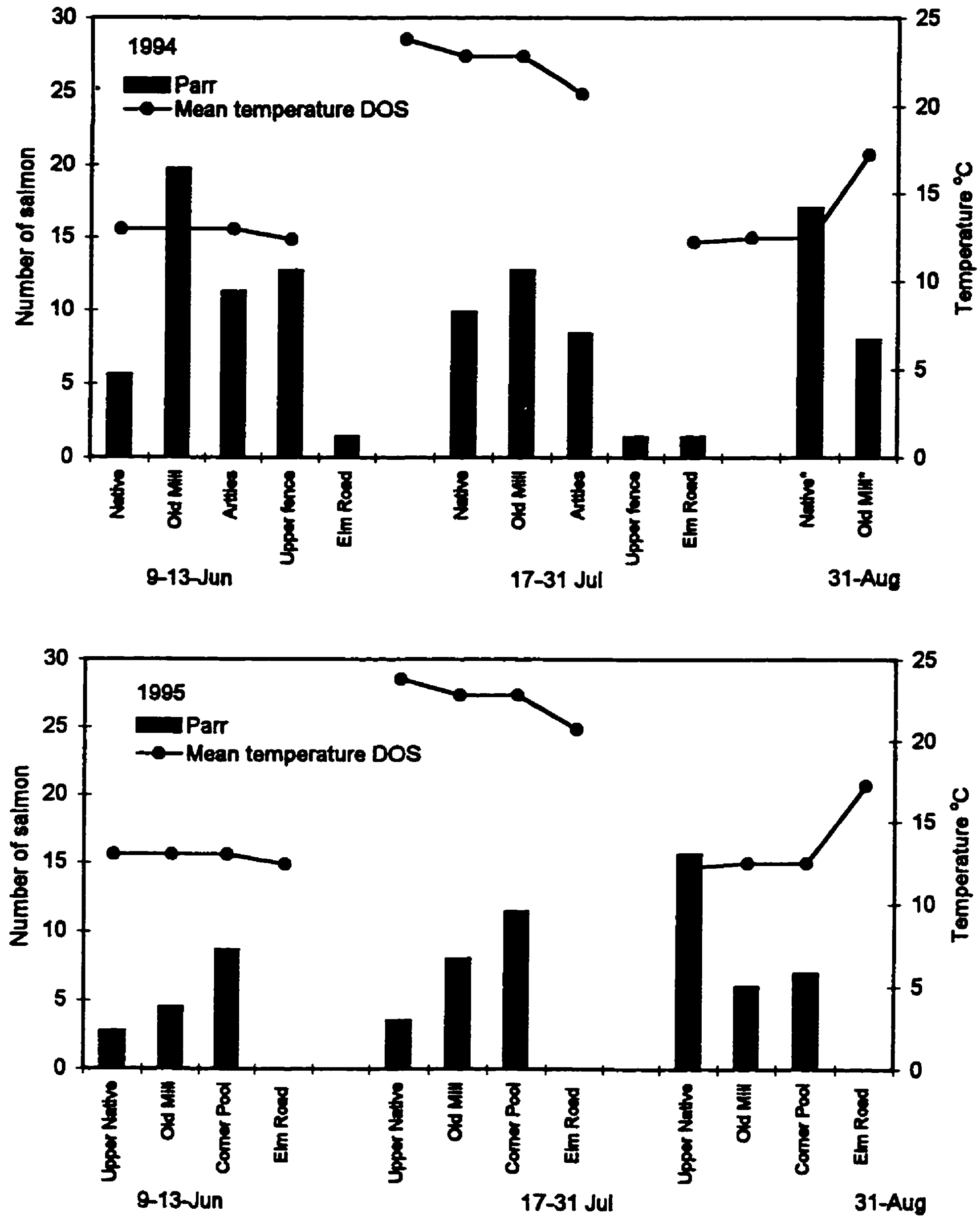


Figure 39. Atlantic salmon parr captured per $30m^{-1}$ stream length in electrofishing sites, Midgell River, 1994 -1995. DOS = day of sampling, *= closed electrofishing method.

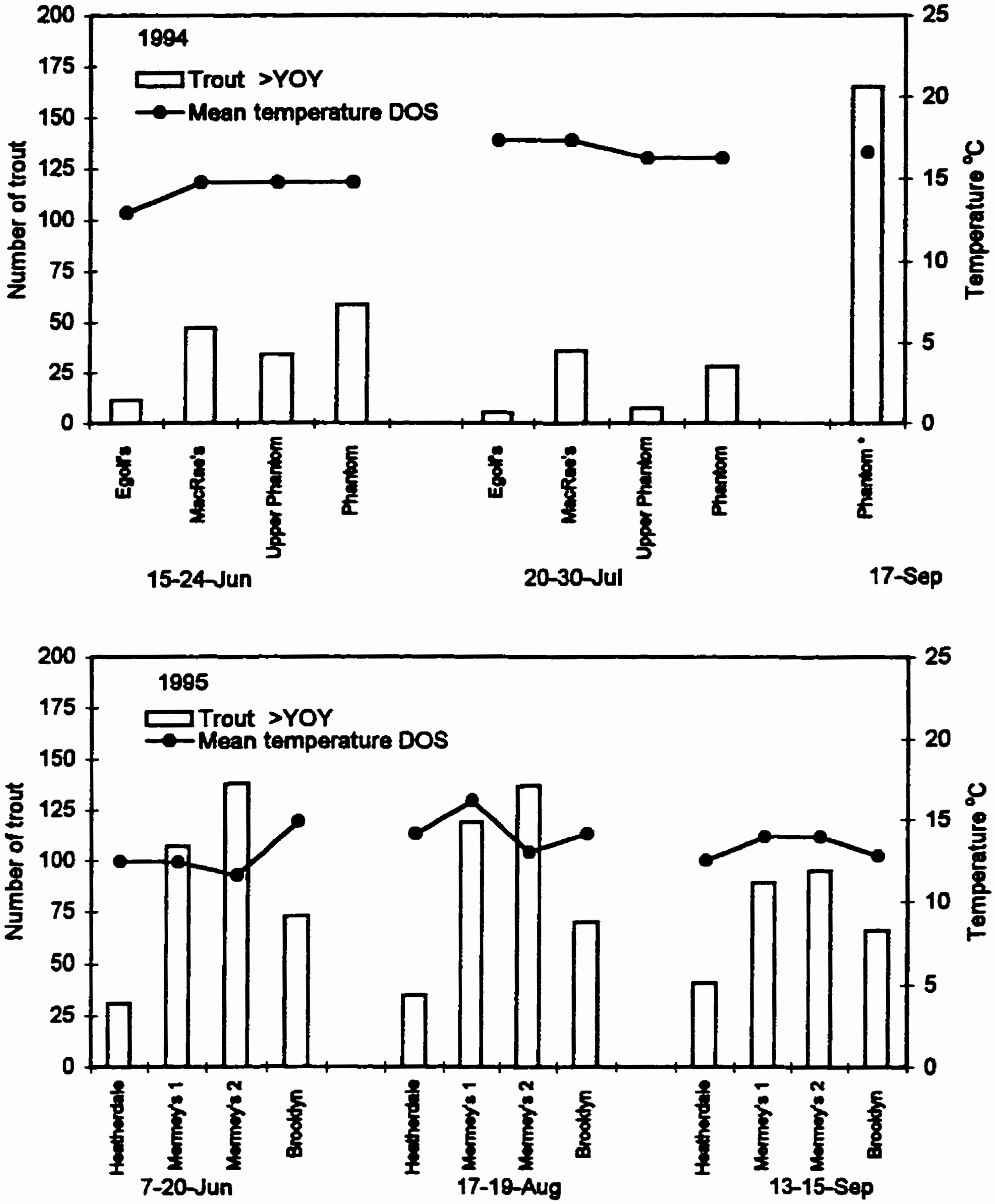


Figure 40. Brook trout captured per $30m^{-1}$ stream length in electrofishing sites, Valleyfield River, 1994 -1995. DOS = day of sampling, * = closed electrofishing meth

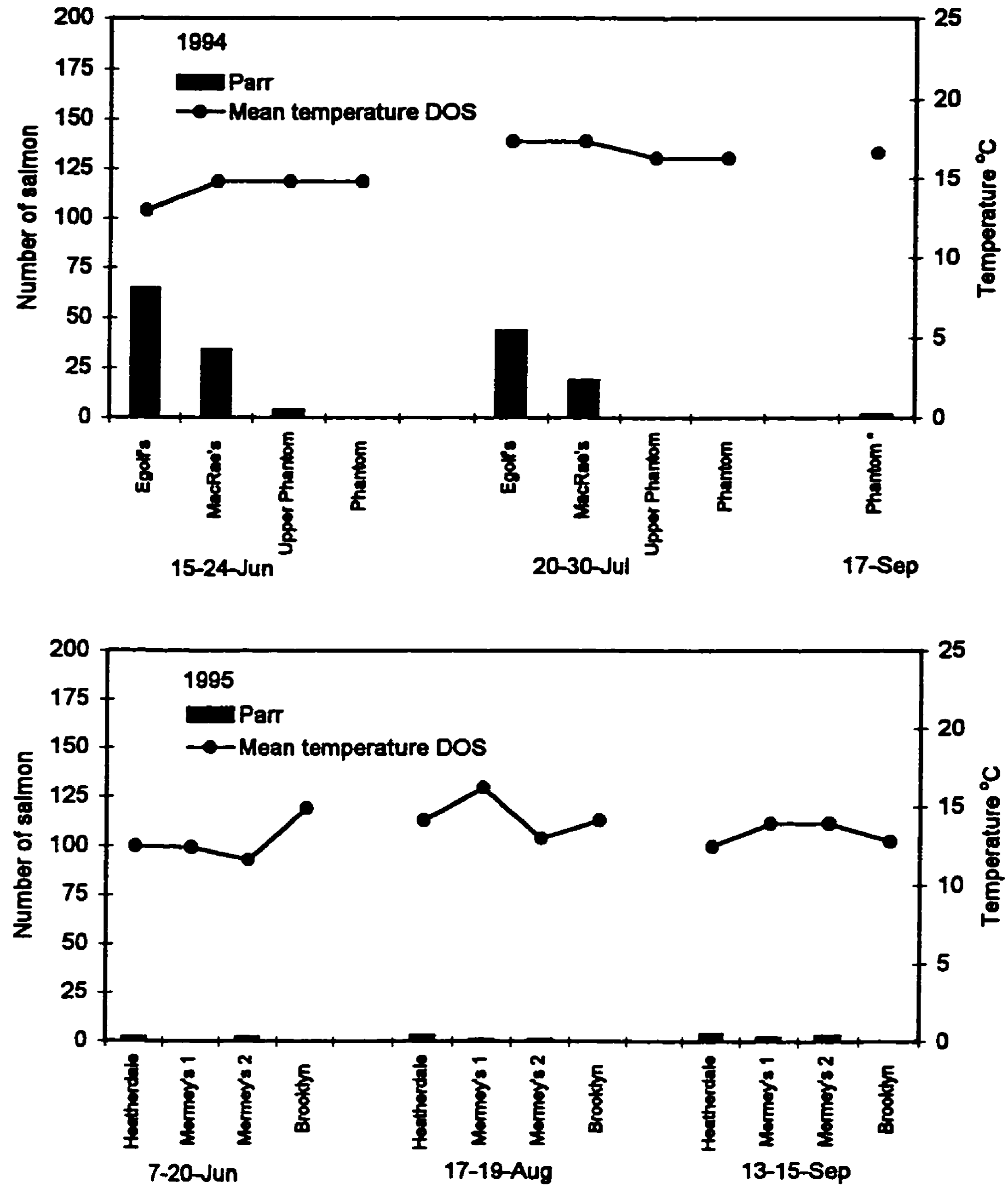


Figure 41. Atlantic salmon parr captured per $30m^{-1}$ stream length in electrofishing sites, Valleyfield River, 1994 -1995. DOS = day of sampling, * = closed electrofishing method.

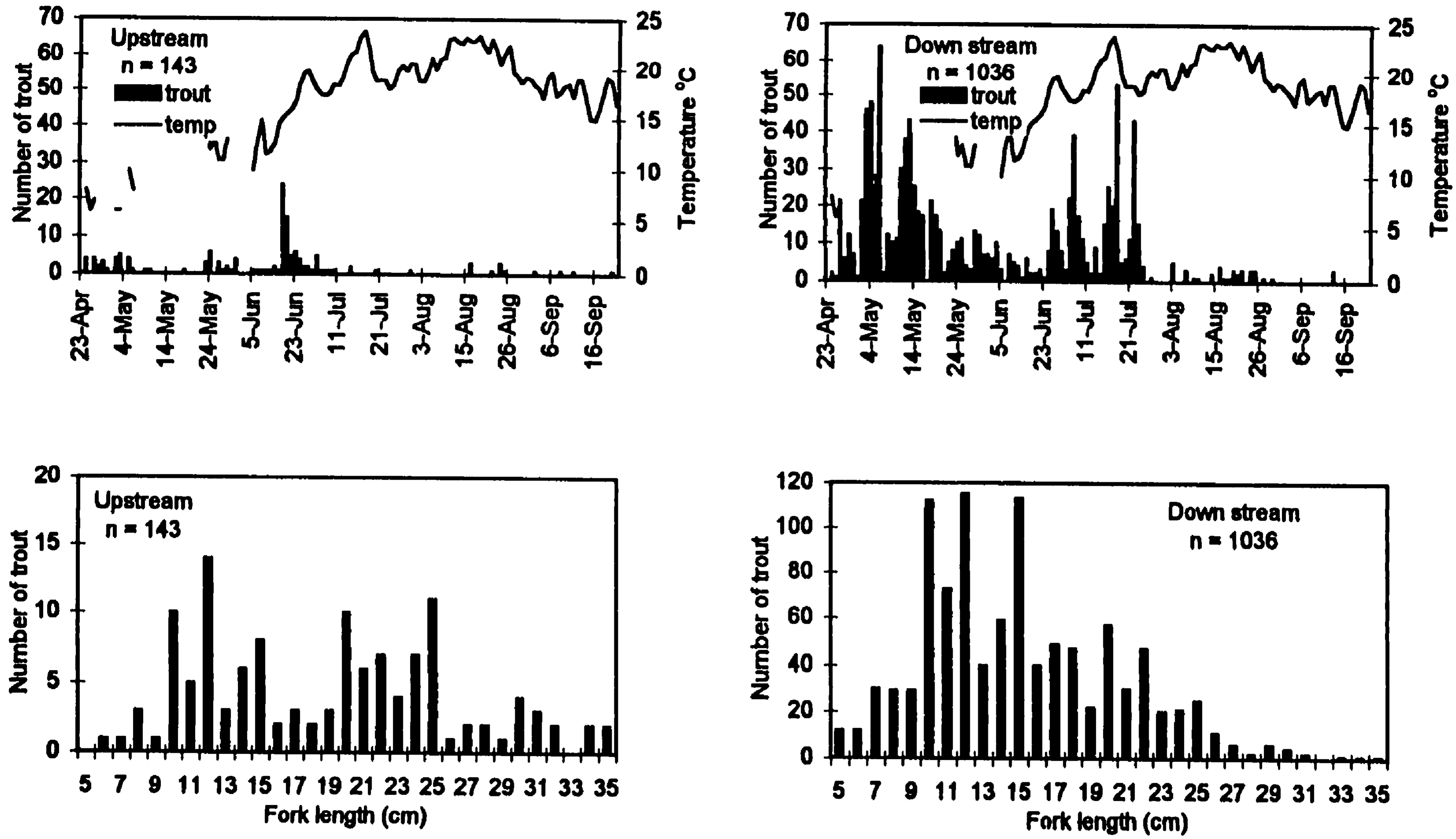


Figure 42. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream traps of the Native counting fence, Midgell River, 1994.

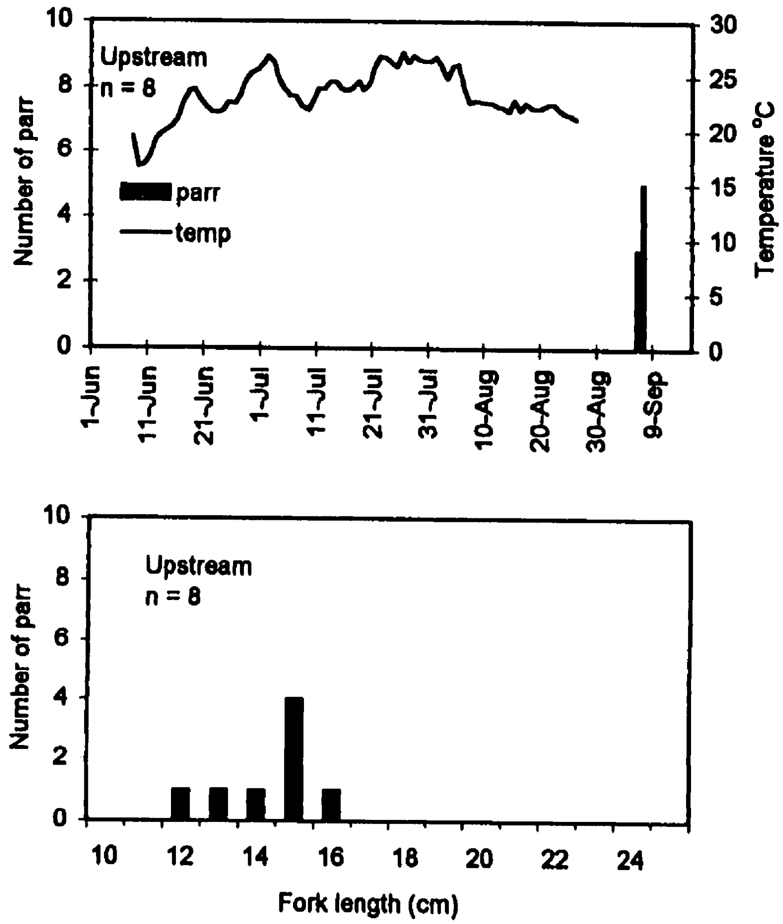


Figure 43. Water temperature, numbers and fork length frequency of trout captured in the MacDonald's Pond fishway trap, Midgell River, 1995.

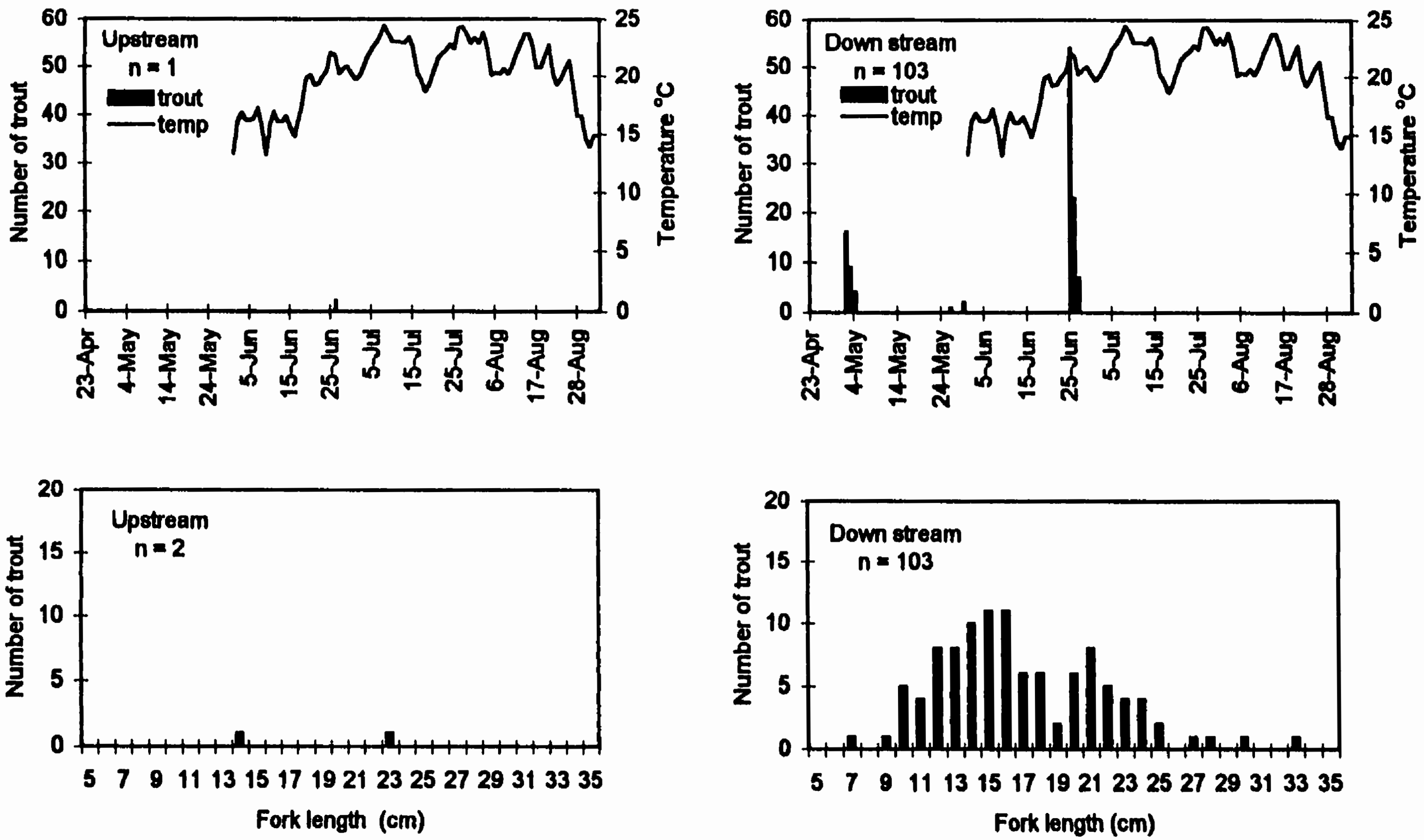


Figure 44. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream traps of the Native counting fence, Midgell River, 1995.

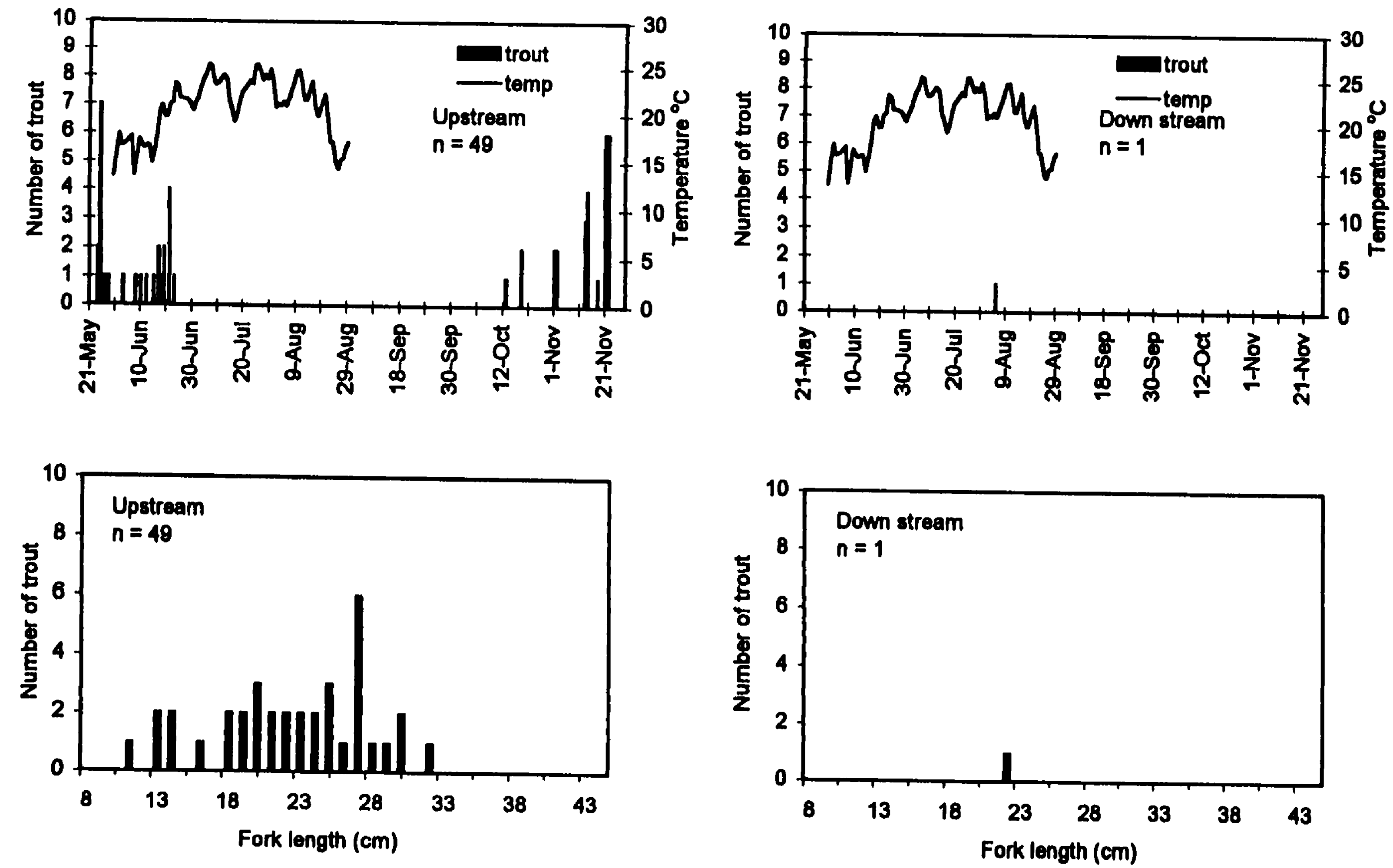


Figure 45. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream traps of the MacDonald's Pond fishway trap, Midgell River, 1995.

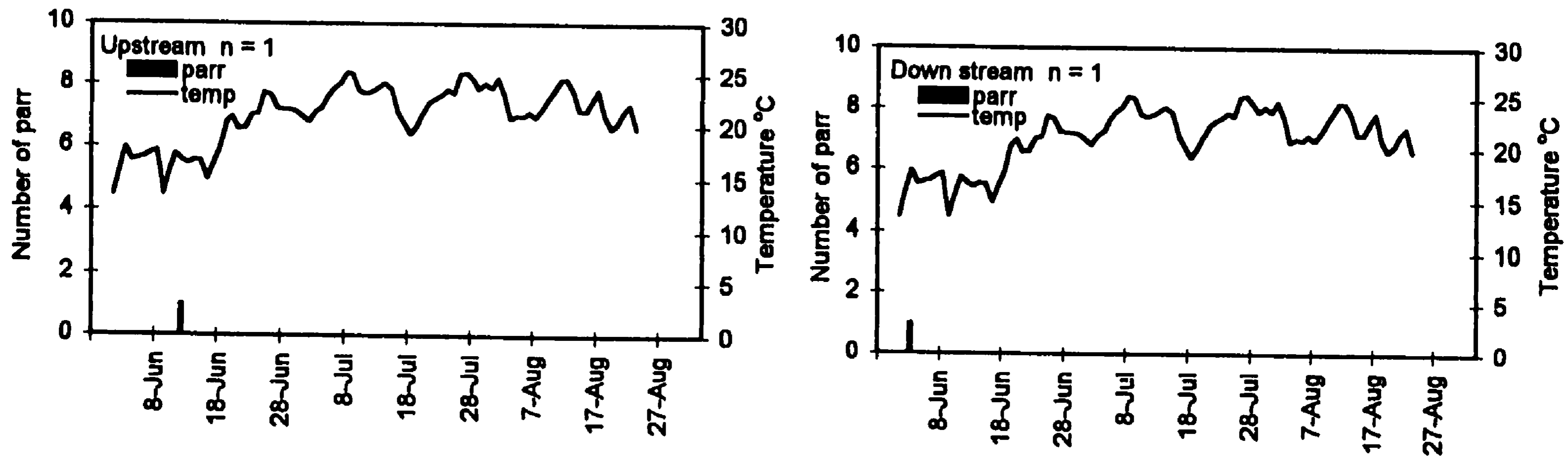


Figure 46. Water temperature, numbers of salmon parr captured in the upstream and downstream traps of the MacDonald's Pond fishway trap, Midgell River, 1995.

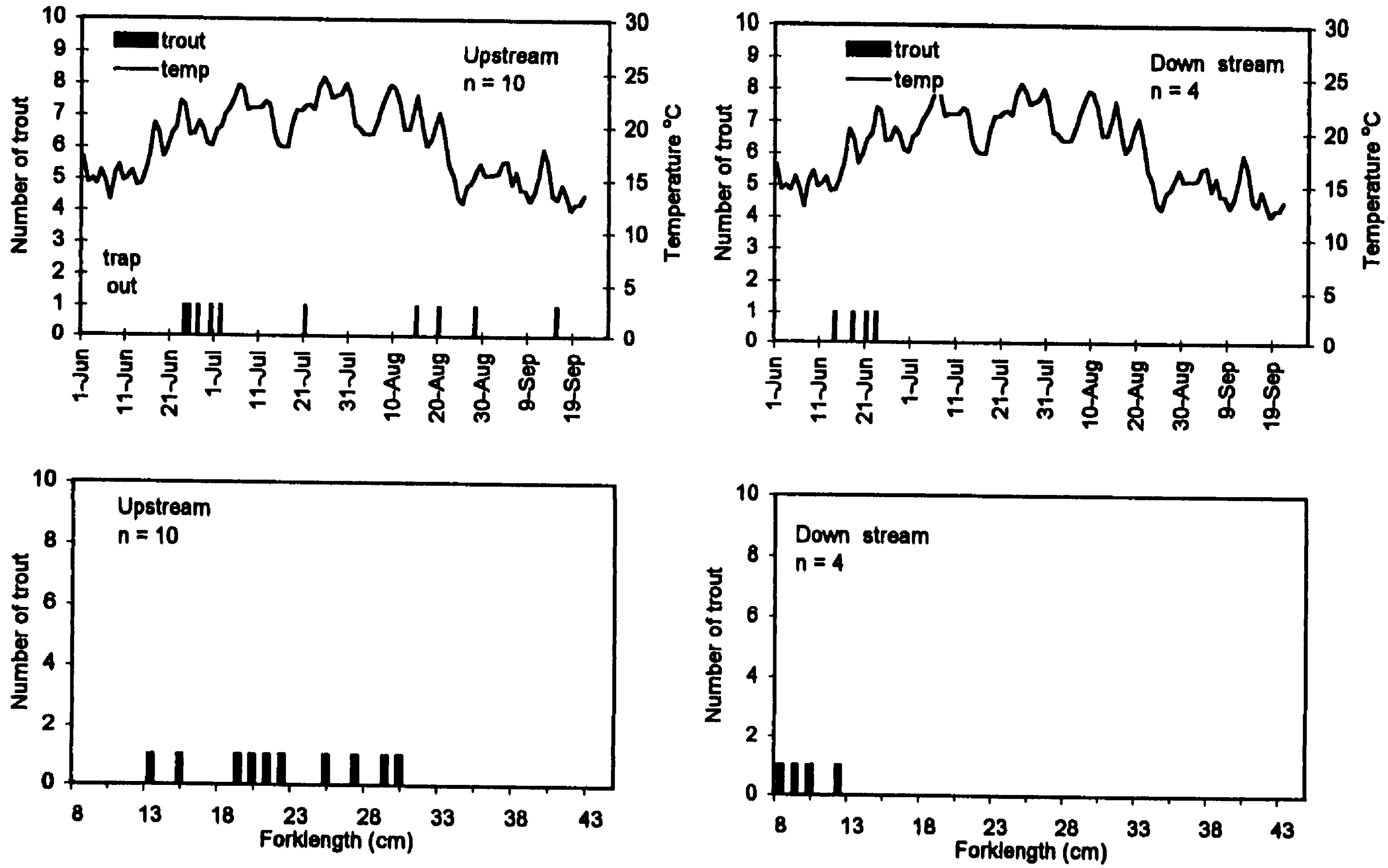
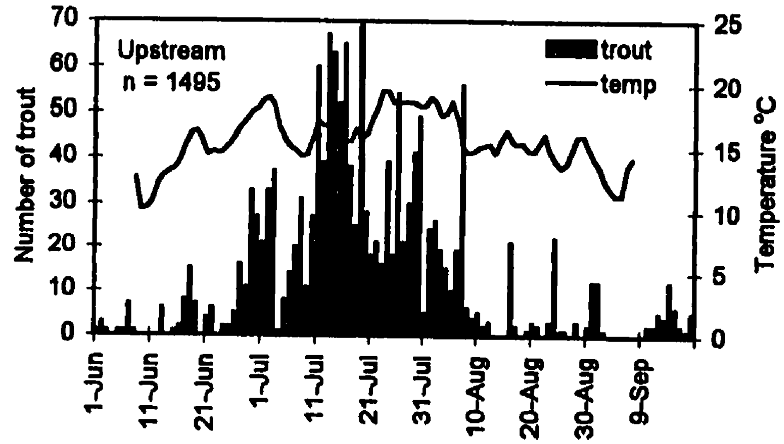


Figure 47. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream traps of the MacDonald's Pond headwater counting fence, Midgell River, 1995.



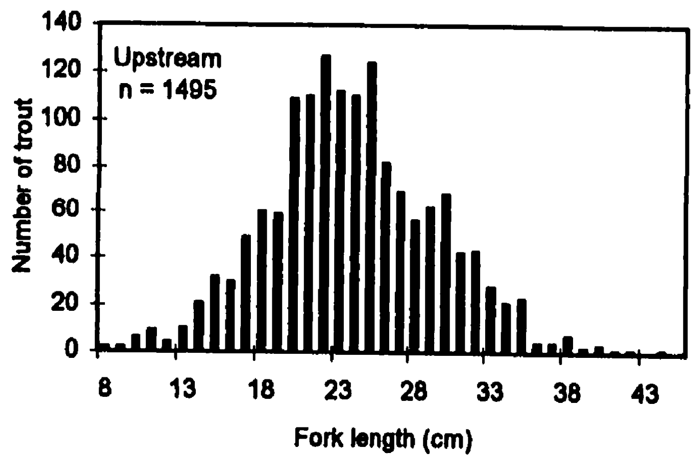


Figure 48. Water temperature, numbers and fork length frequency of trout captured in the Maritime Electric Pond fishway trap, Valleyfield River, 1994.

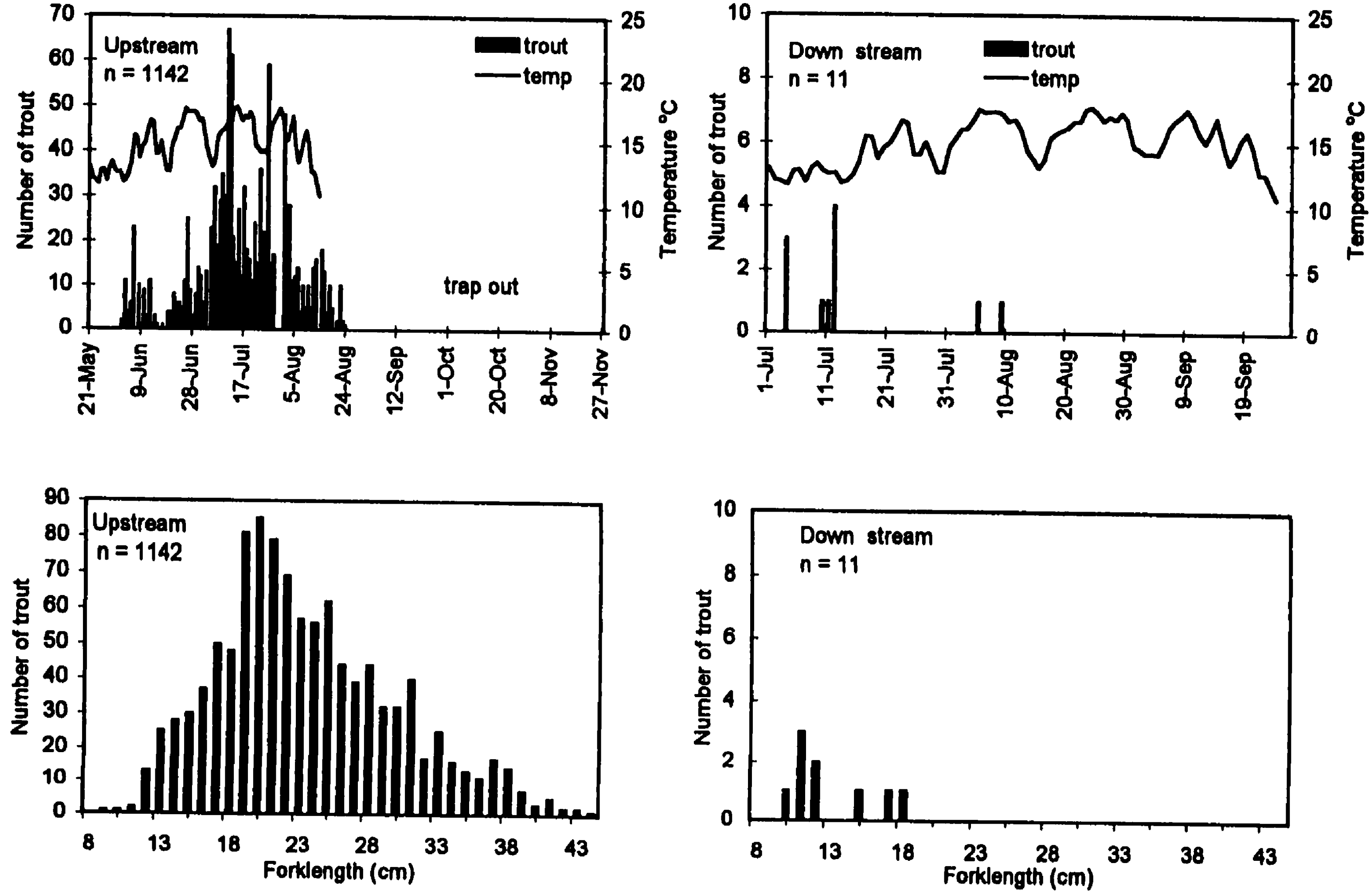


Figure 49. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream traps of the Maritime Electric Pond fishway trap, Valleyfield River, 1995.

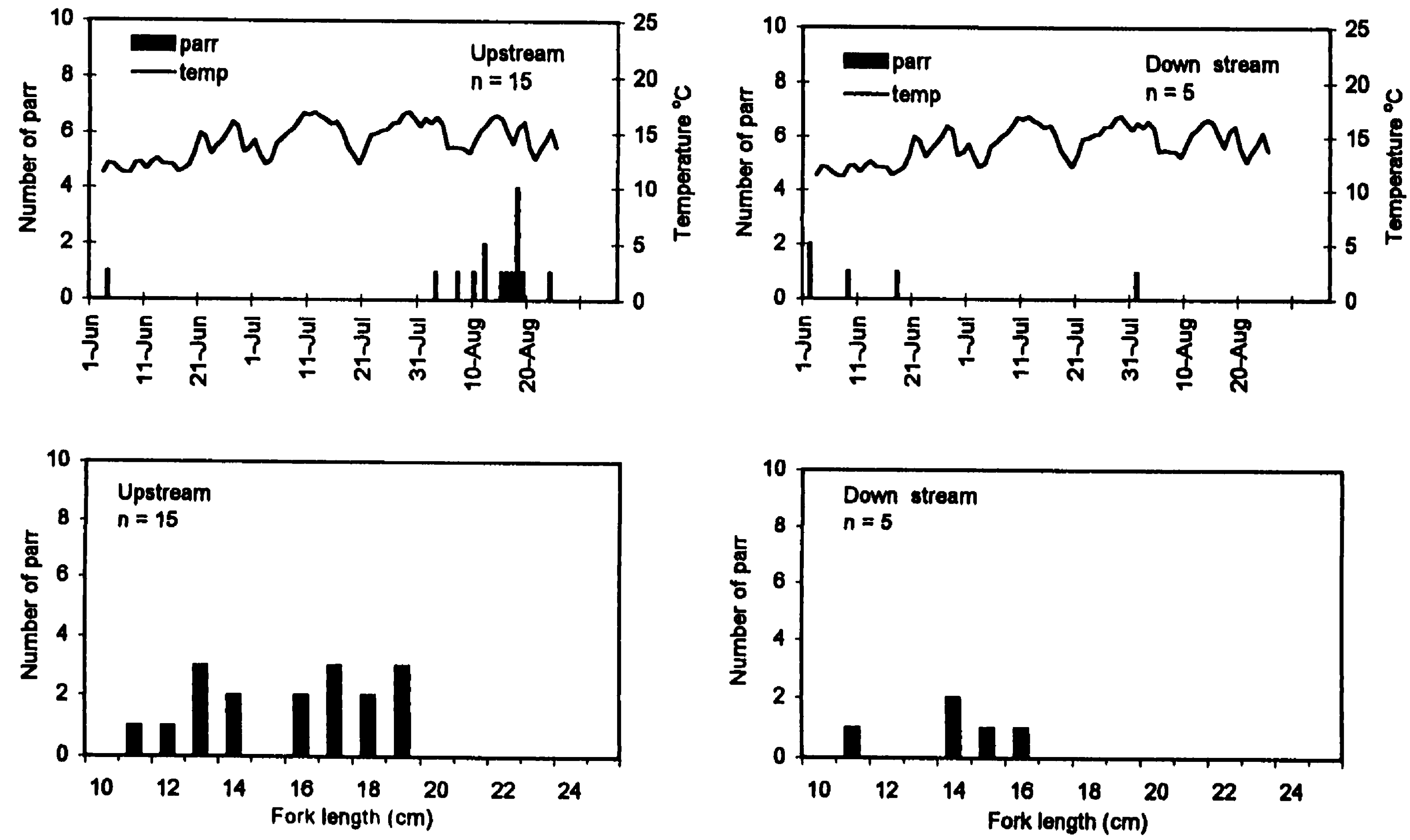


Figure 50. Water temperature, numbers and fork length frequency of salmon parr captured in the upstream and downstream traps of the Maritime Electric Pond fishway trap, Valleyfield River, 1995.

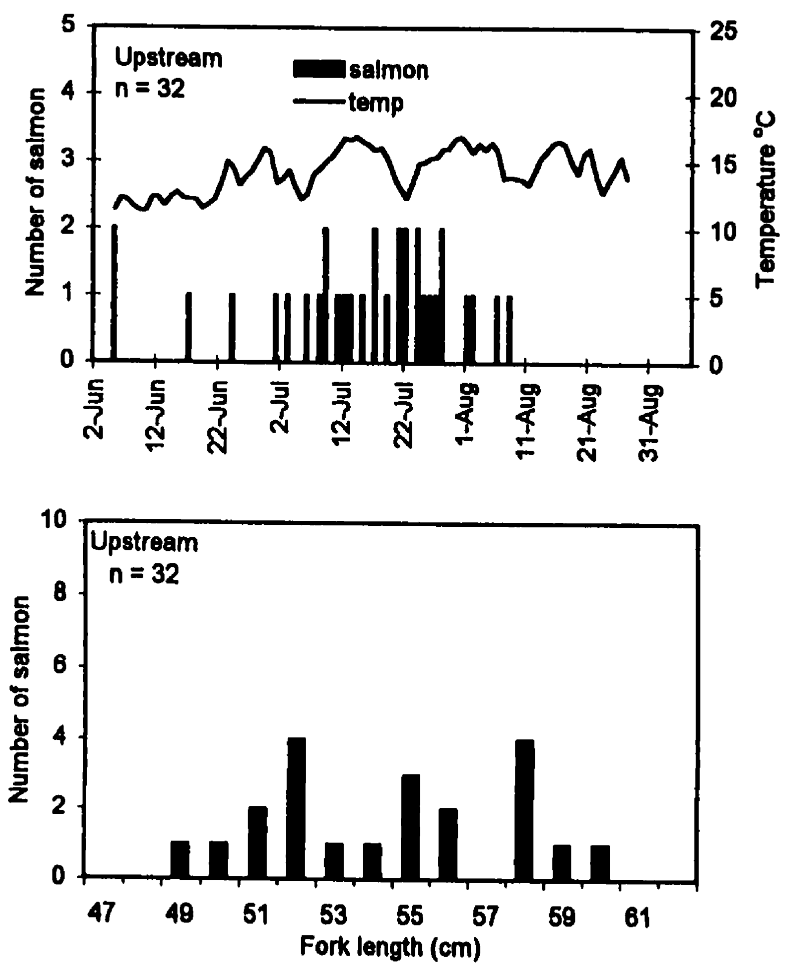


Figure 51. Water temperature, numbers and fork length frequency of adult salmon captured in the Maritime Electric Pond fishway trap, Valleyfield River, 1995.

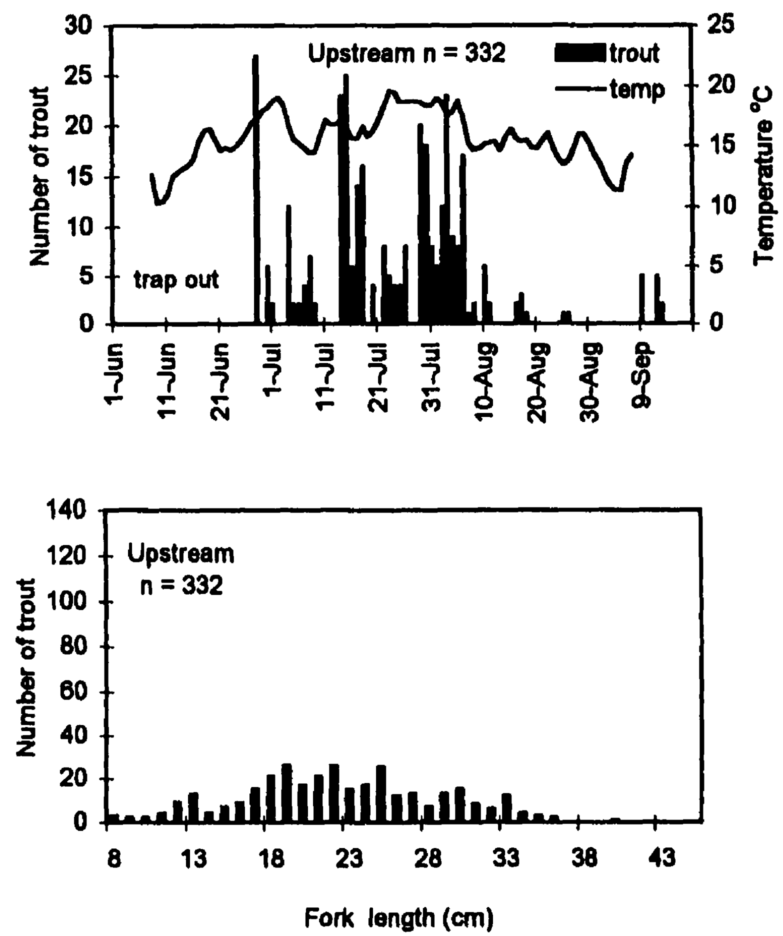


Figure 52. Water temperature, numbers and fork length frequency of trout captured in the Maritime Electric Pond headwater fence, Valleyfield River, 1994.

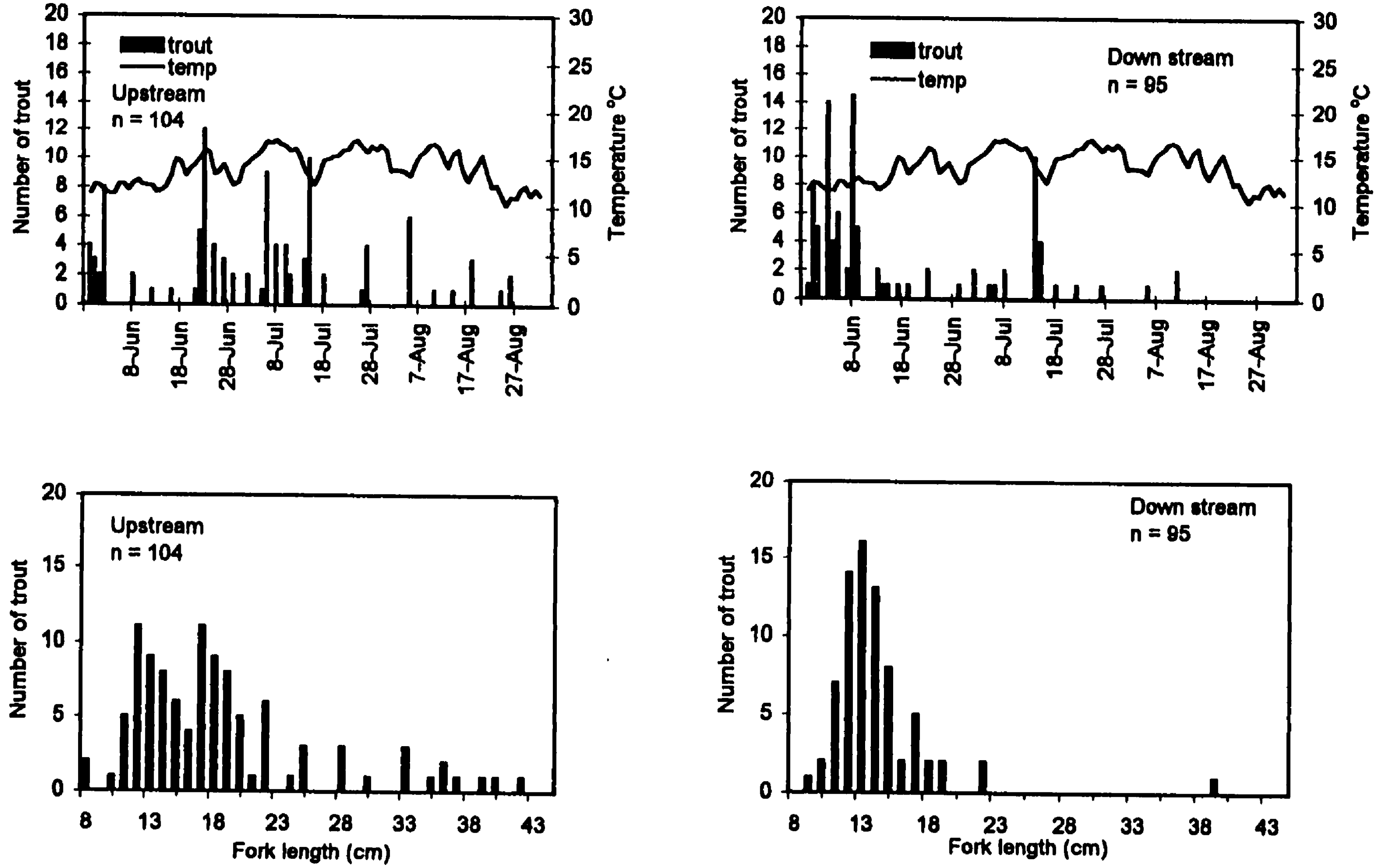


Figure 53. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream of the Maritime Electric Pond headwater fence, Valleyfield River, 1995.

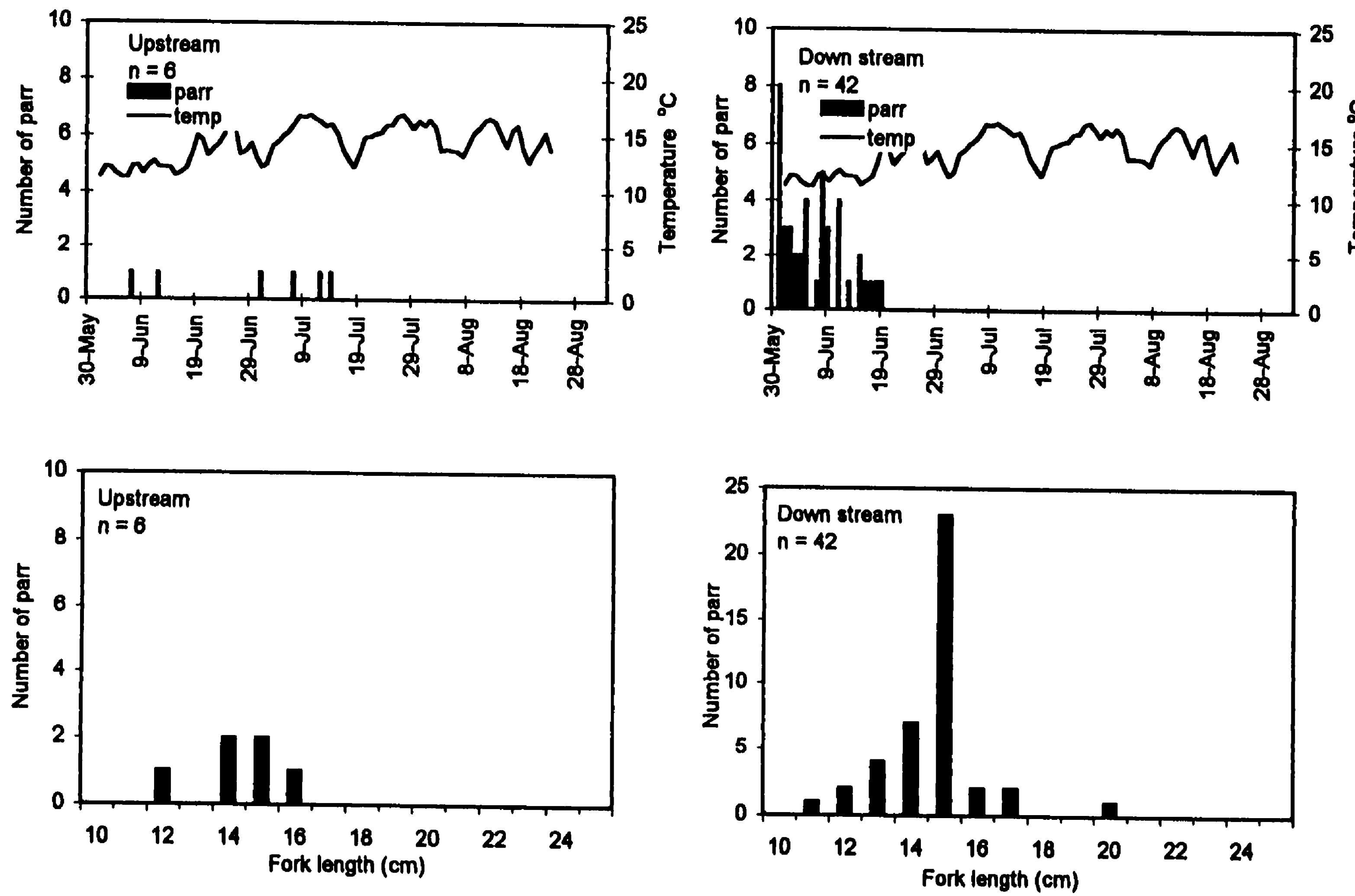


Figure 54. Water temperature, numbers and fork length frequency of salmon parr captured in the upstream and downstream traps of the Maritime Electric Pond headwater fence, Valleyfield River, 1995.

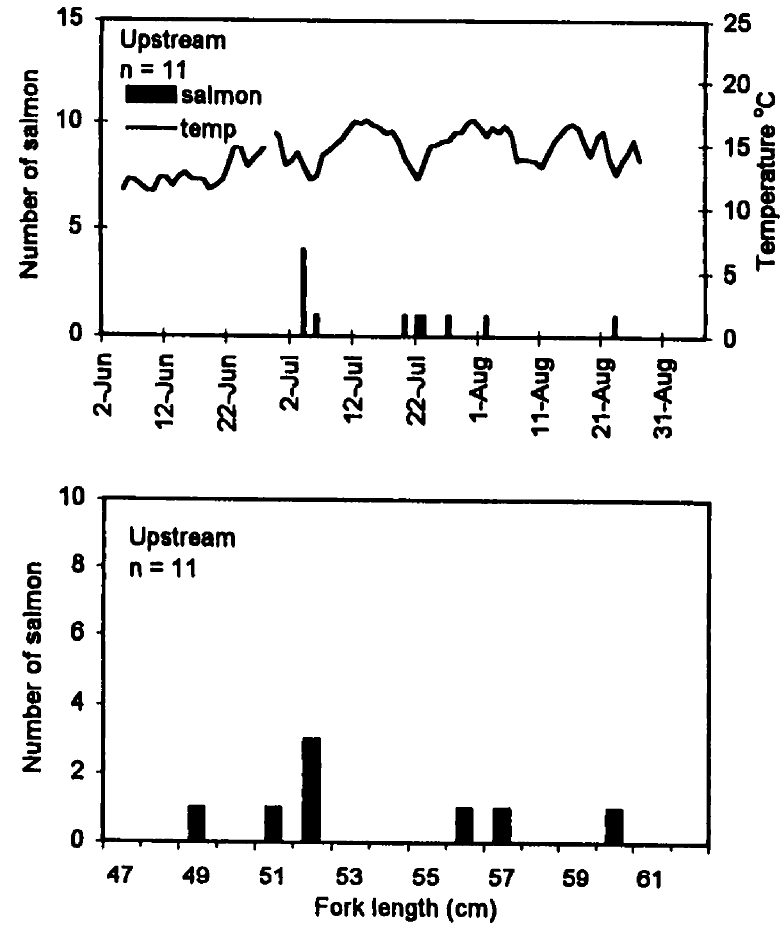


Figure 55. Water temperature, numbers and fork length frequency of adult salmon captured in the Maritime Electric Pond headwater fence, Valleyfield River, 1995.

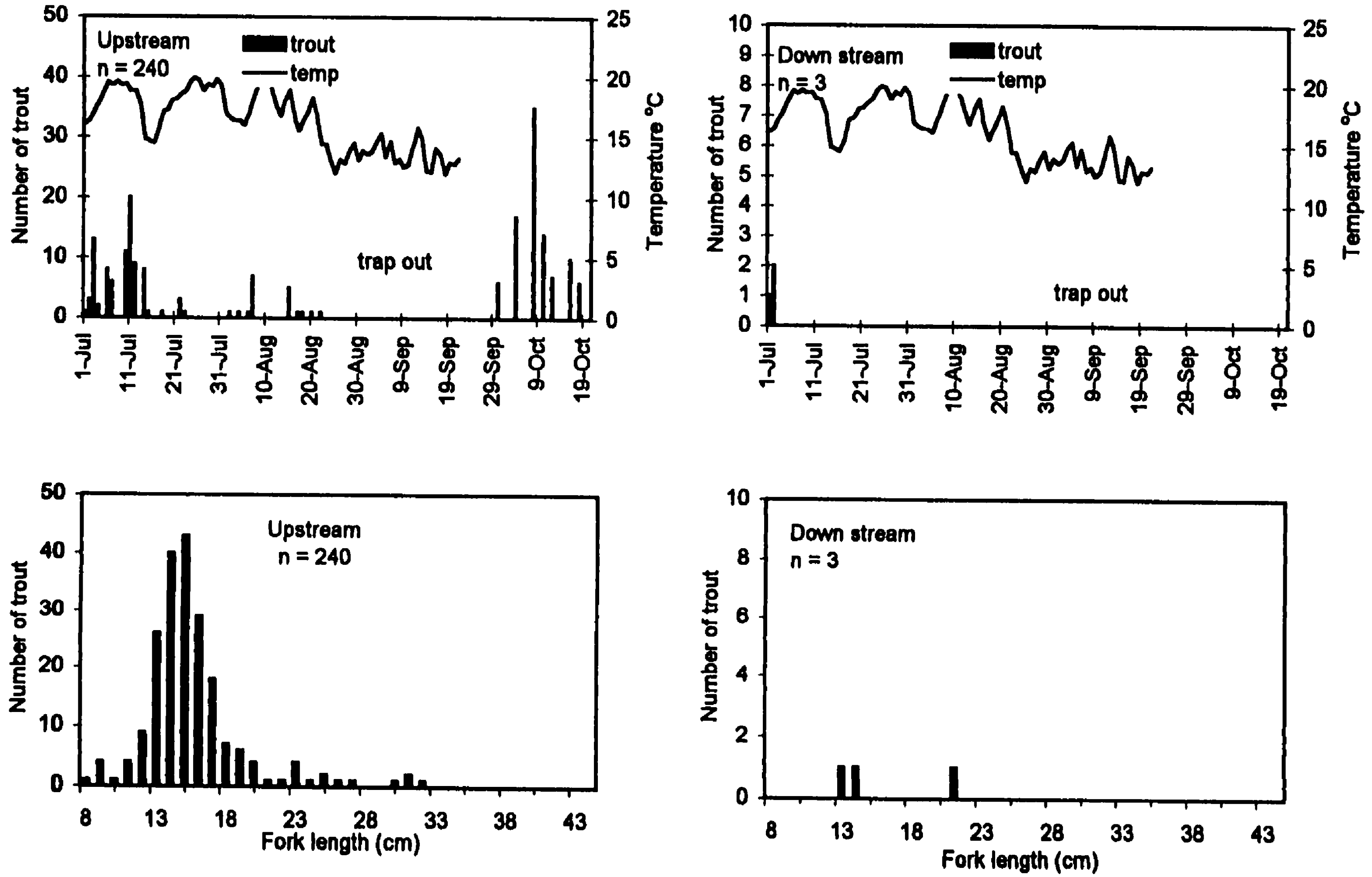


Figure 56. Water temperature, numbers and fork length frequency of trout captured in the upstream and downstream of the Egolf's Pond fishway trap, Valleyfield River, 1995.

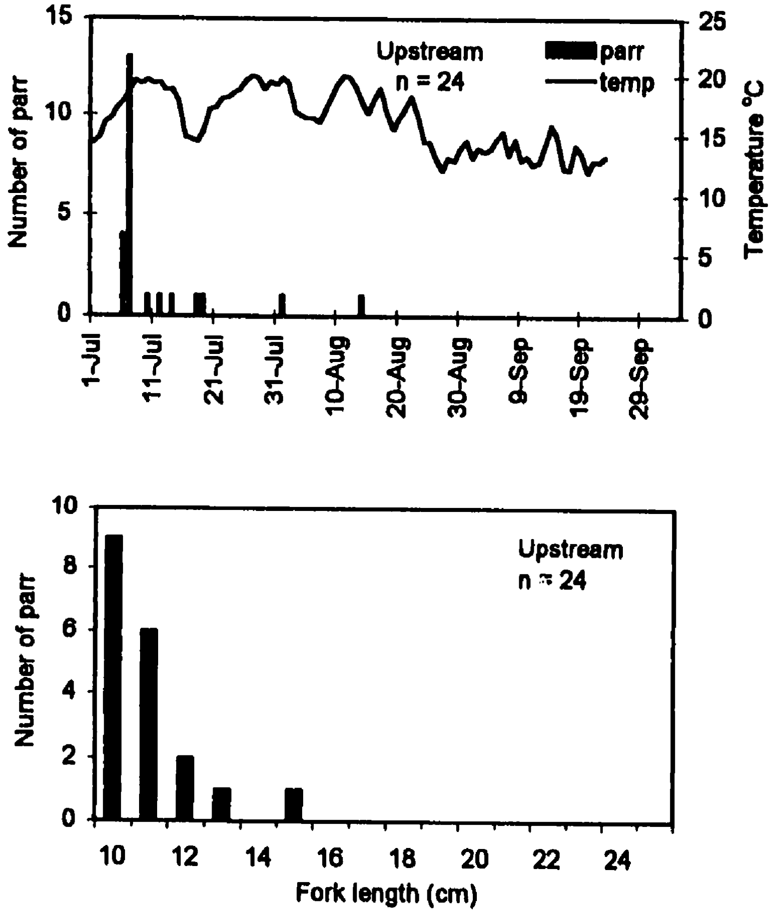


Figure 57. Water temperature, numbers and fork length frequency of salmon parr captured in the Egolf's Pond fishway trap, Valleyfield River, 1995.

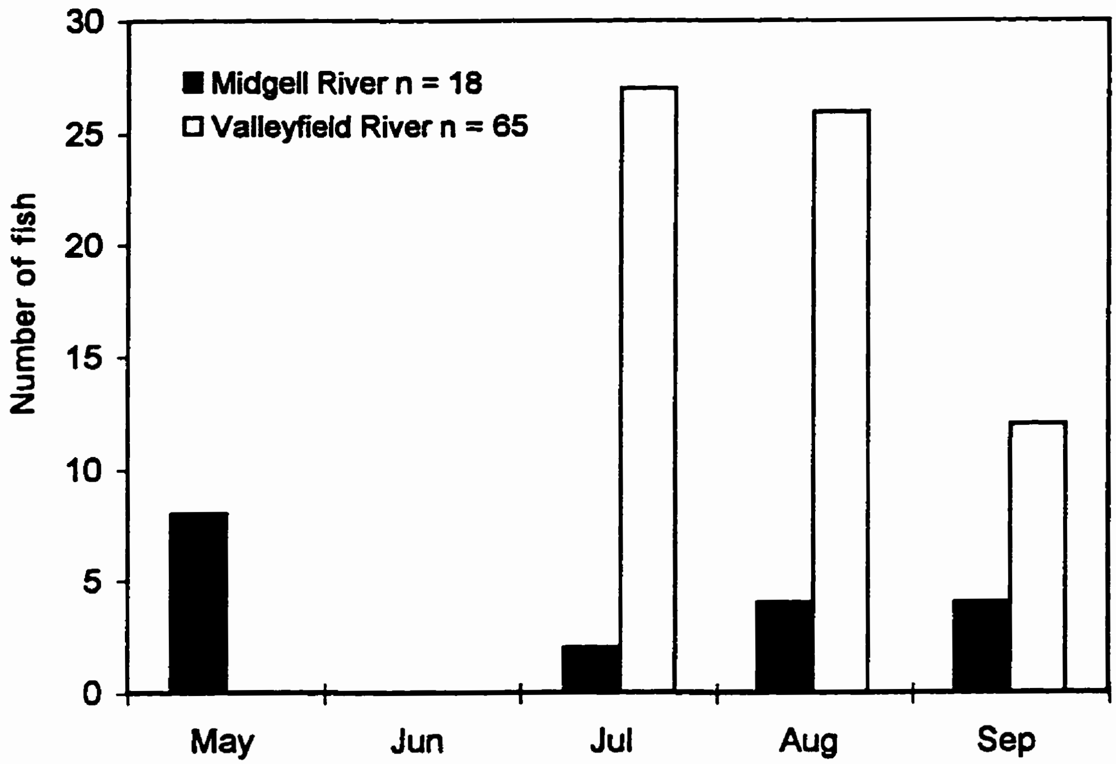


Figure 58. Tagged trout captured by anglers each month in the Midgell River and Valleyfield River, 1995.

Appendix 1. Juvenile salmon stocked in Midgell River and Valleyfield River, 1994 - 1995.

River	Year	Site	YOY	1+ parr	1+ smolts	2+ parr	2+ smolts
Midgell	1993	Native	20,000				
	1995	Downstream from M Pond		9,370			
Valleyfield	1994	Sutherland's			980		
		Downstream from Egolf's Pond			2,895		
		M E Pond			770		
		Browns Creek			1,250		
		M E Pond					1,980
		n/a		8,000			
		Phantom Lane	20,000				
	1995	Brown's Creek			2,100		
		MacRae's Bridge			2,865		
		M E Pond			1,255		
		Downstream from Egolf's Pond		11,585			
		M E Pond					3,940
		M E Pond				1,330	

n/a = not available
M Pond = MacDonald's Pond
ME Pond = Maritime Electric Pond

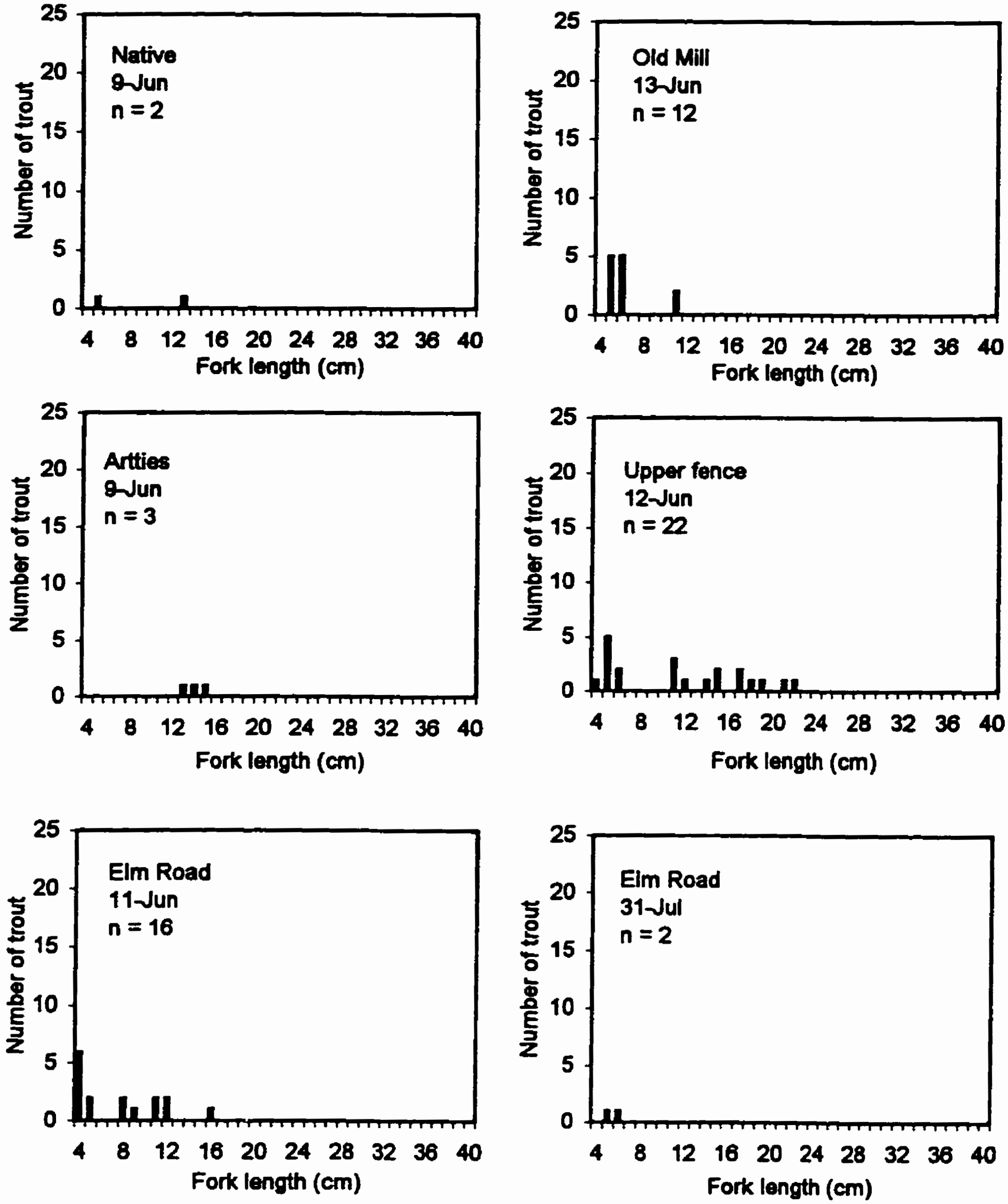
Appendix 2. Location and duration of operation of fish counting facilities on the Midgell River and Valleyfield River, 1994-1995.

River	Year	Location	Operational dates
Midgell	1994	Head of tide	24 April - 24 Aug
		M Pond fishway	16 Jun - 7 Sep
		M Pond inflow	16 Jun - 26 Aug
	1995	Head of tide	2 - 4 May, 26 - 29 May, 26 - 27 Jun
		M Pond fishway	24 May - 22 Nov
		M Pond inflow	14 Jun - 18 Sep
Valleyfield	1994	M E Pond fishway	1 Jun - 18 Sep
		M E Pond inflow	17 Jun - 18 Sep
	1995	M E Pond fishway	1 Jun - 25 Aug
		M E Pond inflow	30 May - 27 Aug
		Egolf's Pond fishway	1 Jul - 23 Aug, 29 Sep - 30 Oct

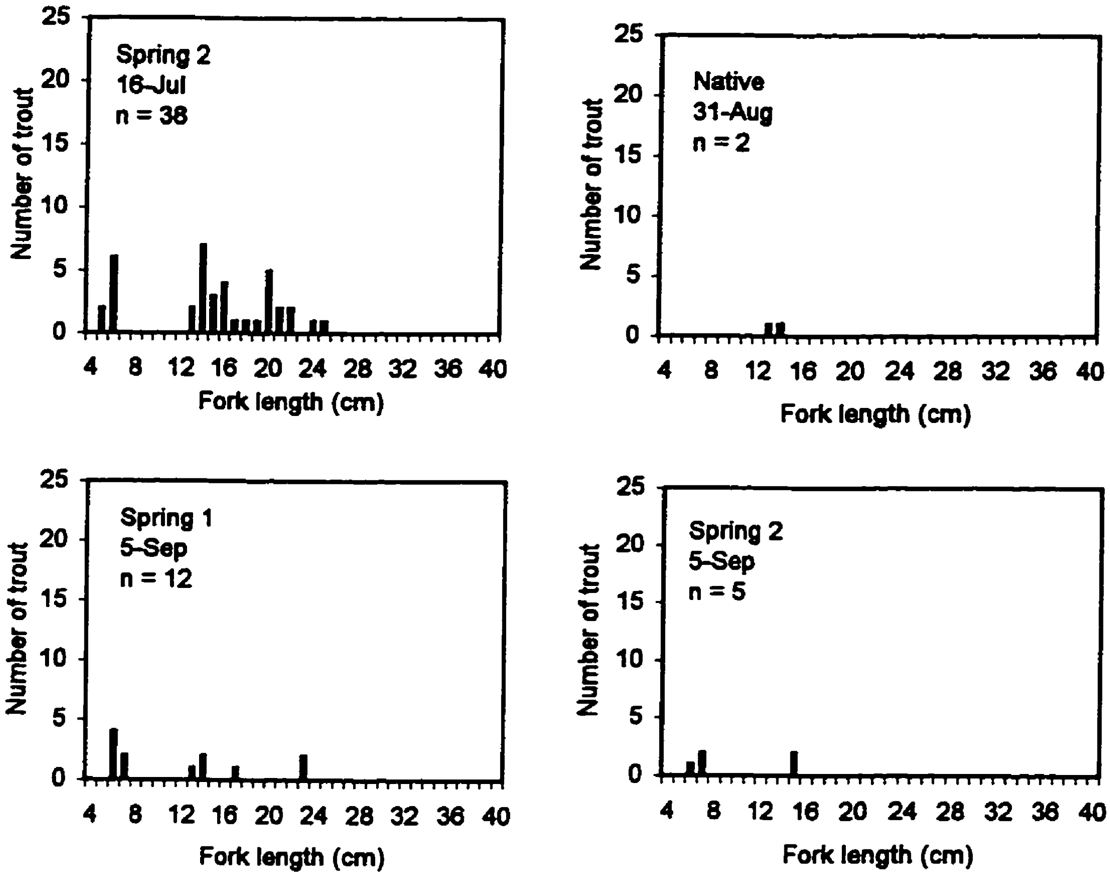
Appendix 3. Regression analysis of various sites used to estimate missing thermograph data, Midgell River and Valleyfield River, 1994 - 1995.

Year	Site w/out data	Site w/ data	Inclusive dates in regression	Estimated dates from regression	Daily temp	Regression equation	r^2	P value
1994	M surface	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.90x + 3.7	0.953	<0.001
1994	M surface	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 1.0x + 1.0	0.936	<0.001
1994	M bottom	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.71x + 5.8	0.818	<0.001
1994	M bottom	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.72x + 4.7	0.638	<0.001
1994	M mid-dep	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.88x + 3.0	0.906	<0.001
1994	M mid-dep	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.85x + 2.4	0.792	<0.001
1994	Old Mill	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 1.0x - 1.3	0.986	<0.001
1994	Old Mill	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 1.3x + 6.4	0.959	<0.001
1994	Native fence	Artties	Jul 1 - Aug 30	Jun 8 - Jun 31	ave	y = 1.0x - 3.3	0.926	<0.001
1994	Native fence	Artties	Jul 1 - Aug 30	Jun 8 - Jun 31	max	y = 1.0x - 2.6	0.873	<0.001
1994	ME inlet	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.73x - 0.57	0.914	<0.001
1994	ME inlet	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.79x - 0.31	0.788	<0.001
1994	ME bottom	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.69x - 0.44	0.850	<0.001
1994	ME bottom	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.66x - 0.49	0.711	<0.001
1994	ME surface	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.77x - 0.68	0.922	<0.001
1994	ME surface	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.86x - 3.0	0.911	<0.001
1994	ME mid-dep	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.75x - 1.2	0.834	<0.001
1994	ME mid-dep	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.72x - 1.3	0.629	<0.001
1994	ME outflow	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	ave	y = 0.77x - 0.81	0.834	<0.001
1994	ME outflow	Artties	Jul 19 - Aug 30	Jun 8 - Jul 18	max	y = 0.76x - 0.65	0.819	<0.001
1995	M surface	Old Mill	Jul 1 - Aug 30	Jun 8 - Jun 31	ave	y = 1.1x - 0.37	0.983	<0.001
1995	M surface	Old Mill	Jul 1 - Aug 30	Jun 8 - Jun 31	max	y = 1.1x - 0.73	0.955	<0.001
1995	M bottom	Old Mill	Jul 1 - Aug 30	Jun 8 - Jun 31	ave	y = 1.7x - 12.7	0.995	<0.001
1995	M bottom	Old Mill	Jul 1 - Aug 30	Jun 8 - Jun 31	max	y = 2.2x - 22.0	0.988	<0.001

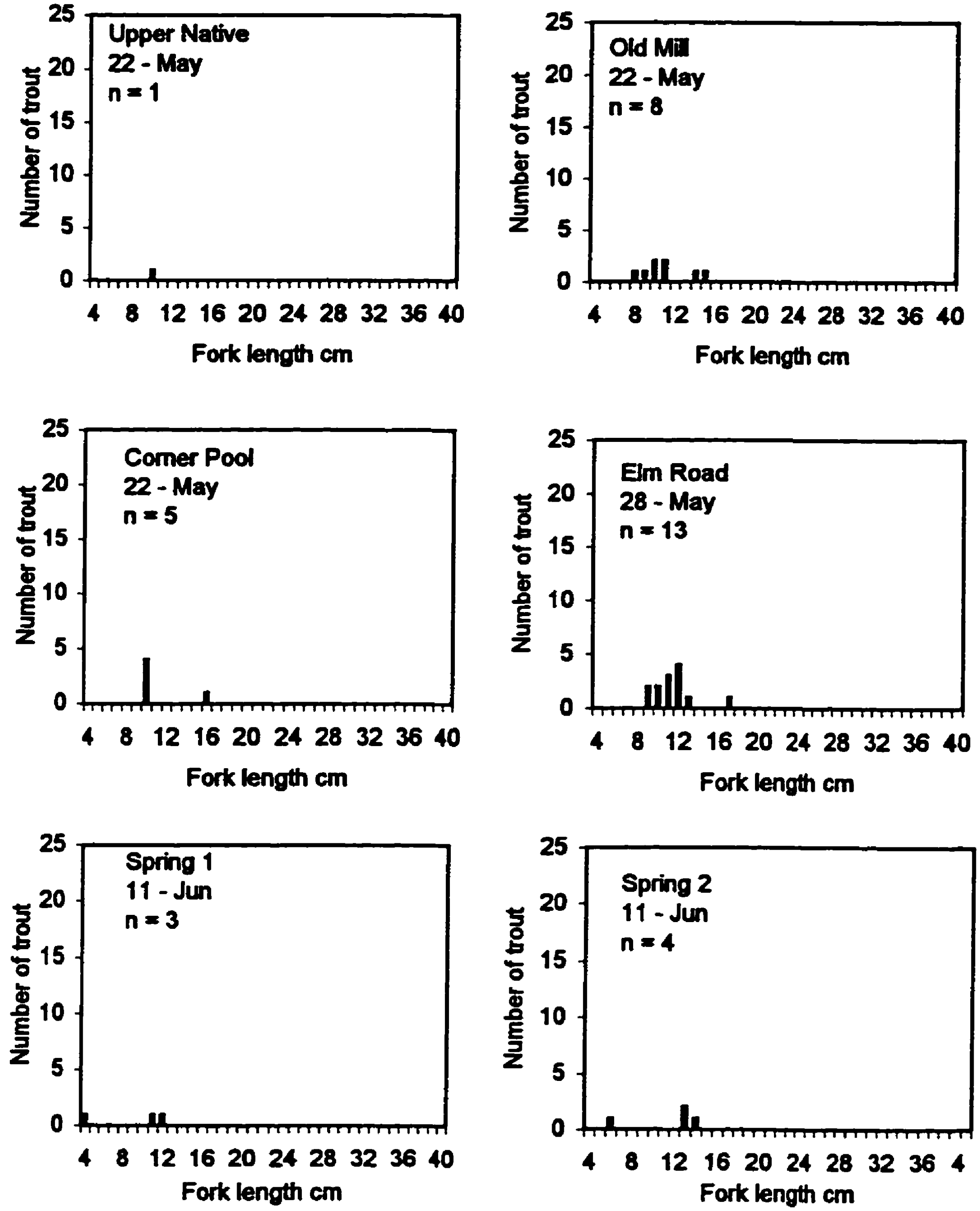
*M= MacDonald's Pond, OMS = Old mill site, ME = Maritime Electric Pond.



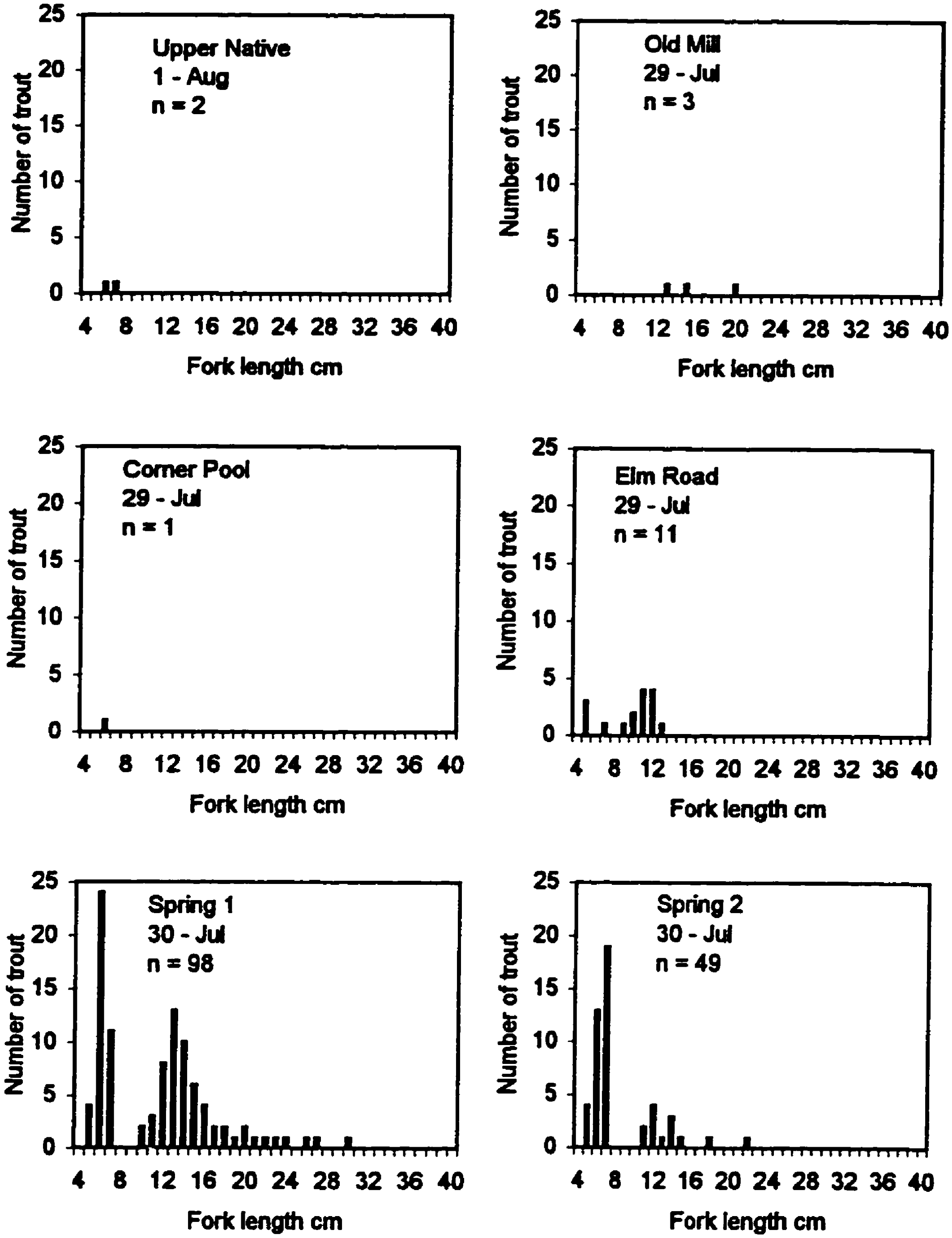
Appendix 4. Fork length frequency distributions of brook trout captured in riverine electrofishing sites, Midgell River, 1994.



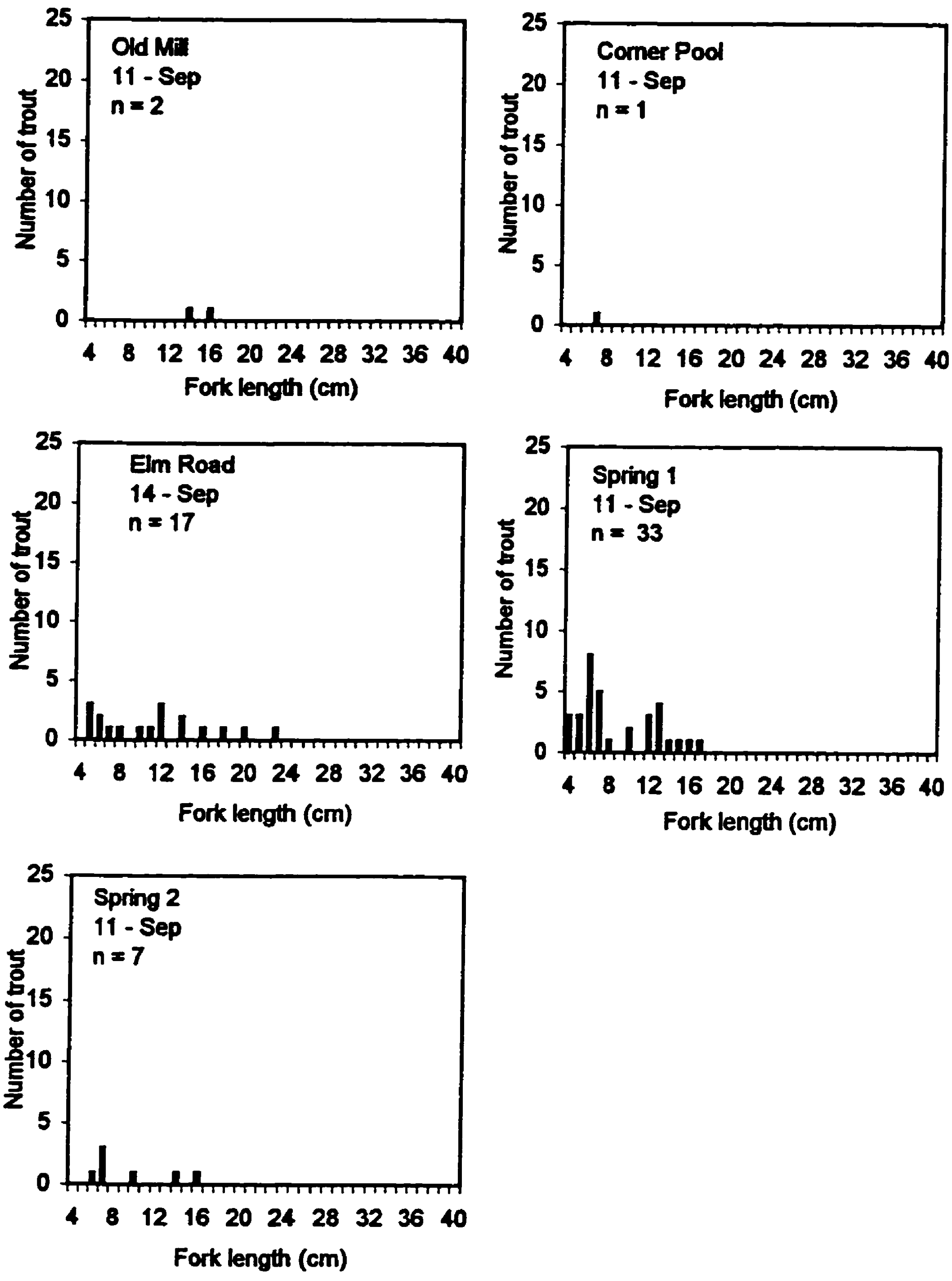
Appendix 4. continued.



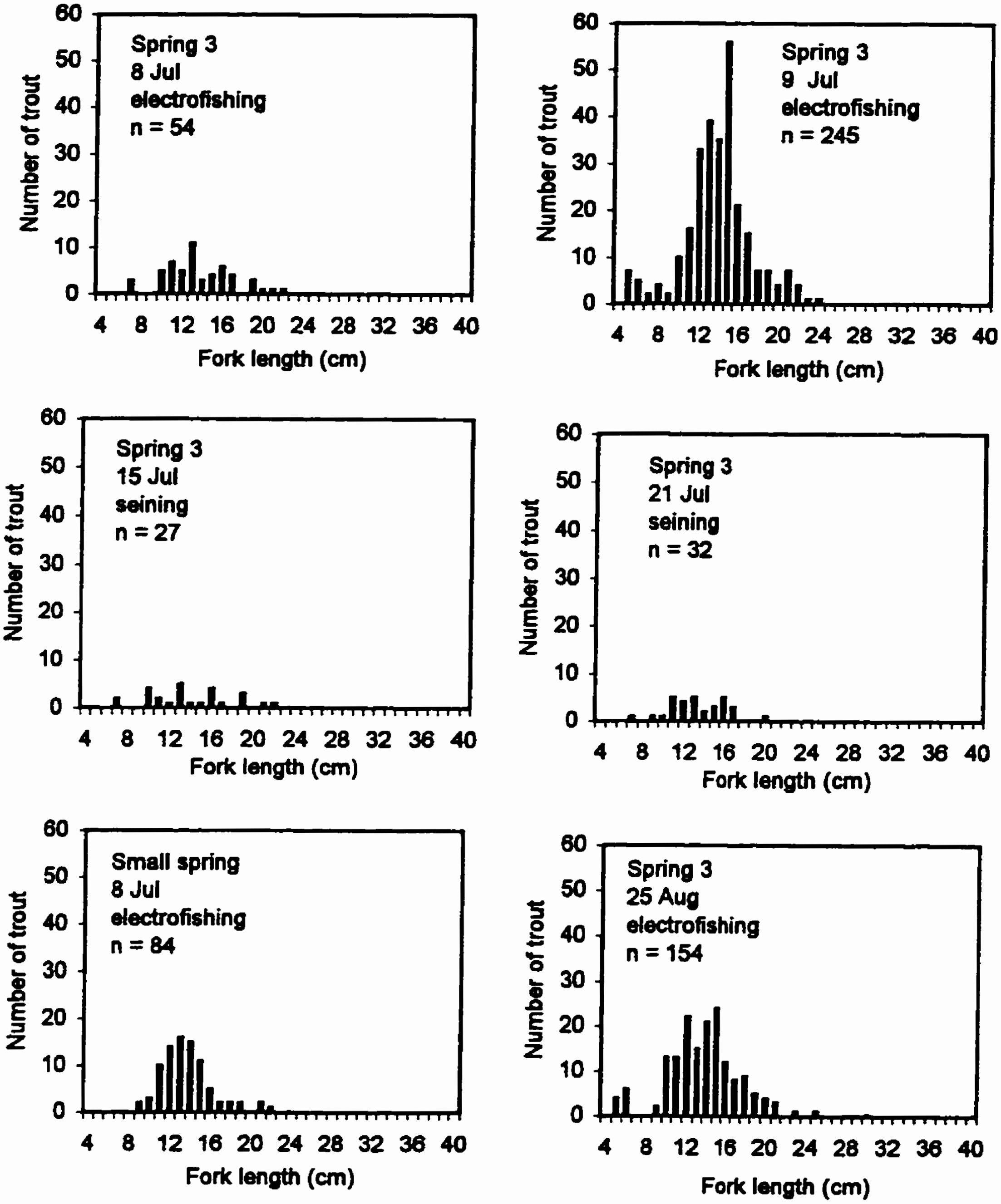
Appendix 5. Fork length frequency distributions of brook trout captured in riverine electrofishing sites, Midgell River, 1995.



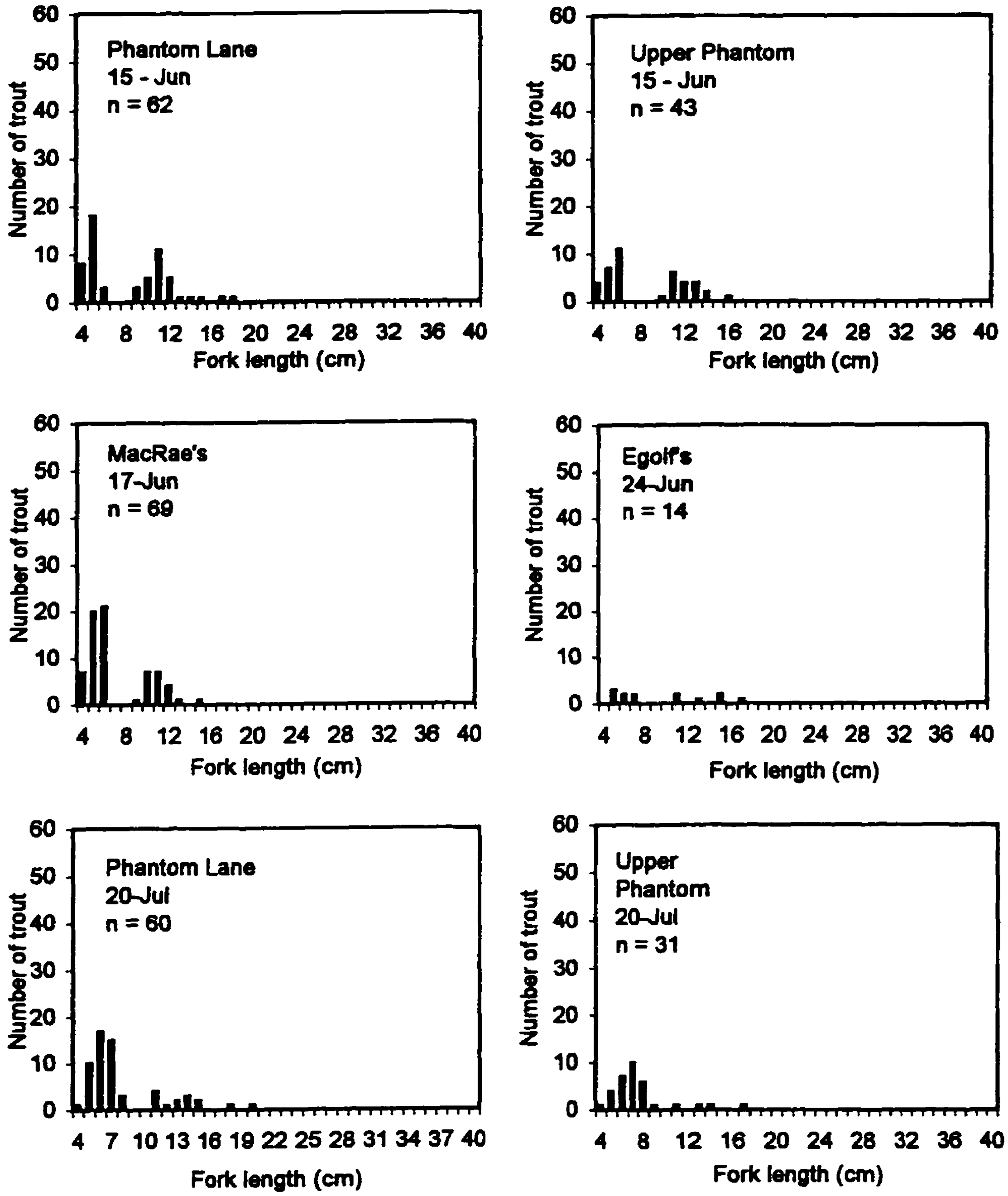
Appendix 5. continued



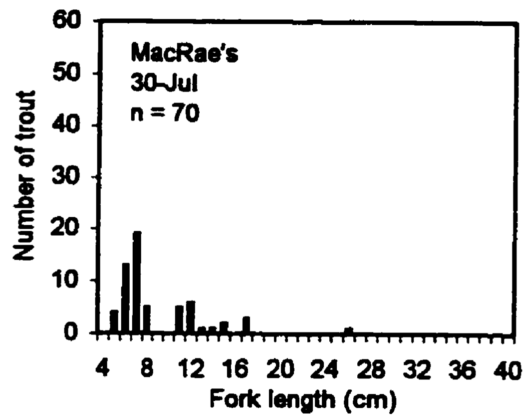
Appendix 5. continued

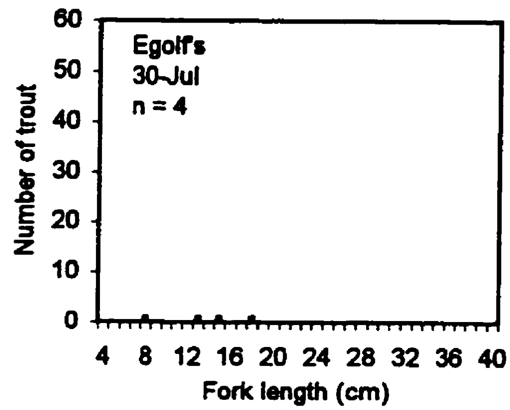


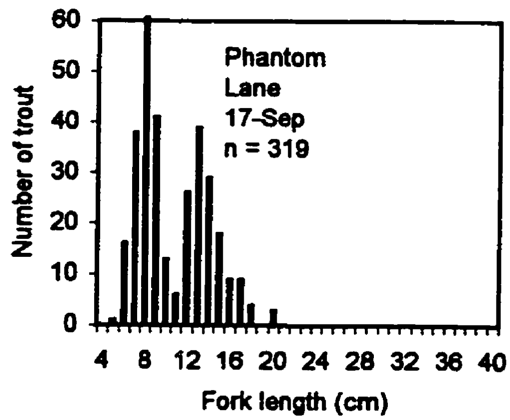
Appendix 6. Fork length frequency distributions of brook trout captured in Spring 3 and Small Spring, MacDonald's Pond, Midgell River, 1994.



Appendix 7. Fork length frequency distributions of brook trout captured in riverine electrofishing sites, Valleyfield River, 1994.







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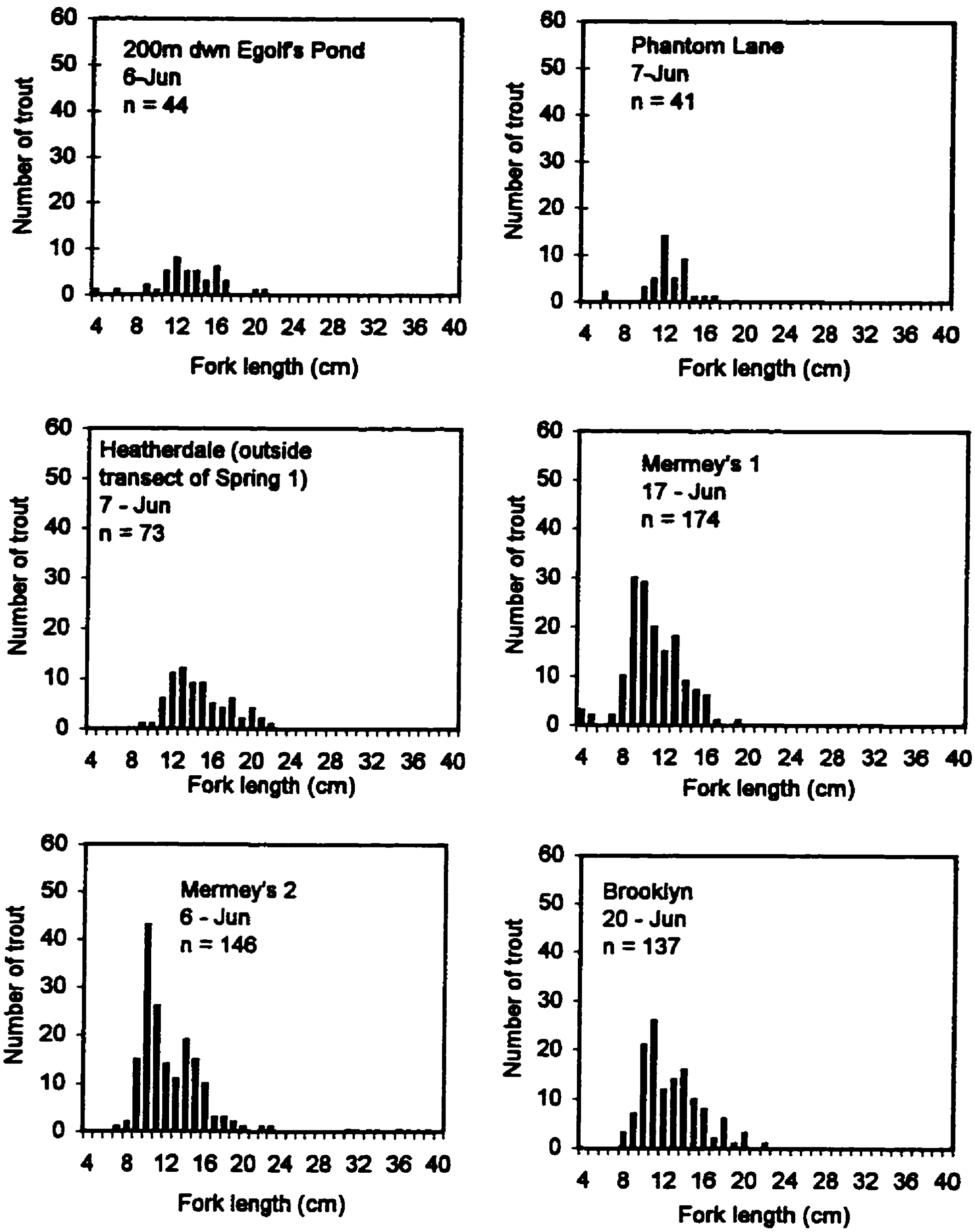
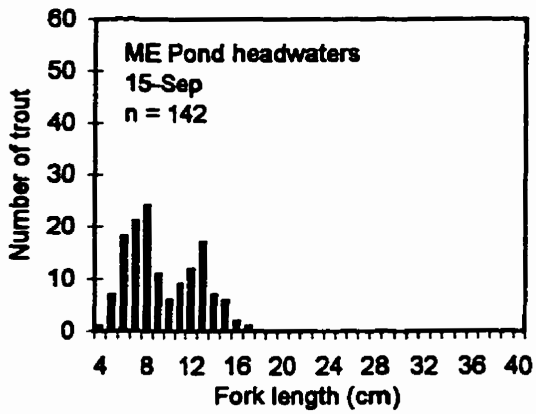


Appendix 8. Fork length frequency distributions of brook trout captured in riverine electrofishing sites, Valleyfield River, 1995.



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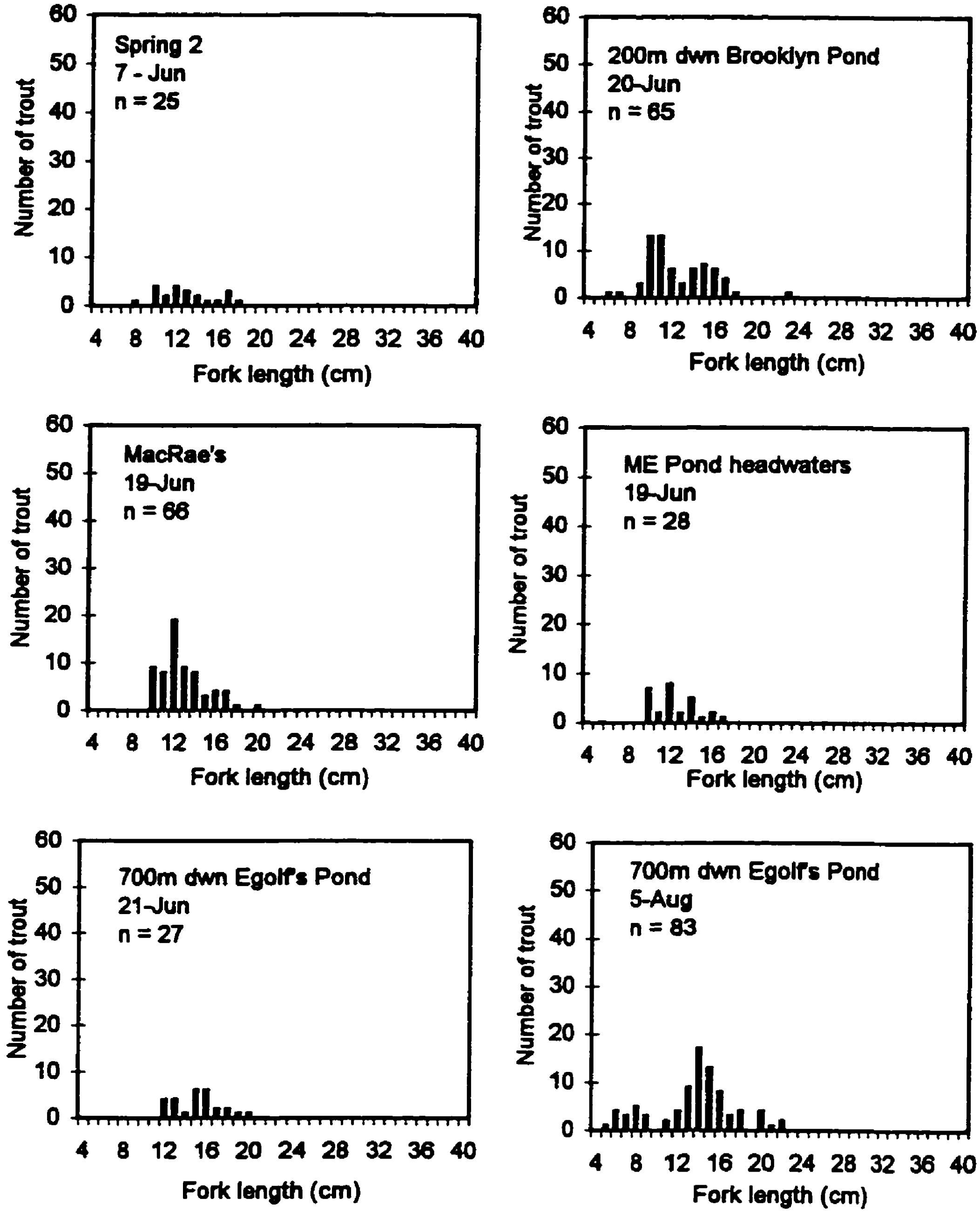

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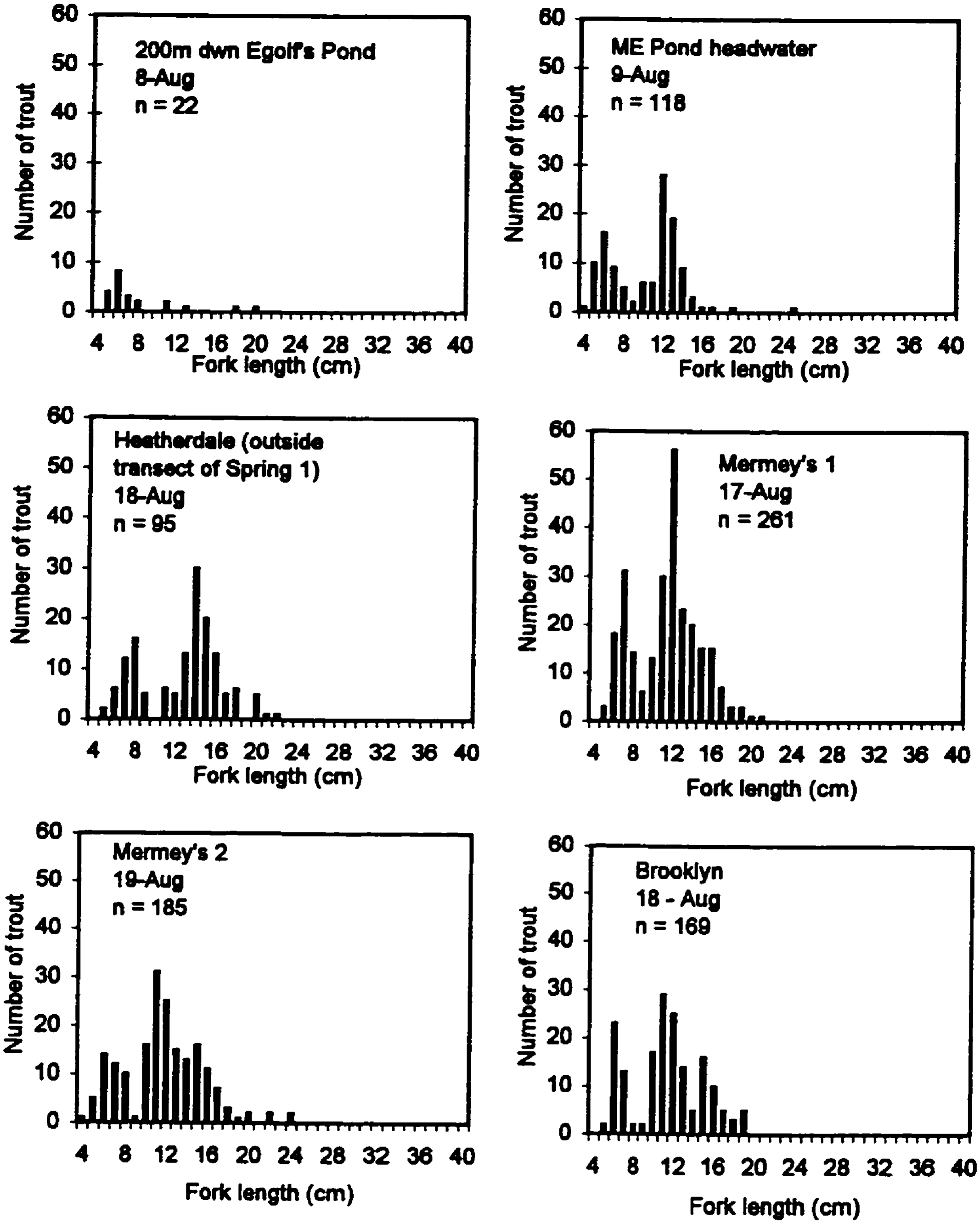

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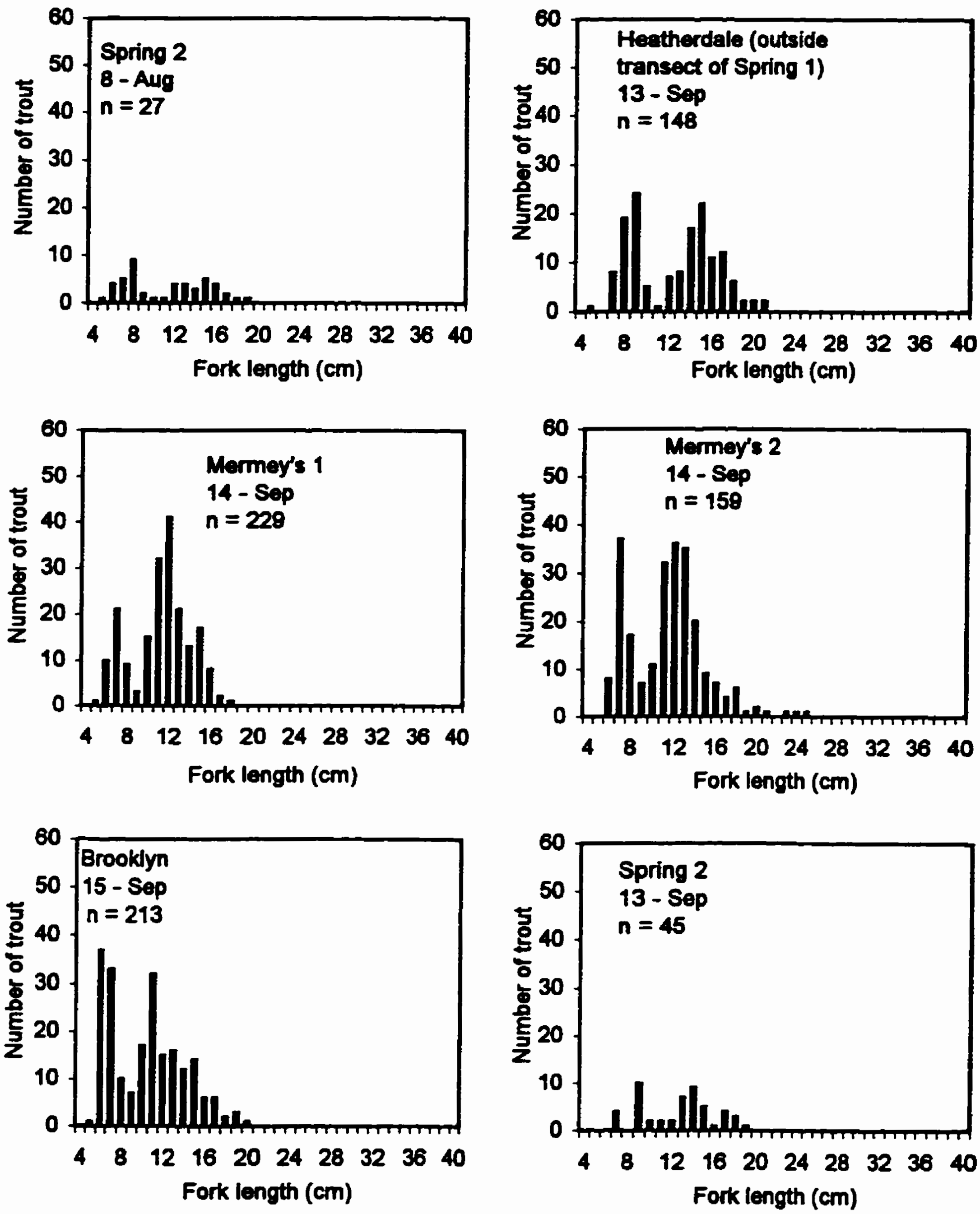

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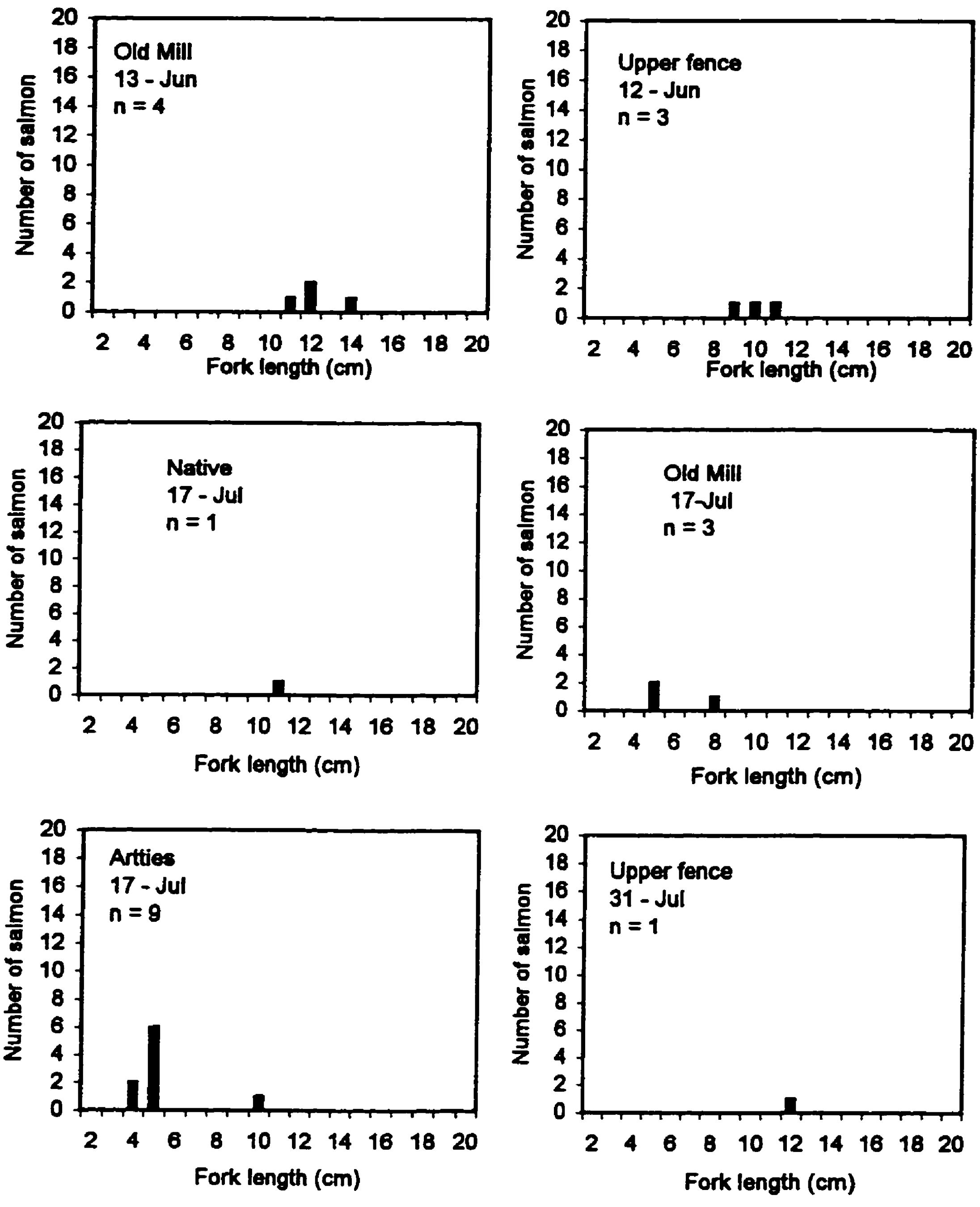
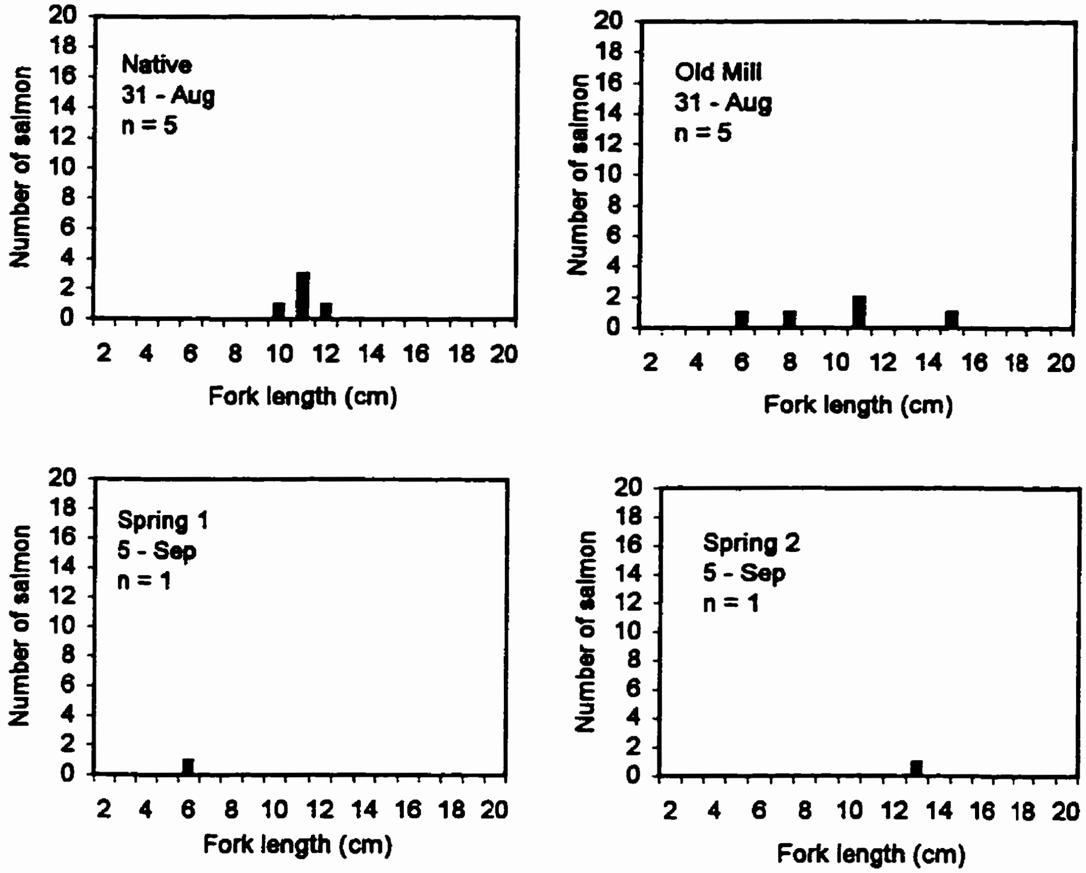


Appendix 9. Fork length frequency distributrions of wild juvenile Atlantic salmon captured in riverine electrofishing sites, Midgell River, 1994.



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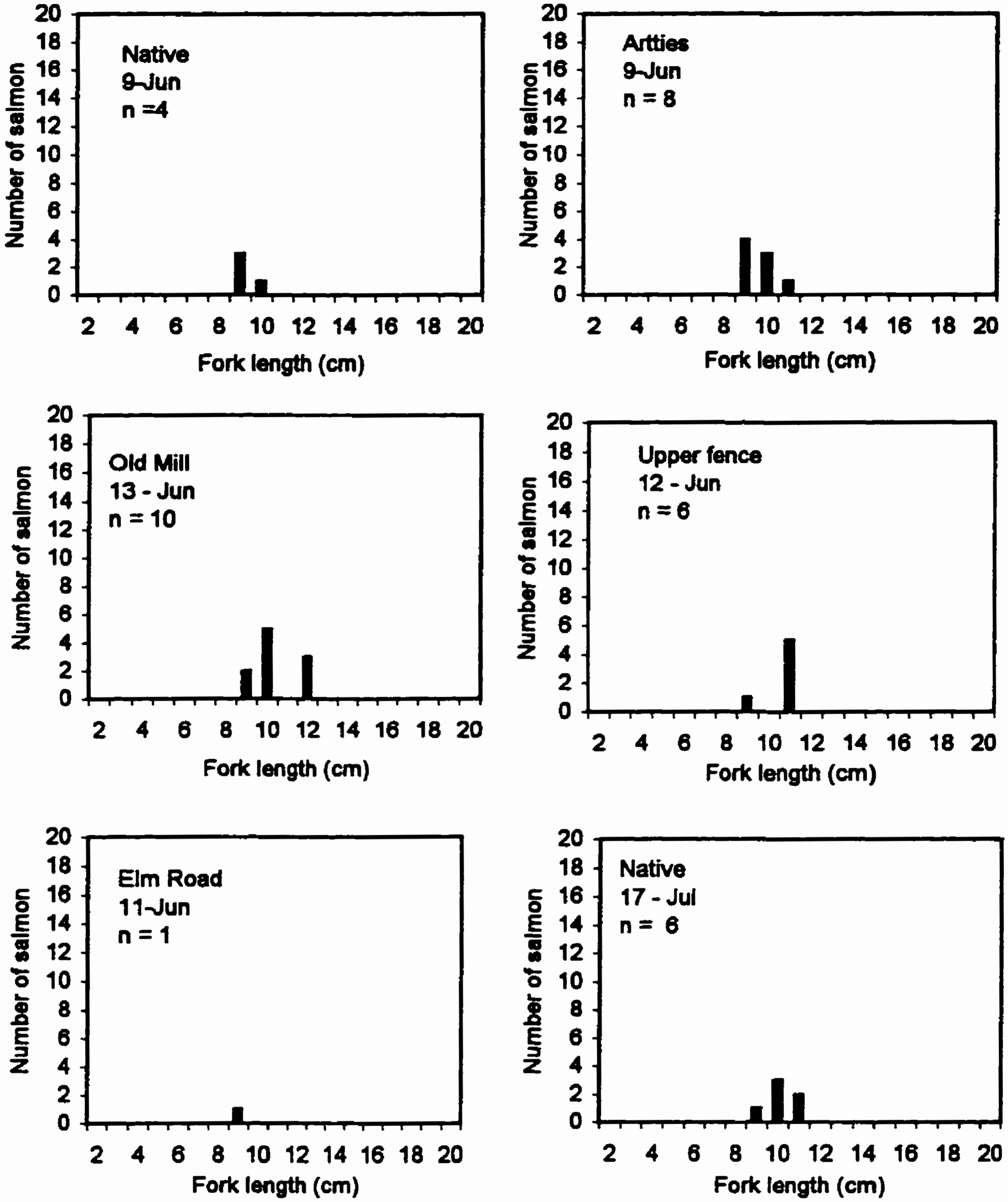
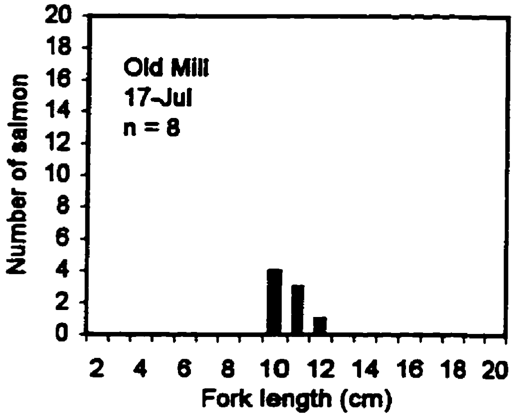
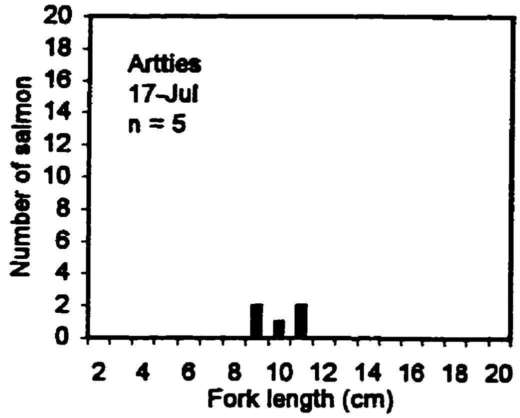
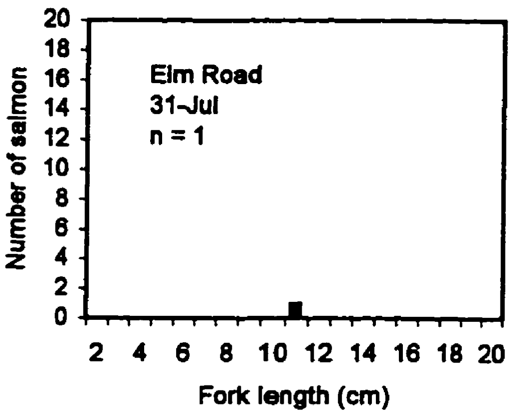
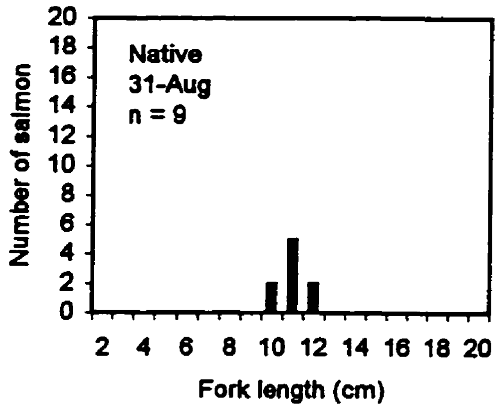


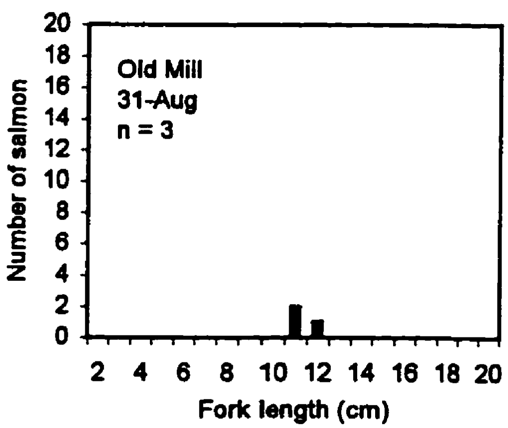
Appendix 10. Fork length frequency distributrions of hatchery (clipped) juvenile Atlantic salmon captured in riverine electrofishing sites, Midgell River, 1994.



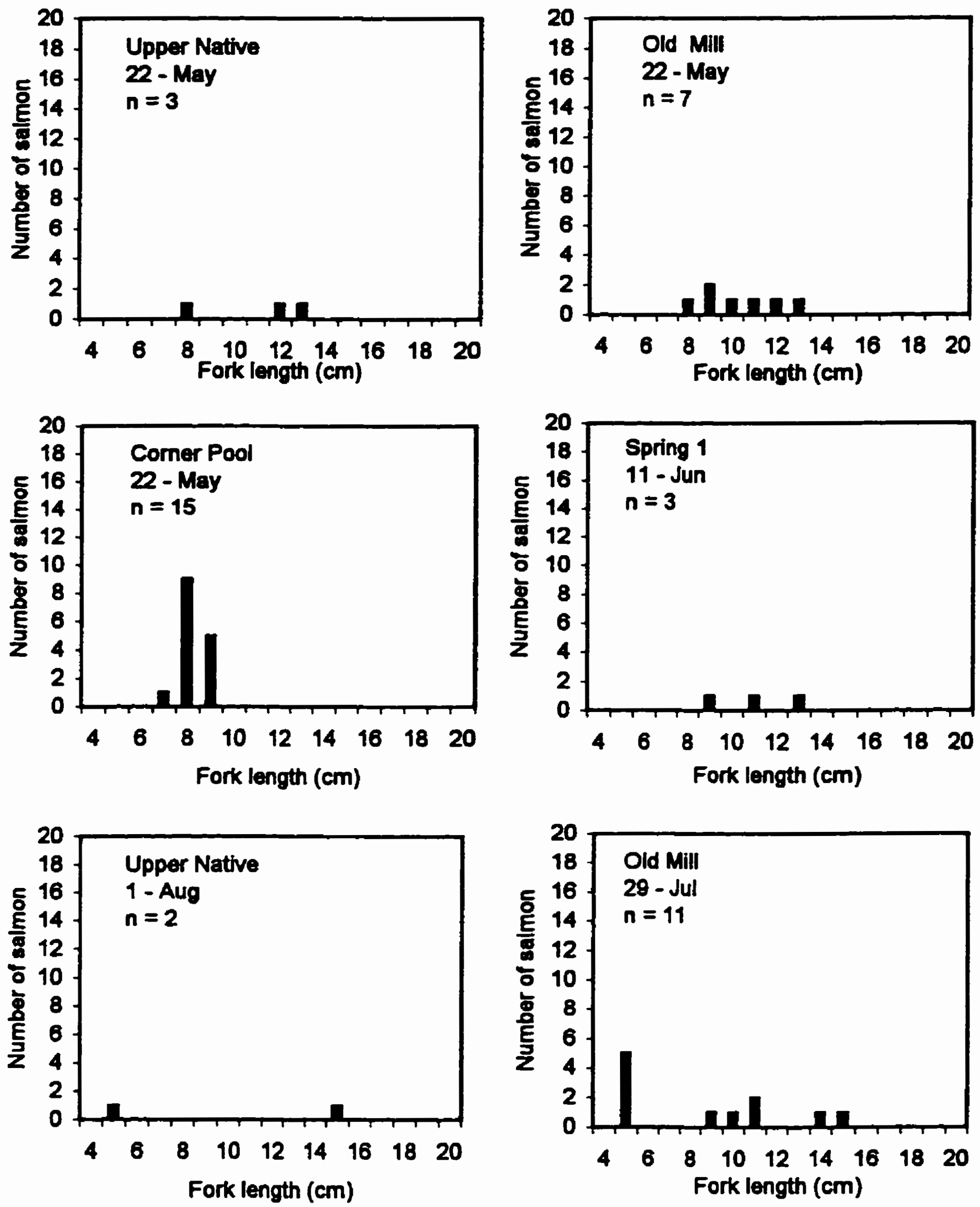




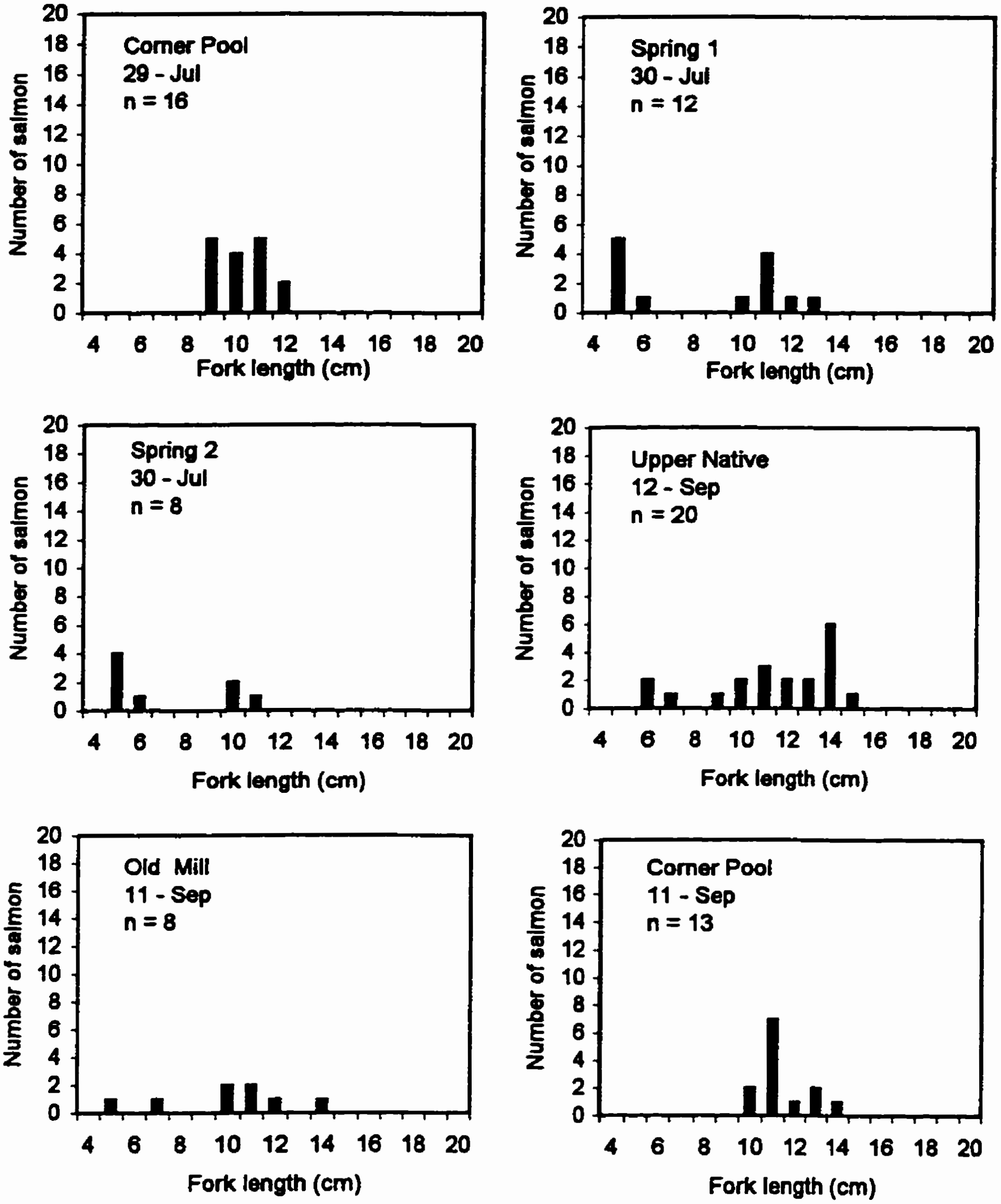




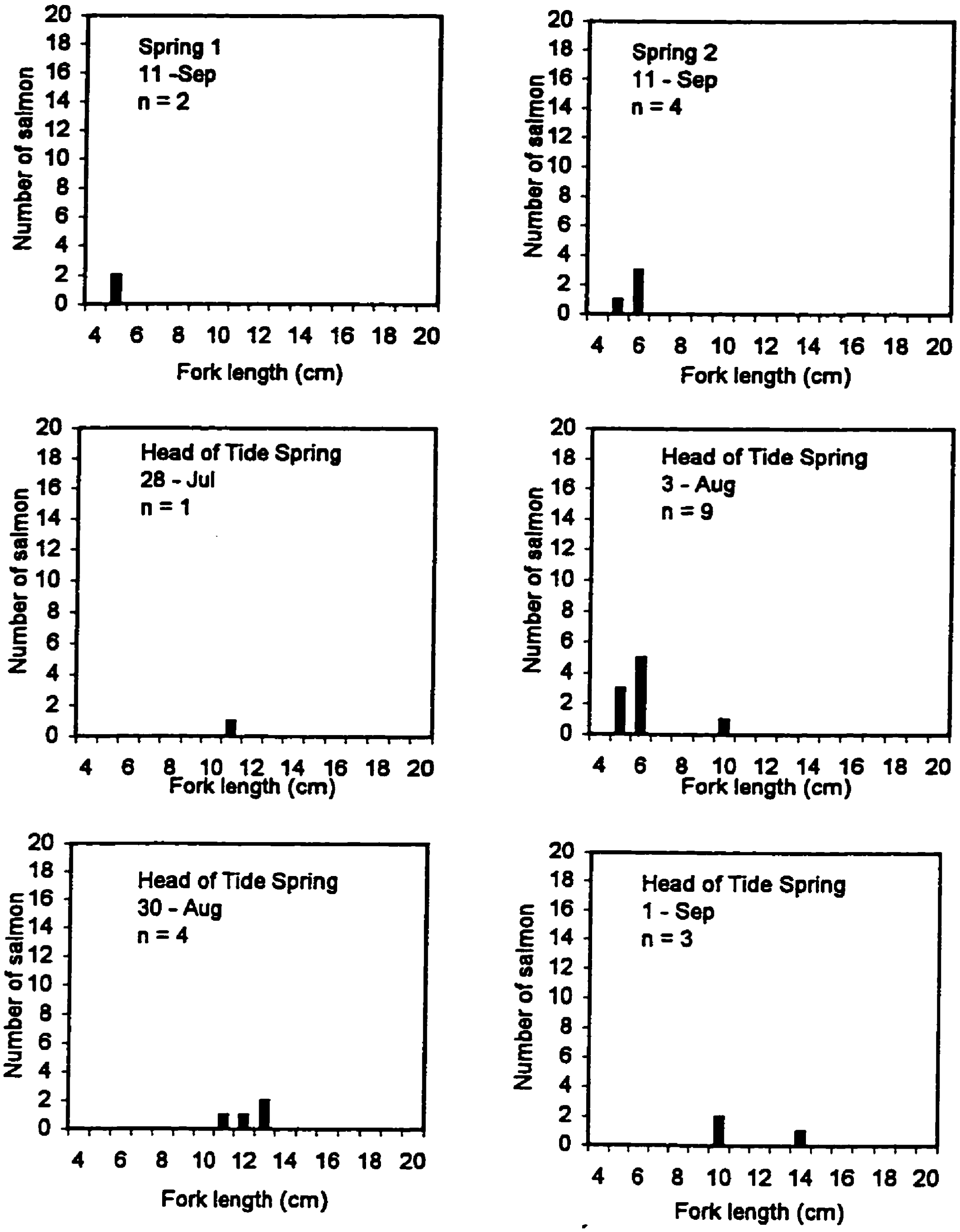
Appendix 10. continued



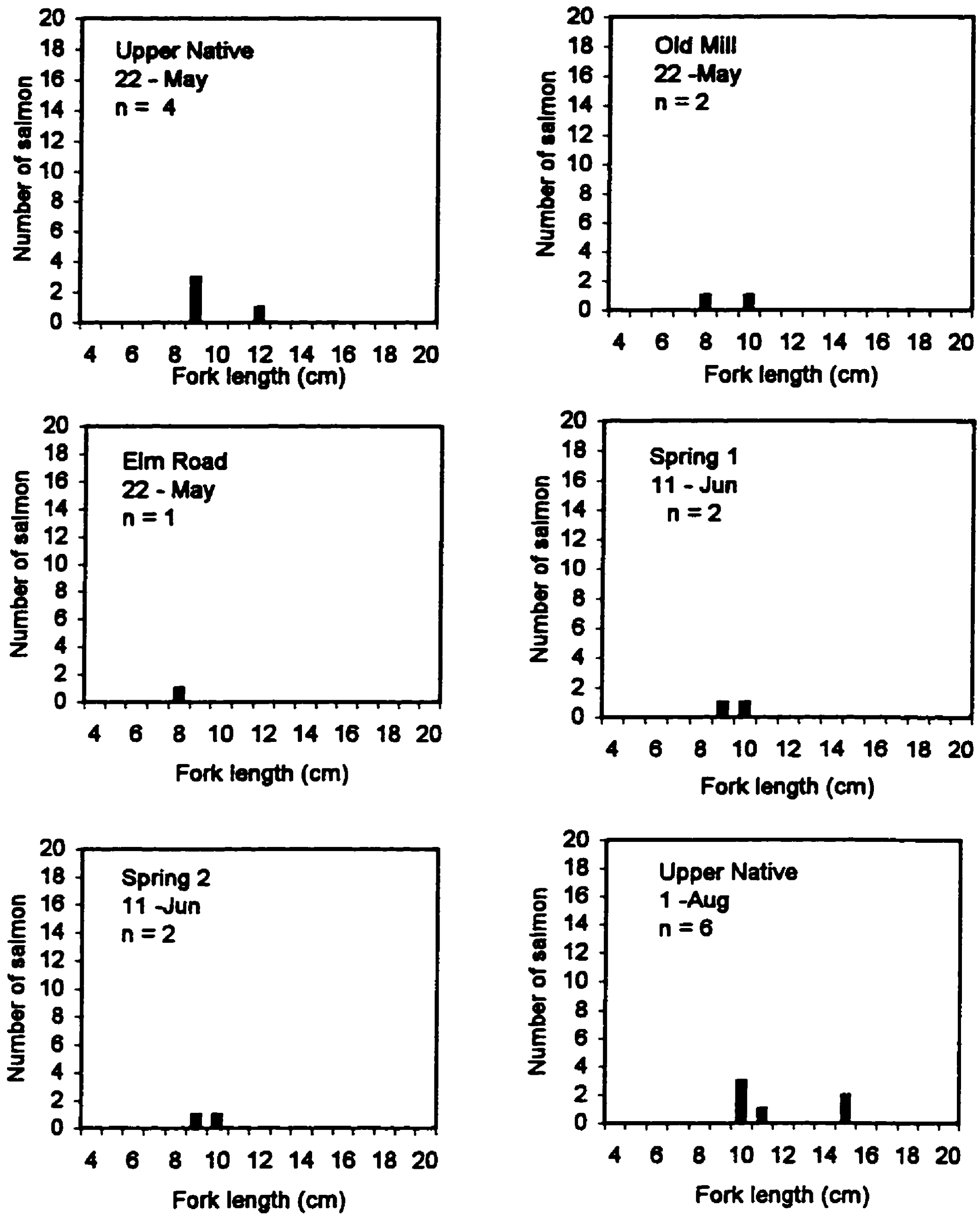
Appendix 11. Fork length frequency distributions of wild juvenile Atlantic salmon captured in riverine electrofishing sites, Midgell River, 1995.



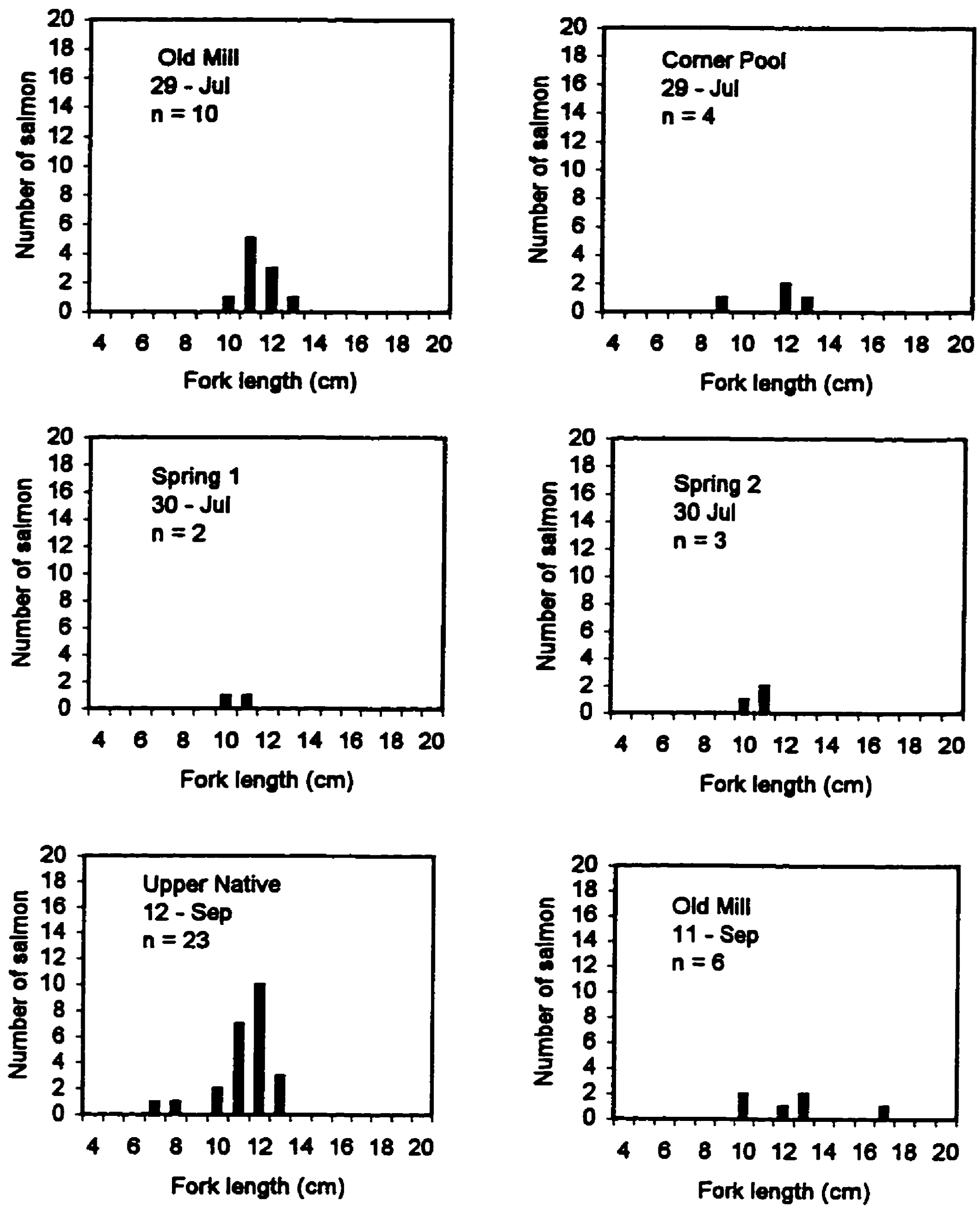
Appendix 11. continued



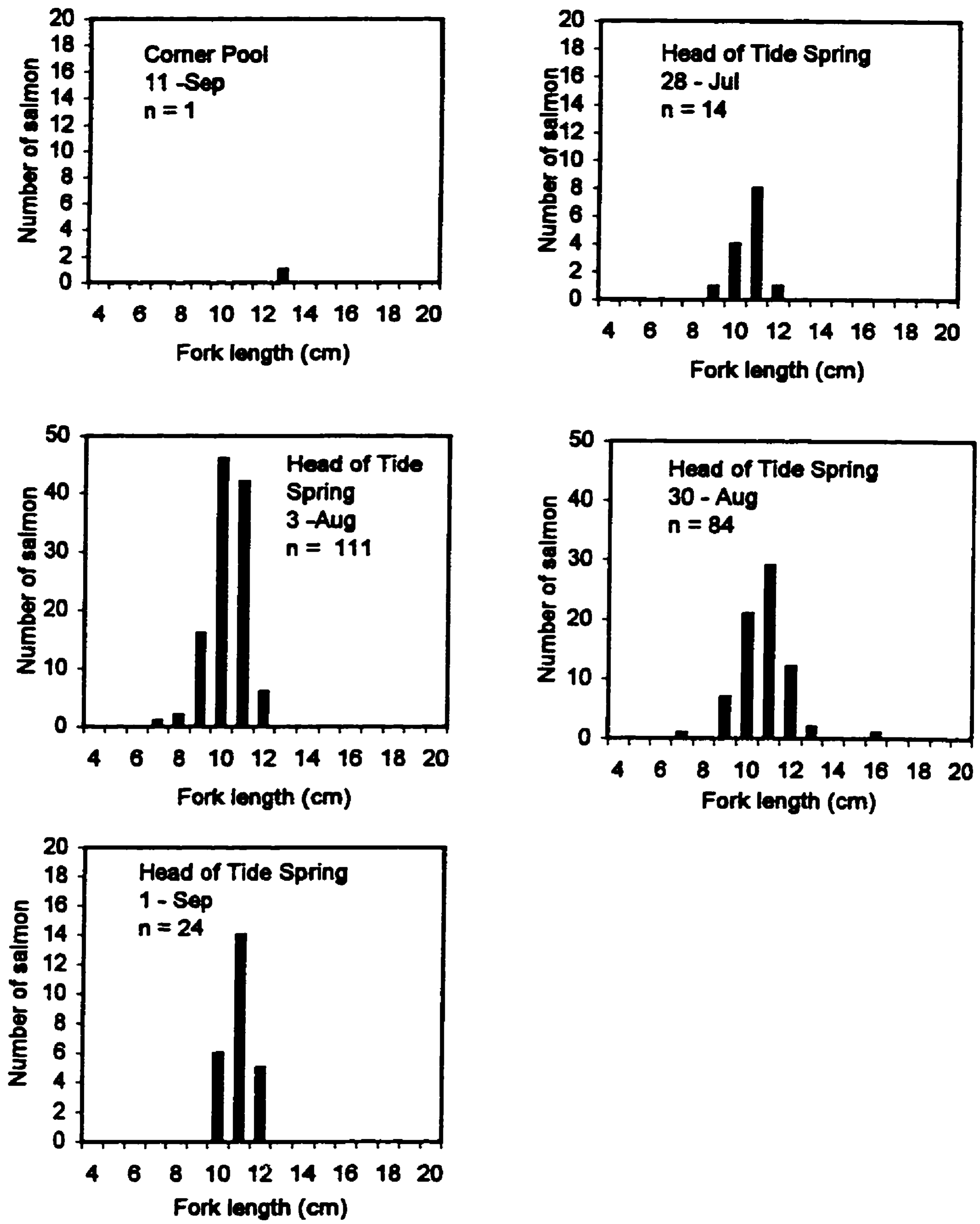
Appendix 11. continued



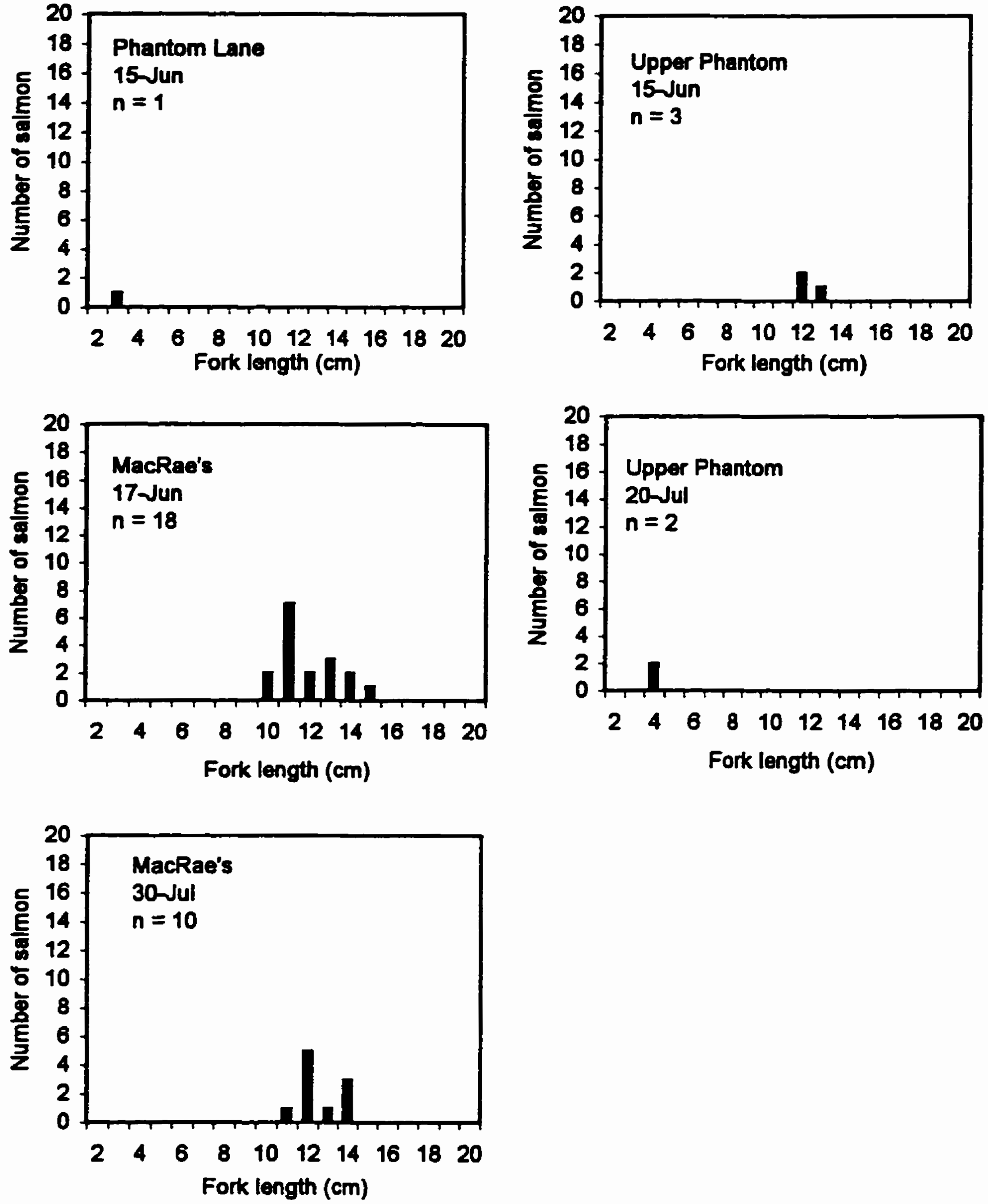
Appendix 12. Fork length frequency distributions of hatchery (clipped) juvenile Atlantic salmon captured in riverine electrofishing sites, Midgell River, 1995.



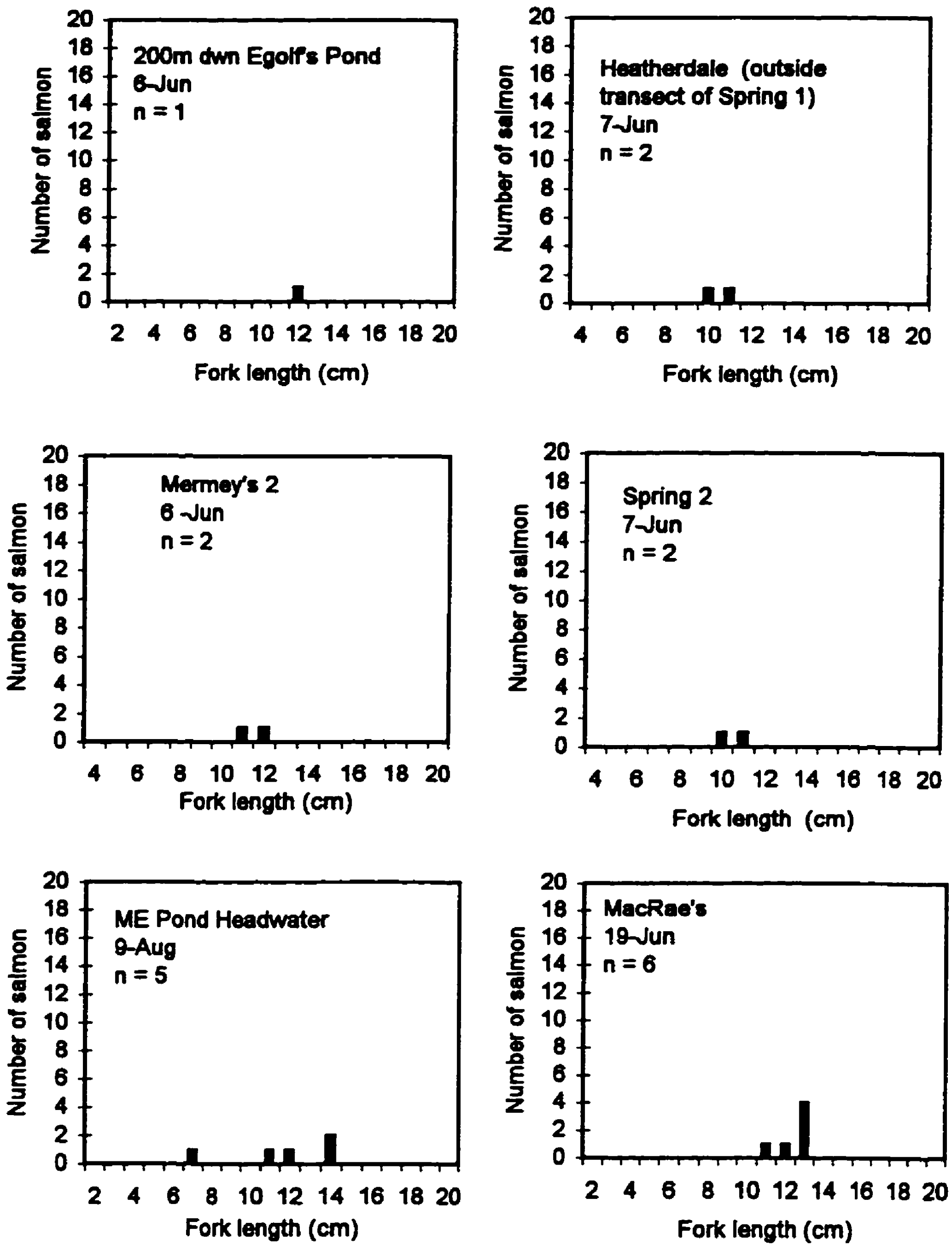
Appendix 12. continued



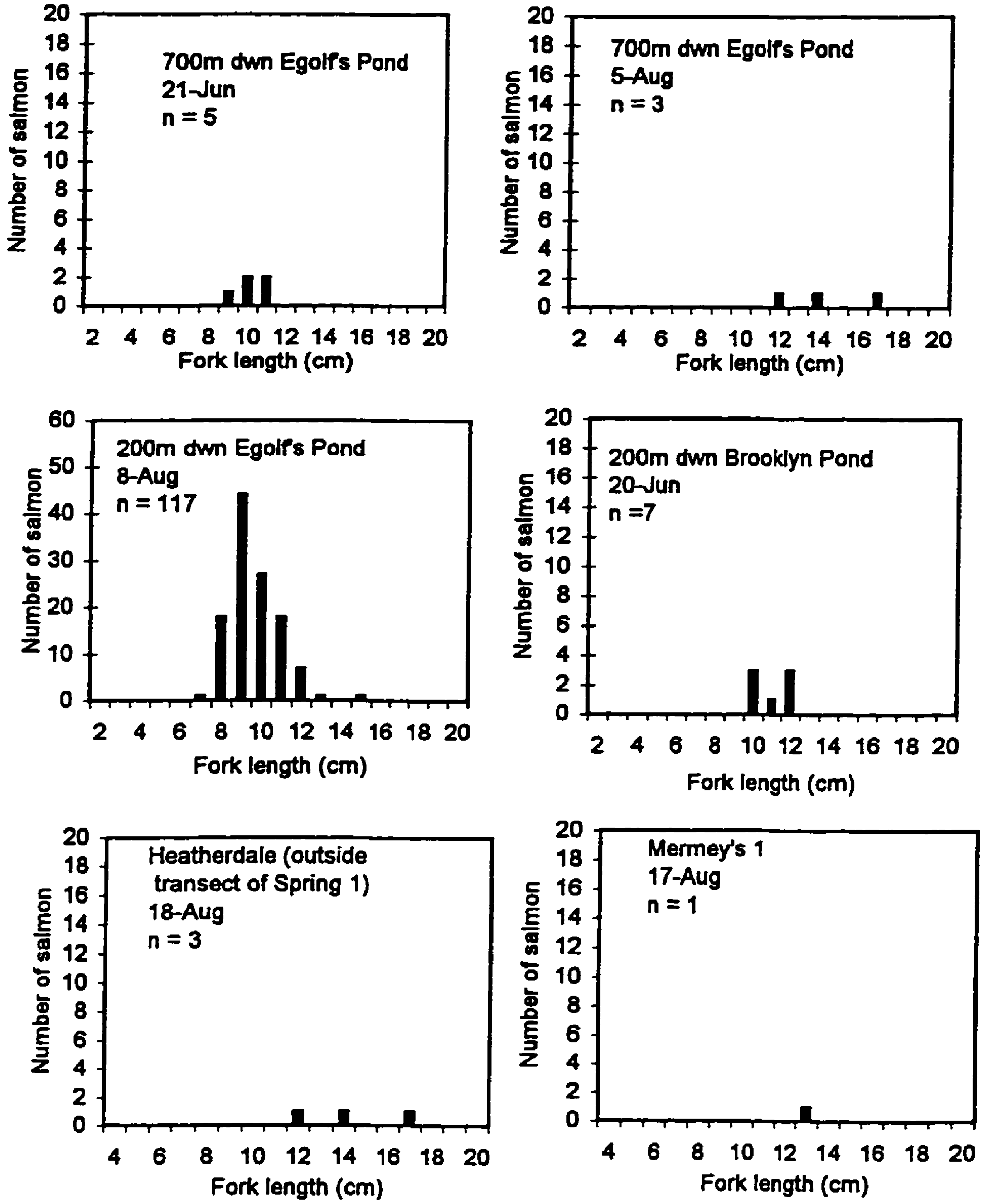
Appendix 12. continued



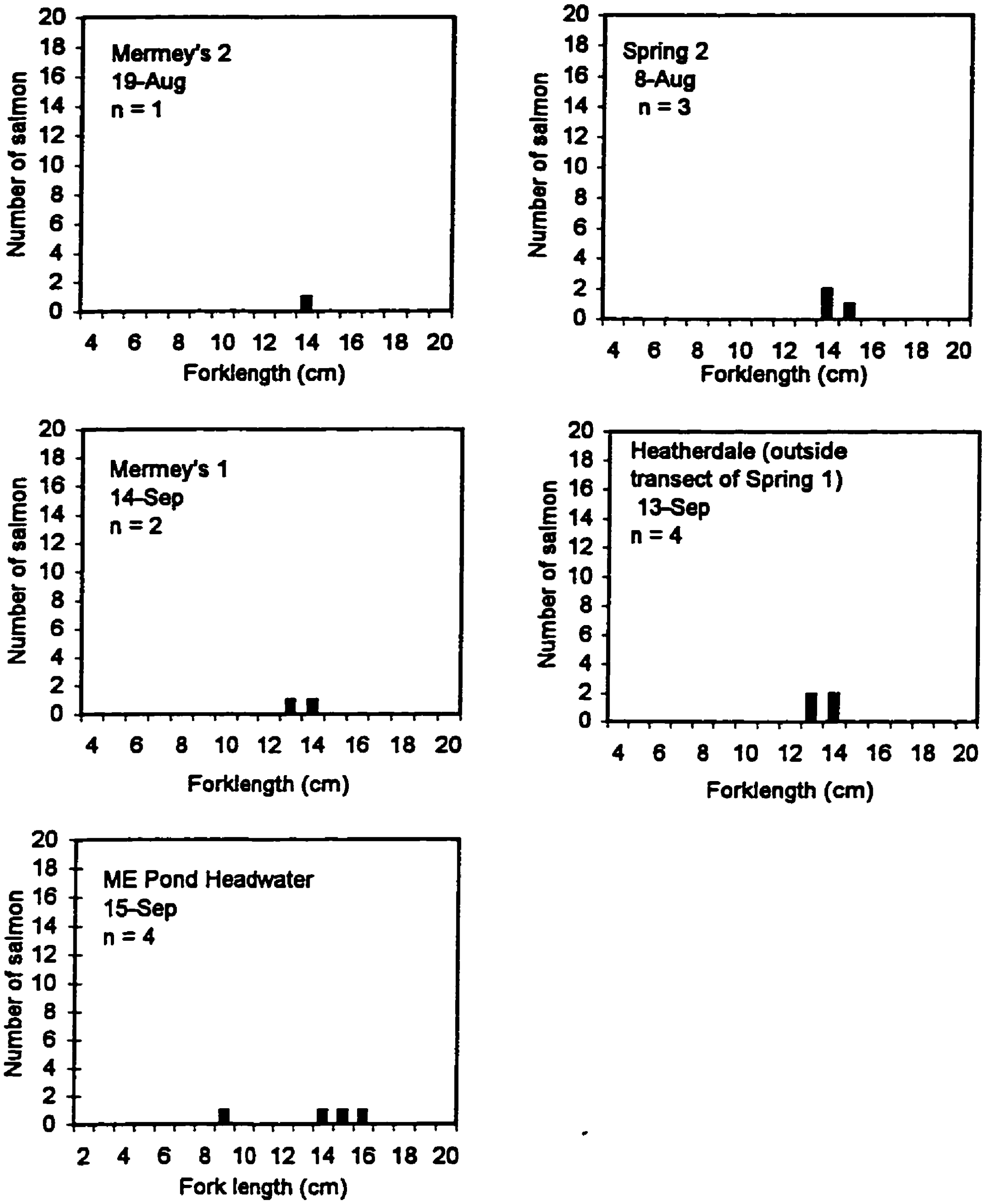
Appendix 13. Fork length frequency distributions of juvenile Atlantic salmon captured in riverine electrofishing sites, Valleyfield River, 1994.



Appendix 14. Fork length frequency distributrions of juvenile Atlantic salmon captured in riverine electrofishing sites, Valleyfield River, 1995.



Appendix 14. Continued



Appendix 14. Continued

Appendix 15. Tags returned by anglers from MacDonald's Pond, Midgell River, 1995.

Tag #	Site tagged	Date angled	Date tagged
987	M Pond	13-May	29-Apr
897	M Pond	5-May	29-Apr
893	M Pond	19-May	10-May
856	M Pond	19-May	6-May
905	M Pond	21-May	6-May
891	M Pond	19-May	15-May
986	M Pond	21-May	5-May
945	M Pond	28-May	28-Apr
994	M Pond	1-Jul	24-May
832	M Pond	5-Jul	11-May
3340	M Pond	2-Aug	12-Jul
937	M Pond	Aug	1-May
3032	M Pond	Aug	28-Jul
3238	M Pond	Aug	28-Jul
3197	M Pond	Sep	2-Aug
4778	M Pond	Sep	15-Aug
4757	M Pond	Sep	15-Aug
3046	M Pond	Sep	28-Jul

M Pond = MacDonald'sPond

Appendix 16. Tags returned by anglers, Valleyfield River, 1995.

Tag #	Site tagged	Date tagged	Date angled	Site angled	Method tagged
4004	ME Pond fishway	19-Jul	25-Jul	MacRae's Bridge	t.
4013	ME Pond fishway	20-Jun	14-Jul	MacRae's Bridge	t.
4038	ME Pond fishway	18-Jul	4-Aug	ME Pond	t.
4045	ME Pond fishway	18-Jul	18-Jul	MacRae's Bridge	t.
4050	ME Pond fishway	23-Jul	6-Aug	ME Pond headwaters	t
4061	n/a	n/a	26-Jul	ME Pond	n/a
4063	n/a	n/a	24-Jul	MacRae's Bridge	n/a
4076	ME Pond fishway	23-Jul	26-Jul	Heatherdale	t.
4082	ME Pond fishway	21-Jul	24-Jul	MacRae's Bridge	t.
4134	ME Pond fishway	23-Jul	Sep	ME Pond	t.
4140	ME Pond fishway	23-Jul	6-Aug	ME Pond headwaters	t.
4155	ME Pond fishway	25-Jul	2-Aug	n/a	t.
4159	ME Pond fishway	25-Jul	10-Aug	Heatherdale	t.
4191	ME Pond fishway	24-Jul	26-Jul	Heatherdale	t.
4201	ME Pond fishway	12-Jul	7-Aug	ME Pond	t.
4204	ME Pond fishway	12-Jul	Sep	Heatherdale	t.
4237	ME Pond fishway	12-Jul	26-Jul	Heatherdale	t.
4247	ME Pond fishway	12-Jul	21-Jul	MacRae's Bridge	t.
4248	ME Pond fishway	12-Jul	21-Jul	MacRae's Bridge	t.
4279	ME Pond fishway	13-Jul	24-Jul	MacRae's Bridge	t.
4288	ME Pond fishway	13-Jul	21-Jul	MacRae's Bridge	t.
4300	ME Pond fishway	14-Jul	25-Jul	MacRae's Bridge	t.
4314	ME Pond fishway	14-Jul	Jul	ME Pond	t.
4325	ME Pond fishway	15-Jul	15-Jul	MacRae's Bridge	t.
4327	ME Pond fishway	15-Jul	26-Jul	Heatherdale	t.
4329	ME Pond fishway	14-Jul	14-Jul	ME Pond	t.
4357	ME Pond fishway	16-Jul	4-Jul	ME Pond	t.
4368	ME Pond fishway	17-Jul	26-Jul	MacRae's Bridge	t.
4788	ME Pond	15-Aug	Sep	ME Pond	f.n.
5005	ME Pond fishway	1-Aug	14-Aug	ME Pond	t.
5083	ME Pond fishway	3-Aug	5-Aug	ME Pond	t.
5125	ME Pond fishway	5-Aug	Sep	ME Pond	t.
5157	n/a	n/a	14-Aug	ME Pond	n/a
5195	ME Pond fishway	6-Aug	9-Aug	ME Pond	t.
5198	ME Pond fishway	1-Aug	6-Aug	ME Pond headwater	t.
5200	ME Pond fishway	26-Jul	26-Jul	ME Pond	t.
5211	ME Pond fishway	26-Jul	27-Jul	Heatherdale	t.
5223	ME Pond fishway	26-Jul	6-Aug	ME Pond headwater	t.
5233	ME Pond fishway	26-Jul	2-Aug	Heatherdale	t.
5255	ME Pond fishway	27-Jul	2-Aug	n/a	t.
5301[a]	ME Pond fishway	28-Jul	2-Aug	MacRae's Bridge	t.
5307	ME Pond fishway	28-Jul	10-Aug	Heatherdale	t.
5308	n/a	n/a	Sep	Heatherdale	n/a
5321	n/a	n/a	14-Aug	ME Pond	n/a
5346	n/a	n/a	Sep	Heatherdale	n/a
5348	ME Pond fishway	27-Jul	10-Sep	Brooklyn	t.
5374	n/a	n/a	6-Aug	ME Pond headwaters	n/a
5391	n/a	n/a	Sep	ME Pond	n/a
5413	ME Pond fishway	9-Jul	Sep	ME Pond	t.
5436	ME Pond fishway	24-Jul	14-Aug	ME Pond	t.
5454	ME Pond fishway	9-Jul	24-Jul	MacRae's Bridge	t.
5482	ME Pond fishway	11-Jul	24-Jul	MacRae's Bridge	t.
5598	ME Pond fishway	10-Jul	31-Jul	ME Pond headwaters	t.
5601	ME Pond fishway	12-Aug	5-Aug	MacRae's Bridge	t.
5615	ME Pond fishway	13-Jul	Sep	ME Pond	t.
5792	ME Pond fishway	16-Aug	Sep	ME Pond	t.
6152	Spring 2	7-Jun	6-Aug	Heatherdale	e.f.
6255	Spring 1	7-Jun	6-Aug	ME Pond headwaters	e.f.
6457	ME Pond headwater	20-Jun	24-Jul	MacRae's Bridge	t.
6613	MacCrae's Bridge	19-Jun	21-Jul	MacRae's Bridge	e.f.
6832	ME Pond fishway	8-Jul	4-Aug	MacRae's Bridge	t.
6834	ME Pond fishway	8-Aug	Sep	Heatherdale	t.
6882	ME Pond headwater	6-Jul	16-Aug	ME Pond head	t.
6901	n/a	n/a	21-Jul	MacRae's Bridge	n/a.
8806	n/a	n/a	4-Aug	Brudenell R.	n/a.

ME Pond = Maritime Electric Pond, t. = trap, e.f.= electrofisher, f.n.= fyke net, [a] = adult salmon

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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