Ecology of Young-of-the-Year Alewives in Gaspereau Lake with Reference to Water Management Strategies in the Black River - Gaspereau River Watershed

Final Report
to
Nova Scotia Power Inc.

prepared by

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February, 1998
ACER Publication No. 47

EXECUTIVE SUMMARY

The ecology of young-of-the-year (YOY) alewives (*Alosa pseudoharengus*) in Gaspereau Lake was studied during the summer and fall of 1997 in order to collect data useful for the development of management strategies for these fish in this watershed.

YOY outmigration was monitored at the outlet to the Gaspereau River between June 8th and November 20th, resulting in the capture of 18,582 alewives. Outmigration rates were highest during October, but the timing of outmigration may have been influenced by discharge volumes from the lake and by the configuration of the control gate at this outlet. About 1.2 million YOY were estimated to have exited the lake via this outlet during the study period. Alewives were still present in the lake in late October, a large number of which moved downstream when the control gate at Forest Home was opened on October 23rd.

Alewife eggs and larvae were present in the Gaspereau River downstream of Gaspereau Lake in June indicating that some spawning activity takes place in the Gaspereau River, both upstream and downstream of the White Rock dam. It is not known whether 1997 was a typical year in this regard.

Alewives were present in all regions of Gaspereau Lake throughout the summer. Larvae were captured until the week of July 27th, after which only juveniles were captured. Alewives were large enough for the Trout River Lake diversion screen to be effective by mid-August.

Although other possible explanations exist, decreases in zooplankton abundance in Gaspereau Lake in early July, and bimodal YOY length frequency distributions throughout July and August suggest that intraspecific competition may be one factor potentially influencing alewife reproductive success wirhin the watershed.

ACKNOWLEDGMENTS

The authors wish to thank the many people who assisted with this project. Keir Daborn, Mark Johnston, Jessica Vast and Scott Moffitt formed the basis of the field crew. Terry Toner and Ken Meade served as scientific contacts with Nova Scotia Power Inc., and Jack Andrews and Garfield Langille (NSPI) assisted with the logistics when working around the hydro system and supplied discharge information used in this report. Insights and observations of this system over the last few decades by local residents and resource users contributed substantially to this project, while at the same time reinforcing the importance of preserving the resources this system provides.

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1. INTRODUCTION

1.1 Background

The Black River - Gaspereau River watershed in Nova Scotia (Figure 1) supports a stock of anadromous alewives (*Alosa pseudoharengus*) that is subject to both recreational and commercial fishing as it ascends the system to spawn during May and June. Adults typically migrate upstream by way of the old Gaspereau River channel to spawn in lakes at the head of the system. Eggs hatch during late June and early July, and young-of-the-year (YOY) then utilize these lakes as nursery areas prior to emigrating seaward during late summer and fall.

This watershed has been extensively modified for hydroelectric generation during the last 80 years. The present system, constructed in stages between 1919 and 1952, includes diversions of the Black River, Gaspereau River, Forks River, and numerous smaller brooks and streams. The system currently consists of over a dozen lakes interconnected by manmade canals and natural waterways. Five generating stations and numerous storage dams are now present in the system, that may present obstacles for migrating freshwater (e.g. white sucker, brook trout), anadromous (e.g. alewife, Atlantic salmon, rainbow smelt, striped bass) and catadromous (American eel) fish.

The commercial and recreational alewife fisheries of the Gaspereau River are of local economic importance. Alewives are fished commercially with square nets, and from 13 to 15 sites have been fished during the 1990's (Hank Sweeney, pers. comm.). Catch statistics are available for the years 1964 to 1997, and during this time the annual catch (both commercial and recreational) has averaged c. 167,000 kg. (range: 24,900 to 471,000 kg).

Biological information about this stock is limited. Assessments of the stock and the related fishery were conducted by D.F.O. between 1982 and 1984 (Jessop and Parker 1988), in

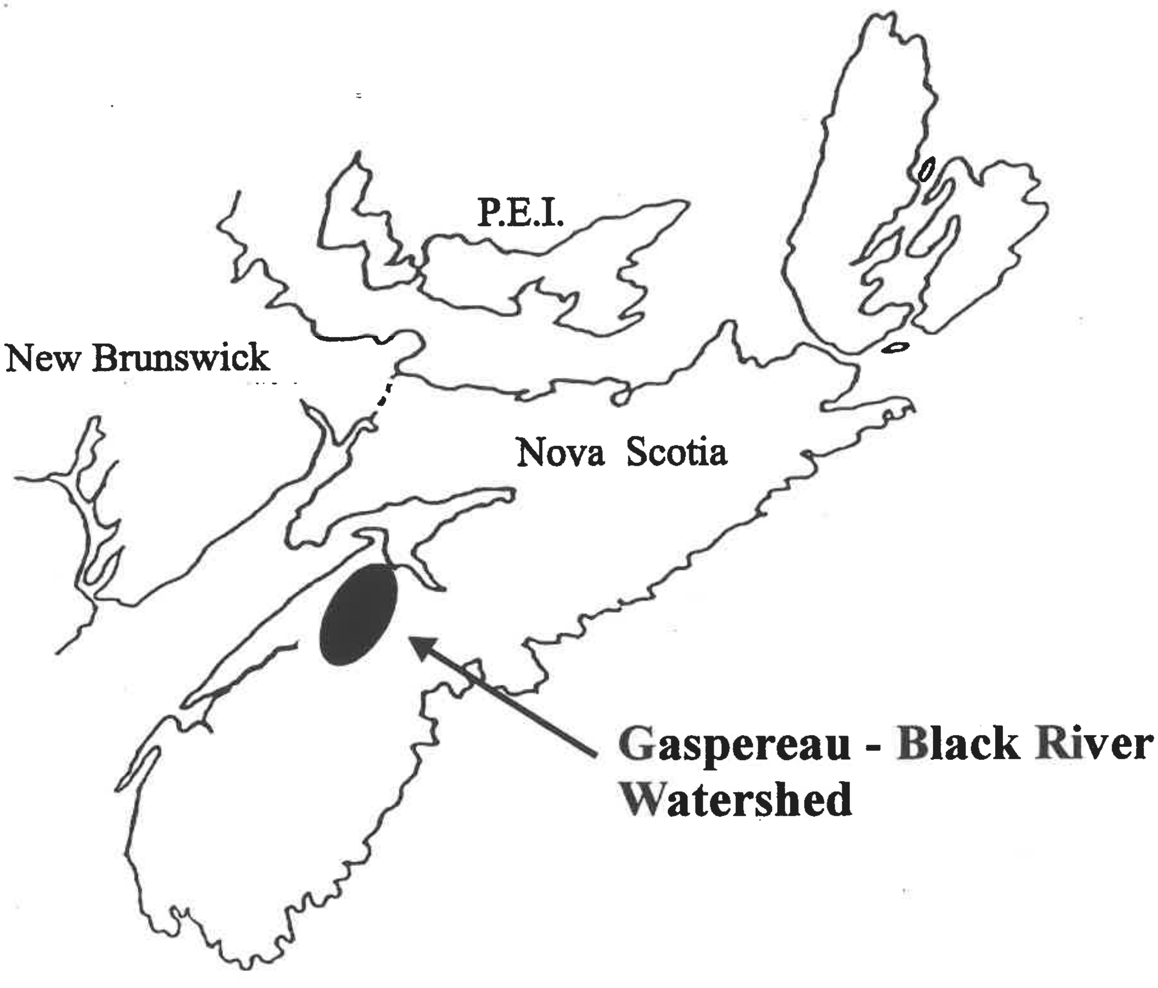

Figure 1. Location of the Black River - Gaspereau River watershed in Nova Scotia.

1995 by Nova Scotia Power Inc. (NSPI, unpublished data) and in 1997 by the Acadia Centre for Estuarine Research (Gibson and Daborn 1997). Biological data relating to adults were also collected during an evaluation of the fish ladder at White Rock in 1970 (Dominy 1971). Some limited information about distribution of young-of-the-year (YOY) within the system was collected during 1983 (Jessop and Parker 1988), and as part of an assessment of a diversion screen during 1996 (Gibson 1996), but alewife juvenile ecology in this watershed is basically unstudied.

Efforts are being taken to minimize the impacts of the hydro-electric developments on this alewife stock. Currently, access to alewife spawning areas in the headwater lakes is provided by two pool and weir fishways: one bypassing the White Rock Generating Station and one bypassing the storage dam at the outlet of Gaspereau Lake at Lanes Mills (Figure 2). A third fishway provides access between Gaspereau and Aylesford Lakes. The control gate at Forest Home is closed when adults first enter Gaspereau Lake. Post-spawning adults return to sea via the outlet at Lanes Mills into the Gaspereau River (bypassing four of the five generating stations). Eggs, larvae and juvenile alewives typically follow the dominant flow patterns when moving downstream. When the control gate at Forest Home is closed, these fish are also carried downstream through the Gaspereau River. When the gate is open, dominant currents flow downstream through the main system. A fish diversion screen was therefore constructed near the outlet of Trout River Pond to redirect fish into the old Gaspereau River channel via Trout River, again bypassing four of the five generating stations. This screen appears effective in diverting larger juveniles, however eggs and larvae are able to pass through the screen (Gibson 1996). Because of this problem, appropriate water management, such as keeping the control gate at Forest Home closed until alewives are of a size when the screen is effective, is an integral part of managing this species in this watershed.

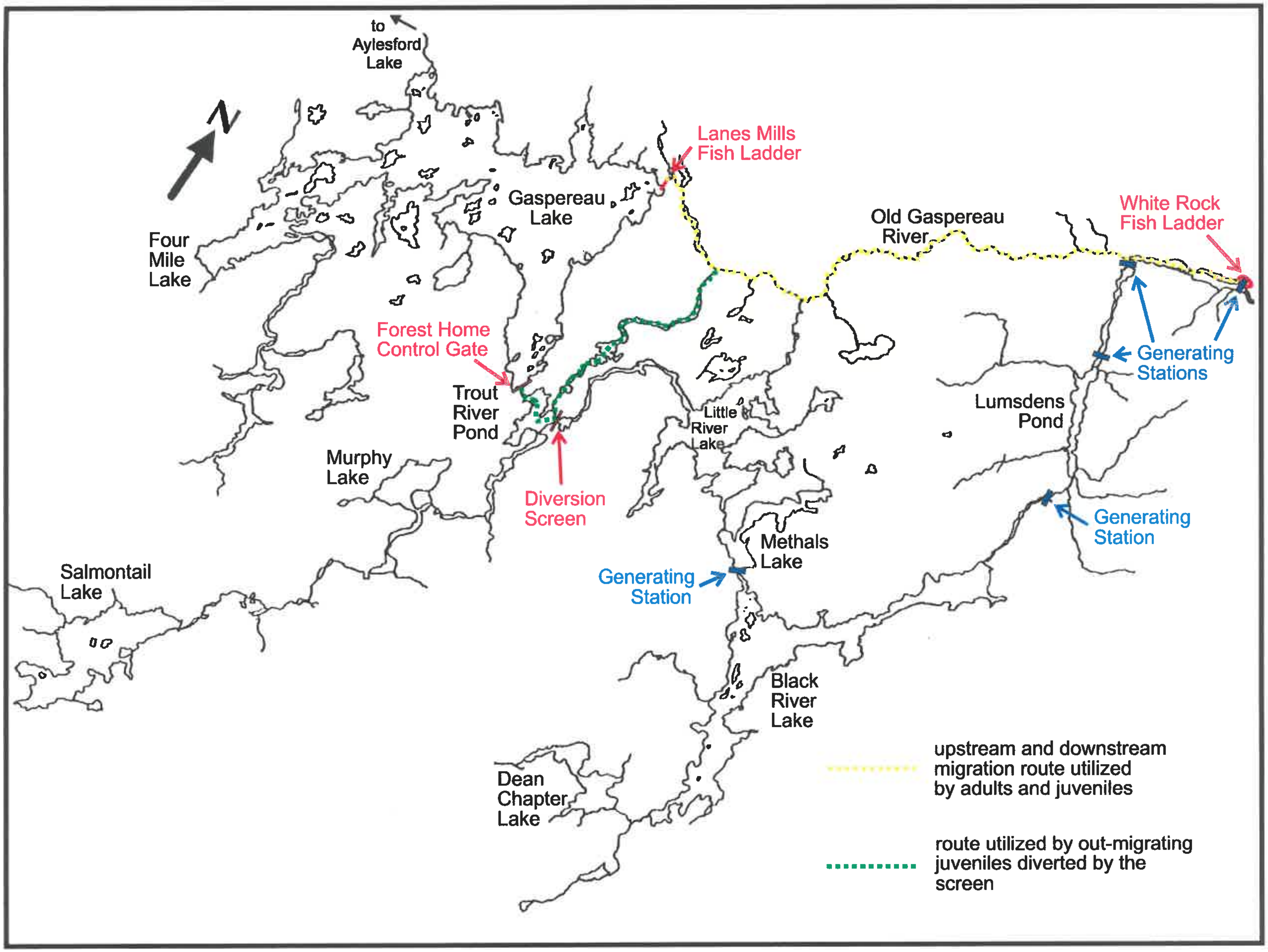

Figure 2. Map of the Gaspereau River System.

1.2 Objectives

This project was carried out in four parts, with the common objective of collecting information to be used in developing and assessing potential management plans:

1. Monitoring YOY out-migration at Lanes Mills

   During 1997, a plan to keep the control gate at Forest Home closed until late fall presented the opportunity to evaluate the potential of the outlet at Lanes Mills as passage for out-migrating juveniles. Factors such as the timing of out-migration events, the size of fish at out-migration, and relationships with environmental factors such as temperature and water flow were to be studied at this location.

2. Monitoring YOY distribution and size in Gaspereau Lake

   In the event that opening the control gate at Forest Home when alewives were still present in the lake was adopted as a water management strategy, YOY alewife distribution and size was monitored within Gaspereau Lake. The objective was to determine when the majority of alewives would be large enough that the screens at Trout River Pond would be effective. This information could then be used to establish guidelines for when the gate could be opened.

3. Egg/Larvae surveys in the Gaspereau River

   During the 1997 stock assessment, fewer adults were estimated to have entered Gaspereau Lake than anticipated, based on the count at the White Rock ladder (Gibson and Daborn 1997). While the fate of fish which do not reach the lake is presently unknown, potential spawning areas (still waters, eddies, and the White Rock headpond) do exist between the White Rock ladder and Gaspereau Lake. Post-spawning adults were observed emigrating seaward at the White Rock fish ladder prior to observing post spawners leaving Gaspereau Lake. This observation raised the question of whether a significant proportion of alewives actually spawn downstream of Gaspereau Lake. While 1997 may have been an atypical year in regard to upstream migrating adults, we decided as part of this project to survey the Gaspereau River, collecting larval and egg presence/absence data, to determine if alewives were spawning in areas downstream of the lake.

4. YOY out-migration at the Trout River Pond fish diversion screen

The final portion of this study involved monitoring alewife out-migration at the Trout River Pond fish diversion screen after the control gate at Forest Home was opened during the fall. Objectives of this portion included determining if significant numbers of alewives remained in Gaspereau Lake in late fall and evaluating the effectiveness of the screen at this time.

2. METHODS

2.1 Monitoring YOY out-migration at Lanes Mills

Out-migration of young-of-the-year alewives at Lanes Mills (the outlet to the Gaspereau River) was monitored by sampling with a 0.5 m diameter zooplankton net. Sampling was conducted in the fishway during the first part of the study. The fishway was de-watered on July 14th at which time the control gate at Lanes Mills was opened. Sampling after this date was in the out-flow below this gate.

The volume of water filtered by the net was calculated from water velocities measured by a General Oceanics Inc. torpedo flow meter (model 2031; high velocity rotor) mounted inside the net. Deployments were typically of 0.5 hr duration, although deployments had to be shortened when large numbers of alewives were captured. Catches were enumerated in the field and the majority of fish released alive downstream of the control gate. A sample of alewives was collected from representative catches, which was preserved in isopropanol until further analysis.

Sampling was conducted at an intensity that covered between 5 % to 20 % of the total time available during each month. A stratified sampling strategy was therefore employed that emphasized time periods during the day when alewives were expected to move, primarily during the late evening and at dawn. Twenty-four hour monitoring was conducted intermittently throughout the season to ensure that sampling was at an appropriate time.

To obtain an estimate of the number of YOY alewives leaving Gaspereau Lake via Lanes Mills, the number of alewives captured during a deployment was standardized first to the density of alewives (number/m^3), based on flow meter readings, and then to the rate of outmigration (number/hr.), based on discharge volumes supplied by Nova Scotia Power Incorporated. Because sampling was stratified to increase the probability of catching fish by fishing at times when alewives were expected to be moving, the mean rate of outmigration calculated from the samples for a given time period would be a biased estimator of the true mean rate of outmigration for that time. To correct for this bias, the day was divided into 24 strata (each 1 hour long). The mean rate of migration was then calculated for each strata and summed to obtain final estimates using methods summarized by Krebs (1989):

1. Stratified mean migration rate (number/hr.):

$$x_{st} = \frac{\sum_{h=1}^{24} N_h x_h}{N}$$

2. Stratified migration total:

$$X_{st} = N x_{st}$$

3. Variance of the stratified mean migration rate:

$$\text{var}(x_{st}) = \sum_{h=1}^{24} \left[\frac{w_h^2 s_h^2}{n_h} (1 - f_h) \right]$$

4. Variance of the migration total:

$$\text{var}(X_{st}) = N^2 \text{var}(x_{st})$$

5. Confidence intervals were obtained from t-distributions after estimating the effective number of degree of freedom:

$$\text{d.f.} = \frac{\left(\sum_{h=1}^{24} g_h s_h^2 \right)^2}{\sum_{h=1}^{24} \left[g_h^2 s_h^4 / (n_h - 1) \right]}$$

where:

1. N_h = Size of stratum h (number of days in the time period in question)
2. N = Size of the statistical population (N_h x 24 hr/day)
3. W_h = stratum weight (N_h/N)
4. h = stratum number (hour: 1 to 24)
5. x_h = observed mean for stratum h
5. s_h^2 = observed variance of stratum h
6. n_h = sample size in stratum h
7. f_h = sample fraction in stratum h (n_h/N_h)
8. $g_h = N_h(N_h - n_h)/n_h$

Water temperature at Lanes Mills was monitored using a temperature data logger (Vemco Minilog-T), located mid channel just downstream of the control gate throughout the summer, set to record hourly. A second temperature logger was deployed about 0.5 km upstream of White Rock from July 12th to August 7th to determine if changes in discharge volumes at Lanes Mills were having detrimental effects on water temperature in the river.

2.2 Monitoring YOY distribution and size in Gaspereau Lake

Two sampling methods were used to monitor YOY distribution in Gaspereau Lake. Larval and pre-juvenile alewives were sampled using a 0.6 m (1 mm mesh size) diameter bow-mounted pushnet. Samples were collected by pushing the net in a straight line for 5 minutes at a pre-determined throttle setting. Average boat velocity was 1.44 m/s (s.d. = 0.324) while sampling. Sampling was limited to relatively open areas when using the pushnet because of the shallow depths and rocky substrate in Gaspereau Lake. The volume of water filtered by the net was calculated from flow measurements taken with a model 2030 General Oceanics torpedo flow meter mounted inside the net. Larger juveniles were found to be able to avoid the pushnet, so sampling during August was conducted using a 10 m x 2 m seine. This net was towed parallel to the shore by 1 person walking along the shore and two people towing the other end with a boat. The net was closed off against the shore at the end of the tow, at which time the catch was identified and enumerated. All sampling was conducted during the late evening (1 hour before sunset to 1 am) in an attempt to minimize time of day effects in the resulting data set.

Water temperature was monitored at a water quality station near the centre of the lake at a depth of 1 m and at the bottom (12 m) using temperature data loggers set to record hourly. Surface and bottom dissolved oxygen samples were collected weekly. Samples were collected using a Van Dorn sampler and fixed in the field. Dissolved oxygen concentrations were determined by sodium azide modified Winkler titrations (A.P.H.A. 1995) in the laboratory.

Zooplankton was sampled by towing a 0.3 m diameter, 0.3 mm mesh bongo net at a depth of 0.5 m for 3 minutes at a speed of c. 0.75 m second. The volume of water filtered by the net was measured with a flow meter mounted inside the net. Samples were stored in 1 liter Mason jars, fixed with formalin (c. 5% final concentration) and enumerated in the laboratory. Samples were collected every second week throughout this part of the project.

Three samples were collected on each occasion, one from Lockhart's Cove, one at the water quality station, and one near Lanes Mills.

2.3 Egg/Larvae surveys in the Gaspereau River

During the early summer, surveys for eggs and larvae were conducted at 6 locations along the Gaspereau River by sampling with a zooplankton net (0.3 m, 0.3 mm mesh size). Samples were collected at Lanes Mills, the bridge just downstream of Lanes Mills, just upstream of the bridge in White Rock (Deep Hollow), the bridge over the canal in White Rock, the Gaspereau Bridge, and the Melanson Bridge. These locations were chosen based on accessibility. Deployments were of 10 minute duration, and water velocities were measured with a torpedo meter mounted in the net. Water temperature and conductivity were measured with a Y.S.I. salinity/conductivity/temperature meter (model 33) at each location. While the sampling method is quantitative, because eggs and larvae would need to be drifting in order to be captured (eggs are typically adhesive and larvae tend to avoid fast currents) and because water velocities varied between sites and sample days, the data collected should only be interpreted as presence/absence, not as an indication of the relative importance of these areas.

2.4 YOY out-migration at the Trout River Pond fish diversion screen

Out-migration of young-of-the-year alewives at the Trout River Pond fish diversion screen was monitored by sampling with a 0.5 m diameter zooplankton net deployed in the bypass stream. Again, the volume filtered by the net was calculated from water velocities measured by a General Oceanics Inc. torpedo flow meter (model 2031; high velocity rotor) mounted inside the net. Deployment duration varied between 0.5 hour when no fish or few fish were present to about 2 minutes when large numbers of alewives were present. Data collected during this part of the project are semi-quantitative, since the act of setting the net startled the fish, thus biasing the catch. When few fish were present, this bias was not problematic since deployments were relatively long. However, when larger schools were moving, it was possible to catch a few hundred fish in under a minute, so the act of deploying and retrieving the net did bias the catch on these occasions. Catches were enumerated in the field and, with the exception of samples saved for length determination, the fish were released alive in the bypass stream.

The efficiency of the screens was monitored by towing a 0.5 m (1 mm mesh size) plankton net across the channel downstream of the screen. Water clarity in November was such that visual observation was also possible for determining when schools of alewives were present. It was possible to follow schools back and forth along the screens while observing behavior and watching to see if alewives were passing through the screen. Water temperature at this location was monitored with a temperature logger set to record hourly.

2.5 Laboratory Methods

Larval fish were identified in the laboratory using Jones *et al.* (1978) as a guideline for identification. Samples of alewives from representative deployments were preserved in isopropanol and measured (fork length to the nearest millimeter) in the laboratory. A sample of 20 alewives was measured both fresh in the field and after preservation for 10 days to determine the amount of shrinkage associated with this procedure. Fresh lengths averaged 6.2 % longer than preserved lengths (s.d. = 2.4 %). All lengths reported herein are corrected for this shrinkage.

Zooplankton was identified and enumerated by subsampling (5 replicates) the collected samples and counting the organisms present in the subsample under a dissecting microscope (10 to 50 times magnification). Subsample volumes varied depending on the density of organisms in the sample and ranged from 1 to 5 ml. Counts were standardized by the sample volume and the volume filtered by the net to obtain the number of organisms per liter.

3. RESULTS

3.1 YOY Alewife Distribution and Outmigration

3.1.1 YOY Outmigration at Lanes Mills

YOY outmigration at Lanes Mills was monitored from June 8th to November 20th. Nets were deployed 971 times on 80 days in the field, resulting in the capture of 18,582 YOY alewives (the majority of which were immediately released). The distribution of the catches throughout this period is shown in Figure 3 as the mean number of alewives captured per net deployment during each week of the season. Figure 4 shows a similar distribution standardized by the volume of water filtered by the net. Alewives were captured during all weeks of the project except Nov. 16th. Catches were low during June, but increased during late July. Catches then decreased in late August and few fish were captured throughout September. This decrease was coincidental with decreased discharges at this time. Flows during late July and August were maintained around 1.4 to 2.4 m^3/s (50 to 85 CFS). Flows during September ranged between 0.6 and 1.2 m^3/s (21 to 42 CFS). The highest densities measured during the project occurred during October, after flows were again increased to 1.7 m^3/s (60 CFS). This relationship between discharge and catches is shown in Figure 5.

The physical configuration of the control gate also appears to affect outmigration. During the low flow period in September, the gate was opened a small amount near the bottom. Water passed through this opening before upwelling over a set of stop logs just downstream. On several occasions during this time large schools of alewives (10,000+) were observed swimming back and forth less than a meter from the control gate, however none were moving downstream. When flow was again decreased in late October, the gate was completely open, so that the water only spilled over the stop logs. Alewives moved downstream at this time. Alewives continued to move downstream when flow was

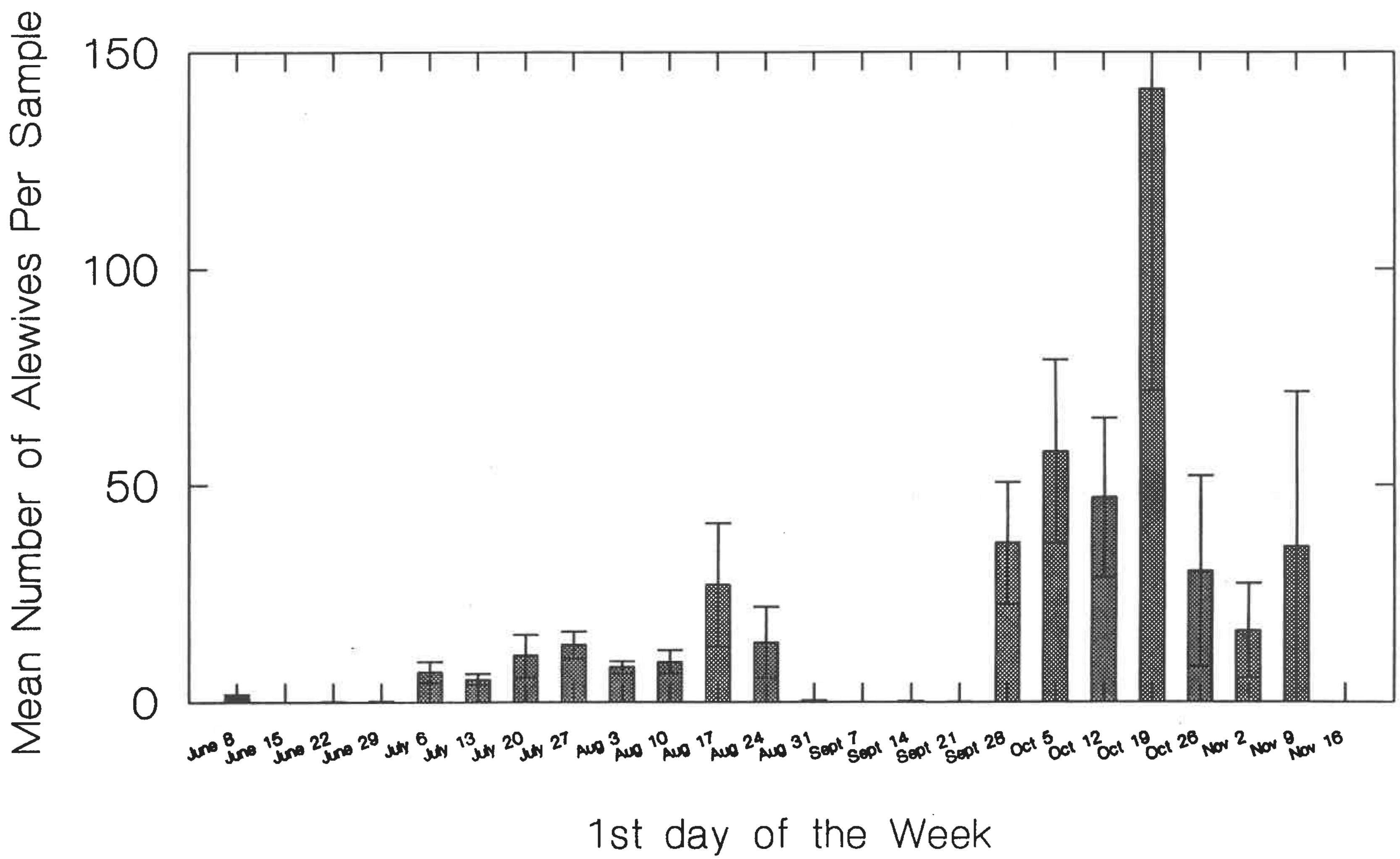

Figure 3. Weekly mean YOY alewife catch at Lanes Mills during 1997. Error bars are standard error of the mean.

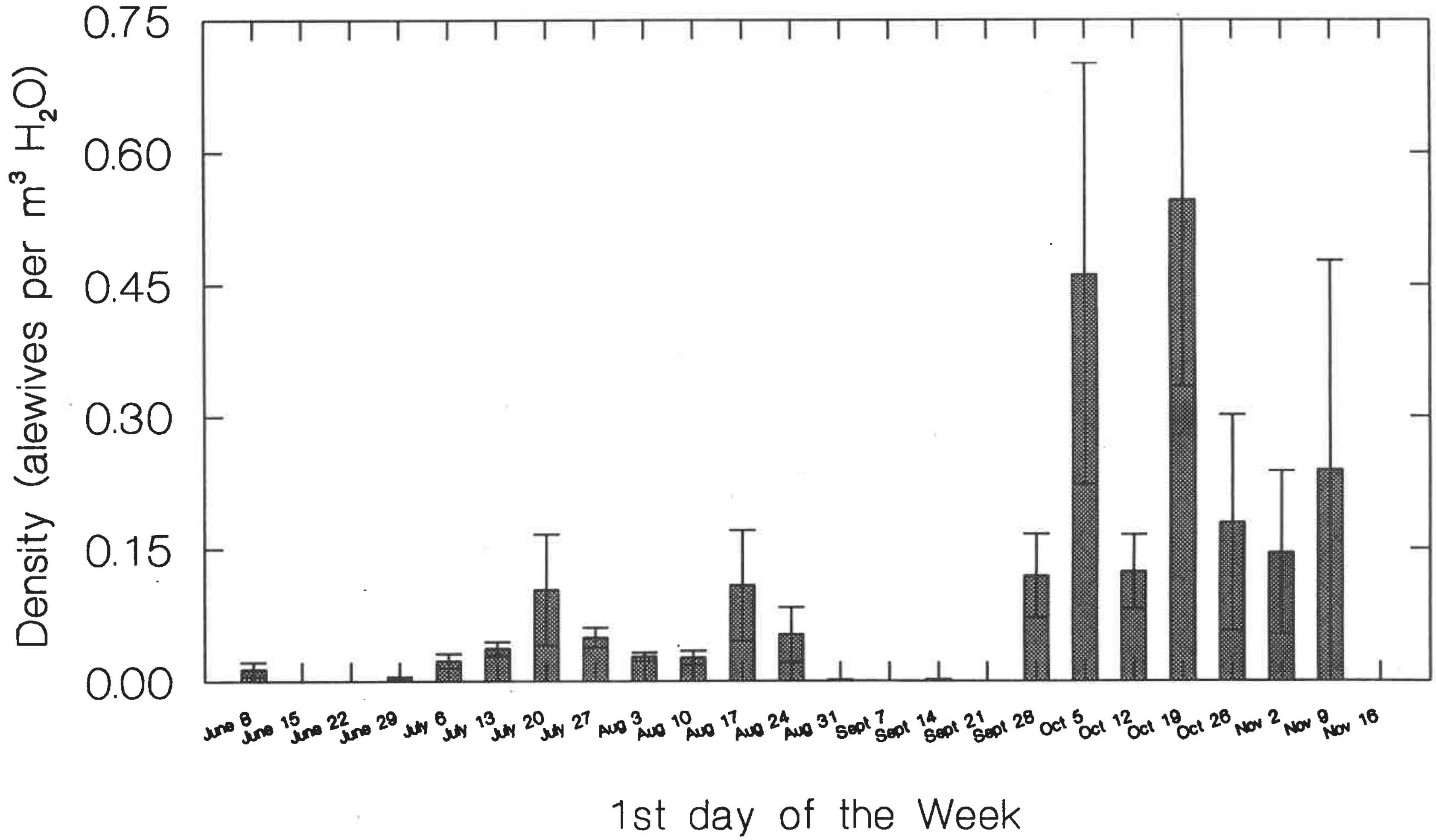

Figure 4. Weekly mean YOY alewife catch at Lanes Mills during 1997 standardized by the volume filtered by the net. Error bars are standard error of the mean.

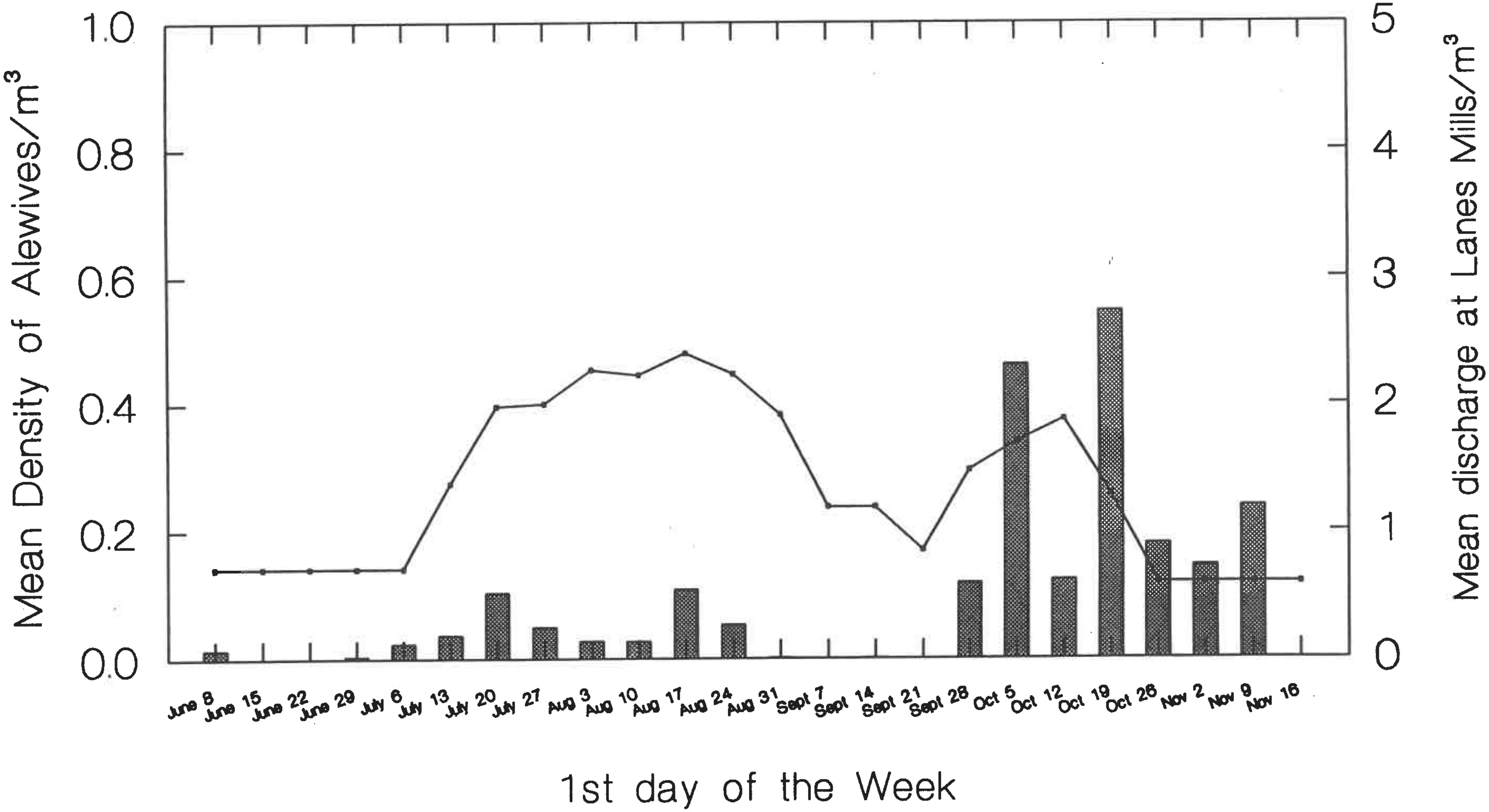

Figure 5. Weekly mean flow at the outlet at Lanes Mills (line), overlaid against the weekly mean density of alewives (bars).

decreased in November, but the gate configuration was such that the water flowed over the stop logs. Because of the relationship between gate configuration, flows and catches, outmigration patterns shown in Figures 3 and 4 are probably atypical in respect to natural patterns.

The timing of migration events throughout the day varied during the season (Figure 6). Evening and night were not sampled during June, but alewives (all larvae) were captured throughout the day. During July, August and September, alewives were captured during evening and early morning periods, with very few captured during the afternoon. During October, the majority of alewives were captured during daylight hours, peaking during the late afternoon. Sampling in November was at too low an intensity to comment on daily migration patterns, but patterns appear similar to that of October.

Estimates of the number of alewives emigrating from Gaspereau Lake each month are shown in Table 1. For all months, the stratified mean number of alewives per hour was lower than the normal mean, showing the effect of the sampling bias. Stratified means were used to calculate monthly total estimates. In all, about 1.2 million YOY alewives were estimated to have moved downstream at Lanes Mills during the study period.

As mentioned above, alewives were observed schooling near the control gate during September but not moving downstream. On September 26th, N.S.P.I. personnel, in response to increasing water levels in Gaspereau Lake, spilled water through a control gate just west of the gate at Lanes Mills. Based on N.S.P.I. personnel descriptions a very large number of alewives (in the hundreds of thousands?) moved downstream via this location within a few hours of this gate being opened. These fish are not included in the above estimate.

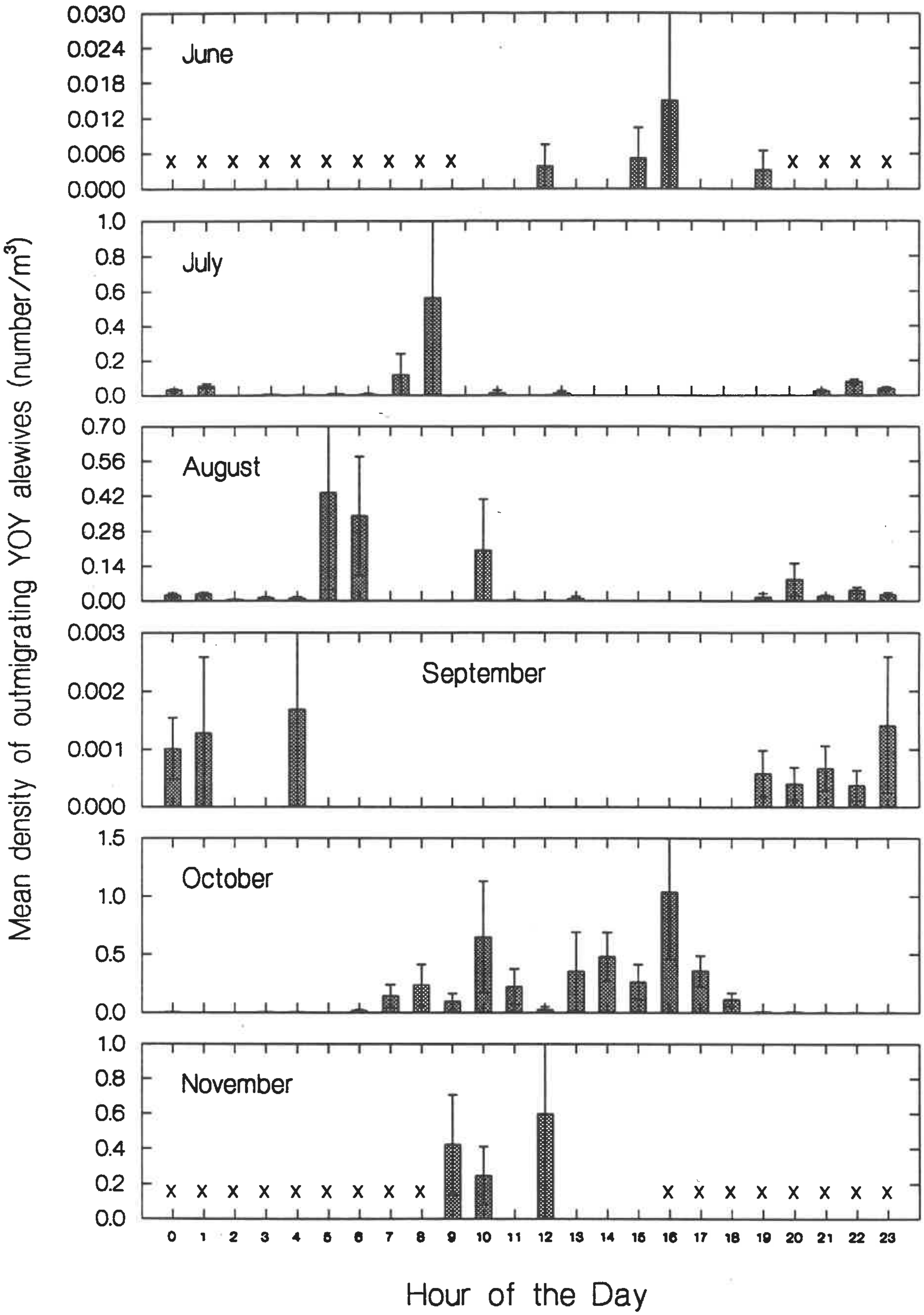

Figure 6. Hourly mean alewife catch during each month while monitoring YOY outmigration at the outlet of Gaspereau Lake at Lanes Mills. Error bars are standard error of the mean. X's mark periods not sampled.

Table 1. Estimates of the number of alewives per month and the total number of alewives to have exited Gaspereau Lake via Lanes Mills during 1997.

Month	Number of deployments	Mean number/hr	Stratified Mean number/hr	Stratified estimate of monthly total	Total 95% C.I. lower limit	Total 95% C.I. upper limit
June 9-30	71	5.5	2.4	1,218	0	2,642
July	195	288.2	272.4	202,687	0	478,585
August	278	466.9	427.0	317,684	99,040	536,327
September	175	2.2	1.4	1,003	135	1,870
October	201	1,407.0	836.7	622,485	429,334	815,635
Nov. 1-20	49	369.3	113.1	54,282	0	79,688
Total	**969**			**1,199,359**	**832,902***	**1,565,814***

*re-calculated from summed variances

3.1.2 Distribution of YOY alewives in Gaspereau Lake

YOY distribution was monitored in Gaspereau Lake between June 22nd and August 26th. Sampling was conducted with the pushnet until the end of July. The seine was used during August. The lake was partitioned into 5 sections (Figure 7), and while possible sampling locations were limited by the lake morphology and bottom type, samples were collected from each of these sections each week. In total, 116 samples were collected with the pushnet resulting in the capture of 1233 alewives. The seine was fished 44 times capturing a total of 1412 alewives.

Larval alewives were present in Lockhart's Cove during preliminary experimentation with a variety of nets on June 16th. Routine monitoring began the week of June 22nd. As shown in Figure 8, catches were highest in all locations except Two Mile and Four Mile Lakes during this week (catches peaked in Two Mile and Four Mile Lakes during the week of

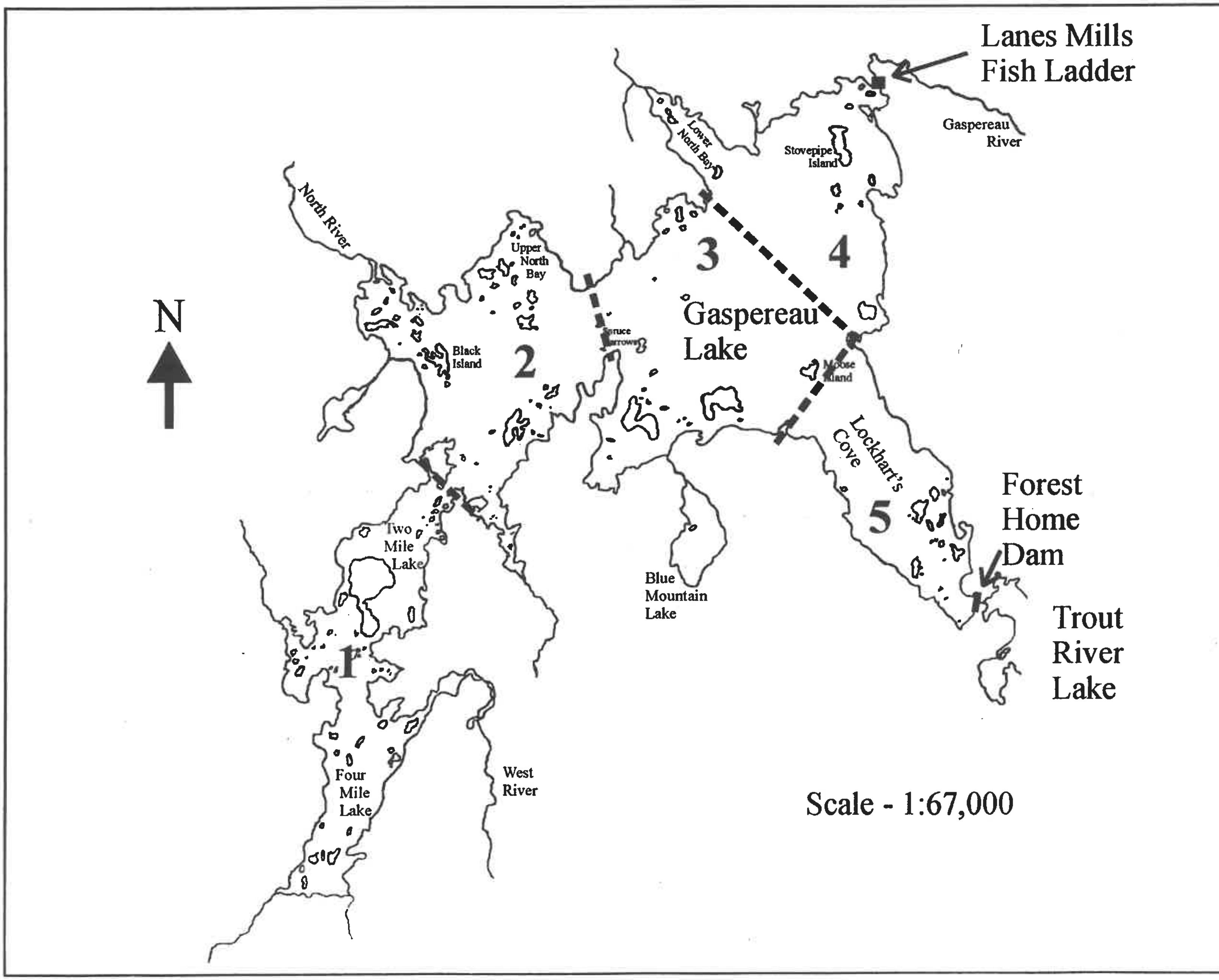

Figure 7. Map showing the partitions of Gaspereau lake for determining YOY alewife distribution.

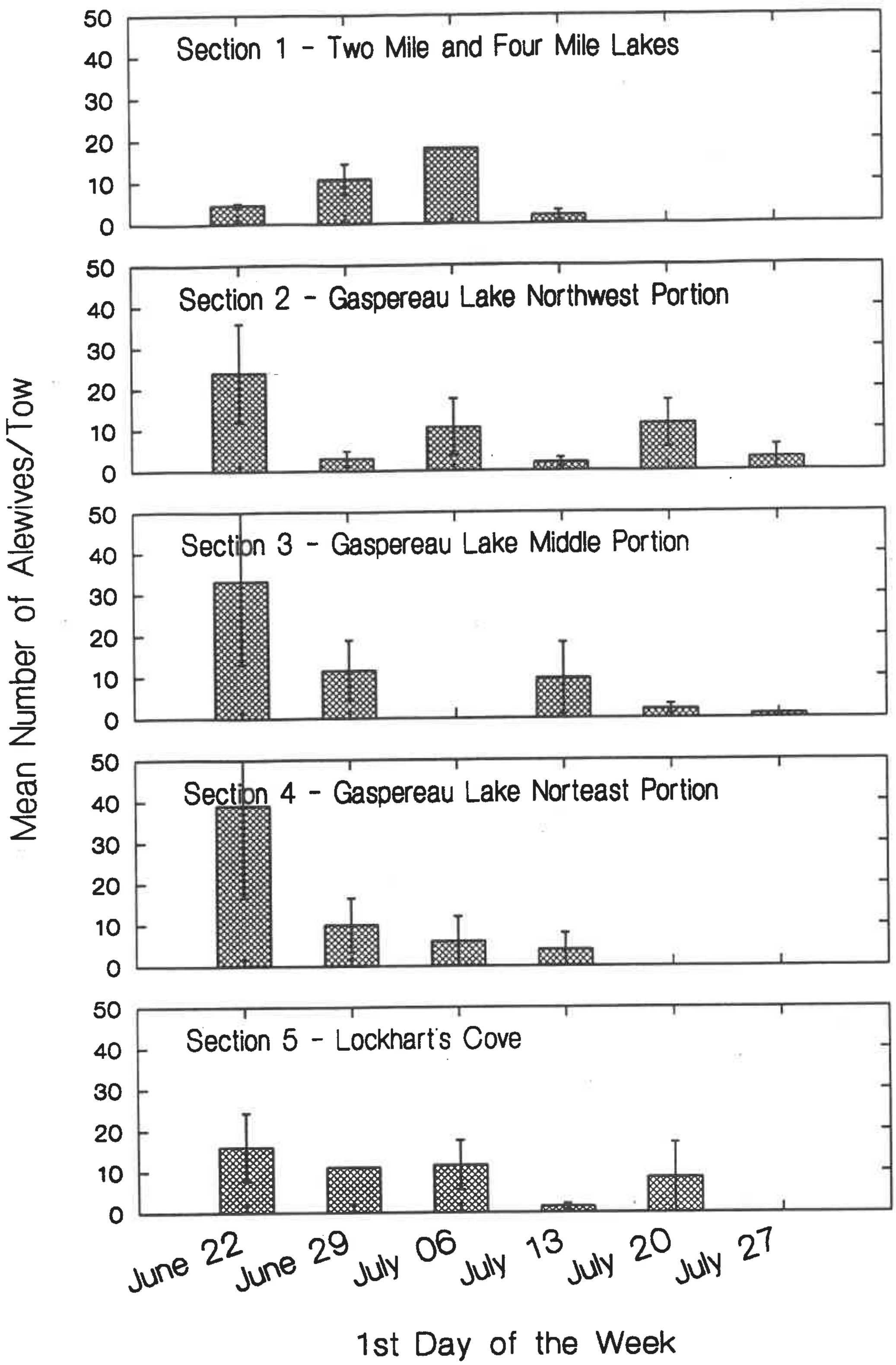

Figure 8. Weekly mean alewife catch while sampling in Gaspereau Lake with the pushnet for each sampling region in Gaspereau Lake.

July 6th). Standardizing the data by the volume filtered by the net (Figure 9) modifies the time series for Lockhart's Cove and the northwest portion of the lake, in that densities were more evenly distributed throughout the study than suggested by the absolute numbers of alewives captured.

The majority of alewives captured while seining were captured in Two Mile and Four Mile Lakes (Figure 10). Catches in this section were high throughout the month of August. Numbers captured in the northwest and northeast sections of the lake declined throughout the month. Comparatively few alewives were captured in the middle section or in Lockhart's Cove.

3.1.3 Egg/Larvae surveys in the Gaspereau River

Because fewer adults were estimated to have entered Gaspereau Lake than expected from observations of fish passing the White Rock station, surveys were conducted in the Gaspereau River, to collect larval and egg presence/absence data, to determine if alewives were spawning in areas downstream of the lake.

Samples were collected at eight locations. Sample volumes were small, typically under 2 m^3. Only two eggs were captured, one at the bridge downstream of Lanes Mills, and one at the Melanson bridge, both during the week of June 1st (Figure 11). Fifteen larvae were captured, 8 of which were also captured during the week of June 1st (Figure 12). Of these 5 were captured at the Melanson Bridge.

As an interesting aside, relatively large numbers of glochidia (parasitic veliger stage of some freshwater bivalves) were captured at the Gaspereau Bridge and the Melanson bridge during early June while sampling for eggs and larvae. Some of the larval alewives at Melanson (about 10 mm in length) had three or four glochidia attached to them.

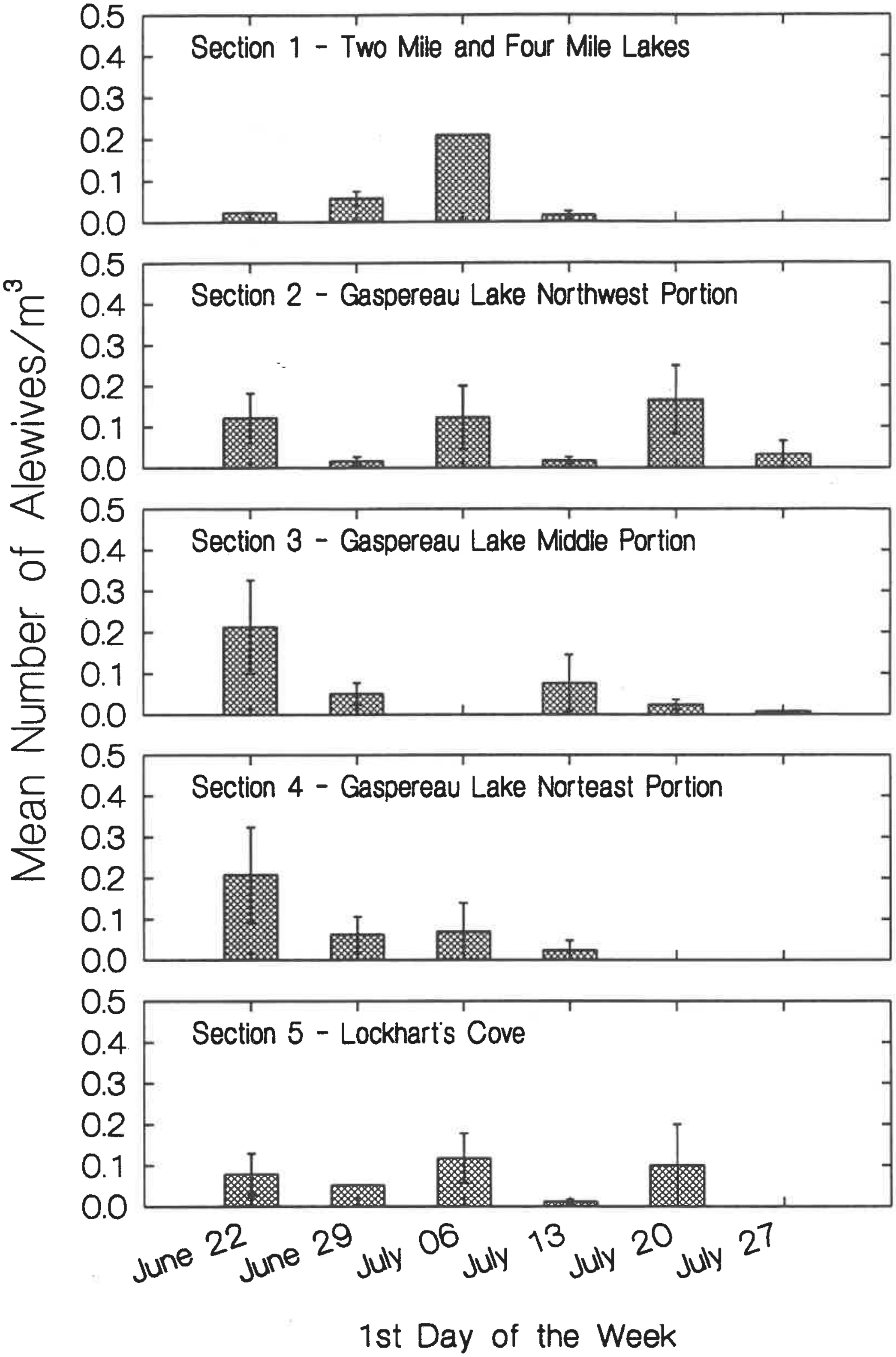

Figure 9. Weekly mean density of alewives estimated by sampling with the pushnet for each sampling region in Gaspereau Lake.

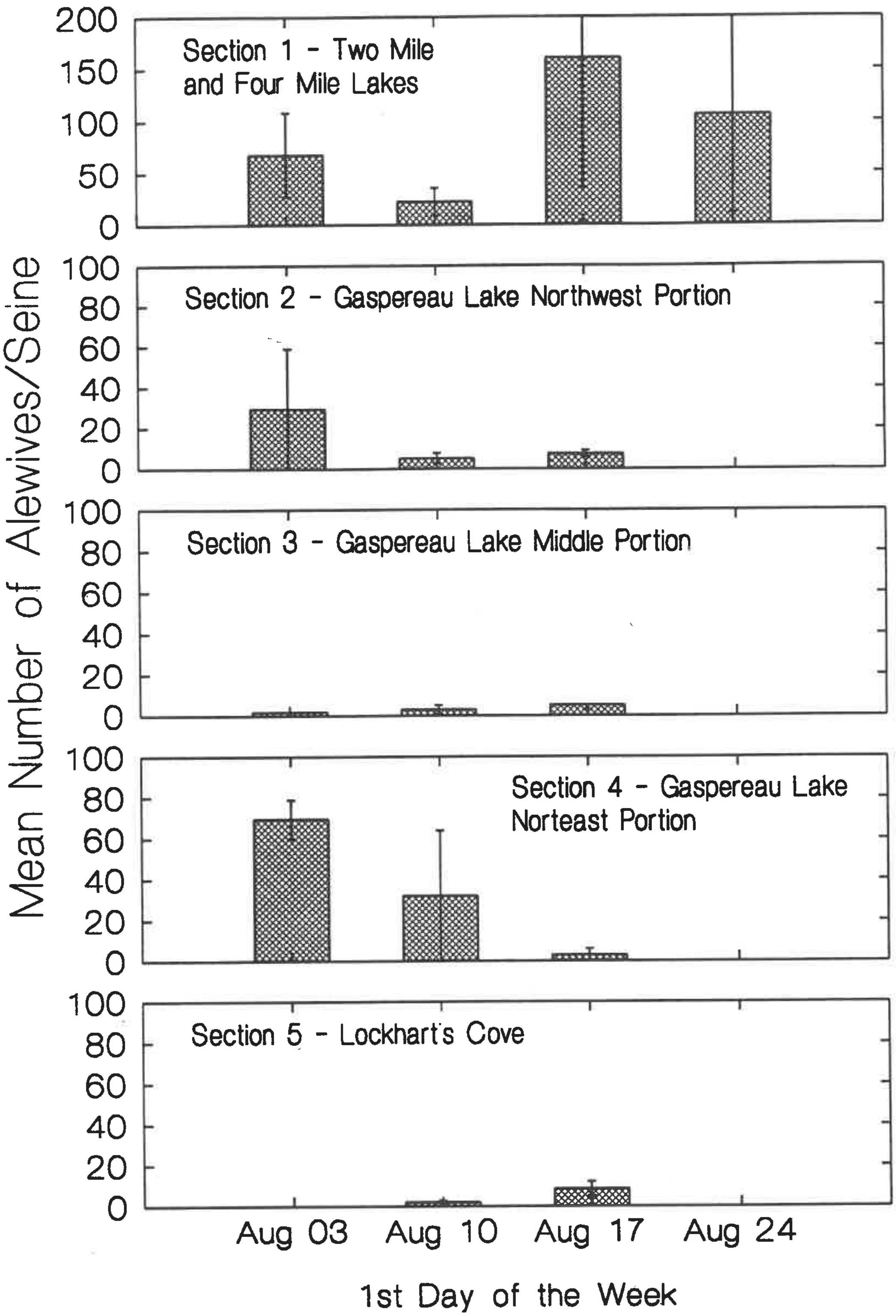

Figure 10. Weekly mean alewife catch while sampling in Gaspereau Lake with the seine for each sampling region in Gaspereau Lake.

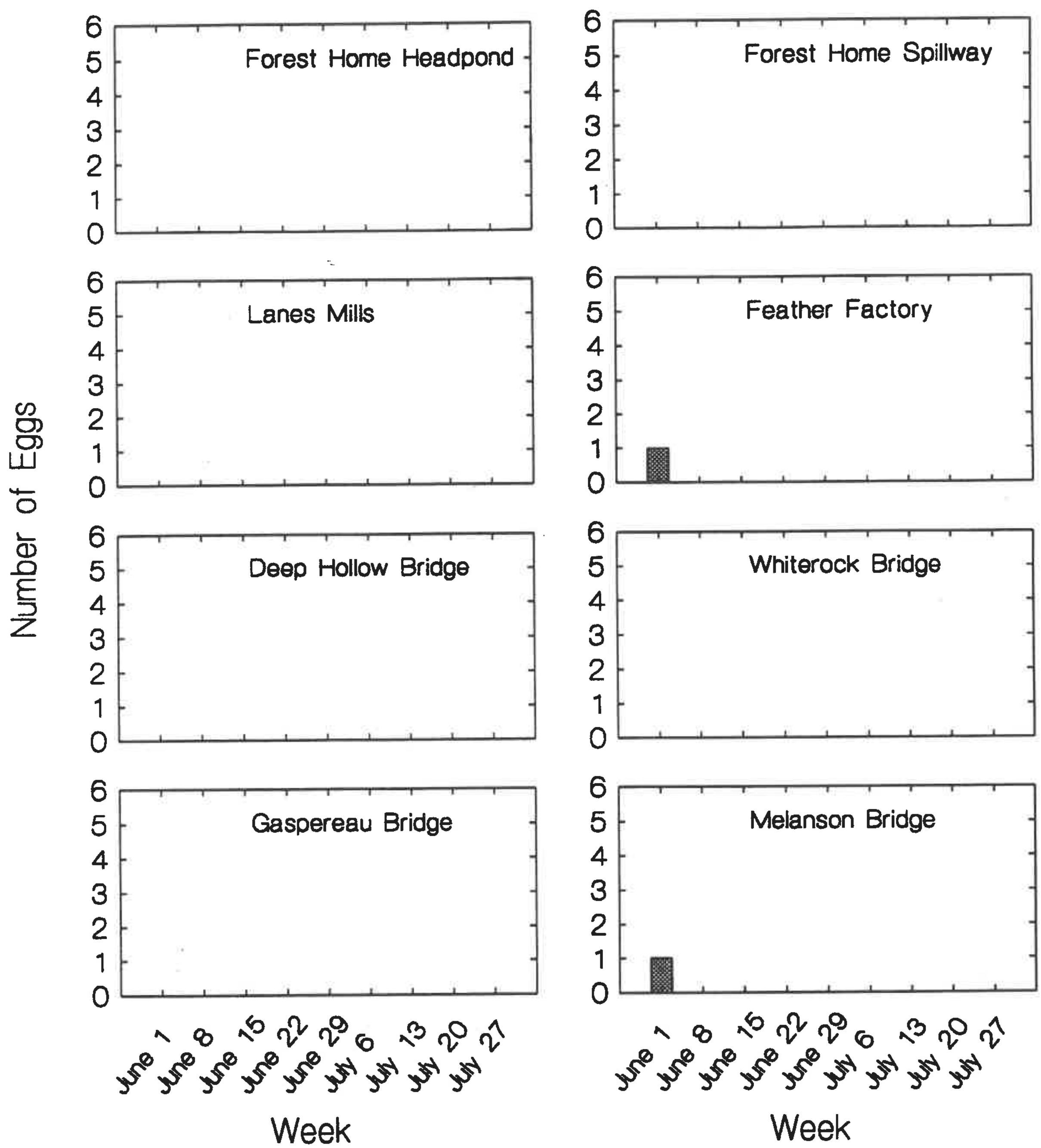

Figure 11. Time, location and result (number of alewife eggs captured) while sampling in the Gaspereau River.

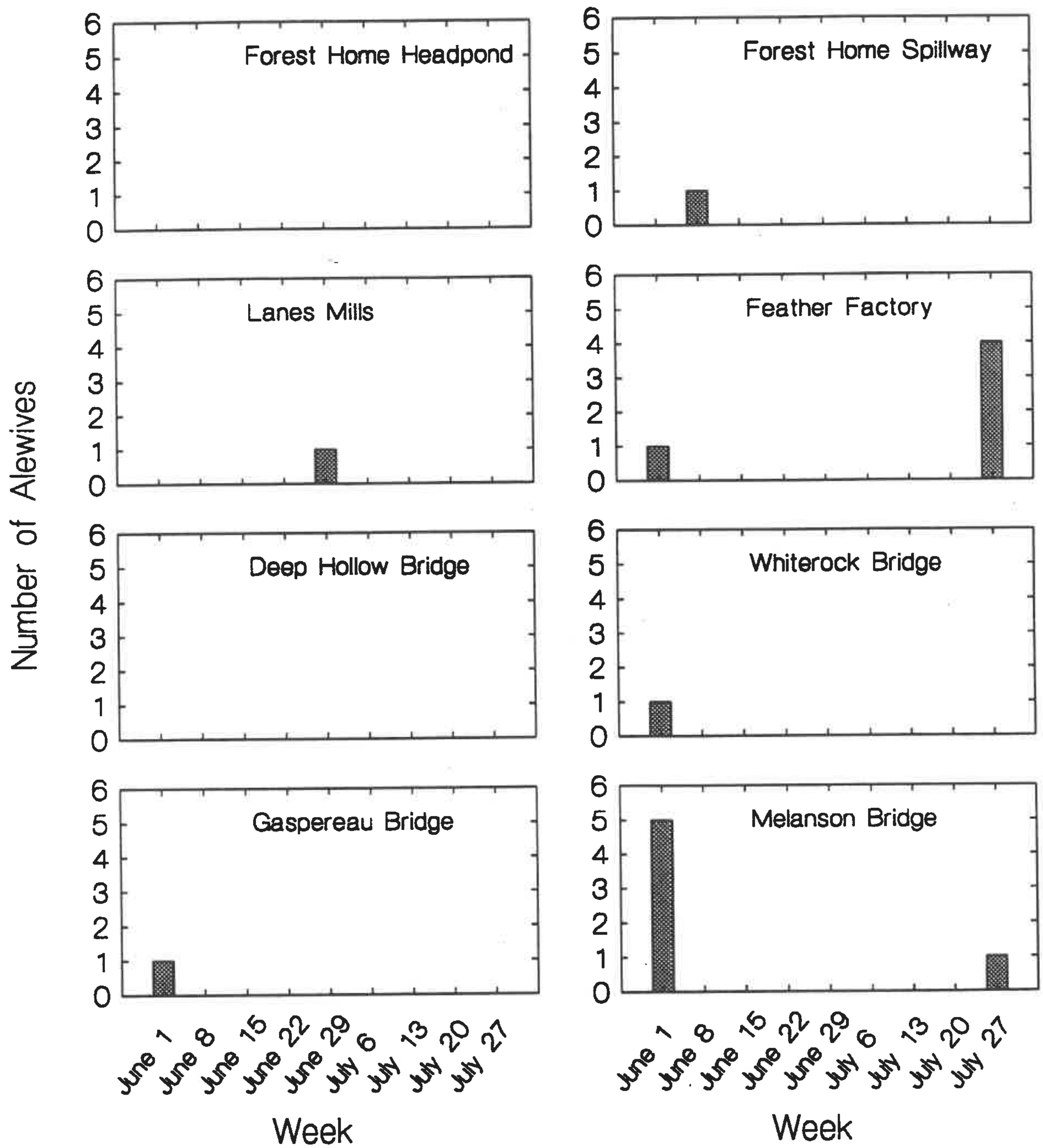

Figure 12. Time, location and result (number of alewife larvae captured) while sampling in the Gaspereau River.

3.1.4 Alewife Outmigration at Trout River Pond

Alewives moved into Trout River Pond immediately after the gate was opened Oct. 23rd. Very large numbers of alewives (1,000,000+ ??) had accumulated in front of the diversion screens by Oct. 30th when the bypass was opened. A large proportion of these fish moved downstream within a few hours of the bypass being opened. Quantitative sampling was not possible on this day because the act of deploying the net in the bypass stream disrupted migration. When migration resumed a few minutes later, hundreds of fish would be captured during a few minutes. These catches were not indicative of the overall rate of movement.

On October 31st, rates of movement had declined to a level which allowed more quantitative sampling (period of disruption short relative to the length of the deployment). Catches were intermittent (long periods without fish, interspersed by short periods of high activity) on the remaining sampling days (Table 2). No alewives were captured after November 13th, but sampling intensity was too low after this time to say that migration at this time had ended.

The plankton net was towed across the channel downstream of the screens on 24 occasions (when alewives were present on the upstream side) to determine if alewives were passing through the screens. No alewives were captured during these deployments. A better indication of screen performance was observation of alewife behavior in the vicinity of the screen. Except for periods following heavy rains, water clarity was such that schools of alewives and the lake bottom (about 1 to 1.5 m depth) were highly visible. It was possible to follow schools of tens of thousands of alewives back and forth along the screens as they searched for a route downstream. Alewives passing through the screens would have been very obvious, but none were seen during many hours of observation.

Table 2. Summary of daily catches in the bypass stream at the Trout River Pond Diversion Screen.

Date	Number of Alewives	Net Soak Time
Oct. 31	1986	115 min
Nov. 1	31	172 min
Nov. 2	1	210 min
Nov. 4	0	322 min
Nov. 5	3	234 min
Nov. 7	1830	192 min
Nov. 10	1	345 min
Nov. 13	c 3300	257 min.
Nov. 14	0	200 min.
Nov. 18	0	145 min.
Nov. 20	0	206 min.

3.2 Environmental data

3.2.1 Temperature

Temperature data loggers were deployed in the fishway bypassing the White Rock dam, the outlet of Gaspereau Lake (downstream of the control gate), the centre of Gaspereau Lake (surface and bottom), near the Trout River Pond fish diversion screen, and in the Gaspereau River just upstream of the Deep Hollow Bridge in White Rock. The time and duration of these deployments varied depending upon data requirements.

In total, 14,870 temperature observations were recorded by these loggers. Time series (hourly temperature) for each location are presented in Appendix 1. Table 3 contains a summary of the values recorded by month. Gaspereau Lake was moderately stratified when the temperature loggers were first deployed at the water quality station

Table 3. Monthly temperature summary statistics for 6 locations in the Gaspereau River watershed during 1997: the surface (1m depth) and bottom (10.5 m depth) of Gaspereau Lake near the centre (G.L.S. and G.L.B., respectively), the outlet of Gaspereau Lake at Lanes Mills (O.L.M.), the Gaspereau River 0.5 km upstream of Deep Hollow Bridge in White Rock (D.H.B.), the Trout River Pond fish diversion screen (T.R.L.), and within the White Rock fish ladder (W.R.F.L.).

		Location					
Month	Statistic	W.R.F.L.	O.L.M	G.L.S.	G.L.B.	D.H.B.	T.R.L.
May	mean	9.78					
	s.d.	2.05					
	min.	5.90					
	max.	13.30					
June	mean	16.50	18.46				
	s.d.	2.25	3.09				
	min.	13.10	12.30				
	max.	21.70	25.90				
July	mean	22.23	23.00	21.91	19.01	20.95	
	s.d.	1.00	1.62	0.58	1.34	2.36	
	min.	19.90	19.60	20.00	16.80	16.50	
	max.	25.00	28.53	23.40	21.60	27.10	
August	mean	20.69	20.87	20.48	19.73	20.41	
	s.d.	1.08	1.00	0.67	0.55	1.66	
	min.	18.80	18.80	19.20	18.80	17.50	
	max.	23.53	23.50	22.10	21.10	24.45	
September	mean	18.04	17.08	17.51	17.29		
	s.d.	1.98	2.84	2.09	2.05		
	min.	13.90	10.70	13.60	13.20		
	max.	21.80	21.10	20.20	20.00		
October	mean	10.22	9.58				
	s.d.	1.97	2.72				
	min.	7.00	4.20				
	max.	15.30	15.50				
November	mean		4.85				4.43
	s.d.		3.06				3.01
	min.		1.30				0.30
	max.		12.20				10.40

(Appendix 1.1). Temperature profiles (not shown) indicated the presence of a thermocline at a depth of about 3 m. This stratification broke down around July 18th, presumably due to high winds present just before that time. While temperature differences developed between surface and bottom water intermittently throughout the rest of the summer, no stable stratification developed during the remainder of the summer.

Water temperatures at Lanes Mills (Appendix 1.2) showed considerably more variation than at the water quality station (compare standard deviations in Table 3 or see Figure 13 a,b). Water temperatures at Lanes Mills warmed more rapidly during the early summer than at the lake centre, reaching a maximum of 28.5 °C on July 1st. Temperatures regularly fluctuated 4 to 5 degrees daily at this time, probably in response to air temperature. Prior to the closure of the fishway (July 14th), water entering the Gaspereau River was being drawn from the surface of a relatively shallow portion of the lake, which could explain these fluctuations. Water temperatures also cooled more quickly at Lanes Mills than at the lake centre during September (Table 3). Water temperature was 0.6 °C when this logger was removed in late December.

Daily temperature fluctuations in the Gaspereau River between Lanes Mills and White Rock were greater than those at Lanes Mills, showing temperature swings of up to 10 degrees daily during June and July (Appendix 1.3). Peaks in daily temperature coincide with peaks at Lanes Mills (Figure 13 b,c), which, given a distance of about 11 km between the loggers, is probably an indication that temperature in the river near White Rock varies more as a function of air temperature than of lake water temperature at Lanes Mills.

Temperature in the White Rock fish ladder (Appendix 1.4) showed considerably less fluctuation than in the river above Deep Hollow bridge or at Lanes Mills. Temperatures at this location peaked July 19th (25°C) and were in the low to mid twenties throughout July and August.

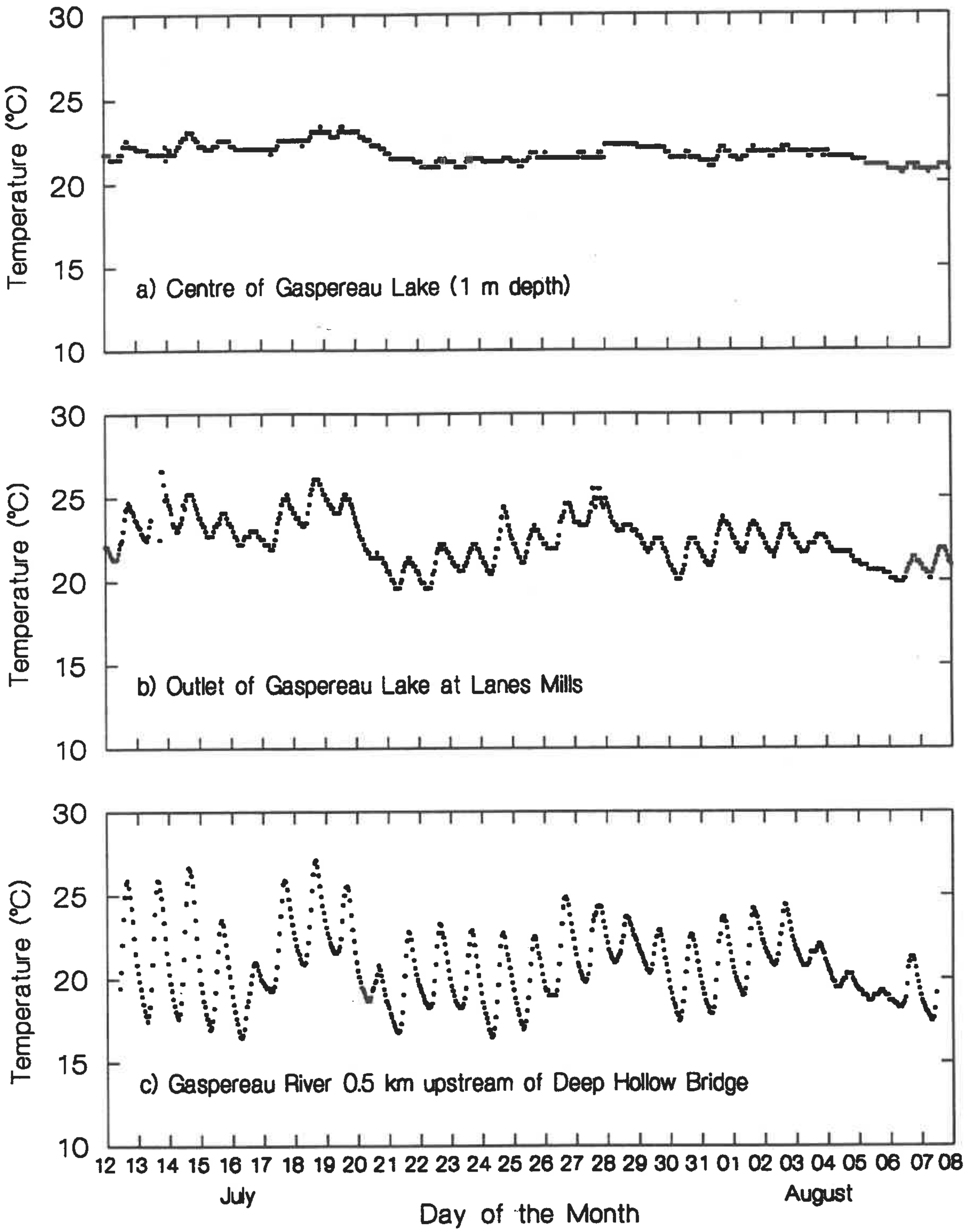

Figure 13. A comparison of daily temperature fluctuations at the water quality station in Gaspereau lake (a), the outlet of Gaspereau Lake at Lanes Mills (b) and the Gaspereau River 0.5 km upstream of the Deep Hollow Bridge.

The temperature data logger at Trout River Pond was only deployed during the period that the diversion screens were in place (November). Water temperature at this location declined from about 8 °C to less than 1 °C during this month (Appendix 1.5).

3.2.2 Effects of changes in outflow at Lanes Mills on downstream water temperature

The temperature logger in the Gaspereau River between Lanes Mills and White Rock was deployed (about 0.5 km upstream of the Deep Hollow Bridge in White Rock) to allow assessment of the effects that increasing discharge at Lanes Mills had on temperature in the Gaspereau River between these locations. Discharge from the lake was increased from c. 0.7 m^3/s to c. 2 m^3/s between July 14th and July 17th. The effect of this increase was to moderate daily temperature fluctuations in the river below Lanes Mills. Statistical comparisons (t-test) indicated there was no statistically significant difference in mean daily water temperature, minimum daily water temperature, maximum daily water temperature or mean daily water temperature range at Lanes Mills for the 10 days prior to this increase in comparison with the 10 days after this increase (Table 4). Just upstream of White Rock, mean daily water temperatures were the same for the ten day period before and after the increase in flow, whereas the minimum daily water temperatures showed a slight increase while the maximum decreased. Neither of these changes was statistically significant at the 95% confidence level, but the combined effect was to decrease the mean daily temperature range by c. 1.8 °C, a difference which was statistically significant at this level.

Table 4. A comparison of water temperatures in the Gaspereau River at Lanes Mills and 0.5 km upstream of Deep Hollow Bridge in White Rock for the 10 day periods before and after increasing the river flows between July 14th and July 17th, 1997.

Temperature Statistic	10 day mean (s.d.) prior to increasing flow (°C)	10 day mean (s.d.) after increasing flow (°C)	p-value (t-test, 18 degrees of freedom in each case)
Lanes Mills:			
Daily Mean:	22.8 (1.5)	22.8 (0.7)	0.575
Daily Min:	21.7 (0.8)	21.5 (1.5)	0.694
Daily Max:	24.3 (1.2)	23.8 (1.6)	0.508
Daily Range:	2.6 (1.1)	2.4 (0.7)	0.642
Deep Hollow:			
Daily Mean:	20.9 (0.6)	20.9 (1.5)	0.995
Daily Min:	18.0 (1.3)	18.7 (1.6)	0.262
Daily Max:	24.8 (1.2)	23.8 (1.8)	0.167
Daily Range:	6.8 (2.3)	5.0 (1.2)	0.042

3.2.3 Dissolved Oxygen

Dissolved oxygen concentration was determined from surface and bottom water samples collected weekly at the water quality station in Gaspereau Lake throughout the summer. Surface samples were more saturated than bottom samples (Table 5). All samples were adequately oxygenated except the lake bottom on July 17th which was below 50 % saturation. This sample was collected just prior to strong winds breaking down the moderate stratification present within the lake at this time (see temperature graph - Appendix 1.1).

Table 5. Dissolved oxygen concentrations measured at the water quality station (see Figure 7) in Gaspereau Lake during the summer of 1997.

Date	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	Oxygen Saturation (%)
July 2	1.0	9.68	20.5	106.6
July 2	12.0	9.44	17.6	98.1
July 11	1.0	9.36	22.1	106.4
July 11	11.0	9.02	17.8	94.1
July 17	1.0	8.72	21.0	97.0
July 17	12.0	**4.12**	18.0	**43.2**
July 22	1.0	9.22	21.0	102.6
July 22	11.0	8.86	19.8	96.3
July 30	1.0	9.32	21.8	105.3
July 30	10.5	8.88	19.3	95.5
Aug. 6	1.0	8.18	21.0	91.0
Aug. 6	12.0	7.86	20.3	86.3
Aug. 19	1.0	8.32	20.5	91.7
Aug. 19	12.0	8.34	19.3	89.7
Aug. 26	1.0	8.86	19.7	96.1
Aug. 26	11.0	7.86	18.8	83.7

3.2.4 Zooplankton

Zooplankton samples were collected on 6 occasions between July 3rd and August 27th, yielding low estimates of zooplankton abundance (Figure 14). While the absolute densities may be low due to a sampling bias (see discussion), because the sampling method was standardized, the trends in abundance are likely valid. Abundances were highest on July 3rd, and dropped by an order of magnitude by July 17th (Figure 14). The cladocerans *Daphnia spp.* and *Holopedium sp.*, and the rotifer *Conochilus sp.* were the most common organisms in the samples.

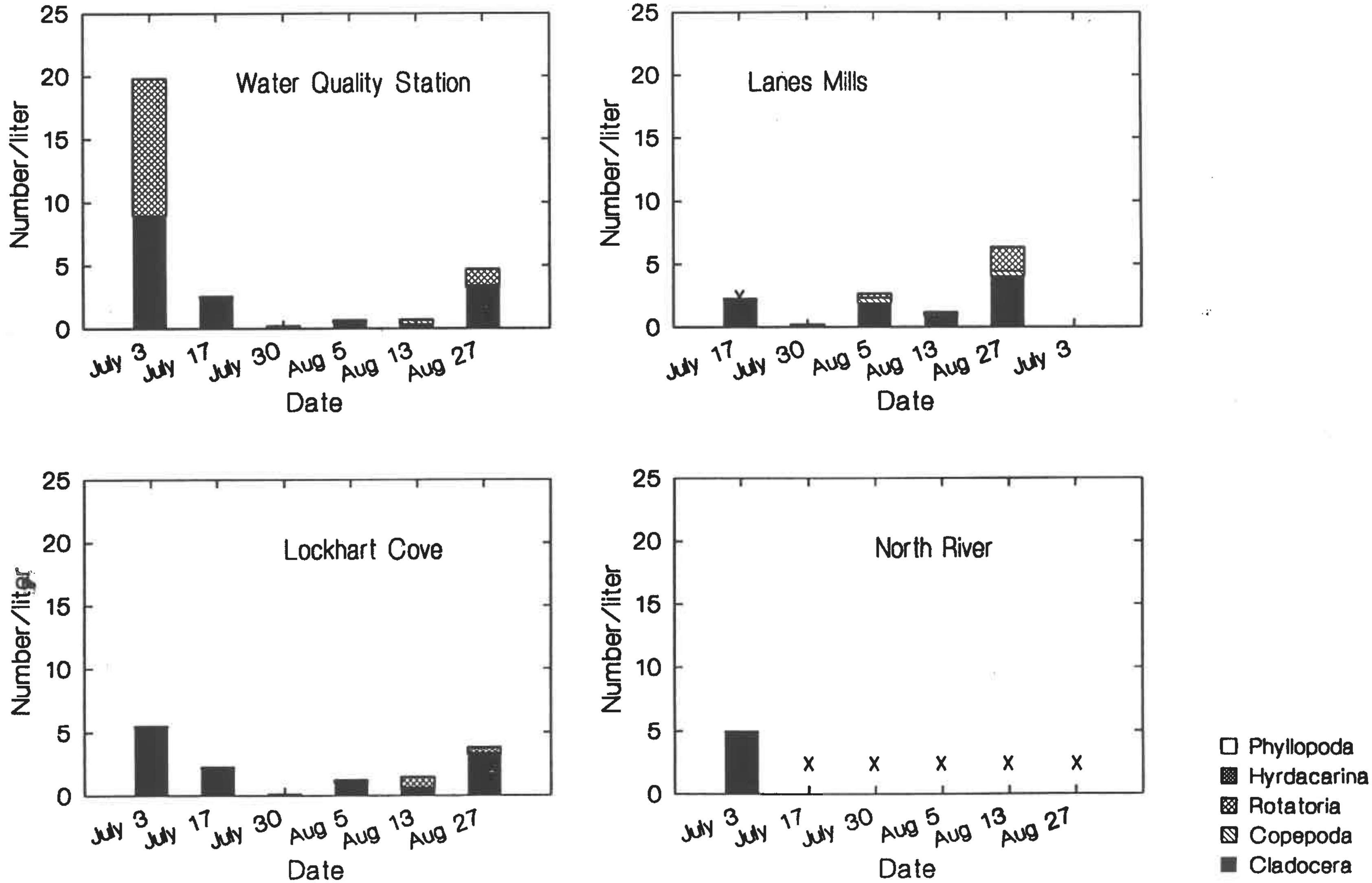

Figure 14. Results of zooplankton sampling in Gaspereau Lake during 1997. X's mark periods not sampled.

3.3 Fork Lengths of Captured Alewives

Fork lengths were measured on a subsample of alewives retained from representative samples throughout the course of this study.

As expected, alewives captured in the lake increased in size throughout the summer (Figure 15). The first pre-juveniles were captured on July 7th, although the majority of alewives captured were larvae at this time. By the week of July 20th, the majority of fish captured were pre-juveniles or juveniles, and no larvae were captured during the week of July 27th. Sampling in August was carried out with a seine which would not capture larvae. The size of alewives captured within the lake was not markedly different between the lake sections.

Alewife size at Lanes Mills increased through June, July and August, increased only slightly during September and then decreased slightly through October (Figure 16). A few larvae were still present during the week of July 27th, but none were captured after this time. Size frequency distributions were bimodal on July 27th, a pattern that occurred intermittently throughout the remainder of the study (Figure 17.1, 17.2). Alewives captured at Lanes Mills averaged slightly larger than those captured in the lake (Figure 18) during corresponding weeks, but during November, were similar in size to those captured at Trout River Pond (Figure 19).

Where sample sizes are large enough to make comparisons (July 13th to Aug. 3rd), alewives captured at Lanes Mills in 1997 were on average either about the same size or smaller than alewives captured at the fish diversion screen in 1996 during comparable weeks (Table 6). Variability in length (standard deviation and range) was also less at Lanes Mills in 1997 than at Trout River Pond in 1996.

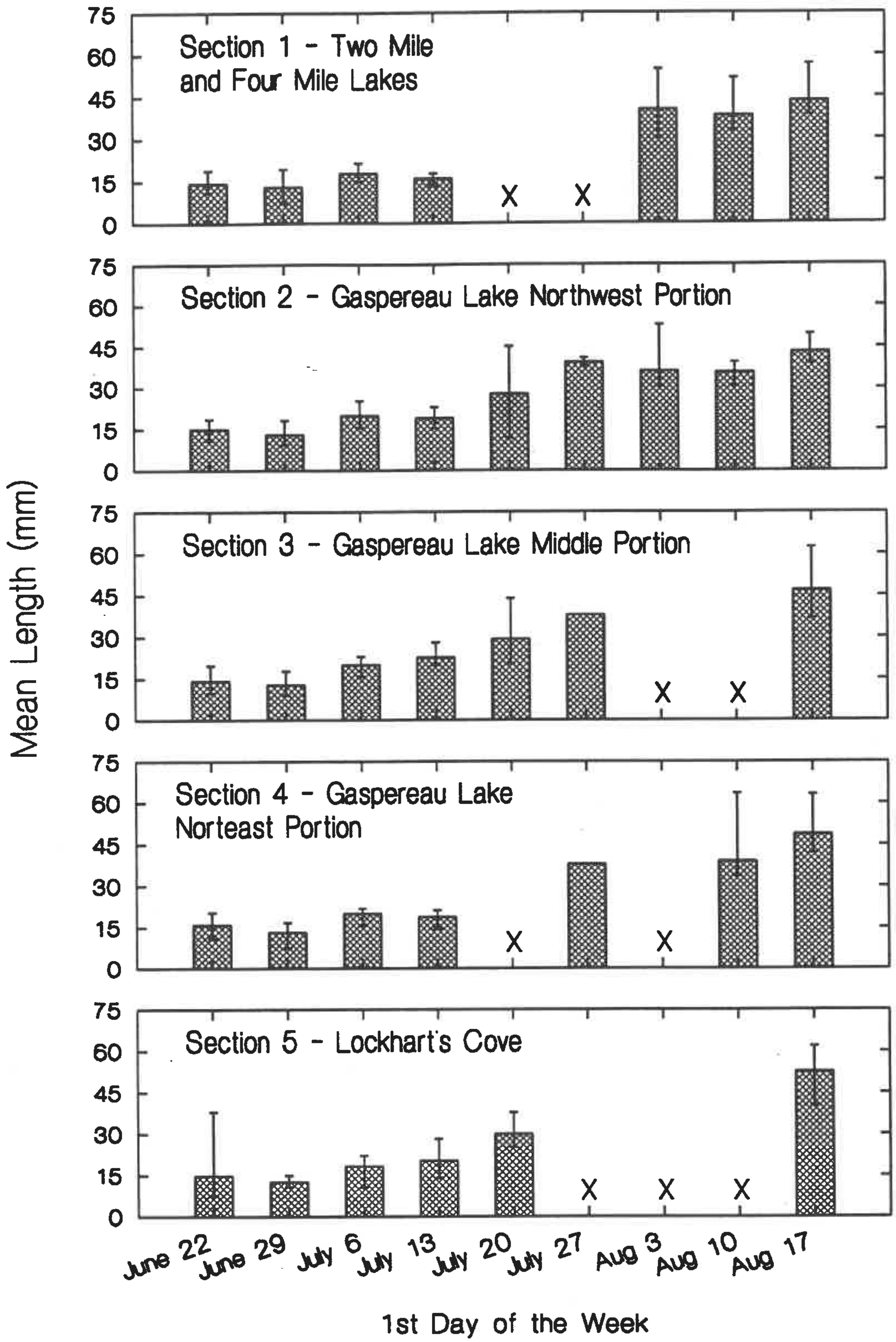

Figure 15. Mean fork lengths of alewives captured in each region of Gaspereau Lake. Error bars are minimum and maximum.

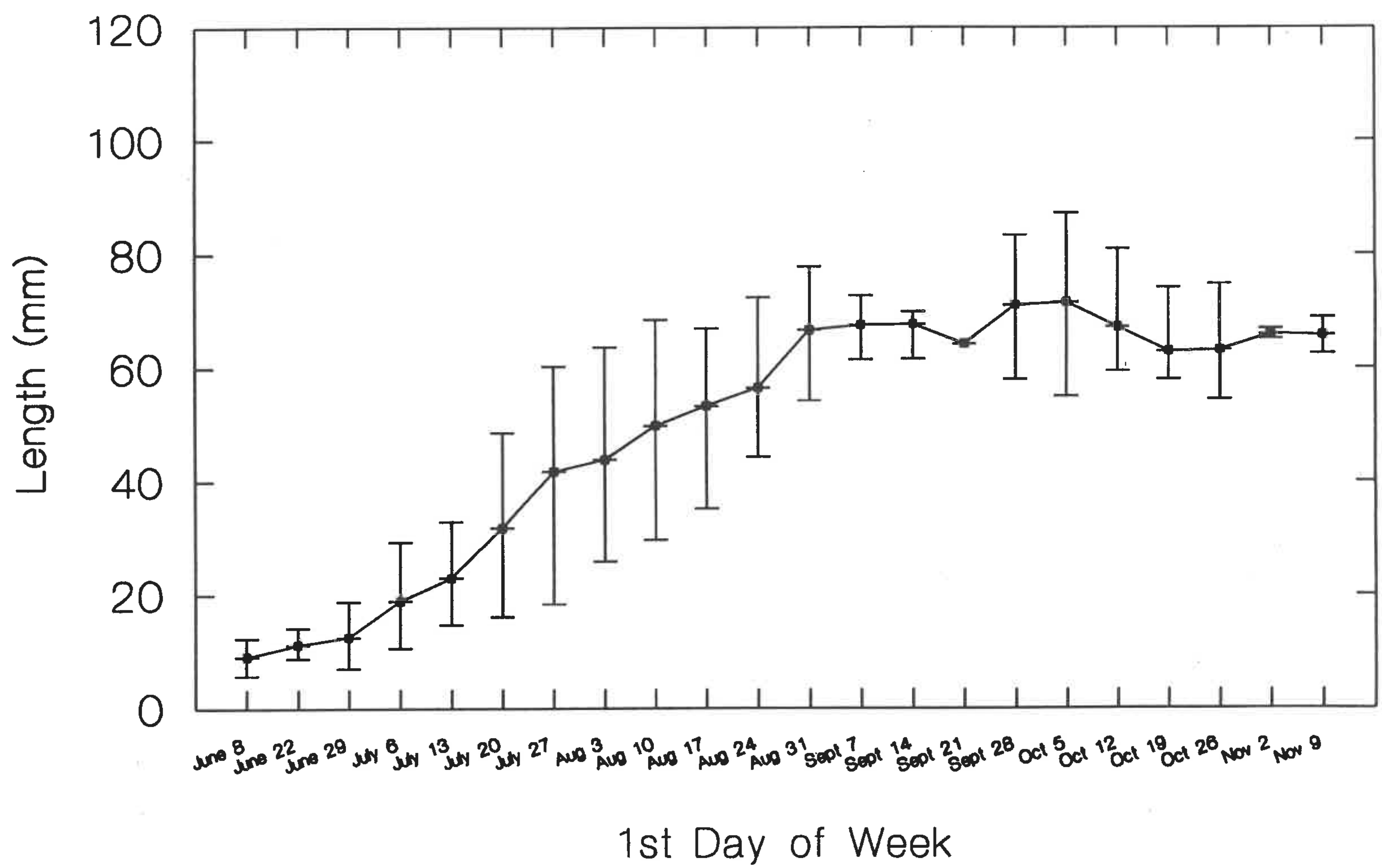

Figure 16. Mean length of outmigrating YOY alewives captured at the outlet of Gaspereau Lake at Lanes Mills. Error bars are minimum and maximum.

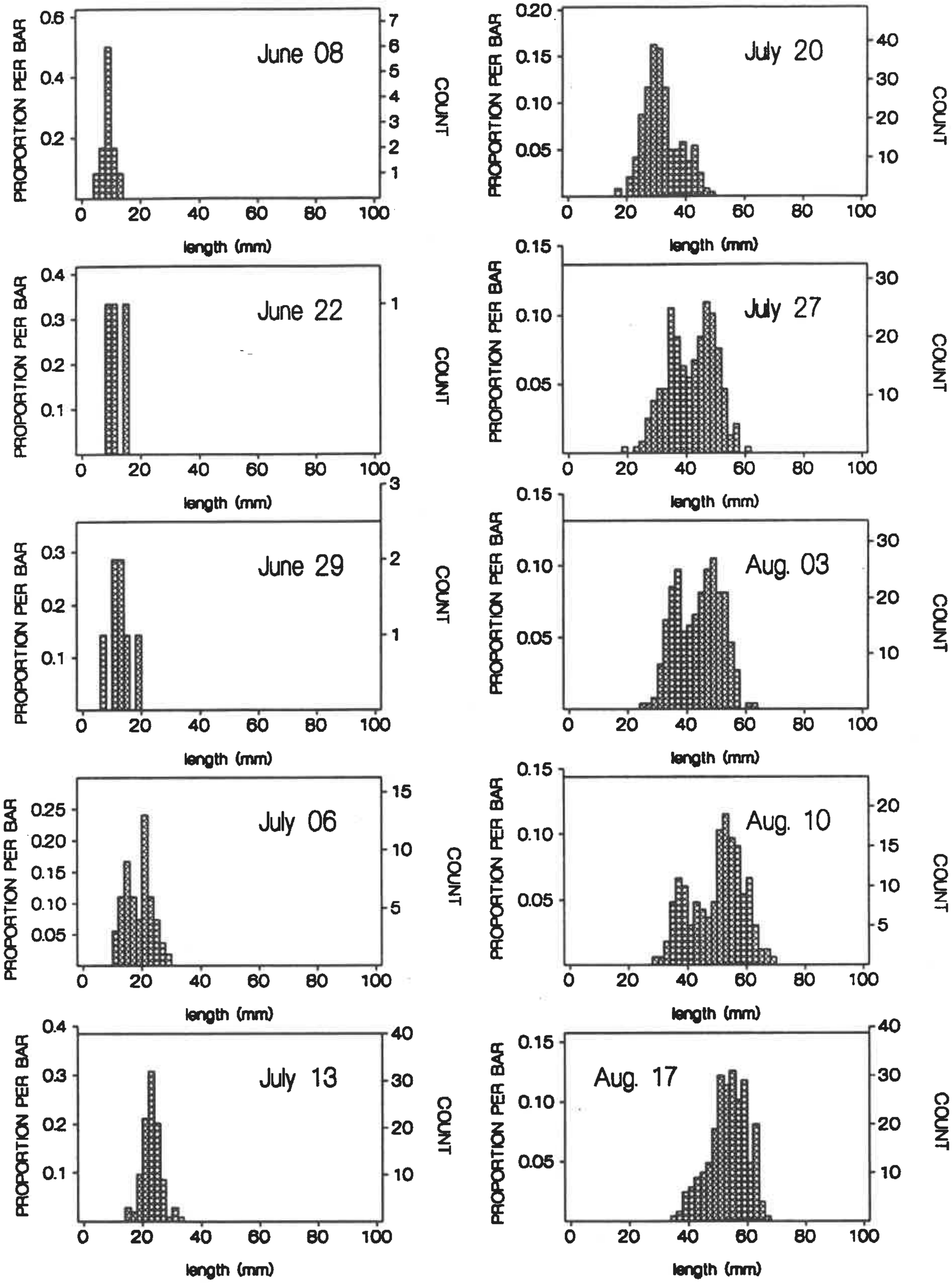

Figure 17.1. Length frequency distributions for alewives captured at Lanes Mills from the week of June 8th to the week of August 17th, 1997.

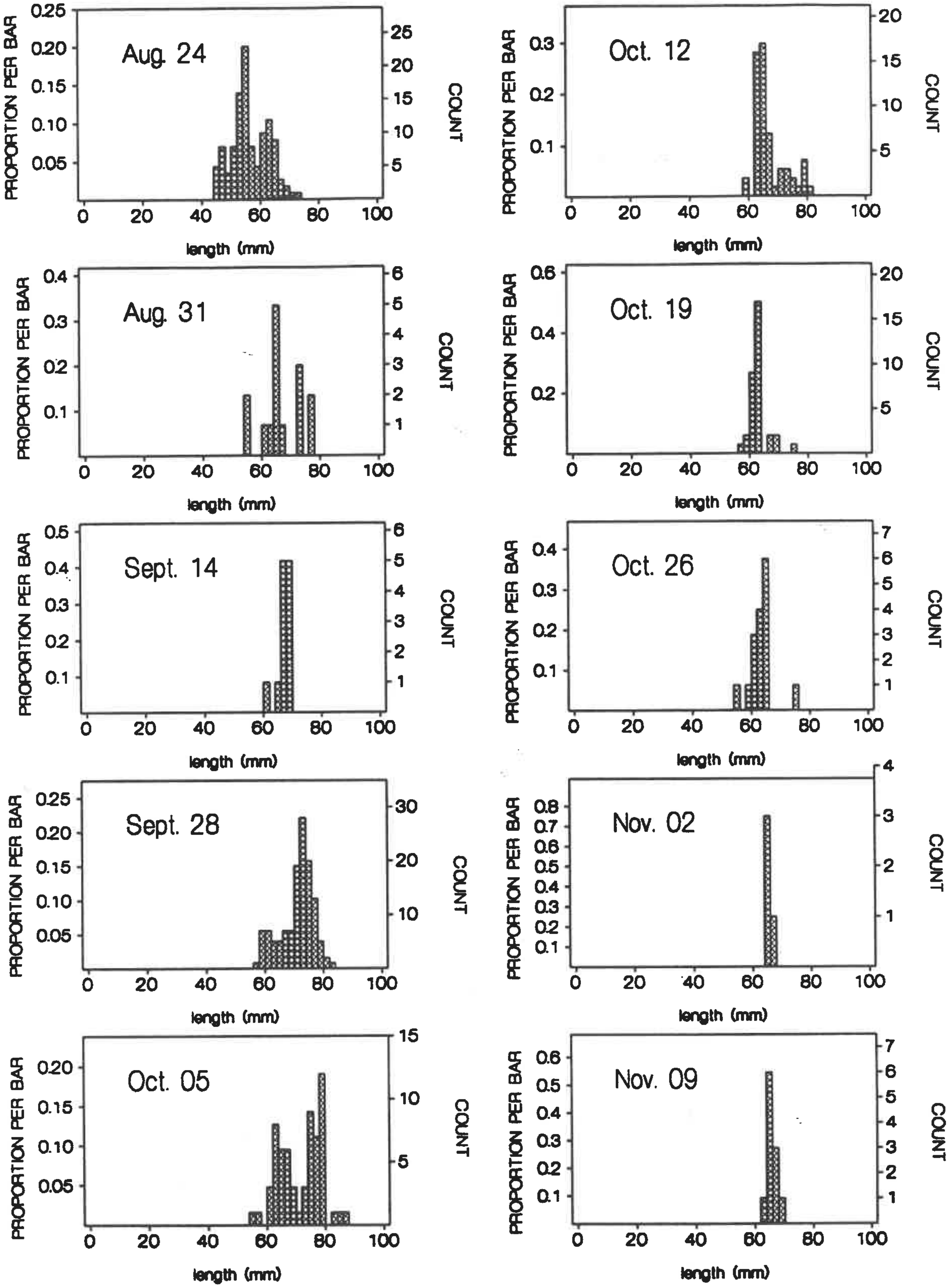

Figure 17.2. Length frequency distributions for alewives captured at Lanes Mills from the week of August 24th to the week of November 9th, 1997.

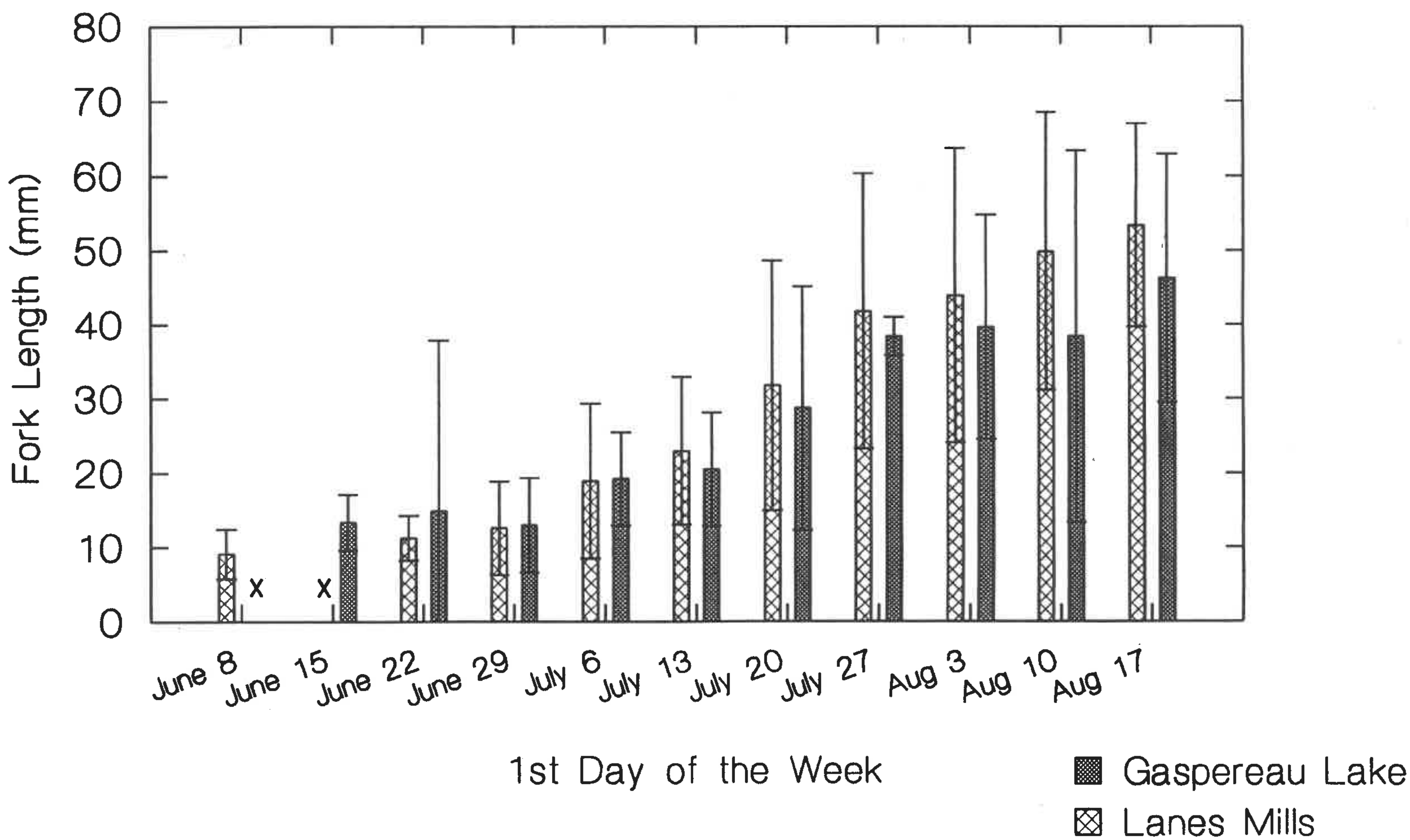

Figure 18. A comparison of the lengths of YOY alewives captured in Gaspereau Lake with those captured at Lanes Mills. Error bars are minimum and maximum.

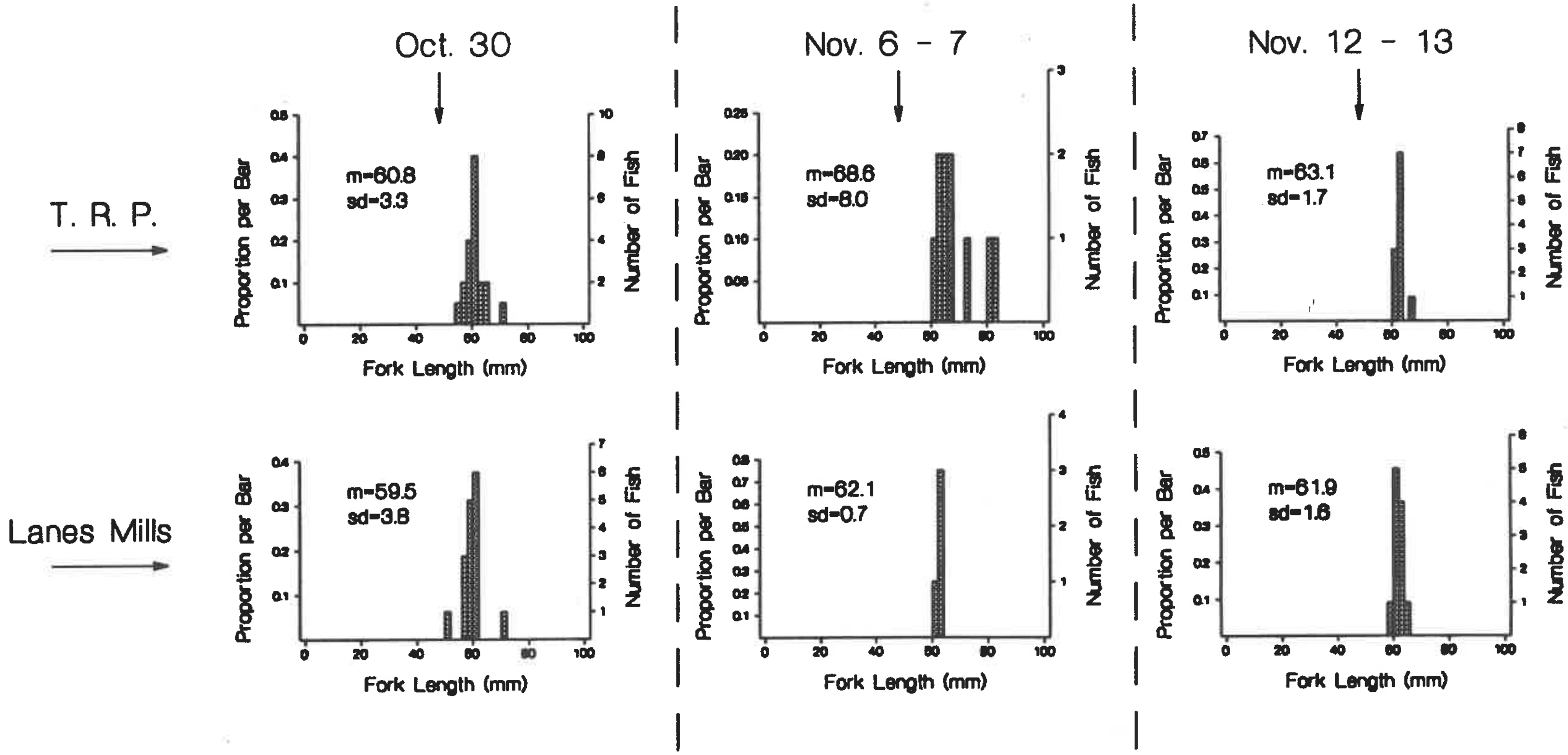

Figure 19. A comparison of the length of YOY alewives captured at Lanes Mills and at the Trout River Pond fish diversion screen after the control gate at Forest Home was opened in late October.

Table 6. A comparison of the size of alewives captured at the Trout River Pond (T.R.L) fish diversion screen in 1996 and those caught at Lanes Mills (L.M.)in 1997.

Week Starting:	Mean Fork Length (mm)		Standard Deviation		Minimum Fork Length (mm)		Maximum Fork Length (mm)		Sample Size	
	T.R.L.	L.M.	T.R.L.	L.M.	T.R.L.	L.M.	T.R.L.	L.M.	T.R.L.	L.M.
July 6	11.6	18.9	3.5	4.5	8.1	10.6	16.3	29.3	4	54
July 13	24.0	23.0	10.2	3.2	7.4	14.7	44.1	32.9	29	104
July 20	37.1	31.8	6.2	6.2	12.9	16.1	59.2	48.6	414	240
July 27	39.2	41.8	8.9	8.0	22.5	18.4	66.0	60.3	122	238
Aug. 3	50.2	43.9	12.7	7.6	25.6	25.9	83.0	63.7	39	257
Aug. 10	44.7	49.8	2.3	8.9	43.0	29.7	46.3	68.5	2	165

4. DISCUSSION

4.1 Egg/Larvae surveys in the Gaspereau River

The presence of the few eggs and larvae captured in the Gaspereau River is an indication that in 1997 some spawning activity took place in the river downstream of Gaspereau Lake. In hindsight, this is not surprising, given the number of suitable locations both upstream and downstream of the White Rock dam. Also in hindsight, the low numbers captured are not really surprising given the timing of the study. This portion of the study was prompted by the presence of post-spawning adults at the White Rock dam prior to observing post-spawning adults leaving Gaspereau Lake (Gibson and Daborn 1997). Some (maybe most) spawning activity in the river must therefore have taken place prior to the onset of monitoring. In order to be available for capture by a stationary plankton net, eggs or larvae would need to be transported downstream by the current. Eggs are typically demersal and spawned in still waters or eddies (in lotic environments) which would limit the numbers available being transported by stream flow. Those that are transported could flush downstream fairly rapidly, thus limiting the time for which they would be available for capture. Similarly, larvae in still waters or eddies would likely remain there, and could possibly use the river bottom micro-topology to avoid being flushed downstream. Also, sampling sites were chosen on the basis of accessability (bridges) simply to get an indication if spawning had occurred in these areas. If more quantitative data are to be collected in the future, egg traps should be installed in suitable locations prior to alewives entering the river, or an active sampling method be used to capture larvae. Once larval transport from Gaspereau Lake begins, data collected from the river would be difficult to interpret. During this study, the majority of eggs and larvae were captured downstream of White Rock during the week of June 1st, prior to the capture of larvae at Lanes Mills. Glochidia present in the lower river are a threat to the survival of larvae in this area, but the extent of this threat is not known.

4.2 Distribution of YOY Alewives in Gaspereau Lake

A few larval alewives were present in Gaspereau Lake during the net trials on June 16th, and were present at the highest abundance during the week of June 22nd in all sections of the lake except for Two Mile and Four Mile Lakes. It seems reasonable that abundances would peak later in these lakes since they were furthest from the entrance to the lake at Lanes Mills.

The rapid decline in alewife abundance during late June and July is typical of many species because larval mortality is highest during the early stages. *Alosa* have high fecundities and mortality of early life stages is typically high. For example, in Brides Lake, Connecticut, Kissil (1974) estimated that only one young alewife for every 80,000 eggs produced survived to migrate seaward and that only 2.9 fry return to the sea for every female entering the lake. While this latter value does not seem adequate to maintain the population, the example does demonstrate high YOY mortality.

YOY alewives were found in all sections of the lake at varying relative abundances. These changes could be in response to changing food availability, predation or other mortality, and immigration and emigration events. Sampling biases could also have influenced results. The pushnet could only be utilized in areas that were boulder free and greater than 1.5 m in depth, which limited where it could be deployed in each lake section. Seining locations were also limited, having to be boulder free with a suitable shoreline for closing off the seine. If alewives were taking advantage of cover in the form of boulders, stumps or marsh areas, they would not be available for capture.

The temperature and oxygen data collected from Gaspereau Lake leads to some interesting speculation. Stratification in Gaspereau Lake probably varies between years. In 1997, the lake was polymictic. A pronounced thermocline was present at a depth of about 3 m in early July, which was broken down by strong winds later in the month, about the time the hypolimnion was going anaerobic. Comparatively weak stratification developed intermittently throughout the remainder of the summer, but was again broken down by the winds. It is likely, therefore, that in a summer without strong winds, a stable stratification develops which could remain in place until the fall turnover. In such years the hypolimnion is probably anaerobic, based on the low dissolved oxygen concentration recorded in late July, 1997. During years with high winds in the early summer (causing mixing which reduces surface and bottom water temperature differences), stratification would be less likely to occur.

When a lake is stratified, the hypolimnion acts as a nutrient sink: nutrients settle out of the epilimnion (where most phytoplankton productivity occurs) and are unavailable for primary production until the stratification breaks down allowing mixing to occur throughout the water column. Phosphorus concentrations in surface water in Gaspereau Lake in August were high (Brylinsky and Gibson 1997), indicating that nutrients were probably not limiting in the epilimnion at that time. If the lake remained stratified throughout the summer, nutrient availability would probably decline, limiting phytoplankton primary production until the fall turnover. The effect of such a scenario on alewives (which feed on zooplankton which in turn graze on phytoplankton) would ultimately depend on the relative importance of phytoplankton productivity relative to littoral zone primary production and allochthonous inputs as food sources for the zooplankton community in the lake. This relationship probably varies in different parts of the lake, in part as a function of basin morphology. These relationships stress the importance of collecting basic limnological data as part of these studies.

Analysis of the zooplankton samples returned lower estimated zooplankton densities than would be expected. This may be due in part to sampling biases such as net avoidance and net clogging (UNESCO 1968), but may be indicative of low abundances. In 1983, Jessop and Parker (1988) used vertical tows to sample zooplankton density, and (excluding copepod nauplii which were not abundant during the 1997survey) estimated densities at under 10 organisms/liter during July (their Figure 11), also very low densities. Because surface tows were used during this study, the two studies are not directly comparable.

Sampling biases aside, because the method was standardized throughout the study, relative trends are probably valid and the decline in abundance between the July 3rd samples and the July 17th samples is probably real. This decline, which occurred simultaneously with the transition from larval to juvenile life stages within the lake, is likely a good indication of changing food availability for YOY alewives within the lake.

Impacts of anadromous and landlocked clupeids on zooplankton populations are well documented. For example, Dettmers and Stein (1992) reported that early juvenile gizzard shad severely reduced zooplankton in an Ohio reservoir. Gorman *et al.* (1991) found that changes in the zooplankton community can actually be used to assess nonanadromous alewife seasonal distribution and movement. Also well documented is the importance of adequate food supplies for early feeding YOY. Welker *et al.* (1994) reported that the growth and survival of gizzard shad are effected by zooplankton availability which may become limiting when larval fish densities are high. Cohort-specific growth rates of larval American shad have been reported to increase linearly with rising zooplankton abundance (Crecco and Savoy. 1985). Food deprivation for as little as two days has significant effects on the survival of shad larvae (Johnson and Drokkin 1995).

4.3 YOY Outmigration at Lanes Mills

Small numbers of larval alewives were captured in the outflow at Lanes Mills during June and early July. These fish were probably entrained in the outflow. By the week of July 20th, the majority of alewives were pre-juveniles or juveniles that may have been actively leaving the lake. Estimated densities of alewives leaving the lake fluctuated to some degree during July and August, but catches during September were very low. The decline in numbers occurred coincidentally with decreased discharges during this time, but the decline in catch could also have been due to the gate configuration. The fact that large numbers of alewives were seen in the immediate vicinity of the gate during September implies that flows were adequate to attract alewives. Alewives moved downstream at even lower flows in November, when flow rates were controlled only by stop logs. They were also willing to follow the low discharge in the bypass stream in August during 1996 (Gibson 1996). From the above, it seems that gate configuration is an important element in ensuring passage of juvenile alewives, and that spilling over stop logs is to be preferred to opening the gate a small amount near the bottom (at higher discharge rates, entrainment may be adequate to ensure passage through the latter configuration). Construction activities may also have played a role in reducing the rate of alewife passage in September. While alewives were not present near Lanes Mills during the day when the old fish ladder was being removed, schools were seen at night, so these activities alone could not be responsible for the reduced rates of movement.

Alewives captured at Lanes Mills were 5 to 20 % larger than those captured in the lake. This relationship suggests that size plays a role in timing of outmigration. The bimodal size frequencies of the alewives through late July and August has interesting implications. Bimodal length frequency distributions have been reported for some, but not all, populations of juvenile alewives. Richkus (1975), for example, reported bimodal distributions while studying YOY alewives in the Annaquatucket River drainage during 1970 - 1973, and found the growth rate of the small size group appeared to decline or approach zero in all three years. Richkus attributed the bimodal distribution to significant recruitment from other areas during the summer, but speculated that depletion of forage could have accounted for the near zero growth rate of the smaller size group. The fact that alewives captured in Black River Lake and Lunsdens Pond in 1996 were substantially larger than those in Gaspereau Lake in late August (Gibson 1996), an observation also reported by Jessop and Parker (1988) in 1983, also suggests that some factor may be limiting alewife growth in Gaspereau Lake. Alternative explanations for these observations include age differences between the sites and recruitment of smaller alewives into Gaspereau Lake from locations upriver. Given that the diversion screen acts as a semi-permeable barrier excluding larger (older?) alewives from passing downstream in the early season, the former is not a satisfying explanation. The latter lacks weight given that the maximum size of alewives captured in Gaspereau Lake is also lower than of those captured in Black River Lake and Lumsdens Pond. From the above it appears that intraspecific competition within Gaspereau Lake may play some role in limiting both growth and year class success within this system.

4.4 Alewife Outmigration at Trout River Lake

Large numbers of YOY alewives moved into Trout River Lake as soon as the gate was opened at Forest Home on Oct. 23rd. At least the majority of these moved downstream when the bypass was opened on Oct. 30th. While quantitative sampling of this initial wave was not possible, visual observations suggest that the numbers moving this first day must have been many hundreds of thousands. Much smaller, but still significant movements of alewives occurred during November, and it is likely that some alewives remained in Gaspereau Lake after the end of this study. The purpose of monitoring at the diversion screen was to determine if large numbers remained in the system at that time of the season. Data collected indicate that a significant fraction of alewives did not leave the lake via Lanes Mills during 1997.

Sampling downstream at the screen and visual observation of alewives in the vicinity of the screen indicate that the screen was an effective barrier for keeping alewives out of the lower system. Impingement was a problem when the water level in the lake was being increased (solved by simply bringing the water level up slowly), but did not appear significant after normal water levels were reached.

Alewives tend to school back and forth across the front of the screen in an attempt to find a passage downstream. Alewives appear to have difficulty locating the entrance to the bypass stream in its current location. If the screen is to continue to play a role in alewife management, reconfiguring the entrance so that the screens guide the fish directly to it should reduce the amount of time alewives spend in front of the screen and thus reduce impingement.

4.5 Recruitment

About 1.2 million juveniles were estimated to have left Gaspereau Lake via Lanes Mills. An unknown number also migrated when the gate was opened at Mosquito Cove in late September and still more moved downstream when the gate was opened at Forest Home. While the latter values are unknown, a very rough guess of the number of YOY leaving Gaspereau Lake via these routes during the study period is 2 to 3 million fish. Is this adequate to maintain the stock at current levels? This question is difficult to answer with the data available.

The 1997 adult spawning run consisted of about 706,000 individuals (Gibson and Daborn 1997). Of the 463 alewives that were aged, 68.4 % were four years old (1993 year class), implying about 483,000 age four alewives in the run. About 82 % of the alewives in the 1997 sample matured by age four, giving a rough estimate of 580,000 four year old alewives in the stock this year.

Instantaneous natural mortality rates (M) of alewives at sea, particularly juveniles, are not known. Jessop and Parker (1988) estimated the instantaneous natural mortality rate of Gaspereau River age 4 yr. and older alewives to be 0.68. Chaput and Alexander (1989) estimated natural mortality (excluding mortality associated with spawning) of southern Gulf of St. Lawrence alewives to be about 0.44 for alewives 4 years old and older. Values of 0.4 are sometimes used in the absence of better data, for example D.F.O. (1997), again for age 4 yr. and older fish. Rates are probably higher for very young fish. Assuming an instantaneous mortality rate of 0.5, and a 0+ age class size of 3 million individuals in 1997, about 400,000 age 4 alewives would be expected to survive to the year 2001.

While providing some insight into reproductive success this year, this analysis is not adequate to answer the above question for a number of reasons. For example, alewife production in the old Gaspereau River downstream of Lanes Mills was not quantified and therefore was not included in the estimated number of outmigrating juveniles. An unknown number of YOY were still present in Gaspereau Lake in late November, that were also not included in the above analysis . These factors, combined with the uncertainty about survival at sea preclude an accurate determination of alewife reproductive success this year. If, in 4 years, it appears that reproduction in 1997 was not adequate to produce a year class of an acceptable size, given the variability that is typical of alewife stocks, and given this 'snapshot' view of the system, sufficient data are are not presently available to say whether this result was part of some natural fluctuation, or due to anthropogenic activities in the watershed based on the data.

If competition within nursery areas is a limiting factor, increasing the size of the spawning run may not substantially increase reproductive success. Reducing competition by increasing available nursery areas within the watershed, or ensuring easy access to nursery areas in the Minas Basin may be the only ways to alleviate this pressure. Pre-juveniles and juvenile alewives apparently survive well in the Annapolis River estuary at salinities of 28 mg/l in July and August (Gibson and Daborn 1995). Whether they would survive equally well in the Minas Basin (which is a very different body of water than the Annapolis River above the headpond: lower water temperatures, much higher tidal range, higher suspended sediment concentrations) is unknown, although juvenile *Alosa* (spp.?) are regularly captured with beach seines in the Minas Basin during mid summer (e.g. Gilmurray 1980).

The introduction of smallmouth bass to this watershed is unquestionably impacting alewives in this system, both through intense predation and probably through larval and juvenile competition. The increase in abundance of these bass may be having more of an impact than any other change in the watershed since the high catches of the late 1970's, and is a factor which should be considered when developing a management plan.

5.0 CONCLUSIONS

The results of this study have many implications for development of a management plan for alewives, ranging from comparatively simple suggestions relating to gate configuration to almost intractable considerations such as the relative suitability of the Minas Basin as an alternative nursery area to Gaspereau Lake. From this study it is clear that the ecology of YOY within the watershed should be at least as important a component of a plan as is limiting alewife passage through the turbines, especially since gains from reducing turbine passage may potentially be offset by increased density-dependent mortality and predation within the lake.

Alternative explanations exist for many of the phenomena that were interpreted as evidence of reduced growth and survival, particularly of later cohorts, due to competition. Many of these alternatives have been discussed. While the evidence for competition being limiting is strong, an analysis of growth and survival of different cohorts throughout the season would be necessary to choose between these explanations. This type of analysis would require assigning ages to juveniles by counting daily growth rings on otoliths. This approach has been applied to a large number of species, including alewives (e.g. Essig and Cole 1986).

If competition and predation effects within the lake do have the capability to offset gains from reduced turbine passage, then ensuring undelayed outmigration becomes another important part of the management plan. Alewives appeared to be able to locate the outlet at Lanes Mills this year, but, if flow rates are decreased in the future, it would be important to ensure that alewives are still able to locate the outlet under that regime. This would require testing by monitoring alewife migration under the new flow conditions.

Alewife migration patterns appear to be very patchy. Monitoring intensity during this project varied between months, peaking at around 15 to 20 % of the time available for outmigration, and was stratified in an effort to maximize its effectiveness. This approach was only moderately successful due to movements occurring at unexpected times and changes in daily migration patterns throughout the season. If monitoring is continued in the future, consideration should be given to the use of automated counters deployed in the outlets. Benefits would include reduced manpower requirements for monitoring (which would help recover costs), and continuous monitoring of fish movement throughout the season. Ecological data are often better understood as fluctuations within bounds rather than variation around a mean value typically interpreted as the norm (Gould 1996), and continuous data are necessary to interpret these fluctuations. However, the use of automated counters for fish of this size pushes the limits of available technology.

Natural mortality at sea is a phenomenon that is not well quantified. If estimates of the numbers of YOY alewives surviving to emigrate to sea are obtained for some years, it would make sense to time future stock assessments in order to estimate the proportion that return. At the same time stock assessments should also be carried out in years when estimates of the number of outmigrants are to be obtained, to help clarify the relationship between the number of spawners and subsequent reproductive success. Consideration should be given to the coordination of these activities to maximize the value of the resulting information.

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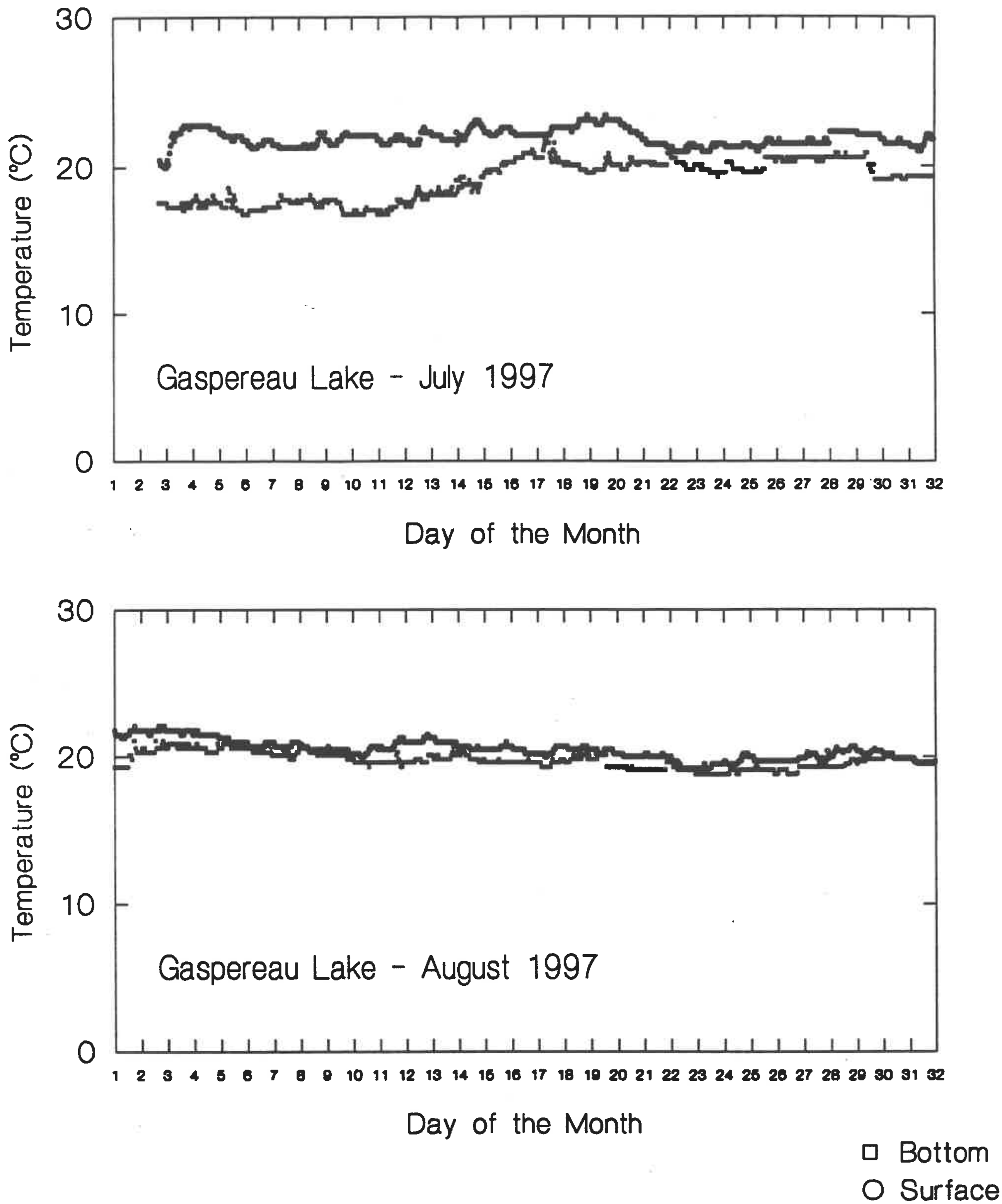
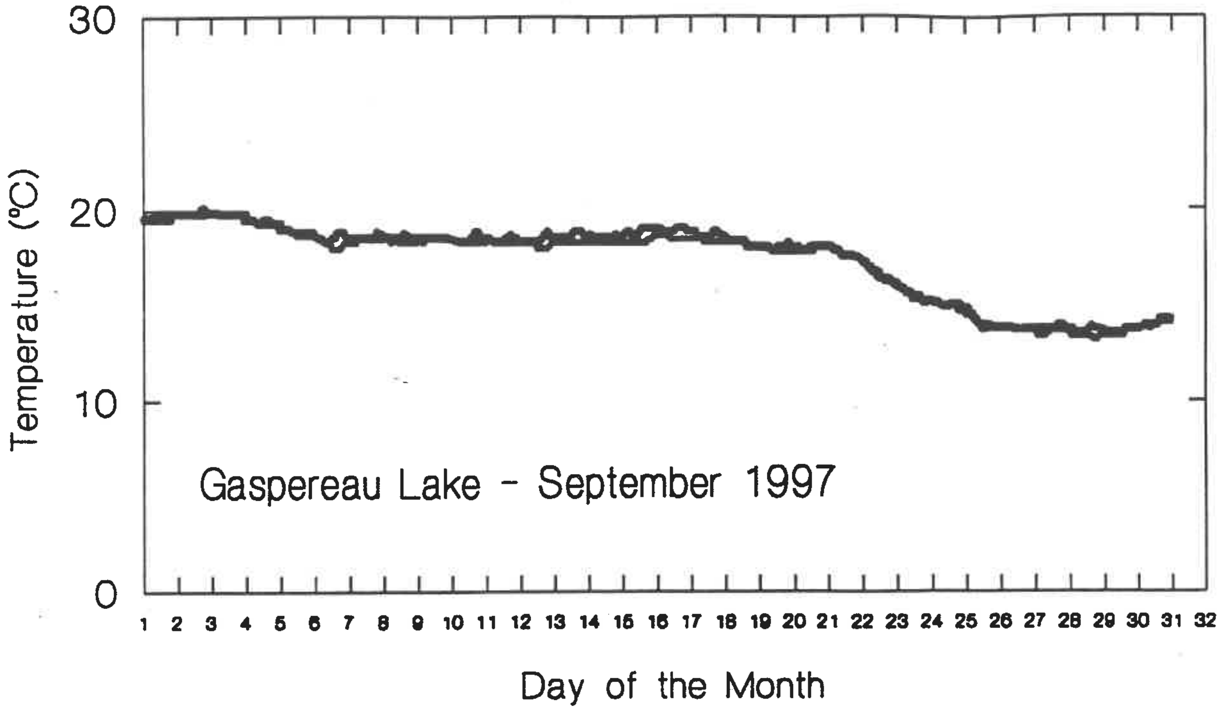
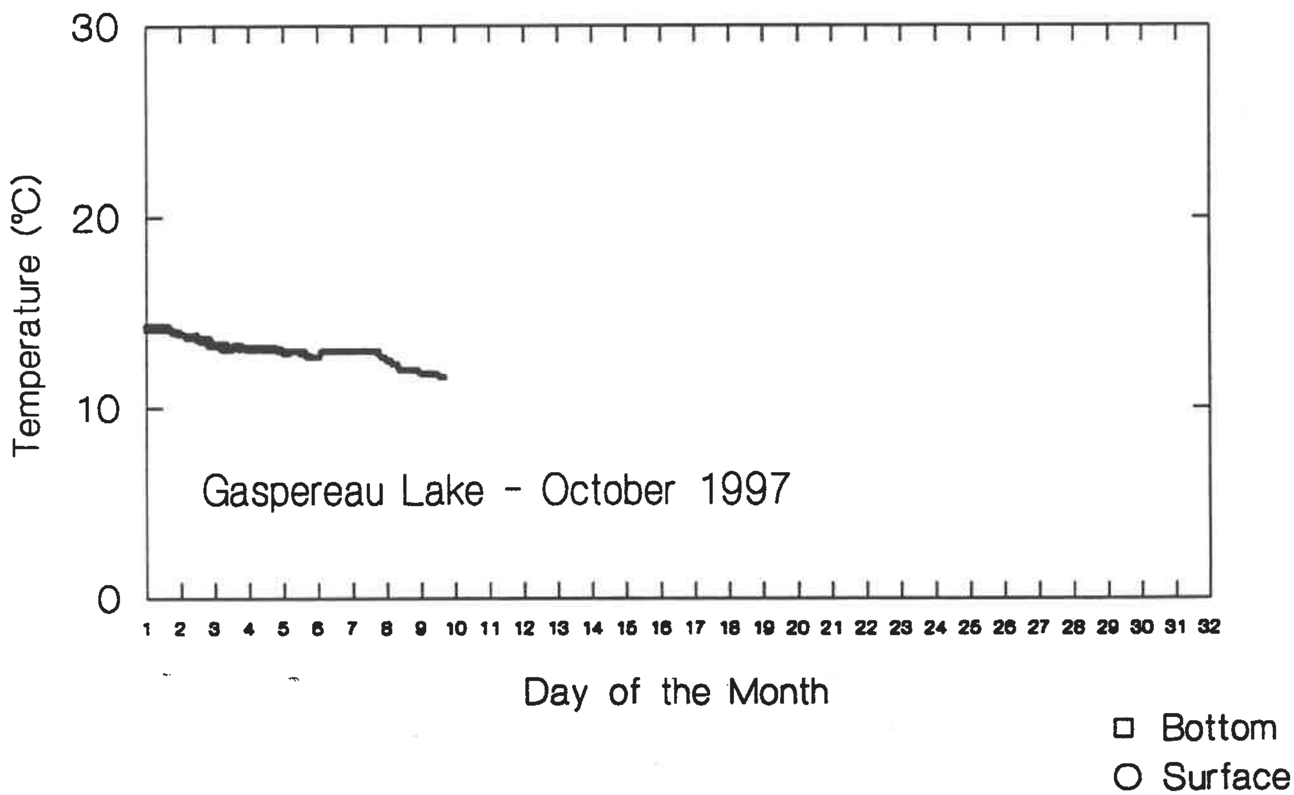
APPENDIX 1. WATER TEMPERATURES RECORDED AT GASPEREAU LAKE, THE LANES MILLS FISH LADDER, THE WHITE ROCK FISH LADDER, THE GASPEREAU RIVER AND TROUT RIVER POND DURING THE SUMMER AND FALL OF 1997.

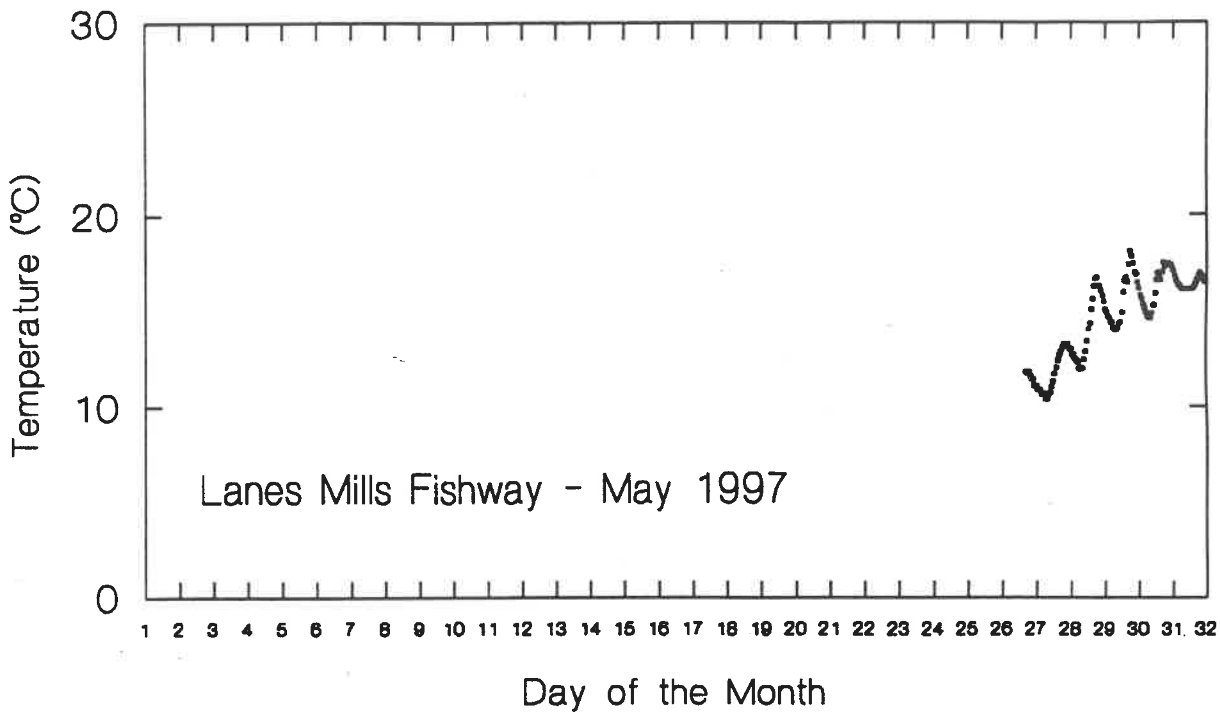


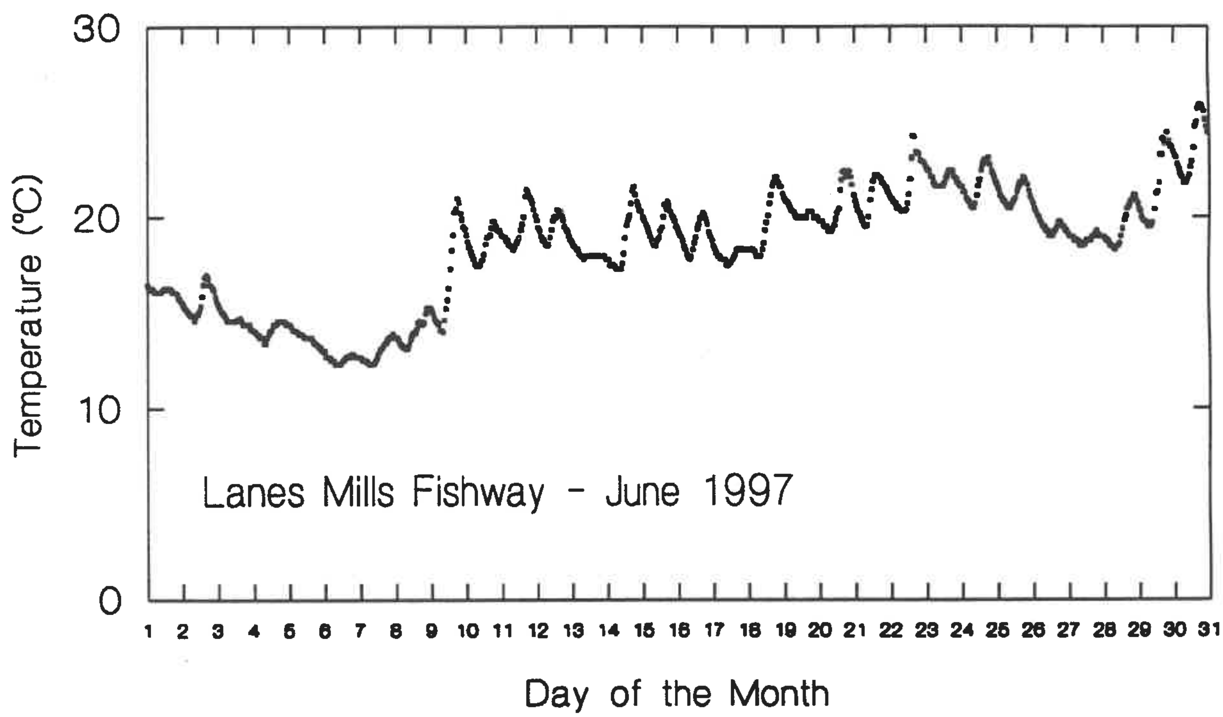
Appendix 1.1. Water temperatures recorded at the water quality station in Gaspereau Lake during July and August, 1997.



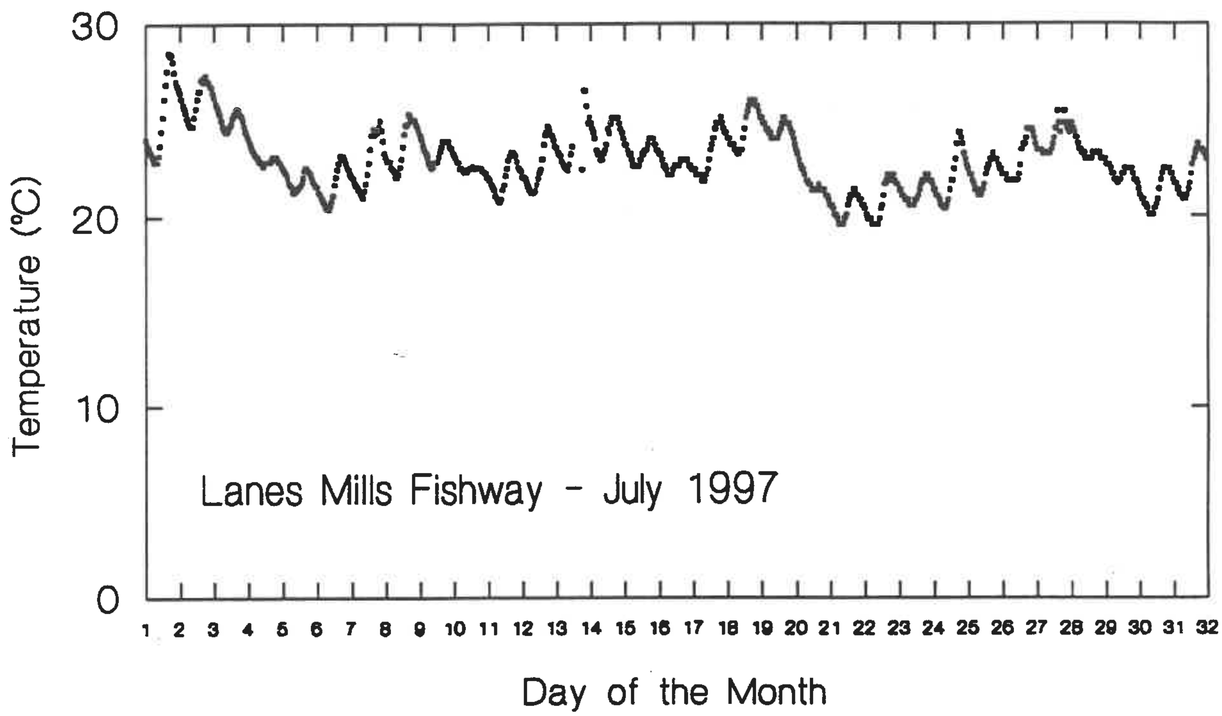


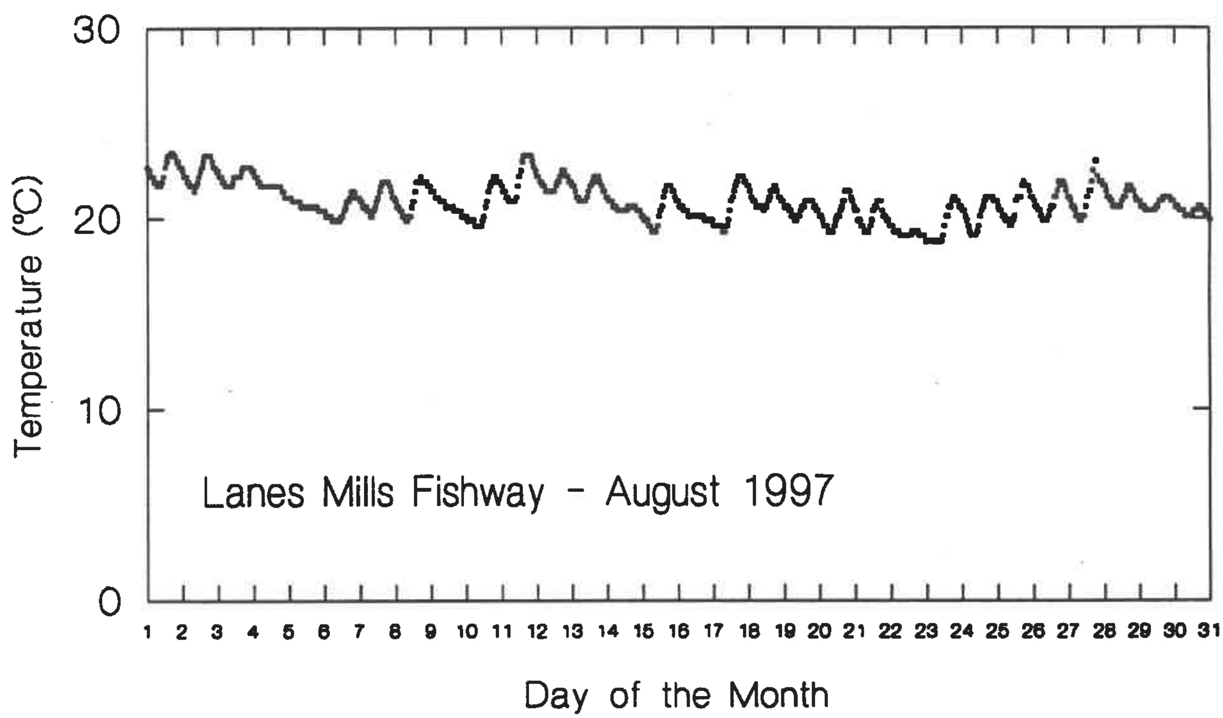
Appendix 1.1 (con't). Water temperatures recorded at the water quality station in Gaspereau Lake during September and October, 1997.



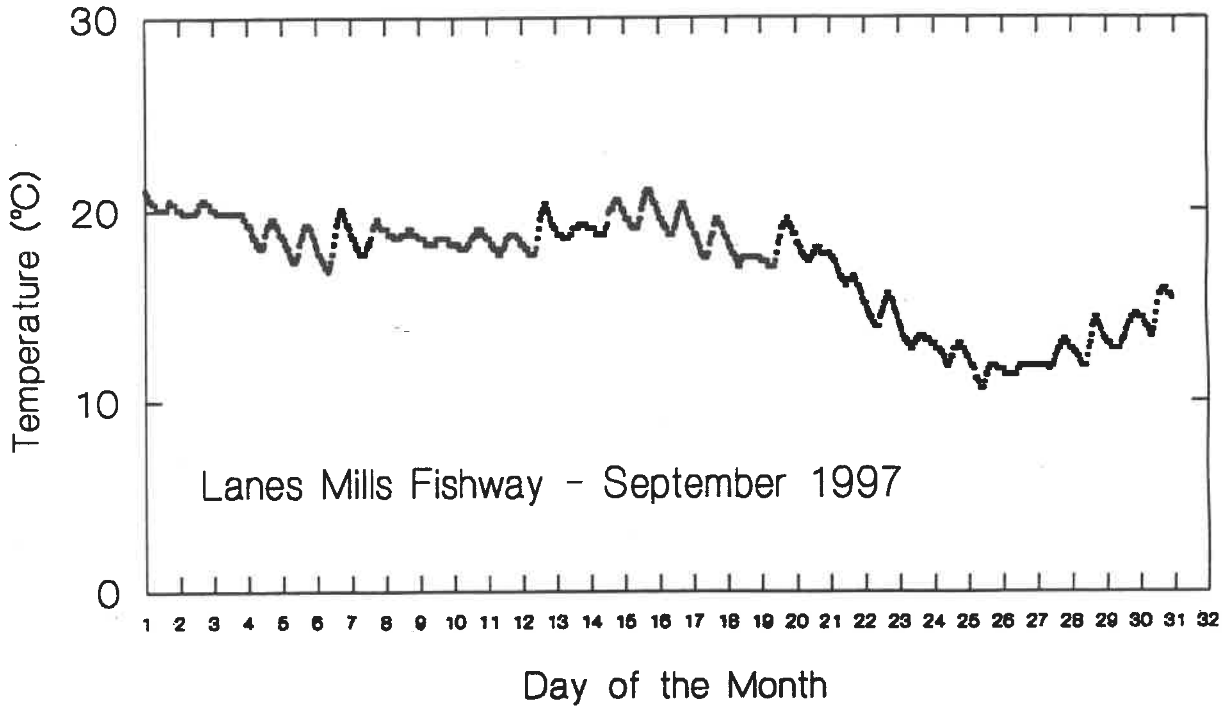


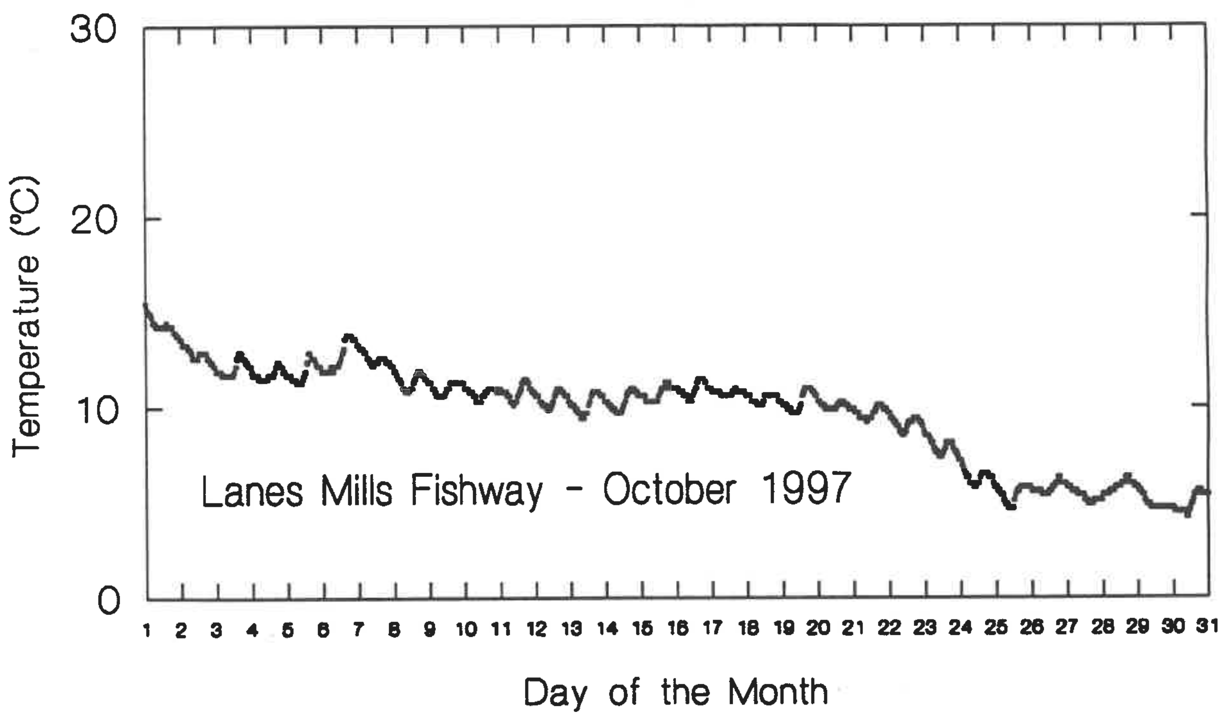
Appendix 1.2. Water temperatures recorded at the outlet at Lanes Mills during May and June, 1997.



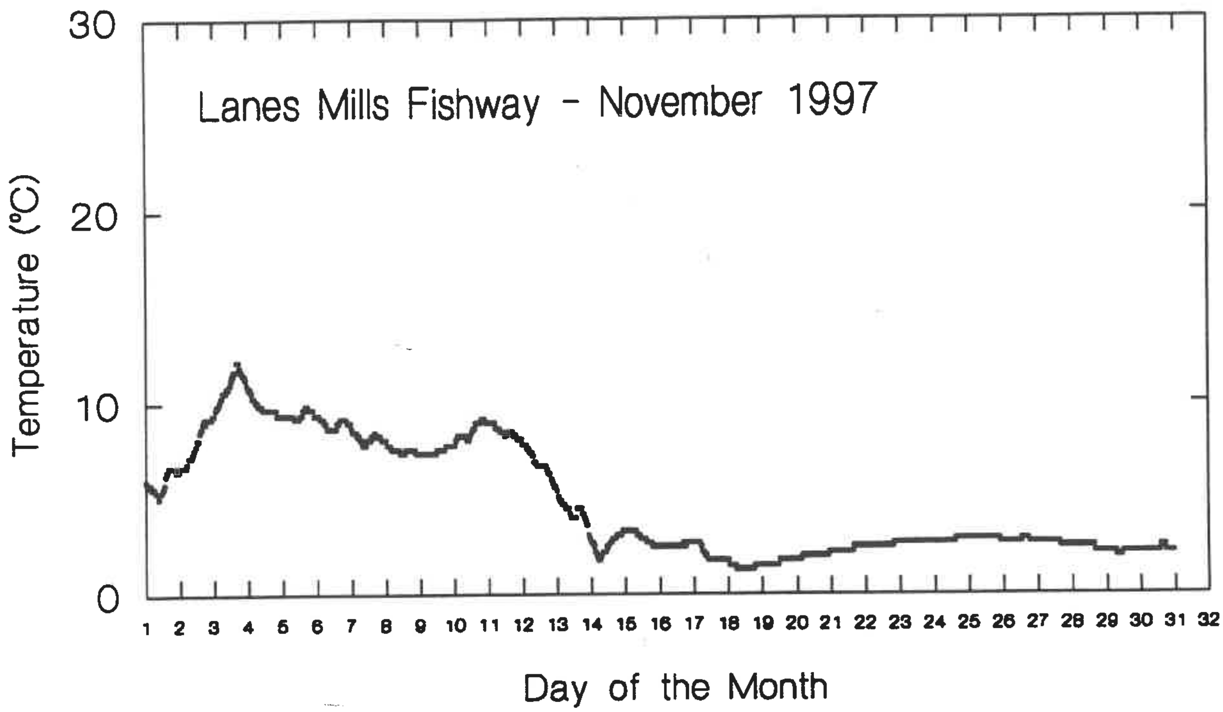


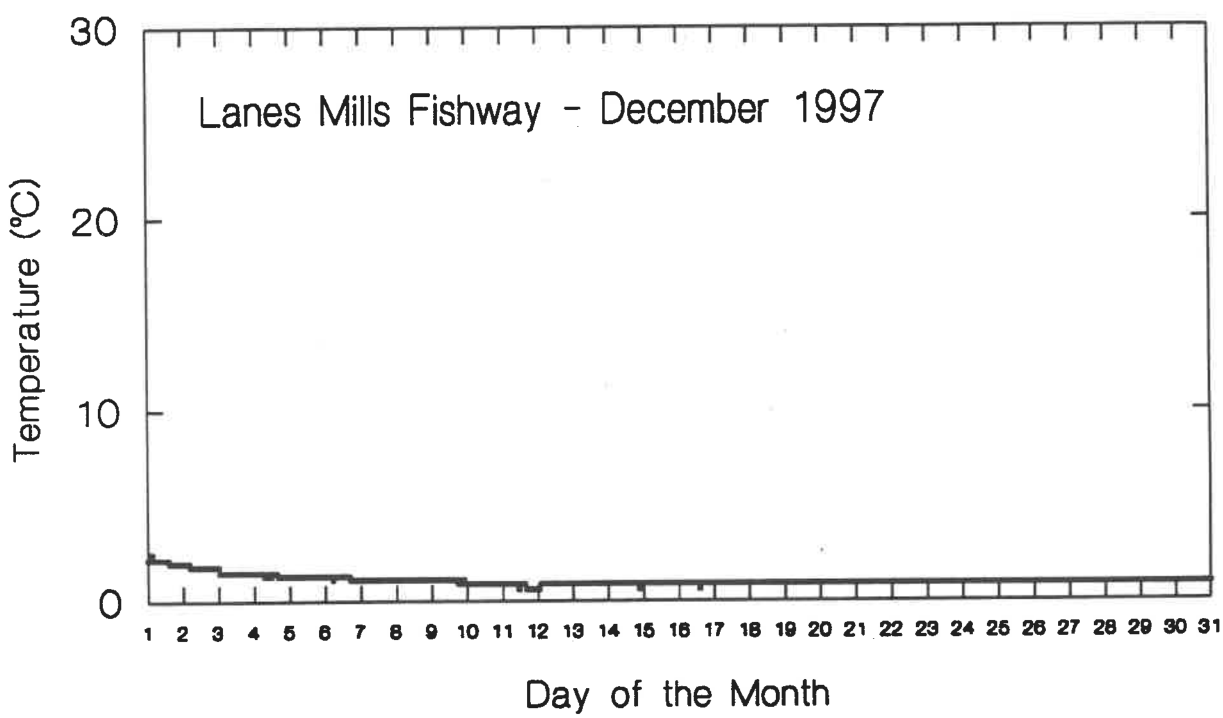
Appendix 1.2 (con't). Water temperatures recorded at the outlet at Lanes Mills during July and August, 1997.



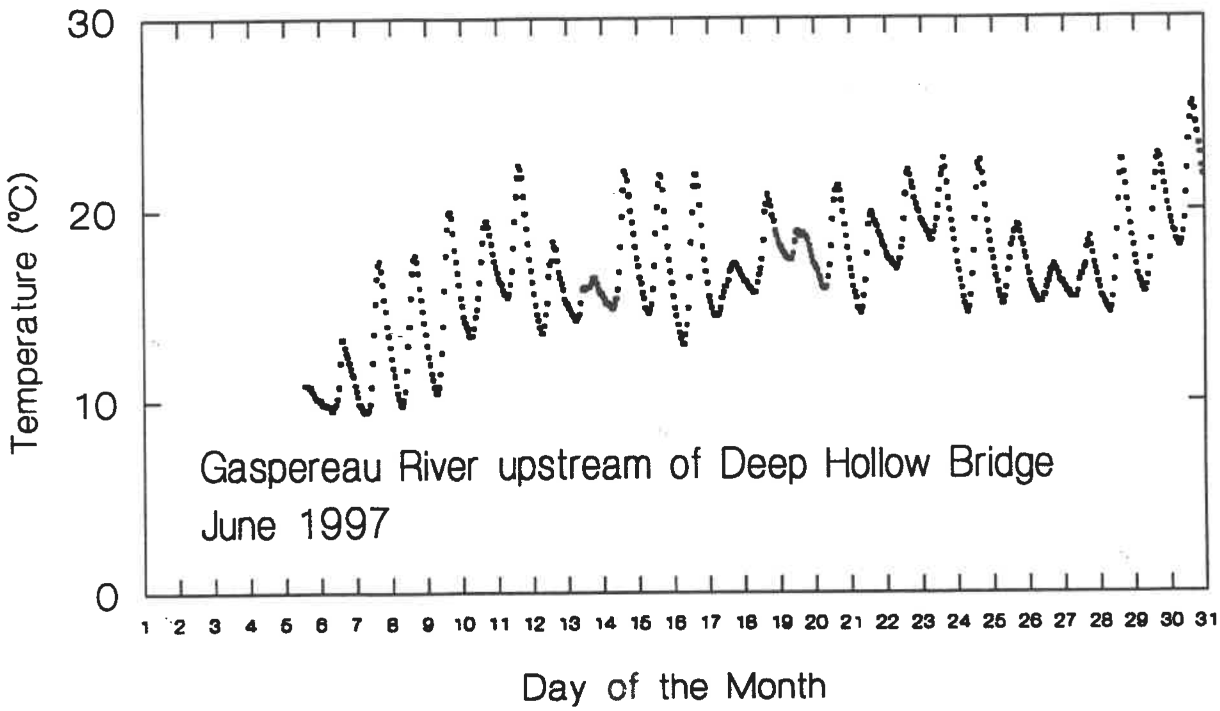


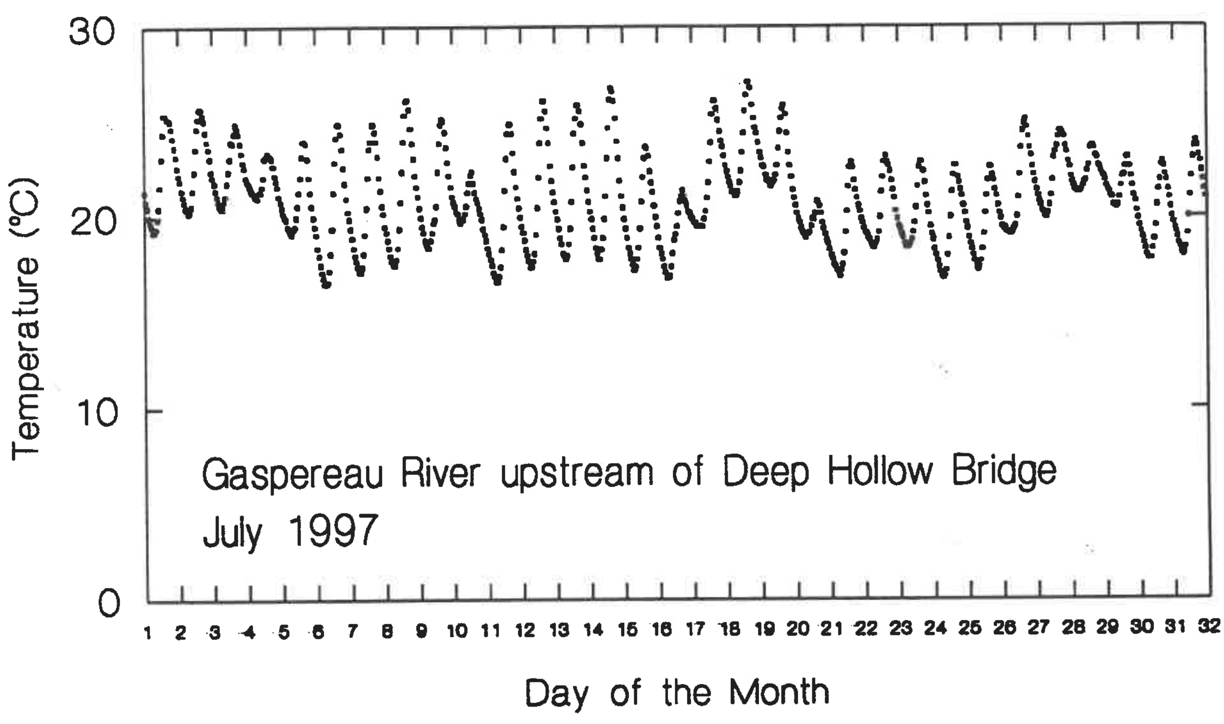
Appendix 1.2 (con't). Water temperatures recorded at the outlet at Lanes Mills during September and October, 1997.



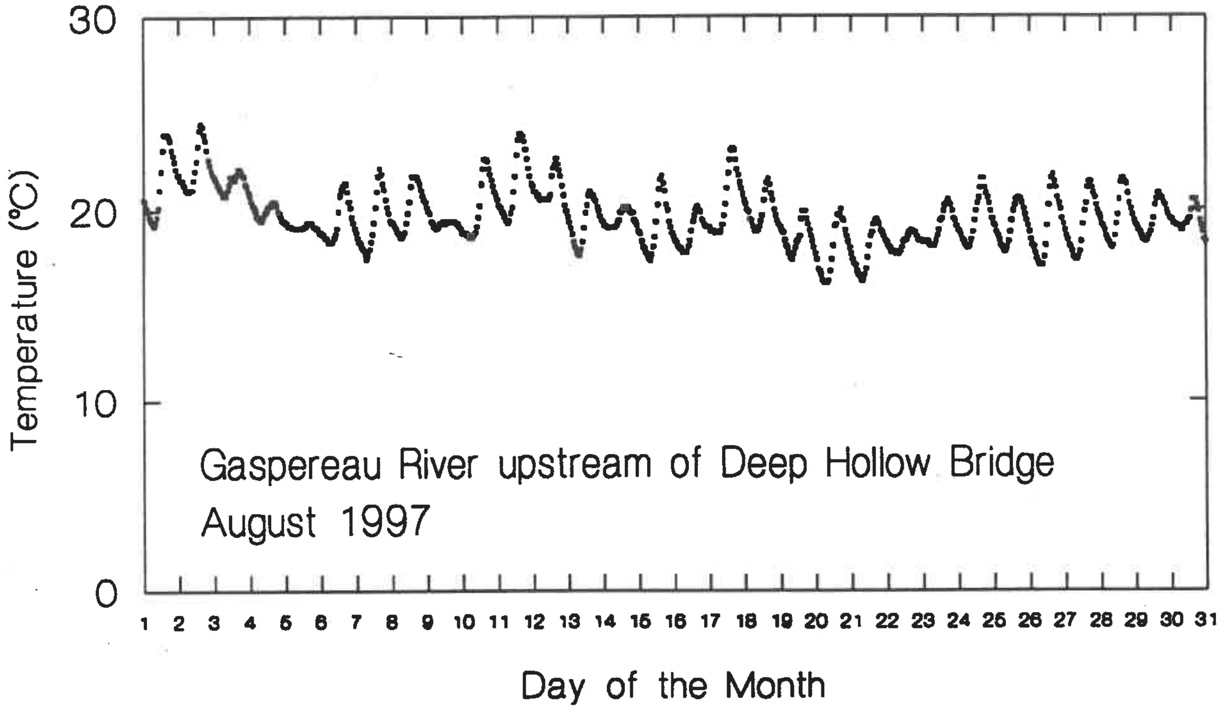


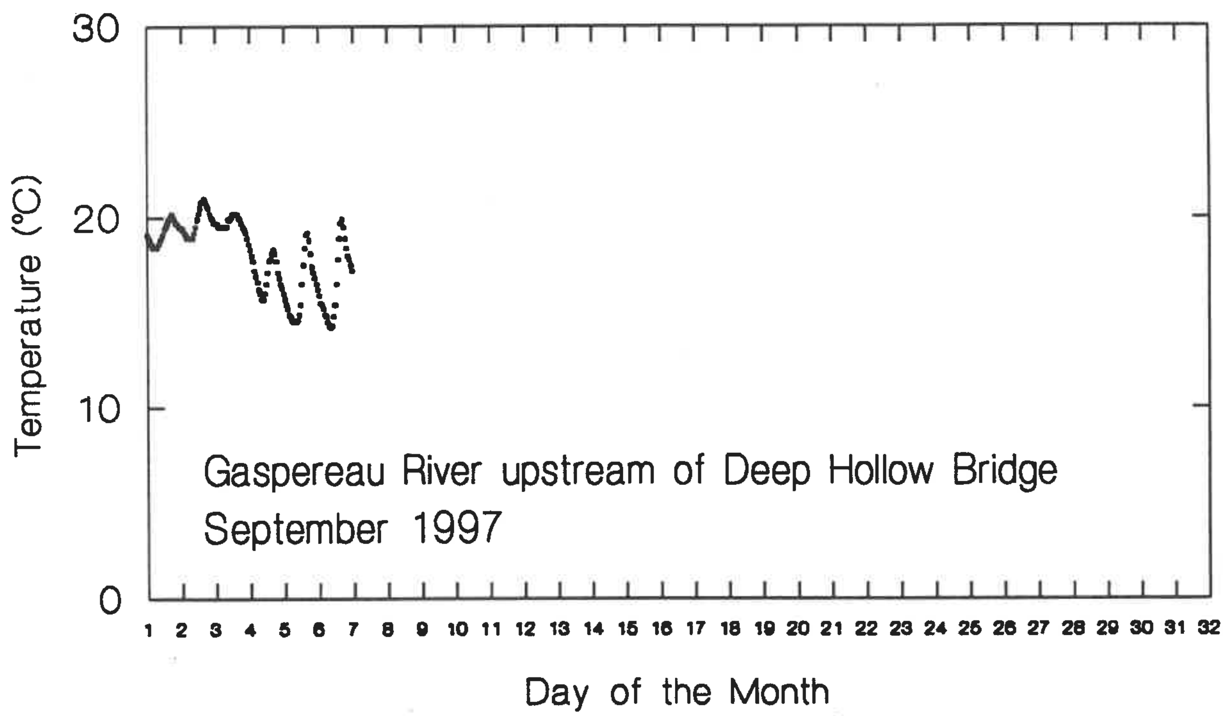
Appendix 1.2 (con't). Water temperatures recorded at the outlet at Lanes Mills during November and December, 1997.



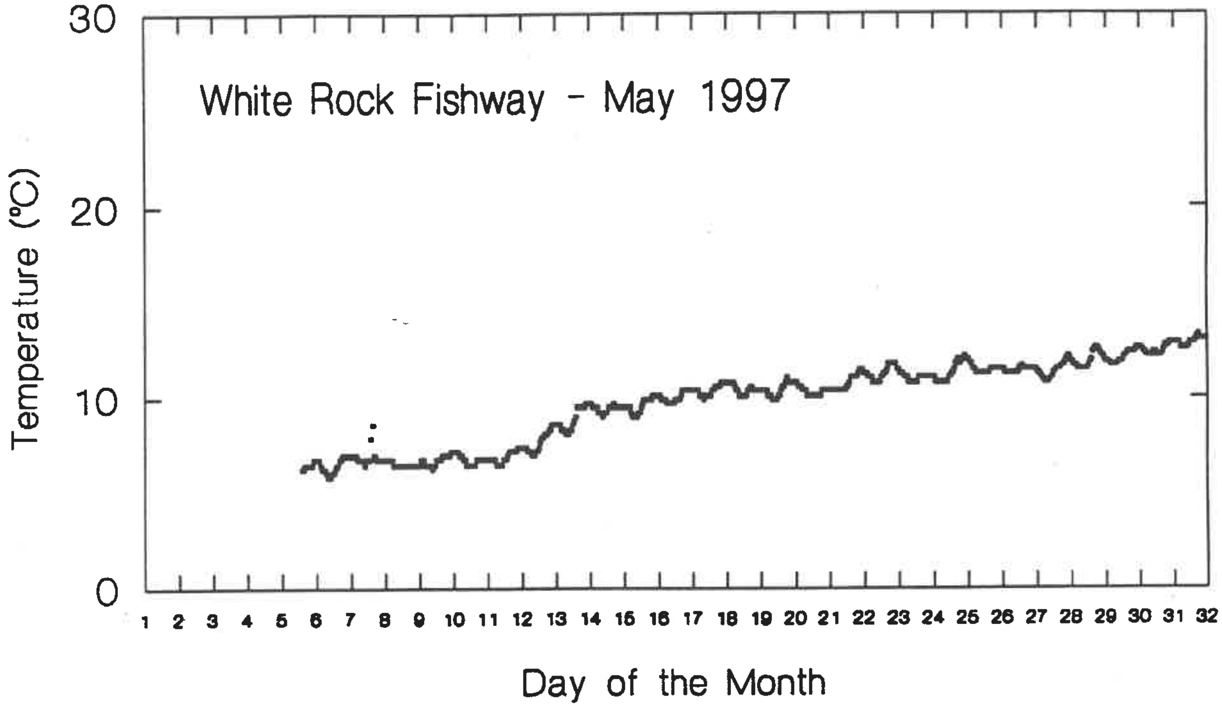


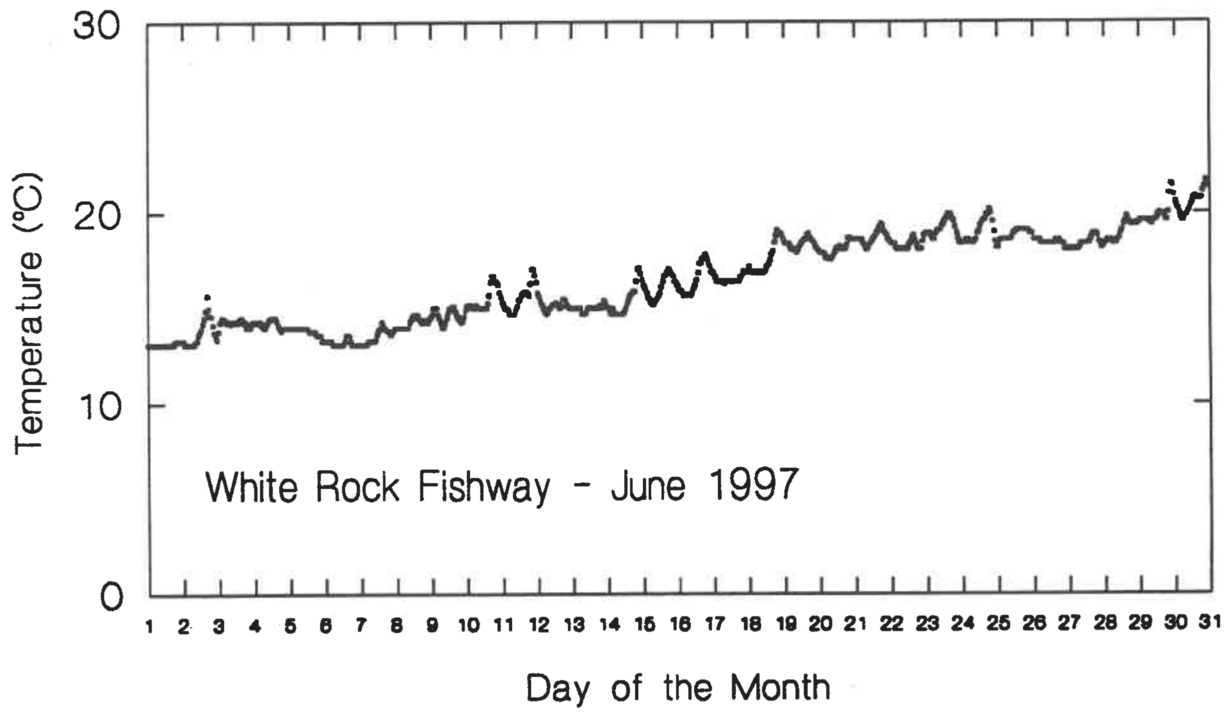
Appendix 1.3. Water temperatures recorded in the Gaspereau River 0.5 km upstream of Deep Hollow Bridge during June and July, 1997.



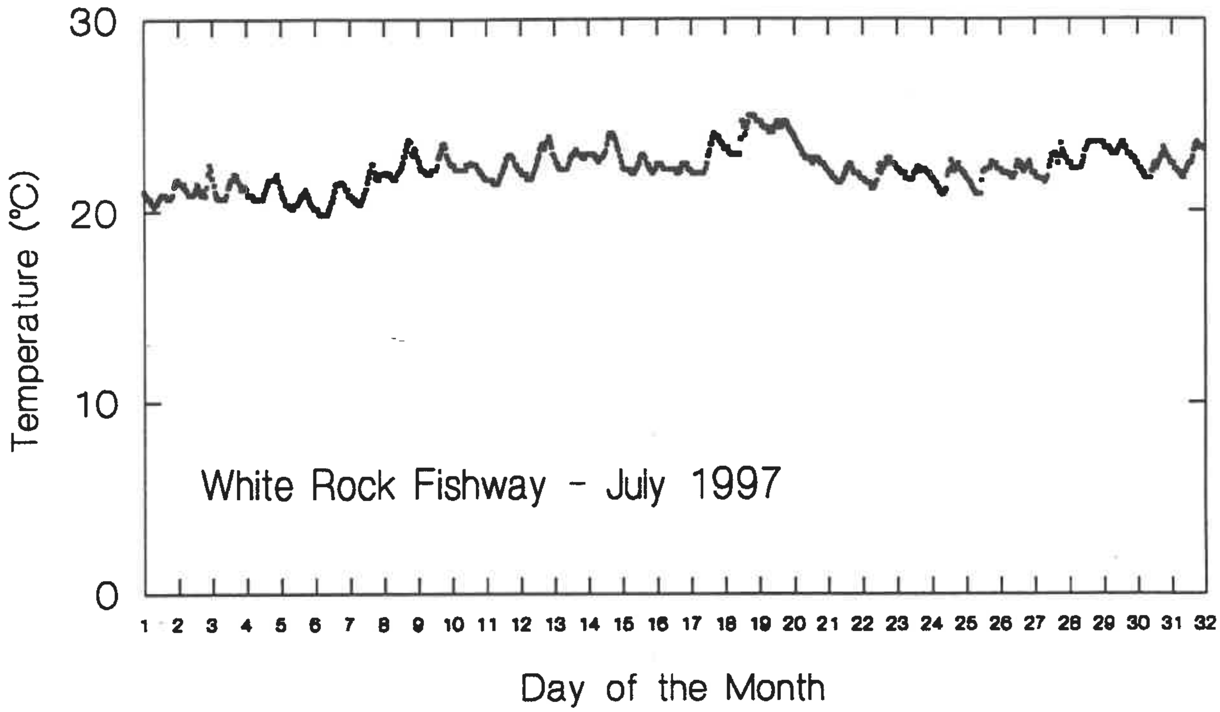


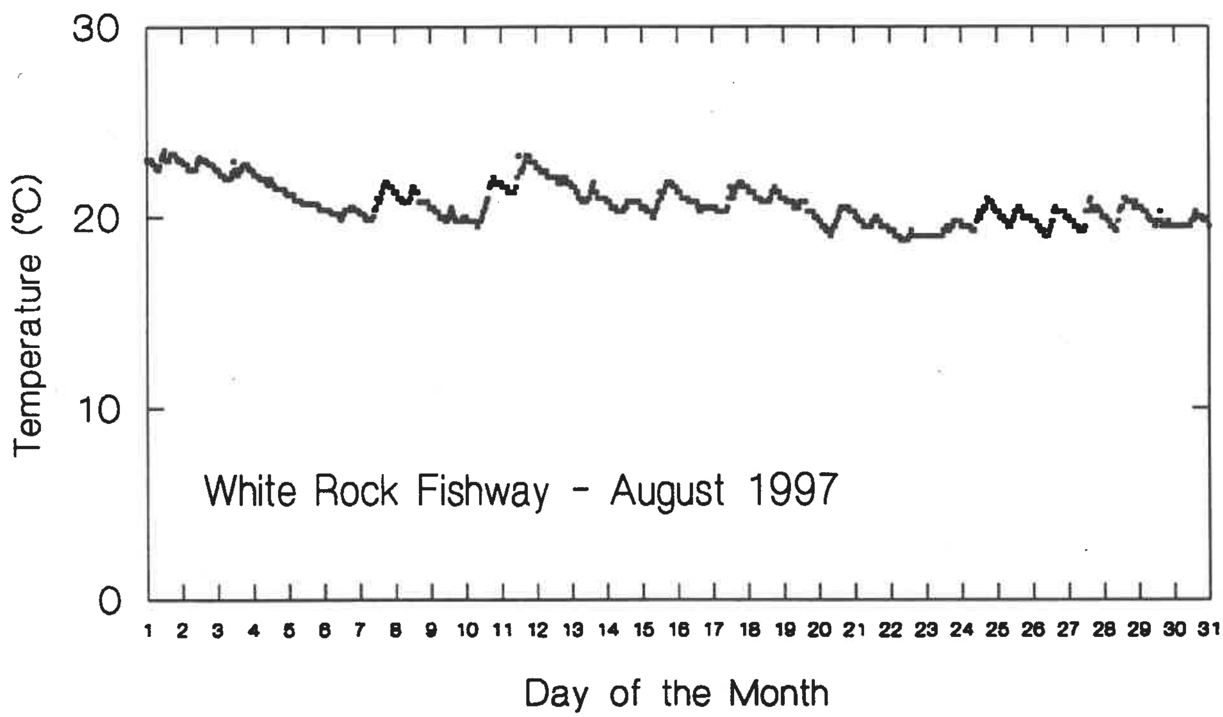
Appendix 1.3 (con't). Water temperatures recorded in the Gaspereau River 0.5 km upstream of Deep Hollow Bridge during August and September, 1997.



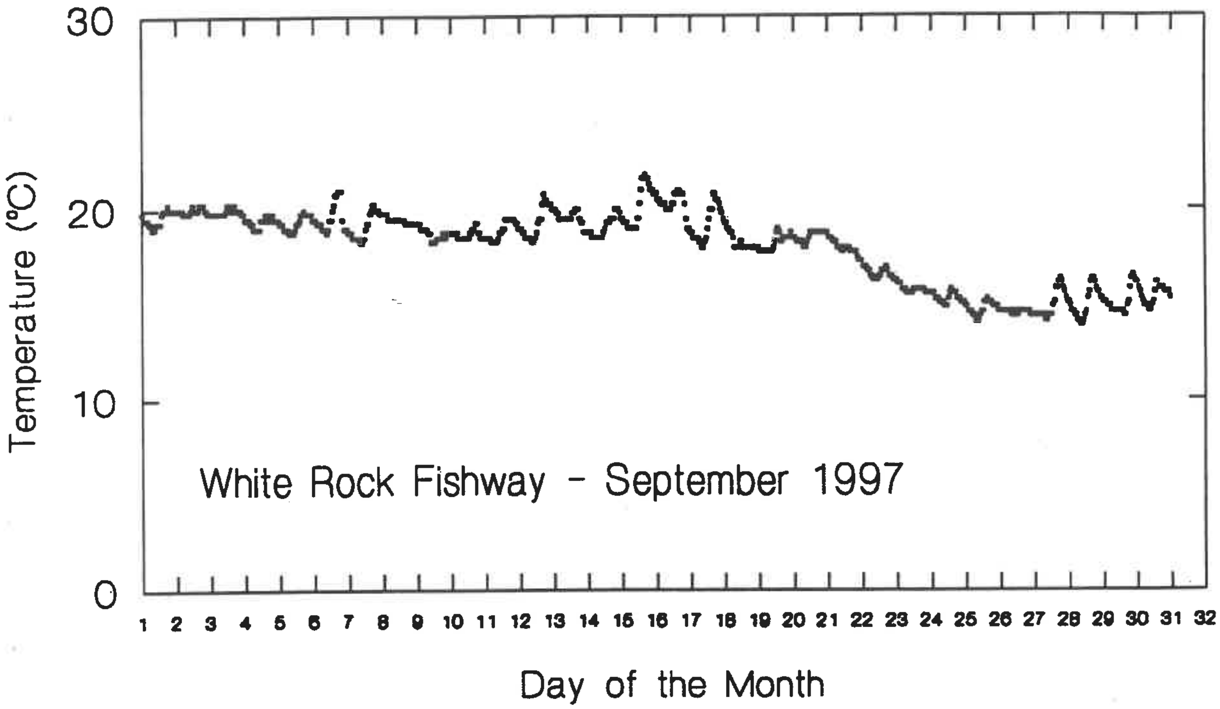


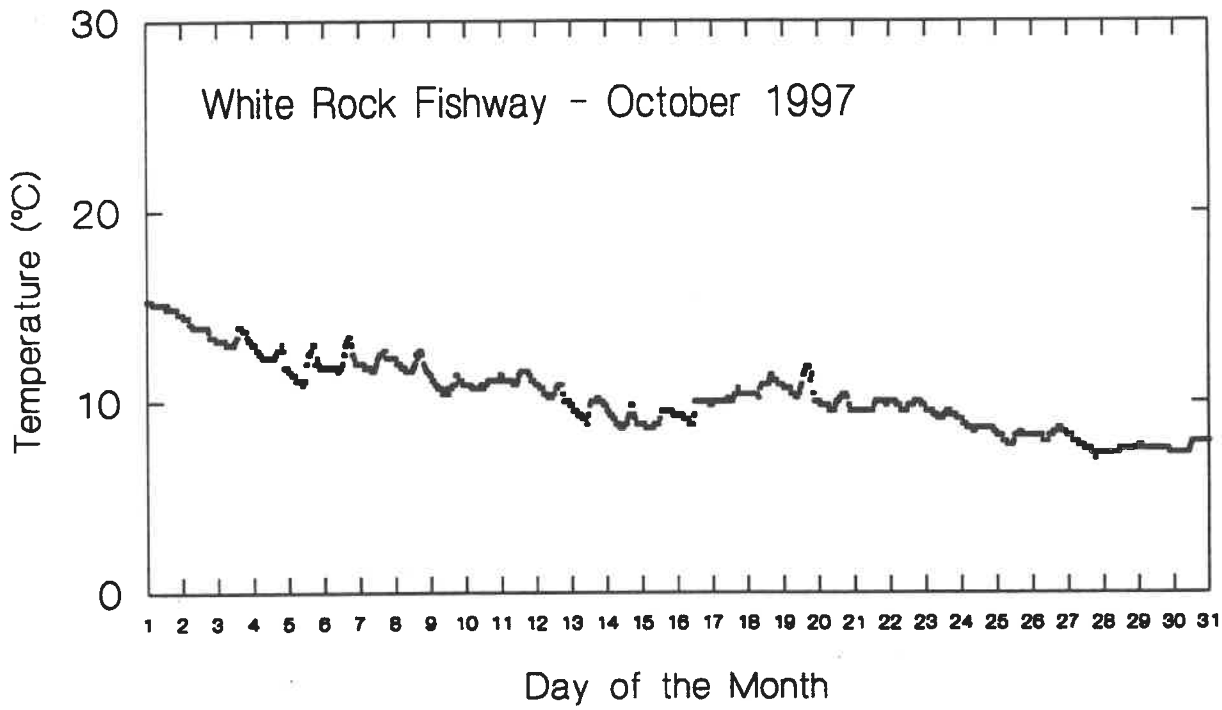
Appendix 1.4. Water temperatures recorded in the White Rock fishway during May and June, 1997.



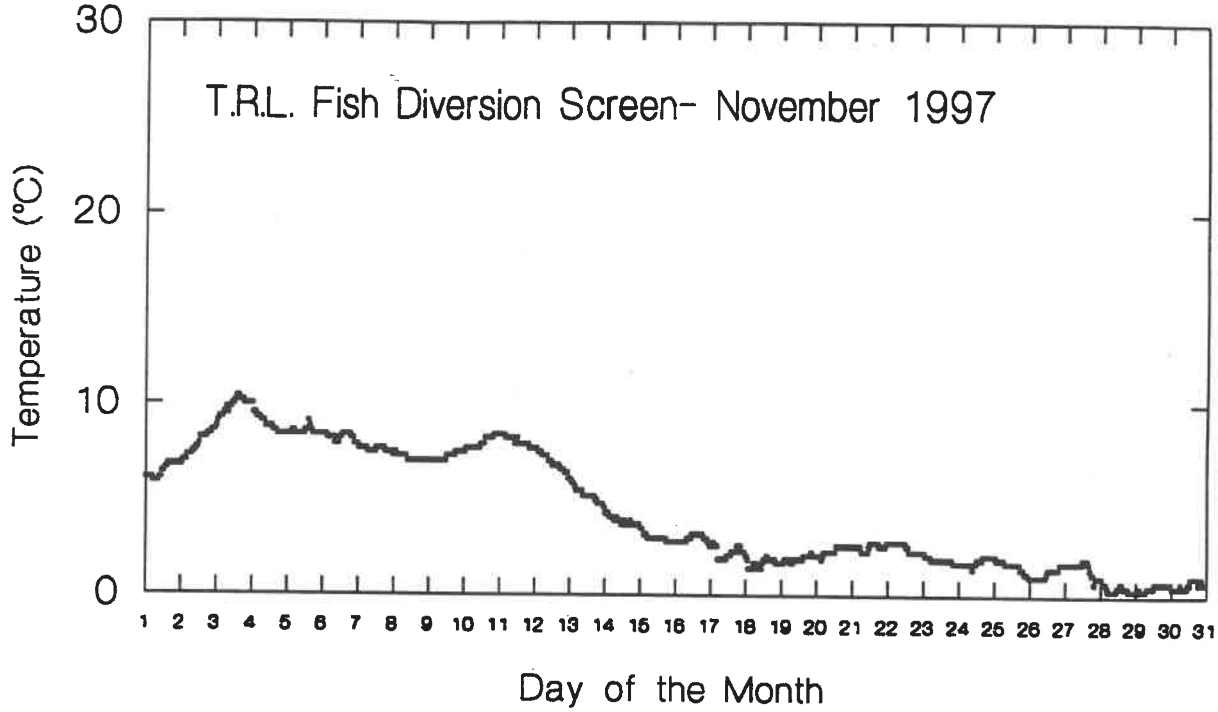


Appendix 1.4 (con't). Water temperatures recorded in the White Rock fishway during July and August, 1997.





Appendix 1.4 (con't). Water temperatures recorded in the White Rock fishway during September and October, 1997.



Appendix 1.5. Water temperatures recorded in Trout River Pond, near the fish diversion screen during November, 1997.