Characteristics of the Gaspereau River
Alewife Stock and Fishery - 1999.

Final Report
to
Nova Scotia Power Inc.

prepared by

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EXECUTIVE SUMMARY

The Gaspereau River – Black River watershed supports a stock of anadromous alewives (*Alosa pseudoharengus*) that is fished both commercially and recreationally as it ascends the river to spawn. Since 1964, this spawning run has averaged about 1.1 million fish. The catch in 1999 (4,772 pails) was two thirds of the 1964 – 1999 mean catch and 85% the median catch for the same time period.

A count of alewives ascending the White Rock fish ladder indicated that 81,326 fish ascended the ladder in 1999, the lowest of 6 counts since 1982. The size of the spawning run was estimated at c.771,000 fish. This estimate is biased low because fish that are not taken by the fishery and that do not ascend the ladder are not included in the estimate. During 1999, alewives were on average the smallest in any assessment of this stock to date. Only 2 year classes of females and 3 year classes of males were present in 1999 (non-impacted stocks may have up to 7 year classes). Because the river water level effects the efficiency (and legality) of fishing traps as well as the effectiveness of the White Rock fish ladder, collaboration between commercial fishers, DFO and NSPI prior to and during the fishing season is essential to reduce the impact on this stock.

Seaward migration of young-of-the-year alewives was monitored at the Trout River Pond diversion screen between August 17th and October 15th. Just under 1 million alewives were estimated to have moved seaward via the bypass stream during that time. Improvements to the entrance of the bypass stream in 1999 appear to substantially reduce the amount of time alewives spend upstream of the screens prior to moving into the bypass stream.

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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*) of local importance. The stock is fished both recreationally and commercially as it ascends the system to spawn during May and June, with an average value of $288,000 per year (range: $24,000 to $1,000,000) during the last 25 years.

Adults of this species spawn in fresh water in the spring, returning to the sea shortly thereafter. Spawning occurs in headwater lakes, stillwaters and back eddies, and eggs hatch after 3 to 8 days at Nova Scotia ambient temperatures. Young-of-the-year (YOY) remain in fresh water until mid-summer or fall, at which time they migrate to sea (Loesch 1987). Alewives then remain at sea until reaching sexual maturity after a period of 3 to 6 years. Alewives can live to over 10 years of age, and may spawn 5 or more times during their life. Over 100 rivers and streams in Nova Scotia support alewife stocks. While little information exists about the many of these populations, the majority are thought to be in decline. In a review of the status of Alosa stocks in eastern North America, Rulifson (1994), dams were identified as the primary factor responsible for this decline.

The Black River - Gaspereau River watershed has been extensively modified for hydroelectric generation during the last 80 years. Modifications include diversions of the Black River, Gaspereau River, Forks River, and numerous smaller brooks and streams, most of which were completed by the early 1950’s. Upgrades and minor changes to the system are ongoing. The system currently consists of over a dozen lakes interconnected by manmade canals and natural waterways (Figure 2). Five hydroelectric generating stations and numerous storage and diversion dams are present on the system. These structures affect fish migration and ecology within the watershed.

Nova Scotia Power Inc. (NSPI), in conjunction with government agencies, community groups and educational and research institutions, has been working towards reducing the impact of its activities upon local fish stocks. Fish ladders, diversion screens, spillways and control gates are some of the tools used by NSPI to limit their impact on these stocks. The operation of these facilities is fine-tuned, as the ecology of these stocks is better understood. Water management strategies, designed to optimize water availability for other users as well as hydroelectric generation, are currently being tested.

Within the watershed, adult alewives typically ascend the watershed 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 YOY then utilize these lakes as nursery areas prior to emigrating seaward during late summer and fall. YOY alewives tend to follow the dominant flow patterns when moving downstream. When the control gate at Forest Home is closed, YOY alewives move seaward via the outlet from Gaspereau Lake to the Gaspereau River at Lanes Mill. When the control gate is open, YOY alewives also move downstream via Trout River Pond, were a diversion screen, located near its outlet redirects the fish back to the Gaspereau River via Trout River. In this way, fish are able to

Figure 1. The location of the Gaspereau – Black River watershed in Nova Scotia.

Figure 2.

bypass 4 of the 5 generating stations in the watershed. As such, proper management of this control gate and the diversion screen are integral to the management of this species within the watershed. Currently, the control gate at Forest Home is closed when the adults enter Gaspereau Lake to spawn (c. early May), and re-opened after YOY are large enough that a diversion screen is effective (c. mid-August). The major storage reservoirs within this watershed are located upstream of the Forest Home control gate. The closure of this gate therefore places limits on water availability for hydroelectric generation or other uses during the closure. The timing and duration of this closure is therefore one of the key management issues within the watershed, affecting not only alewives, but all water resource users within the watershed.

In respect to alewives, the effectiveness of these strategies is evaluated through stock assessments (conducted intermittently throughout the last three decades), studies of YOY ecology in Gaspereau Lake, and by studying patterns of YOY outmigration at both Lanes Mill and at the diversion screen. Information about the performance of the fishery, life history data and stock size has been collected during stock assessments conducted by the federal Department of Fisheries and Oceans (DFO) between 1982 and 1984 (Jessop and Parker 1988), in 1995 by NSPI (unpublished data) and by the Acadia Centre for Estuarine Research, during 1997 and 1998 (Gibson and Daborn 1997, Gibson 1999). Biological data relating to this stock were also collected during an evaluation of the fish ladder at White Rock in 1970 (Dominy 1971). Gibson (1999) summarizes these assessments. During years when assessments were conducted, the spawning run has averaged c.537,000 fish (range: 165,000 to 1,082,000 fish). However, all assessments have been carried out in years when the catch was less than the 30 year median, and therefore lead to an underestimate of the stock size. The stock is comprised mainly of first time spawners, 4 or 5 years of age. Fishing mortality undoubtedly contributes to this truncated age frequency distribution, as estimates of the exploitation rate have ranged from 56.7 % in 1983 to 86.5 % in 1997.

Some information exists about juvenile alewives in this watershed. Jessop and Parker (1988) monitored the distribution of YOY within the watershed during 1983. Information about the timing of outmigration and the size of migrating YOY was collected as part of an assessment of the Trout River Pond diversion screen during 1996 (Gibson 1996). During the summer and fall of 1997 (Gibson and Daborn 1998) and 1998 (Gibson 1999), the ecology of young-of-the-year alewives in Gaspereau Lake was studied to collect data useful for the development of management strategies for these fish. YOY alewives appear to be present in all regions of Gaspereau Lake throughout the summer. Larvae were present until the end of July. During these studies, alewives were large enough for the Trout River Lake diversion screen to be effective by mid-August. YOY alewives within Gaspereau Lake feed predominantly on calanoid copepods and smaller cladocerans (Lent 1999). 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 limit alewife reproductive success in this watershed.

1.2 Objectives

This project was undertaken to provide further information about this stock, focusing on an assessment of the stock and fishery in 1999 and YOY outmigration at Trout River Pond. Information presented in this report includes:

1. An assessment of the alewife stock and fishery

    Information about the status of the stock in 1999, including stock size, fishery exploitation rates, morphological data (length and weight), timing of migration, and life history characteristics (age, growth rates, age at maturity, previous spawning history and mortality rates) were determined and are compared to data collected in previous years.

2. YOY outmigration at the Trout River Pond Fish Diversion Screen

    During 1999, the control gate at Forest Home was opened during mid-August. The timing of outmigration events and the size of fish at outmigration, are evaluated during this study.

2. METHODS

2.1 Alewife Count at White Rock (Total Count)

Data to assess the status of the alewife stock were collected as fish ascended the fish ladder bypassing the White Rock generating station. Alewives were counted as they passed through a v-notch, counting weir located near the top of the ladder. When attendants were not present and at night, the weir was closed to prevent fish passage, thus ensuring a total count.

Number of alewives per 15-minute interval was recorded for all intervals between 0800h and 2000h (0730h to 2030h during peak migration) during the majority of the run. During periods at the beginning and end of the run, when few fish were ascending the ladder, the length of the count interval was increased and the weir operated as a trap. The trap was checked several times daily to enumerate captured fish. This allowed researchers to focus on other aspects of this project while still meeting the objective of a total count.

Fork length, weight and sex were recorded for 10 fish more or less randomly selected from every 1000 alewives that ascended the ladder. Scale samples were collected from these fish and used to determine age and previous spawning history. The criteria of Cating (1953) and Judy (1961), for determining spawning marks and annuli on American shad scales, was used while processing these scales. These criteria are commonly used for alewives (Marcy 1969). Scales were cleaned with water, mounted on glass slides and projected on Bristol board with a projecting microscope prior to reading.

All fish sampled were externally examined to confirm that they were in fact alewives and not blueback herring (*Alosa aestivalis*). The catch at Millett's net site was also monitored for the presence of blueback herring, using peritoneum color as the primary distinguishing characteristic between the species.

Water temperature, water levels above and below the White Rock dam, and weather observations were recorded four times daily throughout the spawning run. Water temperature was also monitored using a temperature data logger (Vemco Minilog-T) located in the river c.3 km downstream of the dam.

2.2 Statistical Analysis of Fishery and Life History Characteristics

Mean length, maximum observed length, mean age, maximum observed age, mean age at maturity, sex ratios, percent repeat spawners, Von Bertalanffy's growth coefficient and theoretical maximum length (asymptotic length), and instantaneous mortality were calculated for males and females in order to describe the stock.

Population growth rates, expressed as Von Bertalanffy's growth coefficient and theoretical maximum length, were estimated by iteratively seeking a least squares solution to the Von Bertalanffy growth equation (Ricker 1975):

$$l_t = L_\infty(1 - e^{-K(t - t_o)})$$

where:

l_t = length at age t L_∞ = theoretical maximum length
K = growth coefficient t_o = theoretical age when length = 0.

Data used for fitting this model were a composite of two sets. Length-at-age for ages 1 to 3 years was estimated by back calculating from the distances between annuli measured on a set of scales from 50 males and 50 females (randomly chosen from those aged). Because scale erosion or re-absorption occurs when alewives spawn, use of this method for older age classes would lead to erroneous estimates. Therefore, length-at-age for the older age classes was estimated from the length of the fish in each age class. This information was not available for the younger age classes since alewives do not typically return to spawn until they are about 4 years old, necessitating the above back-calculations.

Instantaneous mortality (Z) was estimated as the slope of the line:

$$\ln N_t = \ln N_0 - Z(t)$$

where:

N_t = size of the age class at age t
N_0 = theoretical size of the age 0 class
t = age in years
and
Z = instantaneous rate of mortality

Prior to fitting this line, the sizes of the age 4, 5 and 6 classes were adjusted by the percent mature in each age class to account for immature fish not represented in the spawning run. Age 3 fish were not included in the analysis. This approach to estimating mortality requires the assumption that recruitment is constant each year, or that enough year classes are present in the data set that variability in recruitment averages out. Both assumptions are violated in this instance.

Fishery exploitation rates were calculated using catch statistics (number of pails caught) provided by DFO, as an estimate of the size of the catch and the sum of the catch and the White Rock count as an estimate of the stock size. Any fish that escape the fishery and do not ascend the ladder are unaccounted for in this study, resulting in an underestimation of stock size and an overestimation of the exploitation rate.

2.3 YOY Outmigration at the Trout River Pond Fish Diversion Screen

Outmigration 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. The net was deployed at the downstream end of a culvert and captured all fish moving through the culvert when in place. Sampling frequency and duration varied depending on the rate at which fish were migrating. Typically the net was deployed once every 5 minutes (10 to 60 seconds per deployment) when sampling.

To obtain an estimate of the number of YOY alewives leaving Gaspereau Lake via Trout River Pond, the number of alewives captured during a deployment was converted to a rate of outmigration (number/hr.). At this location (Lanes Mill is different), alewives apparently move seaward during the day. Estimates of the number of outmigrants in a given time period are calculated as the mean rate of outmigration for the time period, multiplied by 12 hours multiplied by the number of days in the time period. The variance of the estimate is calculated similarly, and confidence intervals under the assumption of approximate normality. The resulting confidence intervals are small due to the large number of samples, and therefore create a false sense of reliability in the estimate.

Water temperature at Lanes Mill was monitored using a temperature data logger (Vemco Minilog-T), deployed in the fishway throughout the summer, set to record hourly. Temperature loggers were also deployed in the Gaspereau River, about 0.5 km upstream of White Rock, and just downstream of the bridge in Gaspereau to provide a more complete record of water temperature in the river.

3. RESULTS

3.1 Alewife Count at White Rock (Total Count)

During 1999, alewives were first observed at Millett's net site on the Gaspereau River on April 13th. The fish ladder was watered up on this date. The counting weir in the ladder was closed April 25th, and checked 3 to 4 times daily through May 6th. The first alewife was captured in the ladder on that May 5th. Continuous monitoring of the weir began on May 7th (694 fish). The count peaked on May 10th, when 6,288 alewives ascended the ladder (Figure 3). A second peak (5996 alewives) occurred May 24th. Monitoring continued until June 18th, at which time only 4 alewives had ascended the ladder in 3 days. In total, 81,326 alewives were counted while ascending the White Rock fish ladder. Ninety-five percent of the run ascended the ladder between May 9th and June 3rd.

3.2 Blueback Herring

Species identity was checked on all fish sampled at the White Rock ladder (external examination only). As was the case in 1998, all fish were identified as alewives, although a few blueback herring were observed in the catch at Millett's net site near the end of the fishing season.

3.3 Stock Characteristics

3.3.1 Fork length

Fork lengths were measured on samples of 397 male and 425 female alewives collected throughout the run. Males averaged 243.6 mm in length, and females 252.3 mm (Table 1). Length frequency distributions are shown in Figure 4.

Table 1. Fork length summary statistics for the 1999 Gaspereau River alewife spawning run.

Statistic:	Males	Females
n	397	425
Mean (mm)	243.6	252.3
Standard Deviation	10.4	11.2
Minimum (mm)	210.0	224.0
Maximum (mm)	278.0	286.0

Figure 3

Figure 4. Fork Length frequency distributions estimated for male (top) and female (bottom) alewives in the 1999 Gaspereau River spawning run.

3.3.2 Sex ratio

As estimated by the sex ratio of the fish sampled, males were less abundant than females by a ratio of 0.93:1 during 1999.

3.3.3 Age and maturity

Ages ranged from 3 to 6 years for males, and from 4 to 5 years for females (Figure 5). These distributions are based on ages determined for 242 female and 257 male fish. Summaries of the age-frequency distributions are presented in Table 2.

Age at first maturity ranged from 3 to 5 years for both males and females (Figure 6). Mean age at first maturity was 4.18 years (s.d. = 0.46) for males and 4.30 years (s.d. = 0.49) for females. Repeat spawners comprised 11.5% of female, and 15.1% of male alewives sampled.

Table 2. Age summary statistics for the 1999 Gaspereau River alewife spawning run.

Statistic:	Males	Females
n	257	242
Mean (yr)	4.36	4.42
Standard Deviation	0.54	0.49
Minimum (yr)	3	4
Maximum (yr)	6	5

3.3.4 Weight

The weights of 819 alewives were measured to the nearest two grams during the spawning run. Males averaged 194.2g and females 221.8g (Table 3). Weight-length relationships were developed from these data and are shown in Figure 7.

Table 3. Weight summary statistics for the 1999 Gaspereau River alewife spawning run.

Statistic:	Males	Females
n	395	424
Mean (g)	194.2	221.8
Standard Deviation	27.6	32.1
Minimum (g)	116.0	138.0
Maximum (g)	274.0	324.0

Figure 5. Age frequency distributions estimated for male (A) and female (B) alewives in the 1999 Gaspereau River spawning run.

Figure 6. Frequency distributions sowing age at firs spawning for male (A) and female (B) alewives in the 1999 Gasperau River spawning run.

Figure 7. Weight – length relationships for male (A) and female (B) alewives in the 1999 Gaspereau River spawning run.

3.3.5 Growth

Von Bertalanffy growth curves (Figure 8) were derived from male and female length-at-age data collected during this assessment for ages 4 to 6 years, combined with back-calculated length-at-age for ages 1 to 3 years (see methods). The theoretical maximum length for the males was estimated as 305.4mm and for the females as 312.8mm. Growth coefficients were estimated as 0.33 and 0.34 for the males and females respectively.

3.3.6 Mortality

Instantaneous mortality rates, based on the age structure of the 1999 spawning run, were estimated as 2.76 for male and 2.74 for female alewives (Figure 9). These estimates correspond to annual mortality rates of 82.8% for males and 76.0% for females.

3.4 The Fishery: Catch Statistics - 1999

Fishers on the Gaspereau River caught 4772 pails of alewives (Hank Sweeney, DFO, pers. comm.) in 1999. Counts of the number of fish in a pail (22.7 kg) in 1998 averaged 133 alewives (sd = 8.09, n = 6). Based on these counts, and correcting for the difference in the mean weight of fish between 1999 (208.5g) and 1998 (226.5g), fishers caught 689,600 alewife in the Gaspereau River in 1999. Stock size in 1999, estimated as the sum of the catch and the White Rock count, was 770,926 fish. This estimate is based on the assumption that all alewives not captured take the ladder, an invalid assumption. The exploitation rate in 1999, also based on this assumption, is therefore estimated at 89.4%.

Figure 8. Von Bertalanffy growth curves overlaid against fork length-at-age data for male (A) and female (B) alewives sampled from the 1999 Gaspereau River spawning run.

Figure 9. Instantaneous mortality rates estimated for male (A) and female (B) alewives in the 1999 Gaspereau River spawning run.

3.5 Comparisons with Other Years

3.5.1 Life history characteristics

Life history characteristics of the Gaspereau River alewife stock for 7 years during the 1980's and 1990's are summarized in Table 4. Alewives in 1999 were on average the smallest encountered in any of these assessments, and 1999 is the first year that only 2 year classes of a given sex were represented in the assessment. Repeat spawners were less abundant than in any assessment in the 1990's, and the instantaneous mortality rates the highest estimated in any assessment on the Gaspereau River.

Table 4. A comparison of 1999 Gaspereau River alewife stock characteristics with those determined in other years.

Statistic	Year	Males	Females
Mean Fork Length (mm) ± standard deviation	1999	243.6 ± 10.4	252.3 ± 11.2
	1998	247.6 ± 14.7	257.0 ± 16.1
	1997	255.5 ± 10.5	265.0 ± 14.1
	1995	257 ± 12.8 (sexes combined)	
	1984	263.0 ± 12.0*	272.8 ± 11.7*
	1983	252.9 ± 15.0*	268.5 ± 17.8*
	1982	268.7 ± 10.6*	279.4 ± 11.6*
Maximum Fork Length (mm)	1999	278	286
	1998	299	302
	1997	287	315
	1995		
	1984		
	1983		
	1982		
Mean Weight (g) ± standard deviation	1999	194.2 ± 27.6	221.8 ± 32.1
	1998	212.3 ± 42.5	244.6 ± 50.8
	1997	221.4 ± 29.8	253.7 ± 40.3
	1995	367 ± 309 (sexes combined)	
	1984	254.2 ± 38.9*	288.0 ± 44.8*
	1983	232.4 ± 48.6*	290.4 ± 67.4*
	1982	272.1 ± 34.5*	315.7 ± 48.5*

* standard deviations calculated from Jessop and Parker (1988)
[a] calculated from Jessop and Parker (1988)

Table 4 (con't). A comparison of 1999 Gaspereau River alewife stock characteristics with those determined in other years.

Statistic	Year	Males	Females
Mean Age (yr) ± standard deviation	1999	4.36 ± 0.54	4.42 ± 0.49
	1998	4.36 ± 0.60	4.41 ± 0.58
	1997	4.29 ± 0.59	4.50 ± 0.76
	1995	4.79 ± 0.56 (sexes combined)	
	1984	4.8 ± 0.52*	5.0 ± 0.46*
	1983	4.5 ± 0.69*	4.9 ± 0.83*
	1982	5.0 ± 0.49*	5.1 ± 0.49*
Maximum Age (yr)	1999	6	5
	1998	7	6
	1997	6	7
	1995		
	1984	7	7
	1983	7	7
	1982	7	7
Mean Age at First Spawning (yr) ± standard deviation	1999	4.18 ± 0.45	4.29 ± 0.48
	1998	4.10 ± 0.39	4.19 ± 0.42
	1997	4.11 ± 0.39	4.18 ± 0.42
	1995	4.6 ± 0.55 (sexes combined)	
	1984	4.63[a]	4.82[a]
	1983	4.36[a]	4.61[a]
	1982	4.89[a]	4.89[a]

* standard deviations calculated from Jessop and Parker (1988)
[a] calculated from Jessop and Parker (1988)

Table 4 (con't). A comparison of 1999 Gaspereau River alewife stock characteristics with those determined in other years.

Statistic	Year	Males	Females
Repeat Spawners (%)	1999	15.2	11.5
	1998	32.7	23.5
	1997	15.1	24.8
	1995	16.9 (sexes combined)	
	1984	15.4	11.5
	1983	12.1	22.0
	1982	8.2	12.2
Instantaneous Mortality Rate (Z)	1999	2.76	2.74
	1998	1.76	1.43
	1997	1.39	1.21
	1995	1.75	
	1984	2.66	
	1983	0.91	
	1982	0.63	
Exploitation Rate (%)	1999	89.4*	
	1998	68.5	
	1997	86.5	
	1995	< 88.3 (see text)	
	1984	69.9*	
	1983	56.7*	
	1982	80.9*	

* values calculated from catch statistics adjusted by weight (see text)

3.5.2 The fishery

The 1999 alewife catch on the Gaspereau River (4,772 pails) was two thirds of the 1964 – 1999 mean catch and 85% the median catch for the same time period (Table 5). The catch during this time period is shown in Figure 10.

Figure 10

Table 5. Summary of Gaspereau River alewife catches between 1964 and 1999:

Statistic	Catch (pails)
Mean	7,147
Minimum	1,099
Maximum	20,744
Median	5,600
1999 catch	**4,772**

Of the years for which data are available, spawning escapement in 1999 was the lowest since 1982 (Table 6), even though the estimated stock size was the second largest of the years when counts were conducted. In 1999, 71.6% of the stock was 4 years of age. Recruitment of the 1995 year class into the 1999 fishery was therefore c.552,000 fish. For comparison, recruitment of the 1994 year class into the fishery in 1998 was c.359,000 fish, and c.484,000 age 4 fish were present in the 1997 fishery.

Table 7. Summary of alewife counts at the White Rock fish ladder, estimated stock size, and the annual catch and exploitation rates of the alewife fishery.

Year	Alewife Count	Catch (number of fish)	Stock Size	Exploitation Rate (%)
1999	**81,326**	**698,600****	**770,926**	**89.4**
1998	171,639	372,400***	544,039	68.5
1997	95,433	611,520*	706,953	86.5
1995	126,933 (part.)	954,960*	>1,081,893	<88.3
1984	111,100	212,966**	324,066	69.9
1983	114,800	150,408**	265,208	56.7
1982	50,400	254,068**	304,468	80.9
1970	60,527	480,000*	540,527	88.9

* assumes 120 alewives/pail
** number of alewives/pail adjusted by mean weight/alewife
*** assumes 133 alewives/pail

3.6 Timing of the Run in Relation to Environmental Variables.

Water temperature and tailrace water level during the count period, overlaid against the count, are shown in Figure 11. As in other years, the start of the count coincided with a sharp rise in water temperature. Water levels at the start of the count period were lower than in other years, but remained more or less constant throughout the fishing season.

Figure 11

3.7 YOY Alewife Outmigration at Trout River Pond

3.7.1 Timing of outmigration

During 1999, the YOY alewife outmigration was monitored between Aug. 17th, (when the bypass stream was first opened, and Oct.15th. Monitoring was conducted daily until Sept. 1st, conducted every second day until Sept. 15th, and then every third day until Oct. 15th. Nets were deployed a total of 4,296 times during 276.5 hours of monitoring, resulting in the capture and release of 41,259 YOY alewives.

Alewives moved into Trout River Pond immediately after the Forest Home gate was opened on Aug. 16th. Very large numbers of alewives had accumulated in front of the diversion screens by Aug. 17th, when the bypass stream was opened, and c.350,000 (95% C.I.: ± 2,400 fish) were estimated to have moved downstream within a few hours of its opening at 1445h. By 2000h, most fish that had accumulated in front of the screens had moved downstream. No alewives were captured moving downstream on Aug.18th or 19th, perhaps as a result of reduced flows due to the Methals generating station being closed. Alewives moved seaward at a rate of 1,000 to 26,000 per day throughout the remainder of August (Figure 12). The rate of downstream migration varied throughout the remainder of the study, peaking on Sept. 17th, at an estimated 142,247 YOY moving downstream (95% C.I.: ± 241 fish). While sampling was not carried out between midnight and 0600h, juvenile alewives were typically not present in the bypass stream until mid-morning, and catches tapered off each day about an hour before dusk (Figure 13). Most fish are therefore thought to have moved downstream during the daily count period. Based on the assumption that outmigration occurs during a 12 hour period each day, c.980,000 YOY are estimated to have moved downstream from Gaspereau Lake via Trout River Pond during 1999 (Table 7).

A few small schools of adults (c. 20 to 100/school) were observed moving downstream via the bypass channel throughout the monitoring period.

Table 7. Estimates of the numbers of YOY alewives to have emigrated from Gaspereau Lake via Trout River Pond during the study period. during 1999.

Time period	Number of deployments	Mean number/hr	Estimate of the total for the time period	Total 95% C.I. lower limit	Total 95% C.I. upper limit
Aug. 17th	51	61,797	350,181	348,383	351,978
Aug. 18th-31st	1914	458	77,040	76,225	77,854
Sept. 1st – 30th	1986	1,264	455,131	453,497	456,766
Oct. 1st – 15th	345	2	322	317	327

Figure 12.

Figure 13. Catch plotted against sampling time while monitoring YOY alewife outmigration at Trout River Pond in 1999.

3.7.2 Size of migrating juveniles

Fork lengths were measured on 1,989 YOY alewives captured at Trout River Pond throughout this study (Figure 14). During the week of Aug. 16th, alewives averaged 72.4mm in length (range: 51.2mm to 89.8mm). Captured alewives were slightly larger at the end of the study, averaging 83.3mm during the week of Oct. 9th (range: 63.0 to 92.0mm).

3.9 Temperature Data

Temperature data loggers were deployed in the outlet of Gaspereau Lake at Lanes Mill, just upstream of the Deep Hollow Bridge in White Rock and at Terry Millett's square net site (downstream of the bridge in Gaspereau Temperature loggers were set to record the temperature hourly.

In total, 14,774 temperature observations were recorded by these loggers. Time series (hourly temperature) for each location are presented in Appendix I. Table 8 contains a summary of the temperature readings by month. As was the case in 1997 and 1998, water temperatures at Lanes Mill showed considerable variability on a daily basis. Water temperatures at Lanes Mill warmed rapidly during the early summer, reaching a maximum of 29.1 °C on July 18th. Temperatures regularly fluctuated 4 to 5 °C daily at this time, presumably in response to changes in air temperature and solar radiation. Daily temperature fluctuations at Deep Hollow Bridge were even greater: up to 10 °C daily during June and July. The maximum temperature recorded at this station was 29.1°C, on both June 30th and July 18th. Water temperature in the Gaspereau River downstream of the bridge in Gaspereau also fluctuated by up to 10°C daily, the degree of fluctuation presumably being in part a function of flow in the river. The maximum water temperature recorded at this station was 28.6°C.

Figure 14. Fork length frequency distributions of outmigrating YOY alewives captured at Trout River Pond during 1999.

Table 8. Monthly temperature summary statistics for 3 locations in the Gaspereau River watershed during 1999: the outlet of Gaspereau Lake at Lanes Mill, the Gaspereau River 0.5 km upstream of Deep Hollow Bridge in White Rock and the Gaspereau River 0.5 km downstream of the bridge in Gaspereau.

		Location		
Month	Statistic	Lanes Mills	Deep Hollow Bridge	Gaspereau Bridge
May	mean	17.4	14.3	13.7
	s.d.	2.3	3.4	2.6
	min.	11.7	4.4	7.0
	max.	23.3	23.7	18.8
June	mean	21.9	19.4	20.1
	s.d.	2.1	3.4	1.6
	min.	16.9	12.6	16.5
	max.	27.0	29.1	24.3
July	mean	23.6	21.6	22.6
	s.d.	2.2	3.0	2.1
	min.	17.7	14.9	18.0
	max.	29.1	29.1	28.9
August	mean	21.9	19.8	21.4
	s.d.	2.1	2.5	1.9
	min.	16.4	14.2	17.5
	max.	27.3	27.3	28.6
September	mean	20.5	17.9	20.5
	s.d.	3.1	3.4	2.1
	min.	14.3	11.2	16.3
	max.	26.7	25.4	24.0
October	mean	10.2	9.0	11.9
	s.d.	3.0	2.3	2.7
	min.	6.0	4.4	7.7
	max.	18.7	15.7	18.1

4. DISCUSSION

While the estimated stock size in 1999 (770,926 fish) was the highest of the 7 years for which complete counts are available, the number of fish that ascended the ladder at White Rock was the third lowest in this data set.

Many of the parameters reported during these assessments are based on the assumption that all alewives not captured by the fishery ascend the ladder at White Rock (e.g. stock size, exploitation rate, etc.). This is not a valid assumption, leading to an underestimation of the stock size and an overestimation of the exploitation rate. A simple model that relates the number of spawners to the number of fish that enter the river is:

$$N_{spawn} = N_{total} - N_{fished} - N_{don't}$$

where: N_{spawn} = the number of fish that ascend the White Rock fish ladder
N_{total} = the total number of fish that enter the river
N_{fished} = the number of fish captured by fishers
$N_{don't}$ = the number of fish that don't ascend the ladder

The quantity $N_{don't}$ in this model is unknown, and may significantly bias the estimates of stock size and the exploitation rate. While some uncertainty exists about these parameters, given that the bias leads to an underestimation of stock size, the (biased) exploitation rate estimate of 89.4% during 1999 suggests that no more than 10.6% of the fish that began the spawning succeeded in reaching the top of the White Rock ladder. Depending on the efficiency of the ladder, this percentage may be much lower.

Fish stocks can be managed to meet one of two objectives: to ensure a minimum number of spawners are available each year, or that a minimum portion of the population is available to spawn each year. In the case of the Gaspereau River alewife stock, the biological limits are not known, although they have been calculated for other stocks. Crecco and Gibson (1990) report annual fishing mortality rates at the maximum sustainable yield (u_{msy}) and at stock collapse (u_{coll}) for four North American alewife stocks. The means of these parameter estimates are 64.5% and 77.0% respectively (some of these stocks have been subjected to sustained higher fishing mortality without actually collapsing). These data suggest that an alewife stock is at risk if the proportion of the stock that is available to spawn is less than 23%. Our estimates of exploitation exceed these estimates of u_{msy} in 7 of the 8 years for which data is available, and u_{coll} in 4 of the 8 years. While our estimates are biased high, the cumulative effect of the ladder and the fishery is to reduce the proportion of the population available to spawn even further than is suggested by the exploitation rate.

From a conservation perspective, water management in the Gaspereau River and management of the alewife fishery cannot be uncoupled. In 1999, NSPI, correctly anticipating a dry summer, lowered water levels in the Gaspereau River at the beginning of May, rather than late May, to conserve water for Atlantic salmon. At the lower water levels, less cross-sectional area of the river is available for fish to avoid the fishers' nets, thus increasing the efficiency of their gear. It follows that consultation between the fishers and NSPI, well prior to the start of the fishing season is necessary to ensure that trap sites are appropriately designed for an anticipated water level (and aren't in violation of DFO regulations). Alternatively, water could be managed to reduce the efficiency of the traps, although given water requirements for other species and users, this alternative is probably not feasible.

River level also affects the efficiency of the ladder by changing the hydrodynamics in the vicinity of the entrance. Adjustments to the ladder should therefore be made when the river level is similar to that when fish are present. Observations in 1999 suggest that fish approaching the ladder along the north bank enter the flow from the ladder entrance at an angle of 90 degrees to the flow. These fish would be pushed into the main flow from the turbine by the discharge from the ladder, and would then orient on the flow from the turbine, rather than the ladder. Minor modifications to the entrance to the ladder (at appropriate flows) could substantially improve its efficiency.

The percentages of repeat spawners during this study (11.5% for males and 15.2% for females) are some of the lowest estimated this stock. Only two year classes of females were present. This is somewhat surprising given the lower exploitation rate in 1998. During the monitoring of YOY outmigration during 1998, adults were seen approaching the ladder at Lanes Mill, but seemed unwilling to move downstream (Gibson 1999). Many were still present in Gaspereau Lake when the Forest Home gate was opened in late September. It is not known what effect this had on the survival of post-spawning fish, however the effect of water level in Gaspereau Lake and the configuration of the upstream entrance to the ladder may have a marked effect on the willingness of fish to move downstream. Counts were not conducted at Lanes Mills in 1999, so it is not known whether conditions were similar this year, however fewer adults moved downstream when the Forest Home gate was opened during mid August during 1999.

The size of the 1999 spawning run is of interest in that it coincides with the first spawning of the 1995 year class. During 1995, both Lumsdens Pond and the White Rock canal were drained during the summer for repairs to dams, resulting in a fish kill at Lumsdens Pond, and impeded YOY outmigration during that year. Recruitment of the 1995 year class into the 1999 spawning run was c.552,000 fish, higher than recruitment of the 1994 year class into the spawning run in 1998 (c.359,000 fish) and the 1993 year class into the 1997 spawning run (c.484,000). While the extent of the impact of the system upgrades isn't really known, it didn't reduce the year class size to a level below that of the last two years.

The number of YOY alewives estimated to have emigrated from Gaspereau Lake via Trout River Pond (980,000 fish) is the lower than anticipated. The estimate is similar in size to the estimate of the number of fish moving downstream in 1998 (1.1 million fish) when the gate was opened in late September. The expectation was that more fish would move downstream via this passage if the opportunity was available earlier in the year. Because of the large number of samples, the confidence interval about the estimate is small, creating the false sense of reliability in the estimate. Given the sporadic pattern of outmigration, it is possible that large schools were missed on days that were not sampled. Additionally, without counts of adults entering Gaspereau Lake in 1999, the number of spawners is not known. While these counts were not carried out, the large schools of adult alewives that were present in the upper Gaspereau River 1997 and 1998 were not observed during 1999, suggesting that fewer fish completed the run as far as Gaspereau Lake. Comparisons of the YOY counts are not really appropriate without some index of abundance in Gaspereau Lake (either number of spawners or a larval abundance index), so it is not known whether a larger portion of the YOY outmigrants used this route in 1999.

Based on observations from 1996 to 1999, the modifications made to the entrance of the diversion stream in 1999 substantially reduced the amount of time YOY spend in front of the screens. Fish that are schooling in back and forth in front of the screen are led directly to the diversion stream and as such move downstream more rapidly. These improvements reduce the potential for YOY impingement on the screens.

The closure of the gate at Forest Home to impede YOY alewife outmigration is one of the major limiting factors for water management in this watershed. The gate is typically kept closed until such time as the YOY are large enough that the diversion screen is effective. Based a YOY fork length – body depth relationship (Gibson 1996) and the size frequency distributions in this report, all alewives moving downstream after the gate was opened on Aug. 16th were large enough that a ¼ inch round hole mesh would be too small for fish to pass through them.

In summary, the Gaspereau – Black River alewife stock continues to show characteristics of a heavily impacted stock. Both the fishery and water management affect these fish, and communication and collaboration between the fishers and water managers is necessary to reduce the impacts. A consensus on river level during the fishing season and minor modifications to the entrance of the fish ladder at White Rock are two things that could reduce impacts. Consideration should be given to running water through the control gate at Lanes Mill during the summer, if post-spawning adult alewives move downstream more readily via that location. Determination of the biological limits of impacts requires long time series for the modeling of population dynamics. The stock assessments at White Rock provide the kind of data required to determine these limits, but need to be continued for several years. Given that the stock is impacted by both the fishery and hydroelectric generation, the responsibility to gather this information could be shared. The relative impact of these two groups cannot be separated without some measure of the efficiency of the ladder at White Rock. If this ladder is to play a continued role in the management of this stock, its efficiency should be measured, since the sources of impacts need to be identified for appropriate management decisions to be made.

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APPENDIX I. WATER TEMPERATURES RECORDED AT THREE LOCATIONS IN THE GASPEREAU RIVER DURING THE SUMMER AND FALL OF 1999.

Appendix Ia. Water temperatures recorded at the outlet at Lanes Mill during May, 1999.

Appendix Ia (con't). Water temperatures recorded at the outlet at Lanes Mill during June and July, 1999.

Appendix Ia (con't). Water temperatures recorded at the outlet at Lanes Mill during August and September, 1999.

Appendix Ia (con't). Water temperatures recorded at the outlet at Lanes Mill during October and November, 1999.

Appendix Ib. Water temperatures recorded in the Gaspereau River 0.5 km upstream of Deep Hollow Bridge during April and May, 1999.

Appendix Ib (con't). Water temperatures recorded in the Gaspereau River 0.5 km upstream of Deep Hollow Bridge during June and July, 1999.

Appendix Ib (con’t). Water temperatures recorded in the Gaspereau River 0.5 km upstream of Deep Hollow Bridge during August and September, 1999.

Appendix Ib (con't). Water temperatures recorded in the Gaspereau River 0.5 km upstream of Deep Hollow Bridge during October, 1999.

Appendix Ic. Water temperatures recorded in the Gaspereau River, 0.5 km downstream of the bridge in Gaspereau, during April and May, 1999.

Appendix Ic (con't). Water temperatures recorded in the Gaspereau River, 0.5 km downstream of the bridge in Gaspereau, during June and July, 1999.

Appendix Ic (con't). Water temperatures recorded in the Gaspereau River, 0.5 km downstream of the bridge in Gaspereau, during August and September, 1999.

Appendix Ic (con't). Water temperatures recorded in the Gaspereau River, 0.5 km downstream of the bridge in Gaspereau, during October and November, 1999.