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The Alewife in the Gaspereau River Kings County, Nova Scotia, 1982-1984

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THE ALEWIFE IN THE GASPEREAU RIVER, KINGS COUNTY, NOVA SCOTIA, 1982-1984

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ABSTRACT

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Annual spawning escapements of alewives (Alosa pseudoharengus) to the Gaspereau River, based upon the count through the White Rock fishway, ranged from 50,400 to 114,800 fish. Annual commercial exploitation was estimated as 66% of the return to the river.

Most (> 95%) of the annual fishway counts occurred over periods ranging from 14 to 33 days between early May and early June. The first influx of alewives occurred with rising water temperatures of 10 to 14°C. Hourly fish counts tended to decline through midday before peaking in late afternoon or early evening then declining again as sunset approached. Hourly counts (lagged 4 hours) were positively correlated with water temperature and, when lagged 4 to 5 hours, were correlated (positively or negatively depending upon the year) with turbine discharge. Ascent of the fishway was estimated to take 4 to 5 hours.

Mean lengths of male and female alewives declined over the duration of the run but mean ages did not change. Most fish first spawned at age 4 or 5; 14 to 16% of fish were previous spawners. Male:female sex ratios were equal except in one year when males dominated the early part of the run.

Alewives moved upstream between the White Rock fishway and Gaspereau Lake at an average rate of 4.5 km·day^{-1}. Two to four percent of alewives tagged when spent were recovered in subsequent years, all in the Gaspereau River.

Juvenile alewives grow much larger in the tributary Black River system than in Gaspereau Lake but mortality during downstream passage through the series of hydroelectric turbines along the Black River is believed to greatly reduce subsequent return as adults.

RÉSUMÉ

Les remontées annuelles de frai du gaspareau (Alosa pseudoharengus) dans la rivière Gaspereau, estimées à partir des dénombrements effectués dans la passe à poissons de White Rock, se situaient entre 50 400 et 114 800 poissons. Le taux annuel d'exploitation commerciale a été estimé à 66 % de la remontée totale dans la rivière.

La plupart (> 95%) des dénombrements annuels dans la passe à poissons ont été effectués au cours de périodes de 14 à 33 jours entre le début de mai et celui de juin. Les premiers gaspareaux sont arrivés lorsque la température de l'eau a atteint une valeur se situant entre 10 et 14 °C. La valeur des dénombrements horaires avait tendance à décliner jusqu'à midi, elle augmentait ensuite à un maximum vers la fin de l'aprés-midi ou au début de la soirée avant de décliner encore une fois à l'approche de coucher du soleil. Ces valeurs (décalées de 4 heurs) présentaient une corrélation positive avec la température de l'eau et (décalées de 4 ou 5 heurs) une corrélation positive ou négative (tout dépendant de l'année) avec l'écoulement des eaux des turbines. On a estimé que les poissons traversaient la passe en 4 ou 5 heures.

La longueur moyenne des gaspareaux mâles et femelles diminuait au cours de la remontée, mais non les âges moyens. La plupart des poissons frayaient à l'âge de 4 ou 5 ans et de 14 à 16% avaient déjà frayé. Les rapports des sexes mâles/femelles étaient de un sauf au cours d'une année où les mâles ont dominé pendant la premiére partie de la remontée.

Les gaspareaux se déplacaient vers l'amont, entre White Rock et le lac Gaspereau, à la vitesse moyenne de 4,5 km.jour^{-1}. De deux à quatre pour cent des gaspareaux marqués aprés le frai ont été récupérés les années suivantes, tous dans la riviére Gaspereau.

Les juvéniles atteignaient une taille beaucoup plus importante dans les eaux du bassin de la rivière Black, un tributaire du lac Gaspereau, que dans le lac lui-même, mais il semble que la mortalité due au passage dans la série de turbines hydro-électriques de la riviére Black a pour effet d'en réduire fortement leur retour sous forme d'adultes.

INTRODUCTION

A fishery for alewives (Alosa pseudoharengus), locally known as gaspereau, has existed in the Gaspereau River, Kings County, Nova Scotia (Fig. 1) since colonial times (Knight 1867). The earliest of the dams built on the river were believed to have had little effect on the fish stocks because sufficient fish were able to ascend upriver (Anonymous, Department of Fisheries memorandum, 30 July 1950, Ottawa). A hydroelectric dam with a 3.7 m head constructed in 1919 at White Rock presented the first recognized serious threat to fish passage; a fishway was built in 1920. Difficulties in attracting and moving alewives upstream were soon observed at the fishway, and periodic kills of juvenile fish occurred during downstream passage through the turbines. Various attempts were made at that dam and fishway, and at their replacements, to reduce these problems (memorandum file, Department of Fisheries and Oceans Record Unit, Halifax, N.S.).

Extensive power development beginning in 1930 involved diversion of the upper reaches of the Black, Forks, and Gaspereau rivers and construction of several storage and four (Methals, Hollow Bridge, Lumsden and Hells Gate) power-generation dams (Fig. 1). This development was completed in 1952 with construction of a new White Rock power plant about 3.2 km downstream of the original, which was then breached. The spawning, and much of the rearing, area for alewives has been essentially limited to Gaspereau Lake by these dams and by a fish screen on the outlet (Trout River Pond) of Gaspereau Lake to the Black River system which was designed to divert adult and juvenile fish into the Trout and Gaspereau rivers. Substantial juvenile production occurs in the Black River system because larval and small juvenile alewives pass through the screen mesh. Boaters also occasionally fail to replace a screen that they have removed during boat passage. In 1984, an attempt to increase the production of alewives by utilizing inaccessible rearing area was made by transferring 500 adult alewives from the White Rock fishway to Aylesford Lake. Annual releases of similar numbers of alewives were made between 1985 and 1987. In 1986, completion of a fishway permitted access to Aylesford Lake.

The pool-and-weir fishway constructed at the new White Rock dam did not provide adequate fish passage because of unsatisfactory attraction conditions (poor entrance siting and water flow control). In 1969, structural changes were made which somewhat improved fish attraction and passage (Dominy 1971; 1973). A new fishway, completed in 1980, featured a similar design with improved entrance siting and two additional rest pools. An automatic flow-regulating weir at the upper end maintains a constant water flow of about 0.13 $m^3 \cdot sec^{-1}$ through the upper fishway while the lowermost four pools receive an additional attraction water flow of 0.13 $m^3 \cdot sec^{-1}$ (Fig. 2).

A Francis-type turbine at the White Rock power station generates a maximum of 3300 kw from a flow of 21.5 $m^3 \cdot sec^{-1}$ at a normal head of 18.9 m. In 1983 and 1984, average flow was 14.4 and 16.5 $m^3 \cdot sec^{-1}$ during the May-June period when alewife upstream migration occurred (Pers. comm., J. Andrews, Nova Scotia Power Corporation). During the fish passage season (May to November), flow averages 7.2 $m^3 \cdot sec^{-1}$ (Anon. 1969). Power generation during May and June varies relatively little over a 24-hour period when water availability is high, but provides mainly peaking power when water availability is low.

The alewife fishery of the Gaspereau River employs weir and dip-net apparatus (Fig. 3). A berm of stones angled part way across the stream bed blocks the channel and guides fish upstream towards an opening closed by wire netting on the upstream, side, within which a "square-net" is set on the stream bottom. The square net consists of a rectangular (<1.9 m x 1.9 m) frame of netting suspended from a long pivot-pole by attachments to each corner. When sufficient fish are observed over the net, or when a certain time has passed, the net is raised and the captured fish are dumped into containers and immediately salted. Fishery regulations stipulate that the berms must leave open for fish passage and navigation one-third of the width of the river and two-thirds of the width of the main channel at low tide in tidal portions of the river. In non-tidal waters, no more than two-thirds of the width of the river may be obstructed.

Between 1957 and 1986, the annual gaspereau harvest in Fishery Statistical District (FSD) 41, which consists mainly (80-98%) of fish from the Gaspereau River, averaged 204.6 tonnes (Range 33-643 t; Fig. 4). The catch peaked in the mid-to-late 1970's, then declined sharply until 1986 when it increased.

Catch-effort logbooks were initially issued to square-net fishermen in 1981 for use on a voluntary basis. Few fishermen participated conscientiously in this program. Use of the logbooks was made compulsory in 1986.

Concern about the decline of the alewife harvest in the late 1970's prompted an investiation in 1982 of the conduct of the fishery and the status of the stock in the Gaspereau River. Prior to the 1983 fishing season, preliminary results and observations of the 1982 study were reviewed at meetings between fishery officers and biologists of the Department of Fisheries and Oceans (DFO) and the commercial fishermen. It was reported also that the size of the berms used by square-net fishermen had tended to exceed the legal size. Consequently, renewed attention was given to the size and placement of berms, with the expectation that an increased escapement would result. A specific fishing license for square-nets was also implemented in 1983.

This report examines the results of a project conducted by DFO on the Gaspereau River between 1982 and 1984 to: (a) monitor the commercial fishery, (b) determine the annual escapement of alewives through the White Rock fishway, (c) obtain life history data on the stock, (d) study the movement and distribution of tagged adult fish, and (e) study juvenile alewife growth and distribution.

METHODS

DATA COLLECTION

Catch-effort logbooks were distributed to licensed square-net fishermen operating on the Gaspereau River prior to the start of each fishing season. Independent estimates of catch were obtained from both fishery and inspection officer counts of the number of barrels of salted product for each fisherman.

A V-shaped counting weir made of wire mesh on a wooden frame was installed seasonally in the upper portion of the White Rock fishway. An upstream opening gate allowed the operator to control access through the 30-cm weir entrance and a false floor reduced the water depth to about 80 cm over the white counting board located immediately upstream of the gate. Four consecutive 15-minute fish counts were made each hour between 08:00 and 21:00 or darkness, whichever came first, for each day throughout the run (early May to mid or late June). At high fish densities, control of the number of fish through the counting weir was difficult. Counts exceeding about 250 fish per 15-minute period, as occurred briefly during 1982, are of reduced accuracy. At highest fish densities, backup occurred at the gate which delayed passage by perhaps an hour or more. Inevitably, some counts were not made, particularly during the period after 16:00 when operations were shut down if fish abundance was low. When counting ceased for the day and when counts were temporarily halted, the counting weir gate was closed and locked, thereby halting fish movement upriver. In 1983, daily observations and counts were made for 0.5-1 hour in the morning and afternoon at White Rock fishway between July and mid-September. The trap was left open when unattended. The time spent at the trap depended upon the amount of fish activity in the fishway. Observations continued about twice weekly until the end of October.

Two indices of alewife relative abundance were calculated for hourly and daily intervals (a) daily count/total count x 100, and (b) hourly count/maximum hourly count x 100, where the hourly counts are geometric means over seven days of the (count + 1).

Data collected included hourly records for the period 08:00-20:00 (or until shutdown) of (a) surface water temperatures (°C), (b) cloud cover in tenths, (c) tailrace relative water level (gauge height; cm). A minimum-maximum thermometer recorded overnight water temperatures. Turbine discharge values ($m^3 \cdot sec^{-1}$) for the period 05:00-24:00, May 1 to June 30, for the White Rock power station were obtained for 1983 and 1984 but were unavailable for 1982 (personal communication, J. Andrews, Nova Scotia Power Corporation). Tailrace water level and discharge values reported here are means of the values at the start and end of each hour.

Samples of 50 alewives were dipped from the fishway twice weekly. Eacn fish was promptly measured for fork and total length (mm) and weight (g). Sex and state of maturity (following Nikolsky 1963) were recorded and a sample of cleaned scales obtained from the mid body between the dorsal fin posterior insertion and the lateral line. Age was determined for each fish by counting the number of annuli and/or spawning marks on scales (Marcy 1976). Each scale sample was independently aged twice by the same person and, when readings differed, a third reading was made and an age assigned on the basis of majority agreement.

Transit times within the White Rock fishway and between White Rock and Lanes Mills fishways were studied in 1983. A group of 25 alewives was marked with yellow T-bar flag tags (Floy FD-67F), released in the bottom pool of the White Rock fishway, and the time of their subsequent arrival at the counting weir was recorded. Similarly, a group of 24-50 alewives marked on each of three days with yellow, red, or orange flag tags (a different color was used each day) was released from the White Rock fishway and later watched for at Lanes Mills fishway. In 1983 and 1984, a total of 2,110 spent alewives (594 and 1576 respectively) was marked at the White Rock fishway with yellow, serial numbered Floy FD-68B T-bar tags to obtain information on marine migration.

Distribution of larval and juvenile alewives in 1983 was determined from metre-net tows made weekly in each of Gaspereau Lake, Little River Pond, Black River Lake, and Lumsden Pond. Two tows were made at a single site near shore except in Gaspereau Lake where single tows were made at two widely separated sites. The distance towed ranged from about 100 to 350 m depending upon the geography of the site. In early July, the tows were replaced by weekly beach seining at Gaspereau Lake, Trout River Pond, Black River Lake, and Lumsden Pond. Three sweeps were made 15 minutes apart at each site using a 13.4 m x 2.4 m, 5-mm mesh bag seine in a standard manner, i.e., with one end anchored, the net was extended perpendicular to the shore then the free end was swept around to the shore and the net hauled out. Single collections of juvenile alewives were made by dip-net at the White Rock fishway and from a fish kill at the White Rock power station. All alewives caught were counted and, when possible, released alive except for up to 50 fish per site which were preserved in 5% formalin for later measurement of fork and total length (mm) and weight (0.01 g) after blotting dry. Surface water temperatures (°C) were recorded at each site.

A bottom-to-surface vertical haul using a 0.5-m diameter, 4.2-m-long plankton net with 80 m mesh captured zooplankton at each of three sites (A,B,C) on Gaspereau Lake (Fig. 1) at two-week intervals between 22 June and 29 August, 1983. The volume of water filtered was calculated for each haul and a water temperature (°C) profile at 1-m intervals was obtained at the deepest site (B). Zooplankton catches were preserved in 5% buffered formalin and later counted by species.

STATISTICAL ANALYSIS

Analysis of variance (ANOVA) was used to examine differences among treatment means. When a significant difference (P 0.05) was indicated, multiple comparison procedures were used to further examine the difference. The Tukey-Kramer (TK) method was used when means were unequally replicated (Stoline 1981). Analysis of covariance (ANCOVA) was employed to compare changes during the run in length and age for each sex. Correlation analysis was used to examine relationships between the hourly count (ln(X+1) transformed) and associated water discharge ($m^3 \cdot sec^{-1}$) and water temperature. Sex ratios were tested for agreement with a 1:1 ratio using the G-statistic (Sokal and Rohlf 1980). Proportions were compared after transformation by $\arcsin\sqrt{p}$, where p is the proportion.

RESULTS

COMMERCIAL FISHERY

Since 1961, a maximum of 23 square-nets has been fished. In 1980, 15 square-nets were fished, 17 in 1981 and 1982 and, since 1983, 16 nets have been fished. In most years all licenses issued (one license per square-net) are fished. Comparison of several methods of gathering catch statistics (Table 1) illustrates some of the difficulties in determining the annual catch by the square-net fishery. Estimates by fishery officers often exceed those by inspection officers and both should exceed the logbook totals because logbook returns were incomplete. This comparison was not so in 1982. The total catch of alewives in the Gaspereau River is the sum of estimates of catch in the square, drift, and dip-net fisheries. Drift and dip-net fisheries account for about 21% (range 5-32%) of the total catch (total catch all methods minus square-net catch reported by fishery officer; Table 2). The total catch from the Gaspereau River should, in turn, be less than or equal to that in FSD 41 but this does not always occur. Examination of the logbooks from four fishermen who provided the most complete records of the 1981-1986 fisheries shows much variation in catch-per-unit effort (CPUE) among fishermen and years (Table 2). Mean annual CPUE shows little tendency to increase with increasing total catch in FSD 41 (Tables 1, 2).

FISHWAY COUNTS

Annual escapement, based upon the count through the White Rock fishway, totalled 50,400, 114,800, and 111,100 alewives during 1982, 1983, and 1984, respectively. The seasonal distribution of daily counts was unimodal in 1982 and bimodal in 1983 and 1984 (Figs. 5, 6, 7). Run duration (the number of days having >1% of, and covering at least 95% of, the total count) for these years was 14, 33, and 24 days, respectively. Downstream-migrant, spent adults first appeared in late June in 1983 and early June in 1984, with peak movement during late June in both years. Small numbers of spent adults were observed occasionally until mid-September. Irregular waves of juvenile alewives were observed moving downstream between late July and late October, with the peak in late September to early October.

Certain trends were evident within the seasonal and daily (08:00-20:00) fluctuations in alewife counts from the fishway trap. Adult alewife upstream run timing was linked to rising water temperatures such that the first major peak of each run, defined as the first occurrence of a daily count > 5% of the total count, occurred at mean daily water temperatures between 10.1°C and 13.5°C (Figs. 5, 6, 7). Once the run commenced, no significant correlation existed between daily water temperature and fish count in either 1982 or 1984 (n=35, r=0.05, and n=39, r=-0.28, respectively; $P > 0.05$) although in 1983 there was a significant negative correlation (n=43, r=-0.45, $P < 0.01$). Fish count and tailrace water level were uncorrelated ($P > 0.05$) in all years when counts were lagged behind tailrace water level (r=0.18, -0.15, 0.26, respectively) for from zero to five days. Daily mean tailrace water levels, as expected, were highly correlated with daily mean turbine discharge (n=37, r=0.90; n=41, r=0.94; $P < 0.001$ for 1983 and 1984, respectively). Water temperature and tailrace water level were uncorrelated in 1983 (r=-0.22; $P > 0.05$) and negatively correlated in 1982 and 1984 (r=-0.84 and -0.68, respectively $P < 0.001$).

Although counts varied greatly within and among hours, a daily trend occurred in hourly counts which persisted over weekly and seasonal means for each year (Fig. 8). Hourly counts tended to be relatively high in early morning soon after opening the counting fence, to decline through midday before peaking in late afternoon or early evening and to decline sharply as sunset (May 1 - June 15 mean sunset was 20:45) approached (Fig. 9). Most daily curves followed this bimodal pattern but a few unimodal curves with late afternoon peaks were observed. In 1983 and 1984, seasonal mean water temperatures tended to rise until mid-afternoon or early evening and then to decline but in 1982, the decline did not begin until mid-evening. Extensive cloud cover noticeably reduced the rate and amount of temperature rise but had little influence on the daily pattern of fish movement. A midday low in fish movement occurred whether the sky was clear and sunny (cloud cover < 0.3 over the period 08:00-13:00) or overcast (cloud cover > 0.7). Cloud cover exceeded 0.5 for almost 60% of the run period (range 54-66%) each year and the proportion of the total run that occurred on such days averaged 56% (range 27-76%). No reluctance was observed by alewives to passage of through the fishway on sunny days; in fact, the peak of the run in 1982 and one of the peaks in 1984 were on days with cloud cover of < 0.2. Discharge from the power plant typically was relatively low prior to about 05:00 then rose to a peak in mid-morning after which it declined through mid-to-late afternoon before rising again through early-to-mid evening and finally declining at night.

Correlations varied among years between mean seasonal hourly fish count (ln(X+1) transformed), water temperature (°C) and tailrace water level (cm). The correlations improved, but conclusions were unchanged, except for the 1982 fish count x tailrace level and temperature x tailrace level correlations which became significant ($P < 0.05$), when the high count observed in the first hour of fence operation was discounted. The high count presumably represented accumulated fish which either entered the fishway late in the previous day and remained overnight or which entered the fishway and reached the fence between sunrise (May 1 - June 15 mean sunrise was 04:15) and opening of the fence, or both. Hourly fish count and water temperature were thus significantly correlated in 1982 (n=11, r=0.78, $P < 0.01$) but not in 1983 or 1984 (r=-0.17 and 0.44, respectively; $P > 0.05$). Hourly fish count and tailrace water level were uncorrelated in 1983 and 1984 (N=11, r=0.56 and -0.60, respectively; $P > 0.05$) and negatively correlated in 1982 (n=11, r=-0.81; $P < 0.01$).

Correlations between fish count and both tailrace water level and water temperature would obviously improve if counts were lagged against the latter variables (Fig. 9). The limited (08:00 - 20:00) temporal extent of both tailrace water level and temperature data restricted the analysis so tailrace water level was replaced by discharge ($m^3 \cdot sec^{-1}$) which had a longer time series. Thus, when the fish counts in 1983 and 1984 are lagged 5 hours and 4 hours respectively against discharge (starting at 05:00-06:00), the correlations become 0.86 and -0.81, respectively (n=11; $P < 0.01$). The positive correlation in 1983 resulted from a discharge pattern that increased in the period 05:00-10:00 in 1983; discharge declined over that daily period in 1984. Lagging fish counts 4 hours against water temperatures (starting at 08:00-09:00) in 1983 and 1984 increased the correlation to 0.97 and 0.93, respectively (n=8; $P < 0.01$).

SIZE, AGE, AND SEX COMPOSITION

Mean lengths, weights, and ages of adult alewives (sexes combined) from the Gaspereau River varied between years ($P < 0.01$), with values being greatest in 1982 and least in 1983 (Table 3; Fig. 10). Females averaged longer and heavier than males ($P < 0.001$ each year). As the upstream migration progressed, mean lengths of males and females decreased at a similar rate, i.e., the slopes of the regression of length on date were similar, and negative, for each sex (Table 4). Run progression accounted for 4-7% of the decrease in fish length as determined by the coefficient of determination (r^2) values. From start to end of each migration, the decline in mean length averaged 10 mm for males and 7.7 mm for females. Age-by-date regressions for both sexes did not differ in slope ($F_{1,430} = 0.23$; $P > 0.63$). The pooled regression indicated no change in age over the run ($F_{1,431} = 0.08$; $P > 0.77$). Males averaged younger than females ($P < 0.01$) in two of three years and were of similar age in one year. Regressions of length on date for specific age-groups of each sex had significantly negative slopes except in three of eight cases where the slopes were non-significant from zero (Table 5). No difference in regression slopes were found between sexes. The pooled regressions indicate that, except in 1984, fish of a given age decreased in length during the spawning migration. The distributions of lengths at age approximated a normal distribution when sample sizes were large but were often left skewed when sample sizes were small.

Alewife ages ranged from 4 to 7 years, with over 88% of fish (sexes combined) of age 4 or 5 (Fig. 10; Table 6). Mean length and weight increased with increasing age, although the rate of increase declined after age 5. Most (97%) fish spawned first at age 4 or 5; few did so at age 6 or 7 (Table 7). Mean age at first spawning varied among years (4.47(1983) $<$ 4.73(1984) $<$ 4.89(1982); $F_{2,1232} = 57.230$, $P < 0.025$) as a consequence of the age at which recruits entered the spawning stock. Thus, in 1983 most recruits were age-4 while in 1982 most were age-5. Males averaged younger at first spawning than did females ($P < 0.001$) in two of three years and were similar in age in one year. Although about 1% of all aged fish showed evidence on their scales of having first spawned at age-3, no age-3 fish were found in any year.

Previous spawners annually comprised from 12% to 16% of alewives sampled. Most previous spawners (81%) had evidently spawned only once, 16% twice, and 1% had spawned either three or four times. The proportions (3-year mean) of male and female previous spawners were similar ($F_{1,4}$ = 1.70, P > 0.25).

Male:female sex ratios did not differ from 1:1 in 1982 or 1984 but in 1983 males outnumbered females 1.3:1 (G=23.58, df=11, P > 0.25; Table 8). In 1983, males predominated in the first two and the final samples. In 1984, the overall sex ratio was 1:1 although two samples differed significantly from this ratio.

STOCK DYNAMICS

Age-groups and years of data are too few to do more than a preliminary analysis of the dynamics of this stock. Although alewife year-classes typically recruit to the fishable stock over three years, which biases estimates of the annual survival rate (S) and instantaneous rate of natural mortality (M) upward and reduces the instantaneous rate of fishing mortality (F), the following values have been estimated using the maximum likelihood method (Robson and Chapman 1961; Jensen 1985):

Parameter	1982	1983	1984	Mean
	Year			
Survival (S)	0.53	0.40	0.07	0.335
Mortality (Z)	0.63	0.91	2.66	1.094

An estimate of the average (3-year) fishing mortality rate (F) of 0.41 was calculated from the mean exploitation rate (u) of 0.66, assuming a Type 1 fishery (Ricker 1975), which when subtracted from the average total instantaneous mortality rate (Z) of 1.09 gives an estimate of 0.68 for the natural mortality rate.

Estimates of the size of the age-4 stock for a year-class (YC) used the equation $YC = 4^N + (5^N \times e^M) + (6^N \times e^{2M})$ where N is the number of virgin spawners at age a in year t and M was set at the values of 0.2 commonly used for herring (Doubleday 1985). Thus, the number of age-4 fish was estimated at 299,700, 101,100, and 431,800 in the 1977, 1978, and 1979 year-classes, respectively. The strong 1979 year-class contributed substantially at ages 4 and 5 to the commercial harvest in 1983 and 1984. Data for missing age-groups (age-4 in the 1977 YC, age-6 in the 1979 YC) were estimated from the available data using proportions at age and assuming constant partial recruitments at each age. Based upon the return at a given age of virgin fish, 23% of an average year-class recruited to the spawning stock at age-4, 72% at age-5 and 5% at age-6.

The numbers of alewives harvested by the commercial fishery were estimated (total catch all methods from Table 1 divided by the mean weight per fish from Table 3) at 190,800, 132,000, and 220,700 in 1982, 1983, and 1984, respectively. Exploitation rates, calculated as catch divided by the total return (sum of commercial catch and escapement), averaged 66% (range 53-79%) for the years 1982-1984. Exploitation was highest in 1982. If the Gaspereau River alewife harvest (total catch, Table 2) is assumed to average 90% of the total landings reported for FSD 41, and alewife spawning occurs only in Gaspereau Lake (18.5 km^2), and potential production in the Black River system is ignored, then the average long-term annual harvest from Gaspereau Lake per km^2 of area is 10.0 t.

TAG RETURNS

Alewives (n=24 to 50) which were tagged and released on three different days from the upstream end of the fishway were recovered (n=5) an average of 3.8 days (range 3-5 days) later at either the Lanes Mills fishway at Gaspereau Lake or the dip-net fishery a short distance downstream of the fishway, giving an average movement of 4.5 $km \cdot day^{-1}$. Of 25 tagged fish released in the tailrace, ten recaptured fish took an average of 2.3 days (range 1-8 days) to ascend to the top of the fishway.

The reported recapture rate (3.7%) of the 1984 group of Floy-tagged alewives marked as spent fish was higher than for the 1983 group, as shown below:

Release year	Number marked	Percent recaptured	Year after release 1	2
1983	534	1.9	6	4
1984	1,572	3.7	50	8

Two fish from the 1983 tagging were reported from the fishway in 1984; all other recoveries were made in the square-net fishery.

JUVENILE ALEWIFE DISTRIBUTION AND SIZE

Juvenile alewives collected in different areas of the Gaspereau River system differed in mean size. Trends in mean sample length were similar in Gaspereau Lake (Welton Landing; 0.5 km east of Lanes Mills fishway) and Four Mile Lake in that they declined slightly in early August from their levels in late July prior to increasing steadily until mid-September. The sample size composition from these sites is suggestive of schooling by size between late July and mid-August. Juveniles from Four Mile Lake grew more slowly between mid-August and mid-September than did those from Gaspereau Lake. Juveniles in the Black River system increased in size progressively with distance downstream from Gaspereau Lake such that fish in Lumsden Pond were 65-90% larger than those in Gaspereau Lake during late August through mid-September.

The length of juveniles observed moving downstream at White Rock fishway during August suggests that they originated in the Black River system (August 6, n=50, $\bar{x}$=51.0 mm, SD=5.25; August 31, n=34, $\bar{x}$=85.2 mm, SD=6.91). On the other hand, specimens from a fish kill collected immediately downstream of the White Rock dam powerhouse on July 26 averaged 35.4 mm long (n=24, SD=3.80) and were similar in length to those in Gaspereau Lake. Downstream migrant juveniles observed on September 2 at Lanes Mills fishway were similar in length (n=52, $\bar{x}$=47.0 mm, SD=3.52) to those collected on August 31 at nearby Welton Landing, (Fig. 1; Table 9), but juveniles collected from the Hollow Bridge dam by-pass canal on September 12 were slightly shorter (n=39, $\bar{x}$=82.7 mm, SD=6.16) than those collected on September 13 in Lumsden Pond.

ZOOPLANKTON ABUNDANCE AND SPECIES COMPOSITION

Zooplankton relative abundance and species composition fluctuated seasonally (Fig. 9). On all dates, zooplankton were more abundant (3-40 times) at site C than at sites A and B (Fig. 1).

The most common species of zooplankton were *Diaptomus minutus*, *Bosmina longirostris*, *Cyclops* spp., *Polyarthra* spp., *Keratella cochlearis* and *Daphnia* spp. *Diaptomus*, *Daphnia*, *Bosmina* and *Cyclops* spp. were most abundant in June; all declined in abundance during July but *Diaptomus* and *Daphnia* remained scarce in August while *Bosmina* and *Cyclops* spp. increased in abundance. Rotifera density increased substantially during August.

Water depth at plankton sampling sites A, B, and C (Fig. 1) was 8.5, 11.0, and 6.0 m, respectively on June 22; the surface water temperatures ranged from 19.0 to 22.5°C during the period June 22 to August 29. At site C, the deepest area of the lake, the surface-to-bottom temperature difference was 4.6°C in late June and < 1.0°C in August.

DISCUSSION

The decline in alewife commercial catch on the Gaspereau River from a high of 643 t in 1976 to 50-60 t in the early 1980's may be attributed to overfishing, to fish passage problems at the White Rock fishway, to kills of adult and juvenile fish during downstream passage and to unspecified biological problems. Evidence of variable strengths support these causes. This study has addressed the first three of these concerns.

The lack of a historical time-series of alewife age, growth, and fishing effort data to accompany the catch statistics for the Gaspereau River square-net fishery precludes a basic analysis of stock dynamics. Catch statistics collection methodology is such that a definitive value for the total catch of alewives from the Gaspereau River is difficult to derive. Landings are reported by Fishery Statistical District for all licensed fishermen resident in that district whether they fish in that district or not. This fact creates the possibility (in this case reality) that catches from rivers in other districts could be included in the landings for FSD 41 where the Gaspereau and Avon rivers have the only alewife fisheries. Such additional catch may be substantial. Drift and dip-net fisheries may also bias the catch statistics because these catches are not closely monitored and may not be included in the final tally. The generally higher catch estimates by fishery officers as compared to estimates by inspection officers presumably arise because the former count the number of barrels (91-kg capacity) of fresh salted fish at each fishing site while the latter count the number of repacked pails (23-kg capacity) of salted fish, and weight (moisture) is lost during the curing and repacking process. Log-book totals are lower still because some fishermen either did not return their logs or returned them incomplete or with incorrect information. Fishery officer estimates of total catch by the square and drift-net fisheries would seem to be most useful. Increased attention to the standardization of the process of collecting catch statistics would greatly enhance their value as a management tool.

The observed variation in CPUE will result in poor accuracy for estimates of mean CPUE and for the relationship between annual CPUE and total catch unless a large sample of fishermen is used.

A mean exploitation rate of 66% is not unduly high for a healthy alewife stock. Exploitation rates of 70-95% have been reported for stable runs (Walton 1980; Di Carlo 1982). Exploitation of the alewife and blueback herring run to the Mactaquac Dam on the Saint John River, New Brunswick, has averaged 72% over 14 years (Jessop, unpublished data). However, such rates applied to the depressed Gaspereau River stock may be sufficient to prevent or delay its recovery.

An estimated long-term annual harvest of 10 $t \cdot km^{-2}$ of lake area (excluding the Black River system) seems high in comparison to values (Jessop, unpublished data) of 5.8 $t \cdot km^{-2}$ for the lakes of FSD 56 (Queen's County) of the Saint John River, N.B., and 6.0 $t \cdot km^{-2}$ for the Mactaquac Dam headpond. Biological productivity in the Saint John River is believed to be higher than in the Gaspereau River but comparative data are unavailable for the latter river. Consequently, the catch$\cdot km^{-2}$ of lake area for the Gaspereau River is probably overestimated by the exclusion of the Black River system. The amount of access to the Black River permitted annually by the barrier screens is unknown. Inclusion of the Black River system results in a long term harvest potential of 7.5 $t \cdot km^{-2}$. Whether this can be achieved depends upon whether full access is provided to the Black River and upon the mortality resulting from downstream passage at the various hydroelectric stations.

Although Dominy (1971) recorded an escapement of 60,500 alewives in the Gaspereau River in 1970 prior to a period of high catches, insufficient information exists to determine whether annual escapements of 50,000 to 115,000 fish, as recorded between 1982 and 1984, are adequate to maximize the stock yield.

The interaction of daily fish abundance, water discharge, and water temperature produces variable results depending upon the phase of the alewife migration. The observations that few fish entered the fishway at water temperatures less than 8°C and that the first major peak of the run occurred at 10-14°C are consistent with those by Cooper (1961), Dominy (1971) and Richkus (1974) on the influence of water temperature on the seasonal timing of the spawning migration. This study supports the observation that, at the start of the migration, water temperature acts as a "gating factor" (Richkus 1974) by controlling whether fish present in the estuary will enter and move up a stream (Cooper 1961; Dominy 1971; Saila et al. 1972; Kissil 1974; Tyus 1974). As the spawning season progresses, water temperature rises in response to increasing solar radiation while fish abundance follows a vaguely unimodal or even bimodal pattern which produces no consistent relationship between water temperature and fish abundance (Dominy 1971; Kissil 1974; Richkus 1974; Tyus 1974; this study). The peaks of seasonal movement at high water temperatures reported by Richkus (1974) did not occur in the Gaspereau River.

Seasonal relationships between discharge and fish counts (sometimes lagged) may be significant (Dominy 1971; Richkus 1974) or non-significant, as in this study, depending upon the particular patterns of discharge and fish number which occur. Fishway counts are usually high when stream flow and fish availability are both high; low counts result from low availability whether discharge is high or low. Relative rather than absolute water levels are of importance (Richkus 1974). The generation regime imposed at the hydroelectric station produced a discharge pattern different from that of a natural stream which may explain some differences in results between this and other studies. For example, water temperature and discharge have no obvious causal connection and were found uncorrelated by Richkus (1974) but, in this study, an inverse correlation occurred in 1984, most likely by coincidence.

The daily movement pattern by Gaspereau River alewives of a moderate or absent early morning peak, mid-day period of low activity and strong late afternoon-early evening peak seems typical of alewives (Dominy 1971; Richkus 1974; Tyus 1974). Although no night observations were made, alewife movement upstream has been shown to be primarily diurnal and delimited by exogenous light cycles (Saila et al. 1972; Richkus 1974; Richkus and Winn 1979).

Alewives have been reported to move downstream at night (Dominy 1971). Downstream movement in the Gaspereau River occurred mainly in late afternoon-early evening. Richkus (1974) attributed the midday decline in alewife activity to inhibition of alewife movement at high light intensities but later concluded that endogenous factors were responsible (Richkus and Winn 1979). Observations on the Gaspereau River support the latter explanation best. A higher level of fish movement during midday when the overcast was heavy than when the sun shone (Richkus 1974) was not observed on the Gaspereau River. Alewives, when abundant, entered the fishway equally well on sunny or overcast days.

Some fish could have remained in the White Rock fishway overnight or entered the fishway near dawn and reached the fence prior to the start of counting, thereby increasing the first hour's count. The latter result would suggest that three or four hours are required to transit the fishway.

Although Cooper (1961), Dominy (1971), and Richkus (1974) report that hourly diurnal fish counts (zero lag) were positively correlated with water temperature, such was not the case in two of three years in this study. Given the time required for an alewife to enter and ascend to the top of the long (65 pools) White Rock fishway, significant changes in fish count might be expected to lag changes in water temperature and discharge. Lags of 4 and 5 hours gave significant correlations between fish counts and both water temperature and discharge. The fishways studied by Cooper (1961) and Richkus (1974) are short relative to the White Rock fishway. Dominy (1971) and Richkus (1974) also concluded that diurnal fish movements were more influenced by water temperatures than by water level (or discharge). Limitations in the data stemming from the varying durations of the time series for water temperature and discharge (or tailrace water level) prevent evaluation of the relative influence of these variables on the fish count. However, an increased fish count occurred in late afternoon whether discharge increased or decreased through the morning whereby implying that water temperature, which increased through the morning, until early or late afternoon, was the more important factor. Reported differences in the influence of water temperature and discharge on the diurnal pattern of alewife movement may differ between studies because of differences in local conditions or even methods of data analysis.

The 4 to 5 hour lag, observed between fish counts and water temperature or discharge can be interpreted as the average time required for an alewife to ascend the White Rock fishway. This transit time was slightly less than the 5.7 hours estimated using Dominy's (1973) rate of ascent of 0.19 pools per minute. The increased attraction water flow, improved entrance siting and additional rest pools provided by re-construction of the fishway in 1980 have evidently reduced the transit time and increased the rate of movement from the tailrace to the fishway exit (6-7 days in 1970 vs. 2.3 days in 1983).

Alewives of both sexes typically exhibit a progressive decrease in size and age throughout the spawning run (Cooper 1961; Kissil 1974; Libby 1981, 1982). However, in the Gaspereau River, no decrease in age was observed, probably because only two age-groups form the bulk of the run. The earliest fish were not only the largest and oldest but were also the largest of a particular age group. Males often predominate early in the run (Kissil 1974; Libby 1981) and this was true of the Gaspereau River (Dominy 1971; this study). Males are typically younger in mean age than are females because females often live longer than do males (Richkus and DiNardo 1984) and first spawn at an older age (Marcy 1969; this study). A 1:1 sex ratio usually occurs over the entire run; the exception in the 1983 Gaspereau River run resulted from the large return of age-4 virgin males from the large 1979 year-class. The sex composition of the alewife run to the Gaspereau River is similar to that of other Bay of Fundy rivers such as the Saint John River (Messieh 1977; Jessop et al. 1982) and the Shubenacadie River (Jessop, unpublished data).

The size and age composition of the Gaspereau River stock show evidence of a high mortality rate which may result from excessive commercial exploitation or from turbine-induced mortality of downstream adult migrants. Alewife stocks with lower mortality rates have high (50 - 70%) proportions of previous spawners; the Gaspereau River run averages 14% previous spawners. For example, the alewife run to the Mactaquac Dam, Saint John River, averaged 67% previous spawners during an 11-year period when exploitation averaged 72% (Jessop 1986). The Tusket River has about 55% previous spawners and an intensive fishery (Jessop, unpublished data). Richkus and DiNardo (1984) report alewife runs comprised of 30-40% previous spawners in American streams with moderate to heavy fishing pressure. In the Margaree and Miramichi rivers, heavy fishing pressure has reduced the proportions of previous spawners from about 50% to 20 - 30%, (R. Alexander, DFO; pers. comm.). Dominy (1971) reported an exploitation rate for the Gaspereau River of 87% in 1970 on a run size of about 500,000 fish as compared with the recent exploitation rate of 66%.

No estimates are available for the turbine-induced mortality rates of adult or juvenile alewives during downstream passage at the five generating stations on the Gaspereau River. The annual installation of a barrier screen in Trout River pond has denied most adult alewives access to the Black River system, so adult mortalities during downstream passage have occurred primarily, and infrequently, at the White Rock power station. Delayed mortality would, however, be difficult to detect.

Kills of juveniles are often reported. Most juvenile alewives presumably, due to the barrier screens in Trout Brook Pond, migrate downstream from Gaspereau Lake via the Gaspereau River, thereby descending only through a turbine at the White Rock power station. A small proportion of fish use the White Rock fishway. Juveniles utilizing the Black River system (an unknown proportion of the total) must pass through four other turbines (where bypass facilities are inadequate) prior to reaching White Rock.

Turbine-caused mortality is assumed to act multiplicatively, killing a constant proportion of migrants. Mortality rates of 60-80% found during passage of juvenile alosids through a low-head Kaplan turbine (Taylor and Kynard 1985) may not apply to the Francis turbines used on the Gaspereau River (Ruggles 1980). The pattern of moderate recent exploitation rate, high natural mortality rate, low stock size, and low proportion of repeat spawners suggest that turbine-induced mortality is an important determinator of the proportion of previous spawners while the harvest rate largely controls stock abundance via the stock-recruitment relationship, (Havey 1973; Jessop 1986). A reduction in fishing effort could produce an increase in stock abundance. More spawners are also required at a given level of future return to compensate for a potentially high juvenile mortality during downstream migration. A larger stock size may not increase the proportions of previous spawners if turbine-caused mortality of adults is high and production could remain dependent upon one or two year-classes. The maximum sustainable yield is limited by the amount of spawning and rearing area and the biological productivity of the river system. A sustainable average harvest of 165-200 t may be realized from the Gaspereau River system (including the Black River system) if escapements increase and non-fishing mortality remains constant (as it is assumed to have been over the historical record). Development of a successful alewife run to Aylesford Lake (fishway access was provided in 1986) might increase the potential average harvest to 205-257 t.

Evidence is inconclusive that the larger juvenile alewives from the Black River system began migrating downstream earlier than did the smaller juveniles from Gaspereau Lake. Kissil (1974) and Richkus (1974b) conclude that size and age do not influence the timing of migration, but, in tidal freshwater, larger fish may begin moving downstream prior to the general exodus (Loesch and Kriete 1980). A downstream movement of juvenile alewives beginning in July and peaking between mid-September and early October is comparable to that for streams in Maine (Rounsefell and Stringer 1943; Havey 1973). Richkus (1975) observed that precipitation, declining water temperatures, and increasing outflow were associated with initiation of migratory waves of juveniles.

Downstream migration of juvenile alewives may be initiated by low plankton abundance caused by alewife grazing (Richkus 1975; Vigerstad and Cobb 1978). However, any migration effect could be minimized by juveniles switching to other available food sources as they become increasingly omnivorous with increased size (Hutchinson 1971; Watt and Duerden 1974; Kohler and Ney 1980; Gregory et al. 1983). Such a switch by growing juvenile alewives may account for the increased abundance of copepod nauplii in Gaspereau Lake in mid-August. The seasonal abundance and species composition of zooplankton in Gaspereau Lake is similar to that in Lake Ainslie (Gregory et al. 1983) and is fairly typical of temperate lakes. Transport of zooplankton from Aylesford Lake, which held no juvenile alewives in 1983, may account for the zooplankton abundance at site C in Gaspereau Lake.

The large size of juvenile alewives in the smaller lake area of the Black River system, as compared with those in Gaspereau Lake and particularly in Four Mile Lake, implies a smaller stock and reduced competition for food since there is no evidence that the zooplankton productivities of the systems differ appreciably. The screens at Trout River Pond seemed successful in preventing adult and large juvenile alewives from entering the Black River from Gaspereau Lake. Larvae and small juveniles pass easily, although relatively few reportedly do so (R. Sweeney, DFO, pers. comm.). Nonetheless, the screens may be ineffective due to their poor condition and occasional removal by boaters because substantial numbers of juvenile alewives are observed in the Black River. The Black River is clearly capable of contributing substantially to the alewife production of the Gaspereau River system if the concerns over downstream passage can be solved.

In summary, alewife production in the Gaspereau River system is greatly reduced by the incomplete utilization of potential rearing area, i.e., Black River system by serious problems with downstream fish passage arising from a lack of turbine bypass facilities and consequent mortalities of adult and juvenile fish, and by the ability of the commercial fishery to overharvest the resource, in part by obstructing upstream passage with excessively long berms. Only by devising and implementing solutions to these problems can the full potential of the alewife resource and commercial fishery be met.

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Gaspereau River Fishway Counts 1982

TABLE 1. Comparison of catch statistics (t), obtained from fishery and inspection officers and log-books, for the alewife fishery of the Gaspereau River and of FSD 41, 1980 - 1986.

Year	Square-net fishery: Fishery officer	Square-net fishery: Inspection officer	Square-net fishery: Logbook	Percent of fishermen returning logs	Total catch[a] all methods	Total catch FSD 41
1980	---	91	---[b]	---	---[d]	134
1981	---	36	16	41	---	53
1982	44	25	46[c]	82	56	52
1983	23	23	18	75	34	53
1984	50	49	46	80	60	62
1985	38	43	18	33	54	50
1986	204	166	93	56	215	272

a. Includes square, drift and dip-net catches.
b. Logbooks not issued.
c. Fishery officer believes this value is too high.
d. Data unavailable.

TABLE 2. Catch per unit effort ($kg \cdot hr^{-1}$) for four square-net fishermen, Gaspereau River, 1981-1986.

Fisherman	1981	1982	1983	1984	1985	1986
1	13.4	---	1.4	28.7	---	18.6
2	20.8	9.3	6.0	20.7	18.3	33.9
3	5.6	18.4	12.8	21.9	32.9	44.7
4	6.9	11.2	6.2	28.4	55.9	73.0
Mean	9.8	13.7	5.5	25.4	36.0	40.9

TABLE 3. Mean fork length, weight, and age, by sex and year, for alewives from the Gaspereau River, 1982-1984.

		Male		Female		Combined
Group/Year	n	Mean ± 95% CI	n	Mean ± 95% CI	n	Mean ± 95% CI
Length (mm)						
1982	151	268.7 ± 1.7	145	279.4 ± 1.9	296	273.9 ± 1.4
1983	300	252.9 ± 1.7	231	268.5 ± 2.3	531	259.7 ± 1.5
1984	215	263.0 ± 1.6	235	272.8 ± 1.5	450	268.1 ± 1.2
Weight (g)						
1982	151	272.1 ± 5.5	145	315.7 ± 7.9	296	293.5 ± 5.4
1983	300	232.4 ± 5.5	231	290.4 ± 8.7	531	257.6 ± 5.5
1984	215	254.2 ± 5.2	235	288.0 ± 6.0	450	271.9 ± 4.3
Age (year)						
1982	146	5.0 ± 0.08	142	5.1 ± 0.08	288	5.1 ± 0.06
1983	290	4.5 ± 0.08	223	4.9 ± 0.11	513	4.7 ± 0.07
1984	208	4.8 ± 0.07	226	5.0 ± 0.06	434	4.9 ± 0.05

TABLE 4. Analysis of covariance of length and age by capture date regressions for male and female alewives from the Gaspereau River, 1982-1984.

		Regression coefficient			Equality of slopes			Significance of pooled coefficient			Adj. means		Equality of adj. means		
Year	Factor	Male	Female	Pooled	df	F	P	df	F	P	Male	Female	df	F	P
1982	Length	-0.369	-0.452	-0.411	1,292	0.21	0.65	1,293	20.47	0.001	268.4	279.6	1,293	80.09	0.001
	Age	-0.005	-0.011	-0.008	1,284	0.49	0.49	1,285	3.84	0.05	5.01	5.09	1,285	2.00	0.16
1983	Length	-0.330	-0.191	-0.278	1,527	1.14	0.29	1,528	19.40	0.001	252.8	268.6	1,528	126.26	0.001
	Age	-0.011	-0.007	-0.010	1,509	0.37	0.54	1,510	9.41	0.002	4.50	4.89	1,510	32.79	0.001
1984	Length	-0.341	-0.261	-0.305	1,446	0.42	0.52	1,447	24.91	0.001	262.5	273.3	1,447	96.33	0.001
	Age	-0.002	0.001	-0.001	1,430	0.23	0.63	1,431	0.08	0.77	4.81	4.96	1,431	10.30	0.001

TABLE 5. Analysis of covariance, by age-group, of length and age by capture date regressions for male and female alewives from the Gaspereau River, 1982-1984.

		Regression coefficient			Equality of slopes			Significance of pooled coefficient		
Year	Age	Male	Female	Pooled	df	F	P	df	F	P
1982	5	-0.277	-0.331	-0.303	1,228	0.09	0.76	1,229	11.69	< 0.001
1983	4	-0.194	-0.088*	-0.165	1,267	1.62	0.20	1,268	19.53	< 0.001
	5	-0.261	-0.269	-0.265	1,332	0.01	0.94	1,333	23.27	< 0.001
1984	5	0.034*	-0.128*	-0.051	1,144	0.84	0.36	1,145	0.34	0.56

* Slope non-significant from zero ($P < 0.05$).

TABLE 6. Lengths and weights, by age, of male and female alewives from the Gaspereau River, 1982-1984.

		Male					Female				
		Length		Weight			Length		Weight		
Year	Age	n	Mean	± 95% CI	Mean	± 95% CI	n	Mean	± 95% CI	Mean	± 95% CI
1982	4	12	255.9	± 4.11	232.1	± 11.72	11	259.6	± 3.07	243.3	± 11.74
	5	123	269.0	± 1.69	273.9	± 5.30	109	279.1	± 1.89	313.0	± 8.00
	6	8	272.8	± 11.14	280.9	± 43.19	21	289.8	± 2.53	360.5	± 15.18
	7	3	294.3	± 14.56	345.7	± 7.44	1	304		448	
1983	4	185	244.8	± 1.07	207.5	± 3.32	86	252.2	± 1.53	233.8	± 4.56
	5	67	259.7	± 2.81	250.9	± 8.59	81	269.0	± 2.34	286.8	± 8.53
	6	36	278.7	± 4.26	318.2	± 15.91	51	289.2	± 3.03	367.1	± 13.28
	7	2	284.0		333.0		5	307.8	± 15.93	453.4	± 105.51
1984	4	51	250.9	± 2.46	220.9	± 8.15	25	257.7	± 2.92	235.8	± 11.61
	5	147	265.6	± 1.38	261.1	± 4.84	189	273.3	± 1.37	292.4	± 5.45
	6	9	284.3	± 8.32	323.7	± 32.20	8	293.4	± 9.17	359.9	± 31.14
	7	1	286		360		4	299.0	± 11.55	400.3	± 32.77

TABLE 7. Spawning history of alewives from the Gaspereau River, N.S., 1982-1984.

Year	Age	Number of spawning checks on scale	Number of fish		
			Male	Female	Combined
1982	4	0	12	11	23
	5	0	115	100	215
	5	1	6	8	14
	5	2	2	1	3
	6	0	7	8	15
	6	1	0	10	10
	6	2	1	3	4
	7	2	3	1	4
1983	4	0	182	85	267
	4	1	3	1	4
	5	0	61	70	131
	5	1	6	11	17
	6	0	12	18	30
	6	1	21	28	49
	6	2	2	5	7
	6	3	1	0	1
	7	0	0	1	1
	7	1	1	1	2
	7	2	1	0	1
	7	3	0	1	1
	7	4	0	2	2
1984	4	0	51	25	76
	5	0	124	172	296
	5	1	22	14	36
	5	2	1	3	4
	6	0	1	3	4
	6	1	6	5	11
	6	2	2	0	2
	7	1	0	1	1
	7	2	1	3	4

TABLE 8. Sex ratios, by sample date and year, of alewives from the White Rock fishway, Gaspereau River, 1982-1984.

1982			1983			1984		
Date	n	M:F[a]	Date	n	M:F	Date	n	M:F[a]
			9/5	50	1.9:1*	10/5	50	3.5:1*
24/5	50	1.3:1	12/5	50	2.1:1*	14/5	50	1.6:1
27/5	50	1.5:1	16/5	50	1.2:1	17/5	50	0.8:1
31/5	50	0.9:1	19/5	50	1.2:1	22/5	50	0.6:1*
3/6	46	0.8:1	24/5	50	1.1:1	24/5	50	0.8:1
10/6	50	0.9:1	27/5	50	0.9:1	28/5	50	0.7:1
			30/5	50	0.8:1	31/5	50	0.7:1
			2/6	50	1.5:1	4/6	50	0.8:1
			6/6	31	0.8:1	7/6	50	0.6:1
			9/6	50	1.4:1			
			13/6	50	2.1:1*			
Overall	246	1.0:1		531	1.3:1*		550	0.9:1:1

[a] M = male, F = female

* G - statistic significant at P < 0.05.

TABLE 9. Fork length and weight statistics, by sample date, for juvenile alewives from sites in the Gaspereau River system, 1983.

Site/date	Length (mm)		Weight (g)
	n	Mean ± 95% CI	Mean ± 95% CI
Gaspereau Lake - Welton Landing			
July 21	28	39.2 ± 1.6	0.67 ± 0.10
July 26	55	39.5 ± 1.1	0.65 ± 0.06
August 2	50	36.9 ± 1.3	0.54 ± 0.07
August 8	50	35.6 ± 1.3	0.65 ± 0.09
August 22	8	43.5 ± 2.7	0.98 ± 0.20
August 26	5	46.4 ± 5.0	1.31 ± 0.38
August 31	51	48.2 ± 0.8	1.38 ± 0.07
September 13	47	52.2 ± 0.8	1.82 ± 0.08
Gaspereau Lake - Four Mile Lake			
July 19	31	38.0 ± 1.4	0.66 ± 0.08
July 25	17	33.8 ± 2.6	0.47 ± 0.13
August 4	60	38.0 ± 1.6	0.70 ± 0.10
August 10	60	32.6 ± 0.6	0.39 ± 0.02
August 16	51	35.2 ± 0.5	0.48 ± 0.02
August 22	50	36.2 ± 0.6	0.55 ± 0.03
August 30	51	36.7 ± 0.7	0.62 ± 0.03
September 2	50	37.4 ± 0.5	0.62 ± 0.02
September 13	50	39.8 ± 0.5	0.65 ± 0.03
Trout River Pond			
July 20	4	26.3 ± 5.3	0.19 ± 0.06
July 25	50	33.5 ± 1.5	0.44 ± 0.08
August 5	52	36.2 ± 1.2	0.57 ± 0.06
August 13	54	38.4 ± 1.5	0.75 ± 0.10
September 3	53	46.7 ± 1.4	1.33 ± 0.16
Black River Lake			
July 26	60	40.4 ± 1.5	0.86 ± 0.13
August 25	24	76.5 ± 4.2	5.95 ± 0.79
September 13	24	76.9 ± 2.4	6.66 ± 0.69
Lumsden Pond			
August 24	49	82.2 ± 1.9	6.74 ± 0.62
September 1	47	83.6 ± 1.1	7.08 ± 0.32
September 13	50	85.7 ± 1.4	7.62 ± 0.31

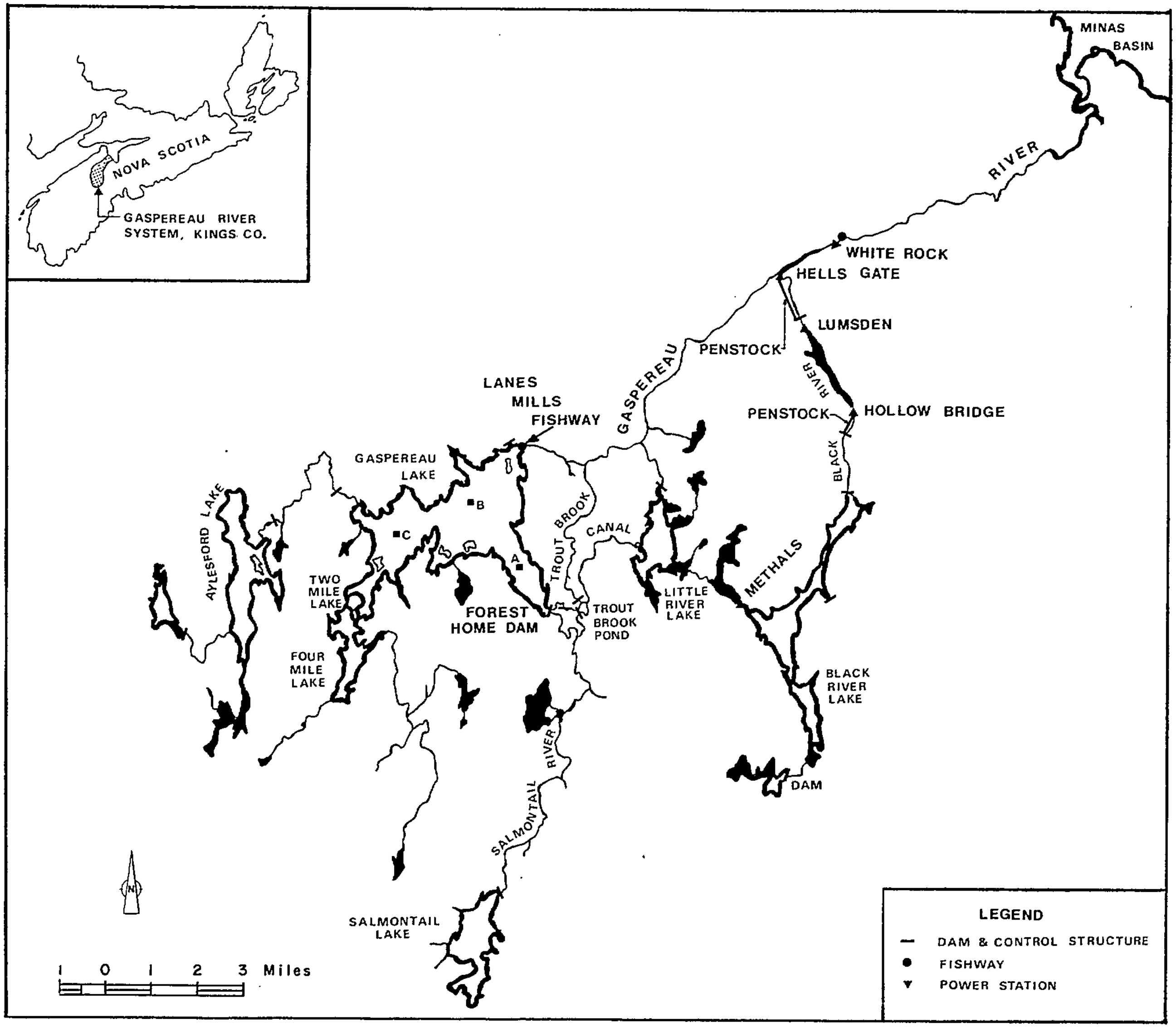

FIG. 1. Map of the Gaspereau River, Kings County, Nova Scotia. Letters (A,B,C) indicate zooplankton sampling sites.

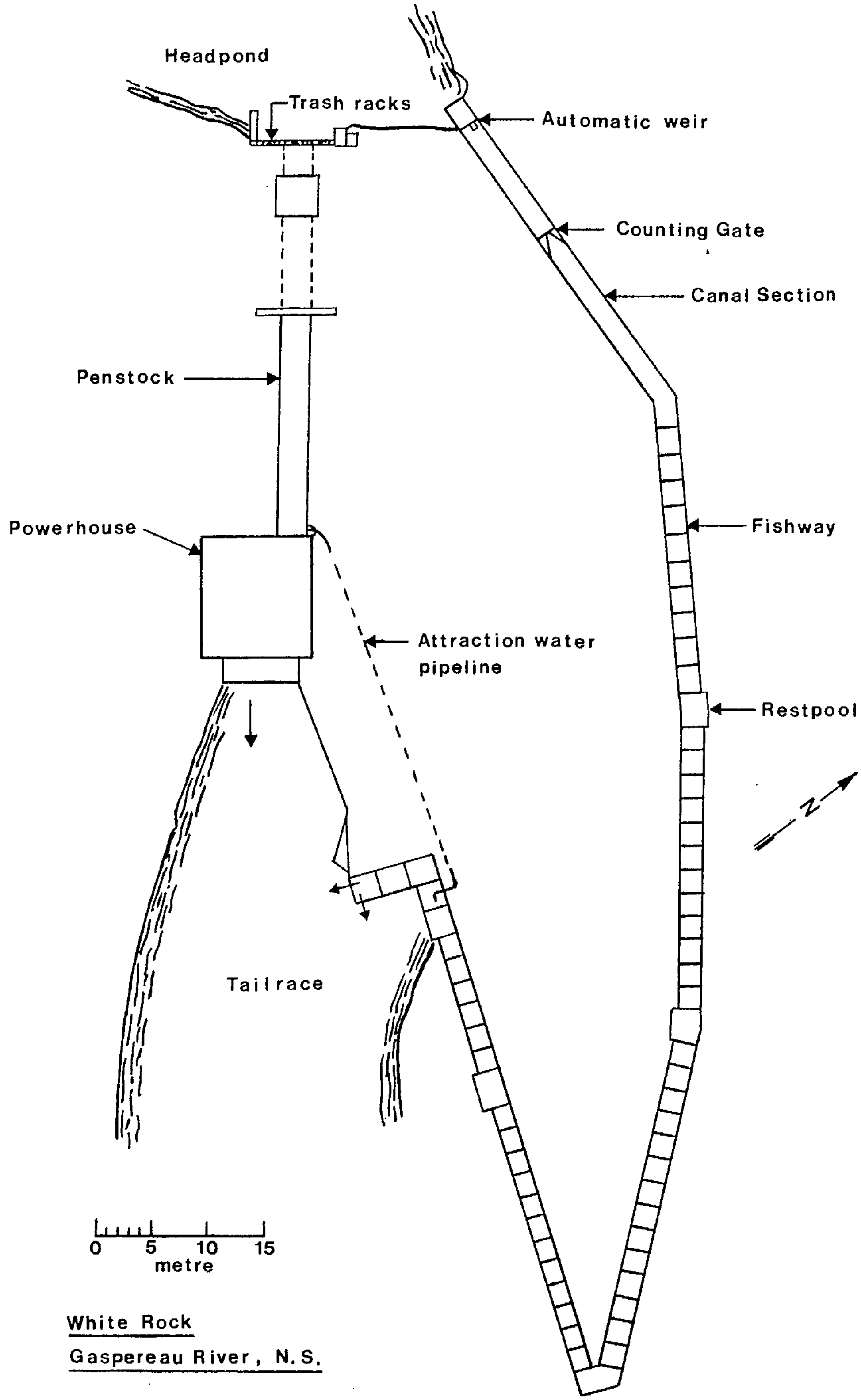

FIG. 2. Plan view of the White Rock fishway and hydroelectric dam, Gaspereau River, N.S.

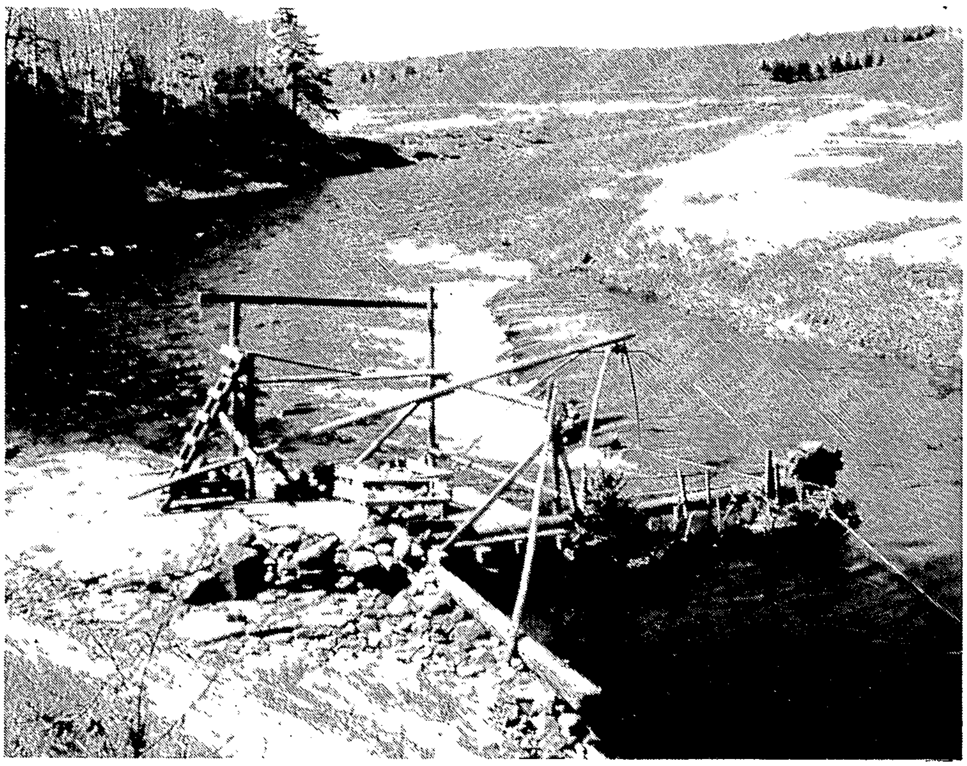

FIG. 3. Sauare-net fishing site, Gaspereau River, N.S.

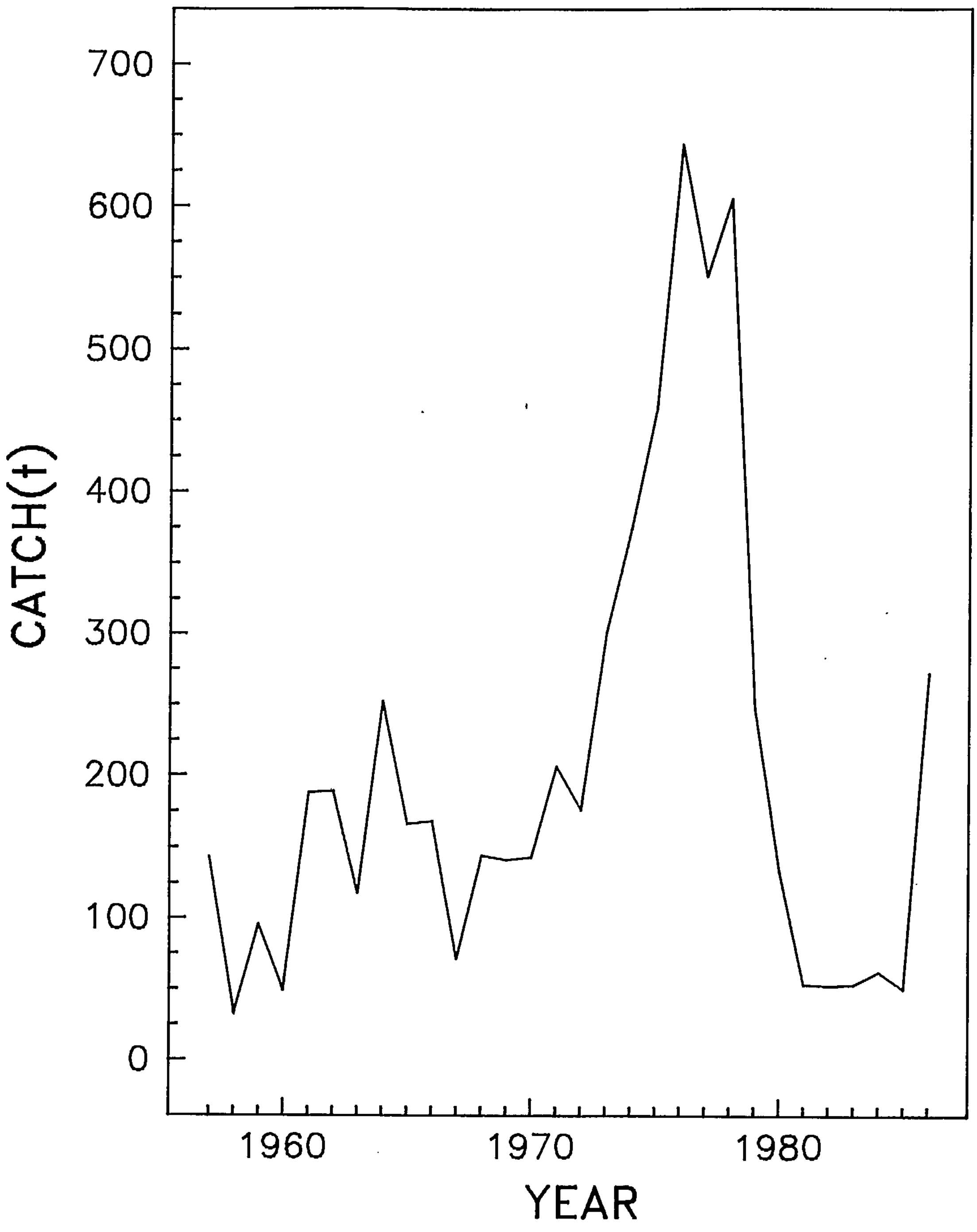

FIG. 4. Reported catches of gaspereau in Fisheries Statistical District 41, which includes the Gaspereau River, 1957-1986.

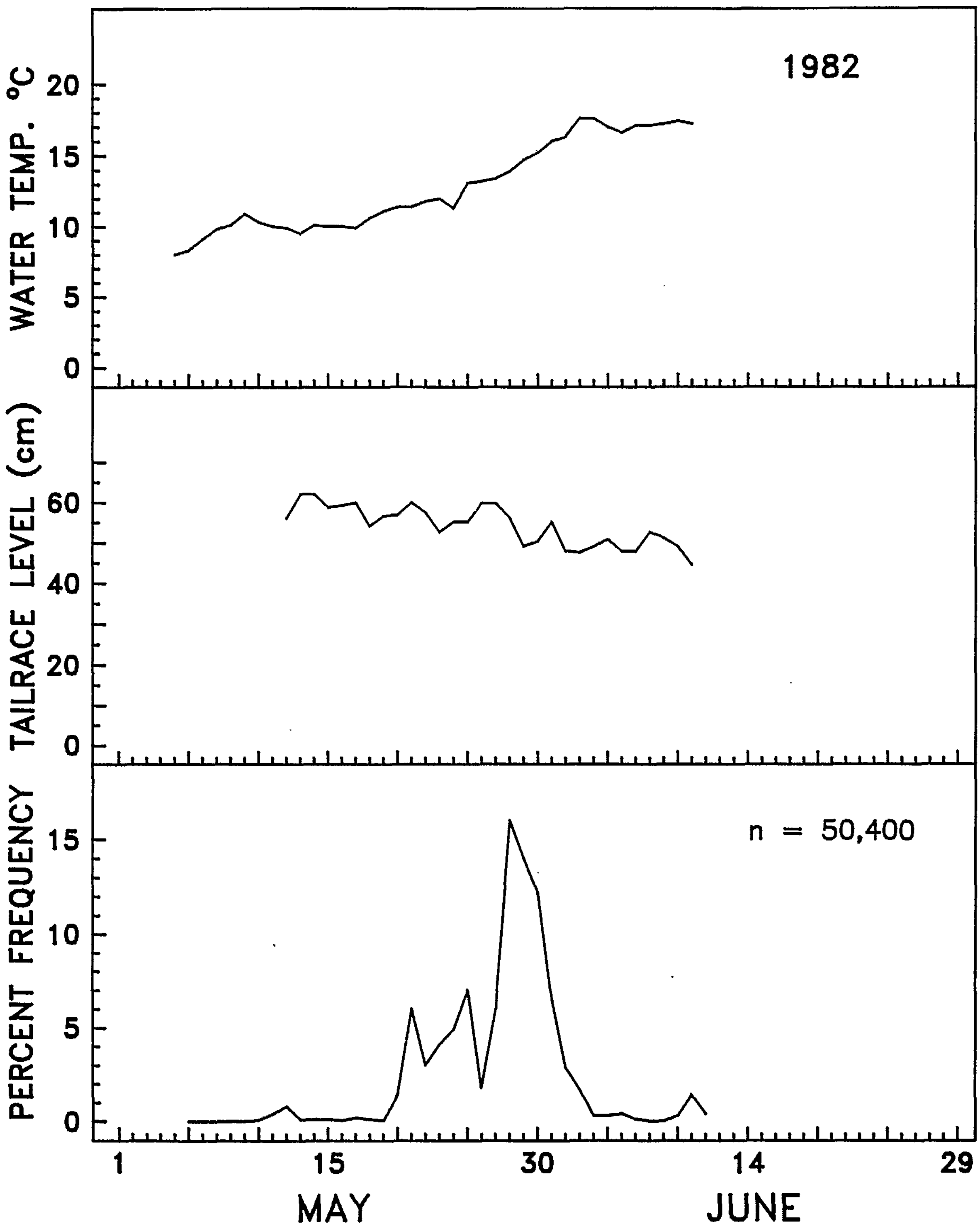

FIG. 5. Daily percent relative count of alewives, tailrace water level, and mean water temperature at the White Rock fishway and power station, Gaspereau River, 1982.

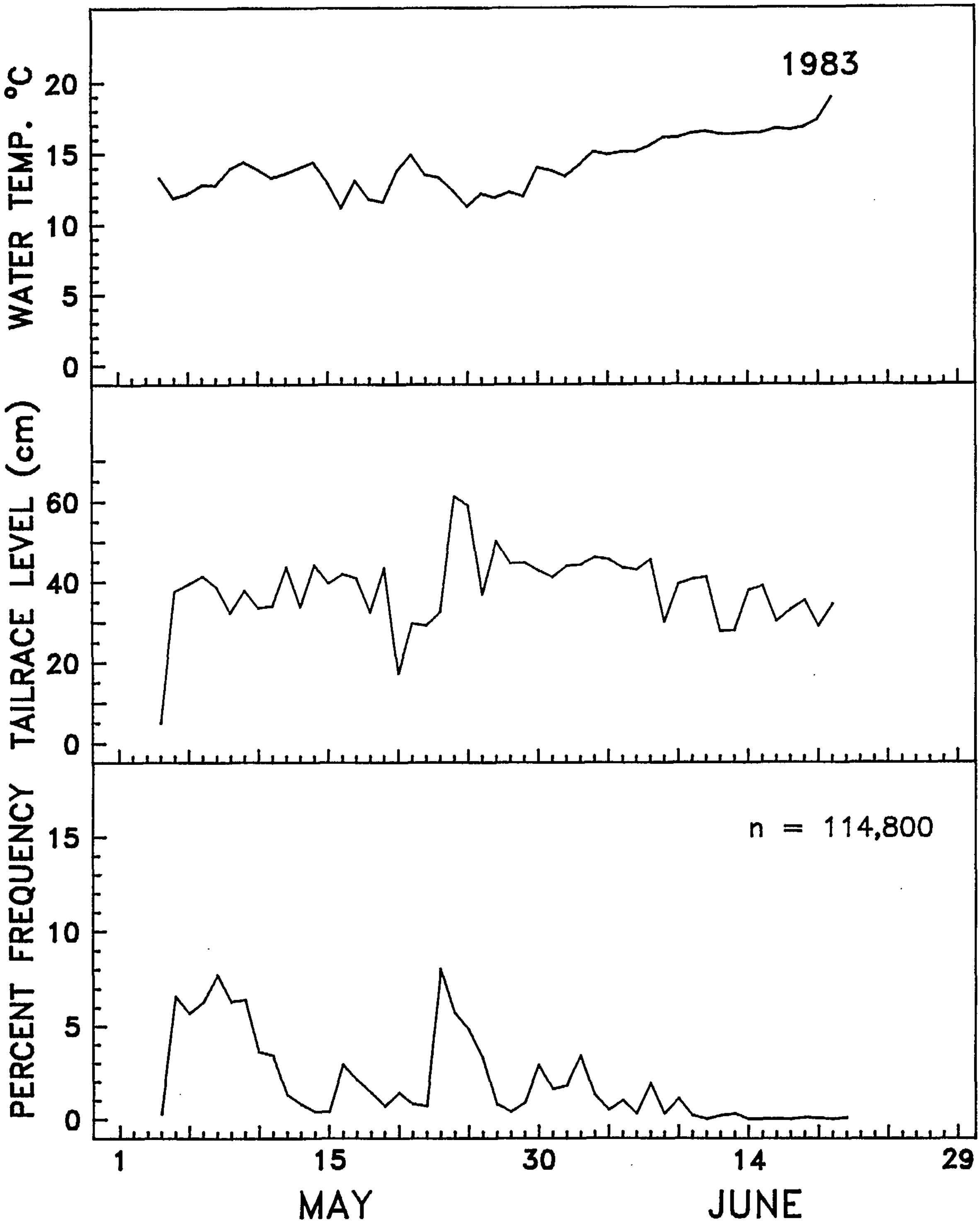

FIG. 6. Daily percent relative count of alewives, tailrace water level, and mean water temperature at the White Rock fishway and power station, Gaspereau River, 1983.

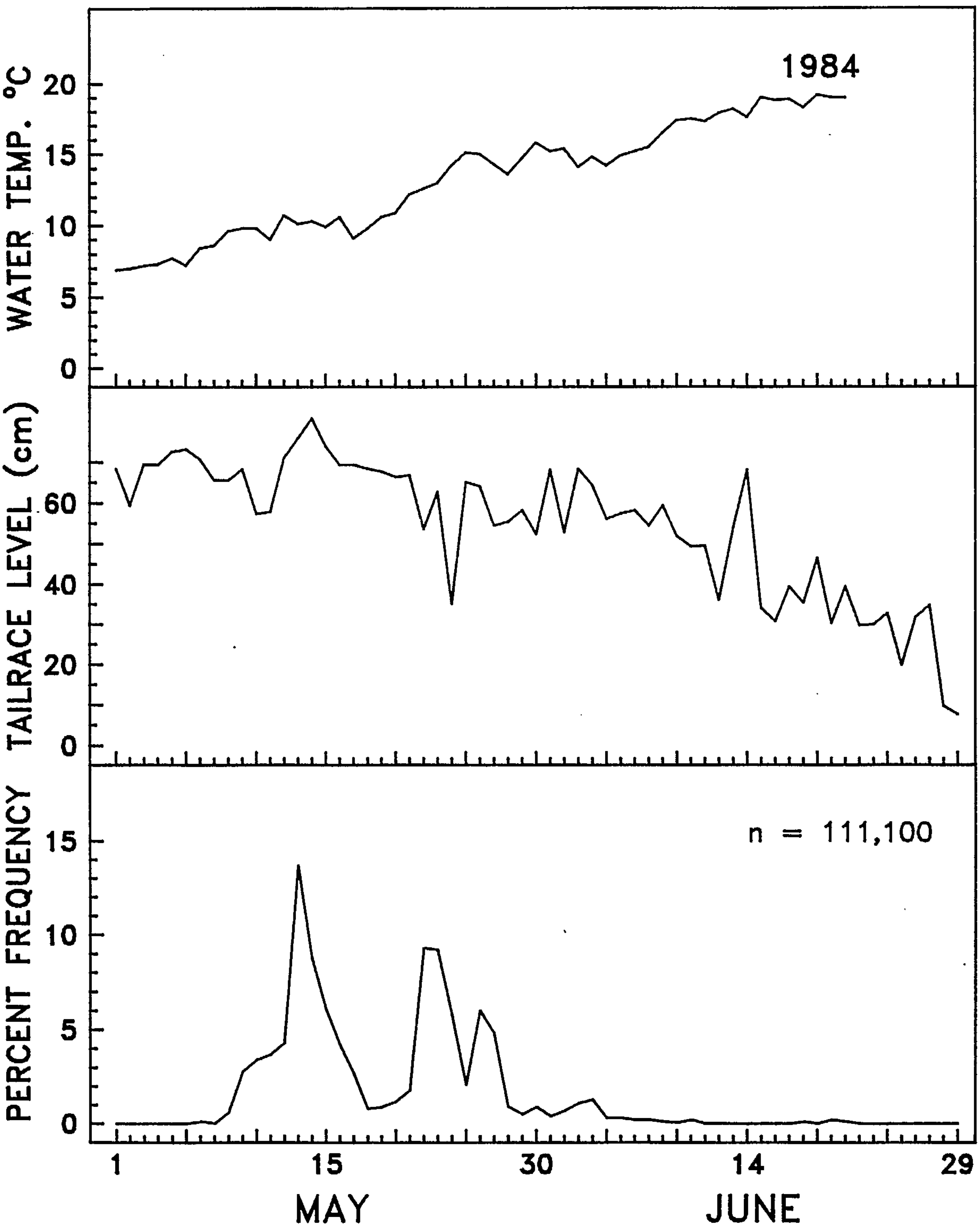

FIG. 7. Daily percent relative count of alewives, tailrace water level, and mean water temperature at the White Rock fishway and power station, Gaspereau River, 1984.

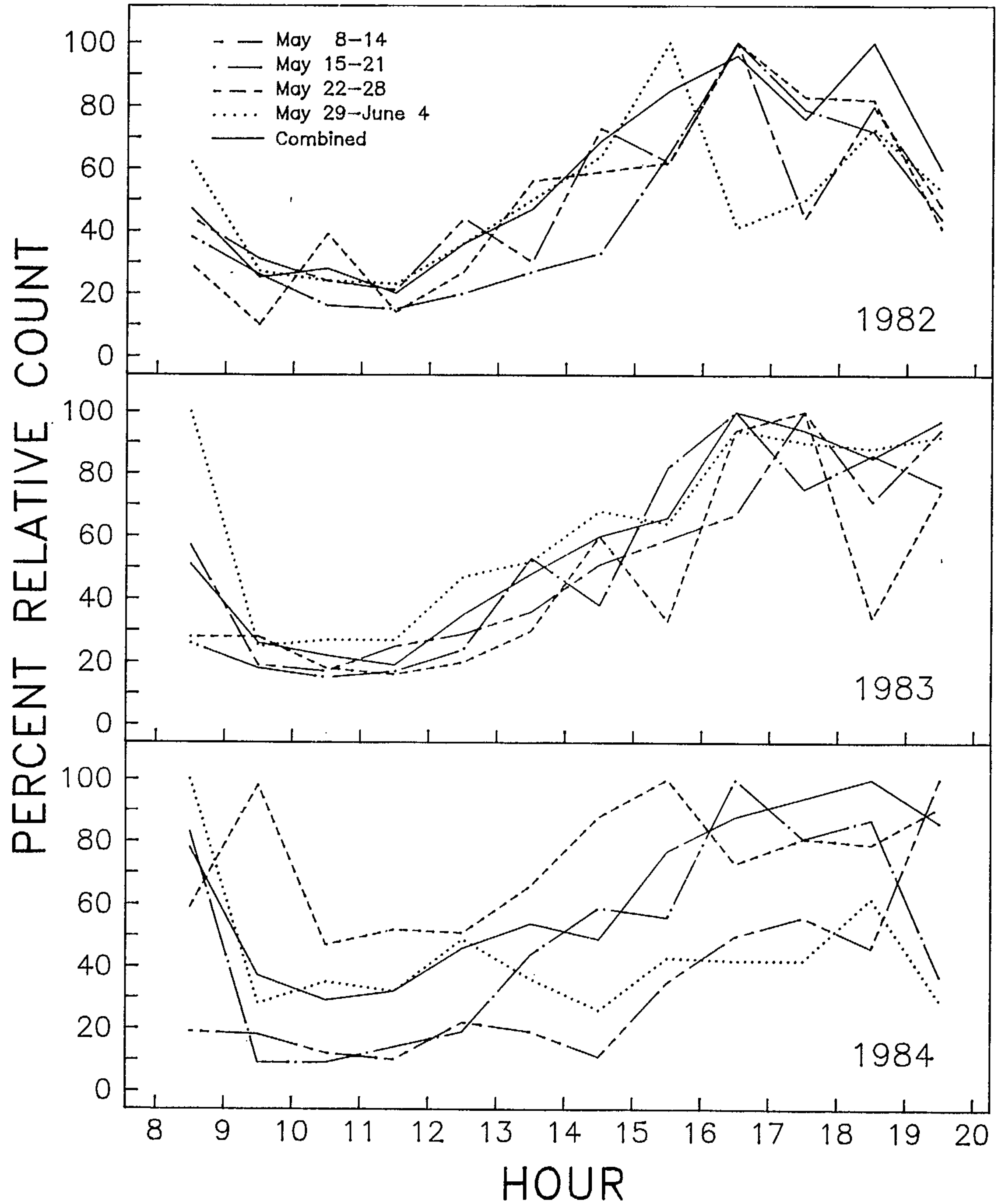

FIG. 8. Weekly means of the hourly count ($\log_e(X+1)$ transformed) as a percent of the largest hourly count of alewives at the White Rock fishway, Gaspereau River, 1982-1984.

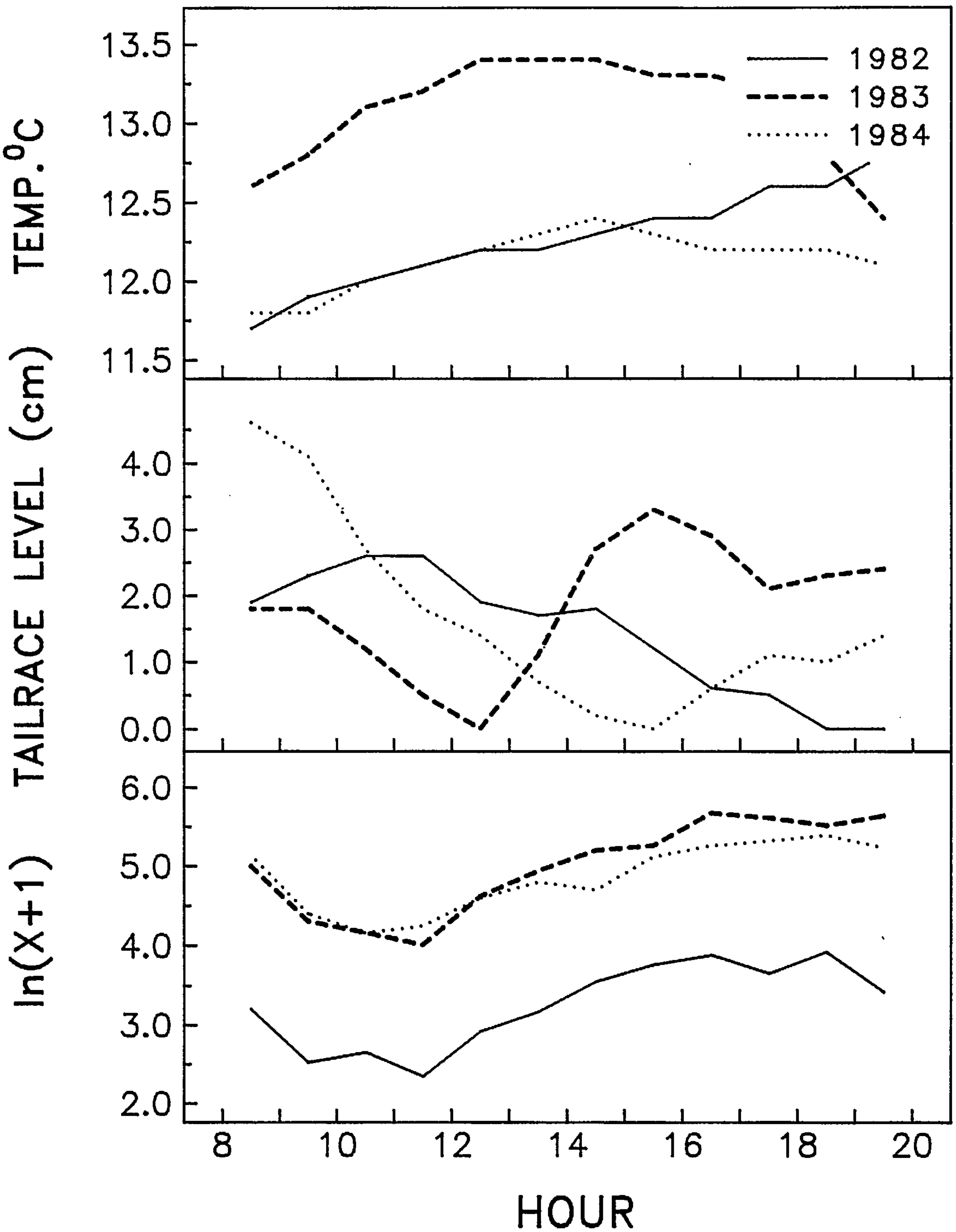

FIG. 9. Seasonal (May 8-June 4) means of hourly alewife counts ($\log_e(x+1)$ transformed), tailrace water level, and water temperature at the White Rock fishway and power station, Gaspereau River, 1982-1984.

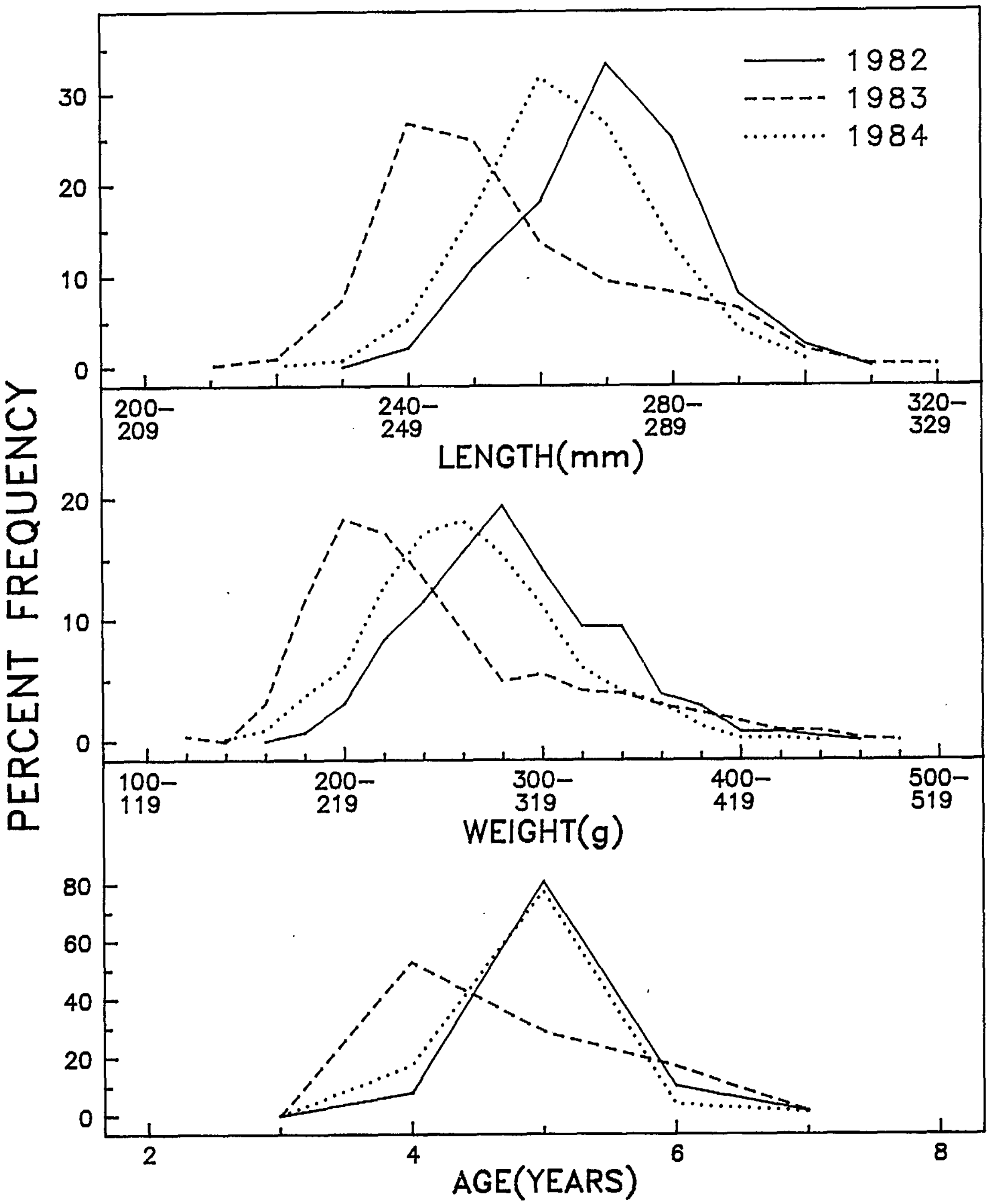

FIG. 10. Percent frequency of annual length, weight, and age distribution for alewives from the Gaspereau River, 1982-1984.

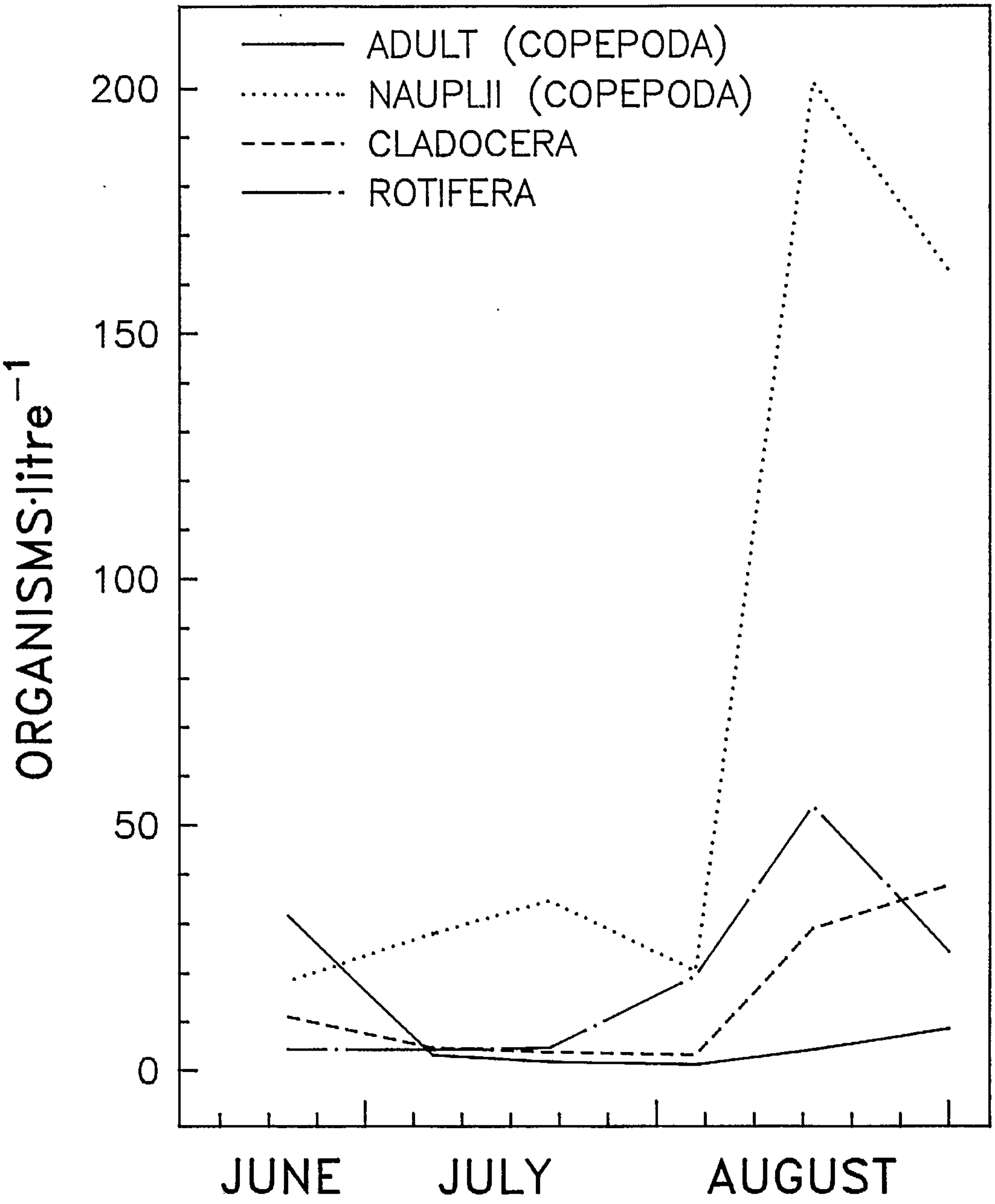

FIG. 11. Seasonal mean abundance (three stations) of zooplankton in Gaspereau Lake, 1983.