The Gaspereau River
Alewife Stock and Fishery 2000:
Data Summary.

Final Report
to
Nova Scotia Power Inc.

prepared by

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EXECUTIVE SUMMARY

During the spring and summer of 2000, Nova Scotia Power Inc. and the Acadia Centre for Estuarine Research collected data about the Gaspereau River alewife stock. The spawning run was estimated to contain just over 850,000 fish. Of these just over 750,000 (88%) were taken by the fishery.

A count of alewives ascending the White Rock fish ladder indicated that 98,883 fish ascended the ladder in 2000. The stock continues to exhibit the characteristics of a heavliy impacted stock. Most the fish (94.5%) belonged to the 1995 and 1996 year classes, and less than 10% of the run were repeat spawners. Alewives in 2000 averaged slightly older and larger than during the 1997 or 1998, largely due to strong recruitment of age 5 fish (1995 year class) into the spawning run in 2000.

During 2000, the control gate at Forest Home was opened on August 16th, presenting young-of-the-year (YOY) alewives with the opportunity to migrate seaward via this route. YOY alewife emigration at Forest Home began on September 6th. Just over 116,000 alewives moved down the bypass stream on September 6th and 7th (Table 5). These fish ranged between in size between 42mm and 97mm in length, and averaged 57.5mm (s.d.=10.6), about 15 to 20 mm smaller than YOY alewives captured in September at this location during 1997 to 1999.

ACKNOWLEDGMENTS

Data for the adult stock assessment were collected by Alex Levy and Steve Murray. Steve Murray assisted with the aging. Data about the juvenile outmigration were collected by Michael Allen and **XXX**. Terry Toner and Ken Meade served as scientific contacts with NSPI. Hank Sweeney (Fisheries and Oceans Canada) provided Gaspereau River alewife catch statistics both for 2000 and for previous years.

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1. INTRODUCTION

The Gaspereau - Black River watershed in Nova Scotia supports a stock of anadromous alewives of local economic and ecological importance (Gibson 2000). Beginning in 1995, Nova Scotia Power Inc. (NSPI), in collaboration with the Acadia Centre for Estuarine Research, has been monitoring the status of this stock to collect baseline data for the development and evaluation of water management strategies currently being implemented within the watershed.

This report contains a summary of data collected about the stock during the year 2000. Information presented in this report includes:

1. An assessment of the alewife stock and fishery:

    The status of the stock in 2000, 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).

2. A summary of stock and fishery characteristics from previous assessments:

    Life history and fishery data 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 and NSPI during 1997 (Gibson and Daborn 1997), 1998 (Gibson 1999) and 1999 (Gibson 2000). Biological data relating to this stock were also collected during an evaluation of the fish ladder at White Rock in 1970 (Dominy 1971). Life history and fishery data from these projects are included as a table in this report.

3. Notes about the timing of young-of-the-year (YOY) outmigration at the Trout River Pond Fish Diversion Screen:

2. METHODS

Methods used during this study were identical to those of 1997 to 1999 (Gibson 2000), with the exception of the calculation of mortality rates.

Instantaneous total mortality (Z) was estimated using maximum likelihood to fit the model:

$$N_{t,s,a,p} = N_{t-1,s,a-1,p-1} e^{-Z_t}$$

where:

$N_{t,s,a,p}$ = the number of fish ascending the ladder in year t, of sex s, of age a, having spawned p times previously

Z_t = the sex specific instantaneous rate of total mortality during year t.

Instantaneous total mortality in a given year is therefore the average survival of mature fish in each sex, age and previous spawning category from the preceding year.

Fishery exploitation rates (μ_t) 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:

$$\mu_t = \frac{Catch_t}{Catch_t + Count_t}$$

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.

Year class strength (recruitment, R_t) was estimated as the number of age 3 fish produced in year t, and was calculated as:

$$R_t = \sum_{a=3}^{6} \left(N_{t+a,a} / e^{-m(a-3)} \right)$$

where m is the instantaneous rate of mortality for immature fish at sea, assumed to 0.4 for these calculations.

3. DATA SUMMARY

3.1 Alewife Count at White Rock (Total Count)

Alewives were first observed at Millett's net site on the Gaspereau River during 2000 on the Gaspereau River on April 18th. Operation of the counting weir in the White Rock fish ladder began April 20th. The first alewife was captured in the ladder on May 5th. The daily total remained less than 50 fish/day until May 17th. Modifications were made to the ladder entrance on May 18th (369 fish) and completed on May 19th (9,394 fish). The count peaked on May 22nd, at which time 15,905 alewives ascended the ladder (Figure 1). A second peak (5996 alewives) occurred May 24th. Monitoring continued until June 17th, at which time only 79 alewives ascended the ladder. In total, 98,883 alewives were counted while ascending the White Rock fish ladder. Ninety-five percent of the run ascended the ladder between May 19th and June 6th.

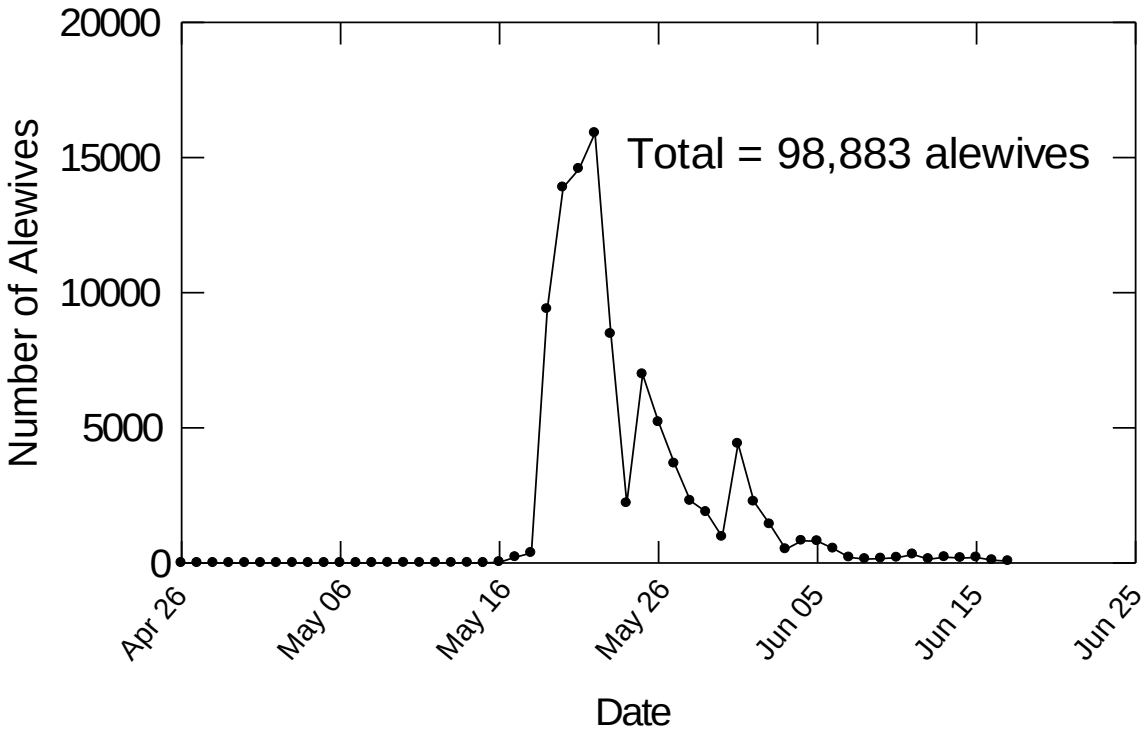

Figure 1. The number of alewives ascending the White Rock fish ladder each day during the year 2000 spawning run.

3.2 Stock Characteristics

3.2.1 Fork length

Fork lengths were measured on samples of 510 male and 486 female alewives. Males averaged 251.6 mm (s.d. = 12.2) in length, and females 263.0 mm (s.d. = 11.6). Length frequency distributions are shown in Figure 2.

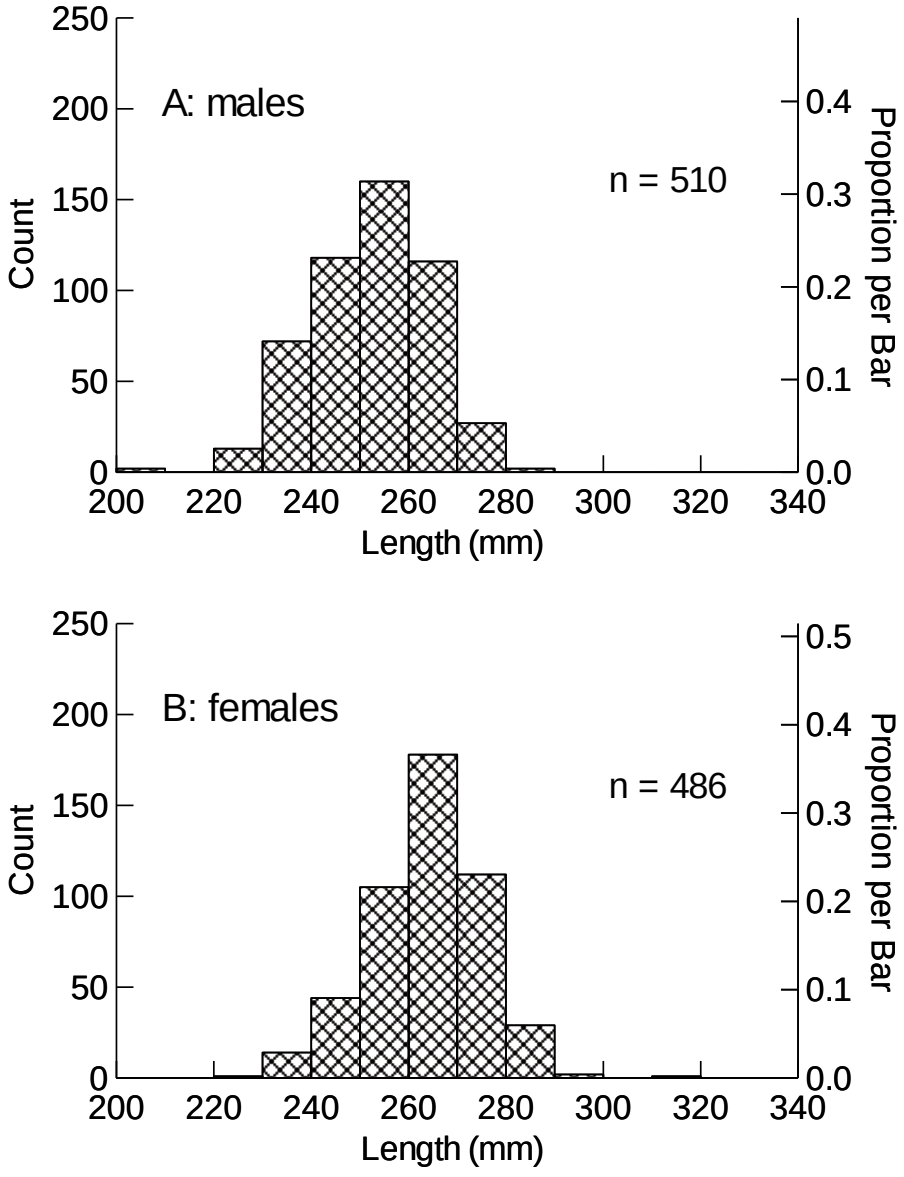

Figure 2. Fork length frequency distributions estimated for male (top) and female (bottom) alewives in the 2000 Gaspereau River spawning run.

3.2.2 Sex ratio

As estimated by the sex ratio of the fish sampled, males were more abundant than females by a ratio of 1.05:1 during 2000.

3.2.3 Age

Ages ranged from 3 to 6 years for both males (mean=4.63; s.d=0.56), and females (mean=4.81; s.d.=0.54), as shown in Figure 3.

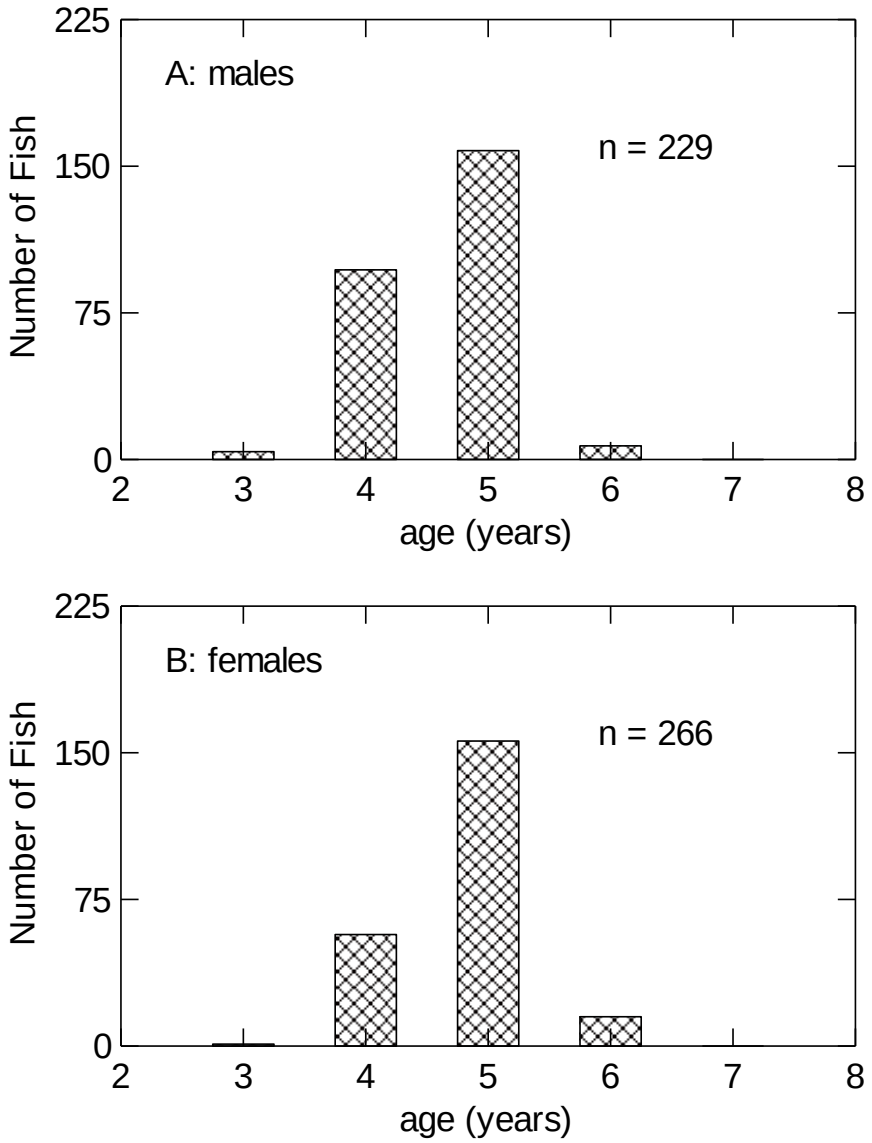

Figure 3 Age frequency distributions estimated for male (A) and female (B) alewives in the 2000 Gaspereau River spawning run.

3.2.4 Maturity

Age at first maturity ranged from 3 to 6 years for both males and females (Figure 4). Mean age at first maturity was 4.53 years (s.d. = 0.55) for males and 4.71 years (s.d. = 0.58) for females. Repeat spawners comprised 7.4% of female, and 11.1% of male alewives sampled.

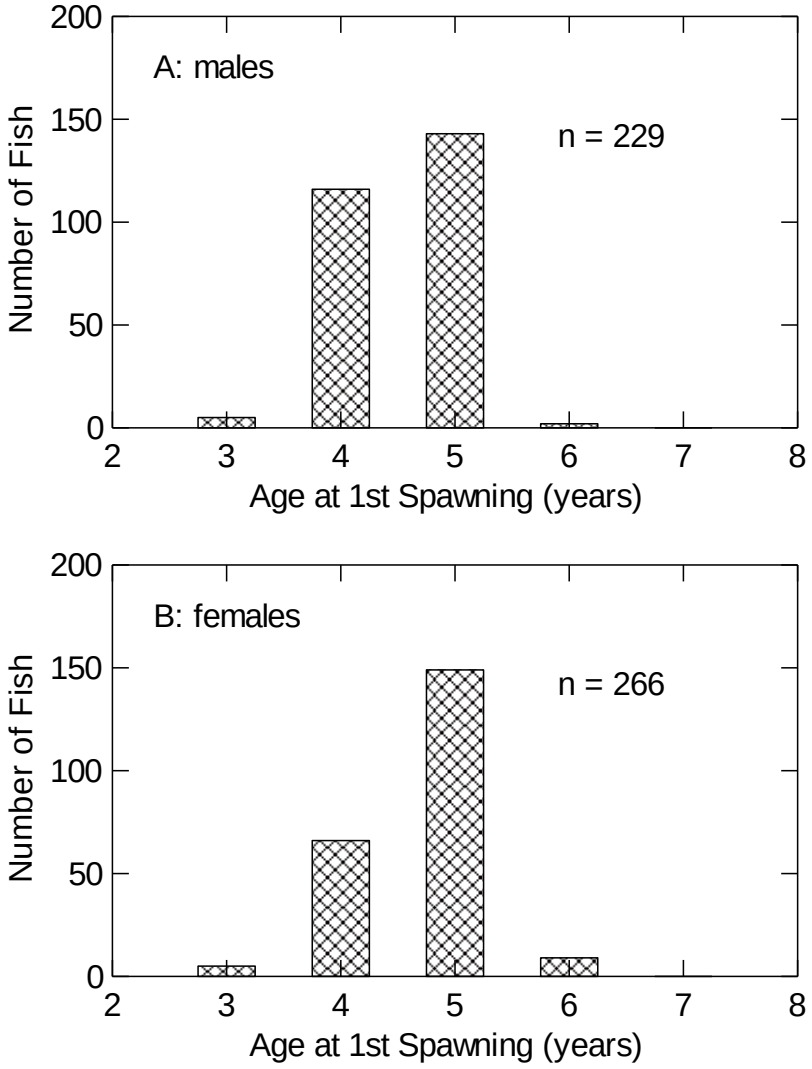

Figure 4. Frequency distributions showing age at first spawning for male (A) and female (B) alewives in the 2000 Gaspereau River spawning run.

3.2.5 Weight

The weights of 503 male and 472 female alewives were measured to the nearest two grams. Weights of males ranged from 124g to 332g (mean=227.0g; s.d.=34.0g) while females ranged between 164g and 358g (mean=265.0g; s.d.=35.0g). Weight-length relationships were developed from these data and are shown in Figure 5.

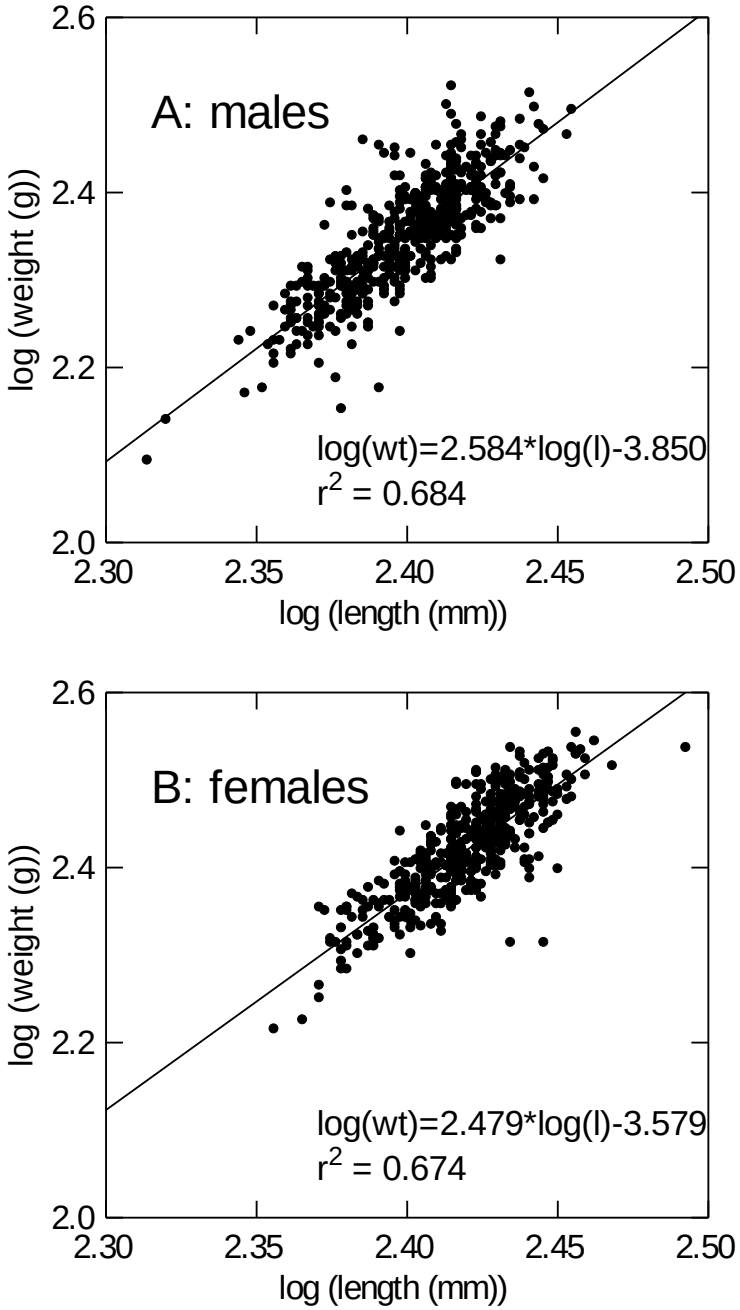

Figure 5. Weight-length relationships for male (A) and female (B) alewives in the 2000 Gaspereau River spawning run.

3.2.6 Growth

Von Bertalanffy growth curves (Figure 6) 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. The theoretical maximum length for the males was estimated as 326.3mm and for the females as 352.8mm. Growth coefficients were estimated as 0.2.8 and 0.32 for the males and females respectively.

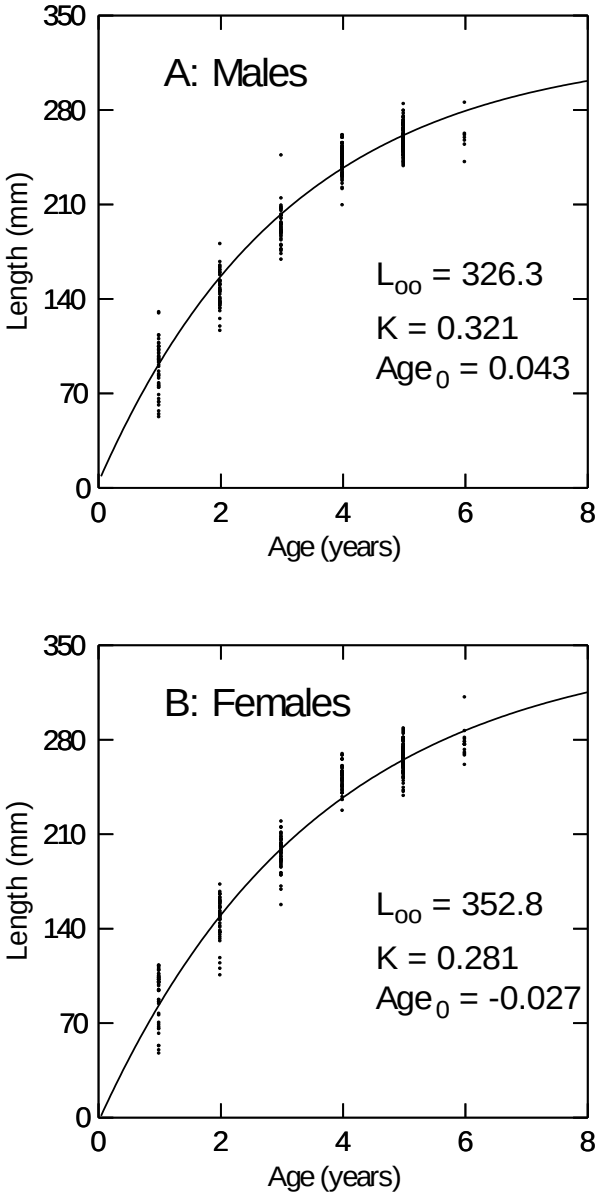

Figure 6. Von Bertalanffy growth curves overlaid against length-at-age data for male (A) and female (B) alewives sampled from the 2000 Gaspereau River spawning run.

3.4 The Fishery: Catch Statistics - 2000

Fishers on the Gaspereau River caught 6,157 pails of alewives (Hank Sweeney, DFO, personal communication) in 2000. 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 2000 (245.4g) and 1998 (226.5g), fishers caught 754,585 alewife in the Gaspereau River in 2000. The stock size in 2000, estimated as the sum of the catch and the White Rock count, was therefore 853,468 fish. This estimate is based on the assumption that all alewives not captured take the ladder, an invalid assumption. The exploitation rate in 2000, also based on this assumption, is therefore estimated at 88.4%. The 2000 alewife catch on the Gaspereau River was between the mean and median catch for the 1964 – 2000 time period (Table 1). The results of previous alewife counts and stock assessments are shown in Table 2.

Table 1. Summary of Gaspereau River alewife catches between 1964 and 2000.

Statistic	Catch (pails)
Mean	7,120
Minimum	1,099
Maximum	20,744
Median	5,600
2000 catch	**6,157**

Table 2. 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 (%)
2000	**98,883**	**754,585****	**853,468**	**88.4**
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

3.5 Year Class Strength and Mortality

While alewives mature between 3 and 6 years of age, the majority do so at either age 4 or age 5. As a result of this, the assessments from 1997 to 2000 give us complete information about the 1994 year class strength, nearly complete information about year class strength for 1993 and 1995, and some preliminary information about year class strength in 1996. The strength of these year classes, defined as the number of fish in the year class that survive to age 3, is shown in Table 3. Table 4 shows the number of fish from each of these year classes maturing at each age, as well as their subsequent. Instantaneous mortality tares are shown in Table 5.

Table 3. Year class strength, as the number of three year old recruits produced in each year class, calculated under the assumption that the instantaneous mortality rate of immature fish at sea is 0.4. The 1995 estimate is adjusted for the assumption that 10% of females and 3% of males will mature at age 6 in 2001.

Year Class	Recruitment: Age 3 Fish
1993	885,551
1994	1,032,953
1995	1,883,876

Table 4. Number of fish by year class, sex and age at first spawning for the 1993 to 1997 year classes.

Year Class	Age at 1st Spawning	Number in 1997	Number in 1998	Number in 1999	Number in 2000
Females					
1993	3	0	0	0	0
	4	215,363	36,595	0	0
	5		40,254	0	0
	6			0	0
1994	3	0	1220	4,597	1,717
	4		153,697	38,307	1,717
	5			114,920	6,869
	6				15,455
1995	3		0	0	5,152
	4			212,986	13738
	5				248,995
1996	3			0	0
	4				97,881
1997	3				1,717
Males					
1993	3	3,121	0	0	0
	4	276,277	48,793	4,597	0
	5		30,495	1,532	0
	6			0	0
1994	3	6,242	4,879	4,597	0
	4		197,611	47,500	0
	5			82,743	8,586
	6				3,434
1995	3		2,440	1,532	1,717
	4			246,696	32,627
	5				236,975
1996	3			4,597	0
	4				166,569
1997	3				6,869

Table 5. Instantaneous total mortality rates for the years 1998 to 2000. The corresponding total annual mortality rates are given in parentheses.

Sex	Year 1998	1999	2000
Male	1.08 (0.65)	1.91 (0.85)	2.06 (0.87)
Female	1.76 (0.83)	2.20 (0.89)	1.52 (0.78)

3.5 Comparisons with Other Years

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 3. Summary of Gaspereau River alewife stock characteristics.

Statistic	Year	Males	Females
Mean Fork Length (mm) ± standard deviation	2000	251.6 ± 12.2	263.0 ± 11.6
	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)	2000	285	311
	1999	278	286
	1998	299	302
	1997	287	315
	1995		
	1984		
	1983		
	1982		
Mean Weight (g) ± standard deviation	2000	227.0 ± 34.0	265.0 ± 35.0
	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)

Table 3 (con't). Summary of Gaspereau River alewife stock characteristics.

Statistic	Year	Males	Females
Mean Age (yr)	2000	4.63 ± 0.56	4.81 ± 0.58
± 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)	2000	6	6
	1999	6	5
	1998	7	6
	1997	6	7
	1995		
	1984	7	7
	1983	7	7
	1982	7	7
Mean Age at	2000	4.53 ± 0.55	4.71 ± 0.58
First Spawning (yr)	1999	4.18 ± 0.45	4.29 ± 0.48
± standard deviation	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 3 (con't). Summary of Gaspereau River alewife stock characteristics.

Statistic	Year	Males	Females
Repeat Spawners (%)	2000	11.1	7.4
	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)*	2000	2.06	1.51
	1999	1.91	2.20
	1998	1.08	1.76
	1997	1.39	1.21
	1995	1.75	
	1984	2.66	
	1983	0.91	
	1982	0.63	
Exploitation Rate (%)**	2000	88.4	
	1999	89.4	
	1998	68.5	
	1997	86.5	
	1995	< 88.3	
	1984	69.9	
	1983	56.7	
	1982	80.9	

*calculated from the count at age curve for the years 1982 to 1997; and from survival between annual counts for the years 1998 to 2000.
** values calculated from catch statistics adjusted by weight under the assumption that all fish captured ascend the White Rock fish ladder

3.6 YOY Outmigration via Trout River Pond

The control gate at Forest Home was opened on August 16th, 2000, presenting YOY alewives with the opportunity to migrate seaward via this route. A barrier was placed in front of the bypass stream entrance so that fish would not be able to move downstream without being counting. YOY alewives were not present in front of the diversion screen until September 6th. Just over 116,000 alewives moved down the bypass stream on September 6th and 7th (Table 5). Fork length was measured on a sample of 493 of these fish. These fish ranged between 42mm and 97mm in length, and averaged 57.5mm (s.d.=10.6) in length (Figure 7).

Table 5. Estimates of the number of YOY alewives migrating down the Trout River Pond bypass stream on Sept. 6th and 7th, 2000.

	Count Period			95 % Confidence Limits	
Date	Start	End	Daily Total	Lower	Upper
Sept. 6	1754h	1928h	73,804	72,672	74,937
Sept. 7	938h	1801h	42,424	41,946	42,903

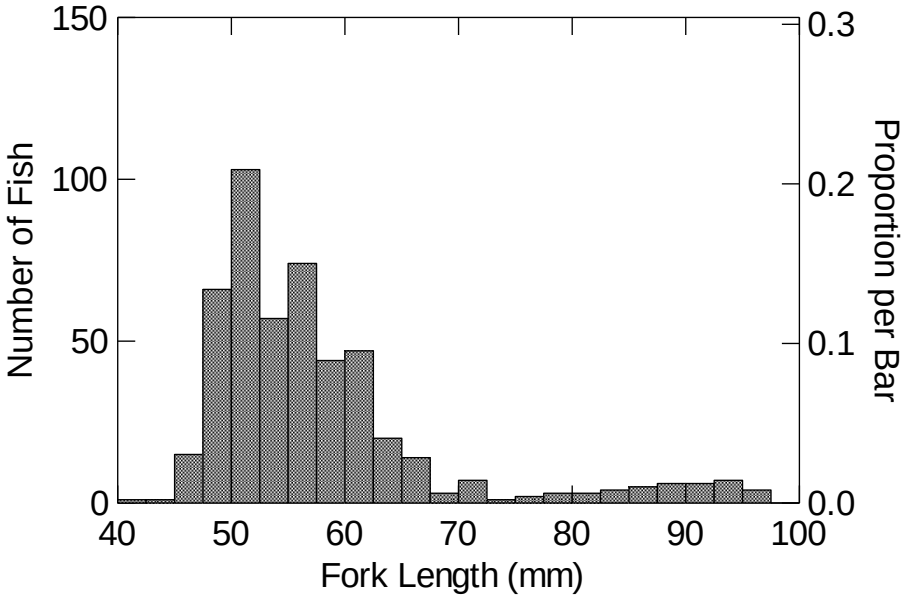

Figure 7. Fork length frequency distribution for YOY alewives captured on Sept 6th and 7th, 2000 at Trout River Pond.

3.7 Water Temperature

Water temperature was monitored in the lower Gaspereau River with a Vemco^{tm} data logger set to record hourly. Water temperature peaked at 26.7 °C in late July (Figure 8).

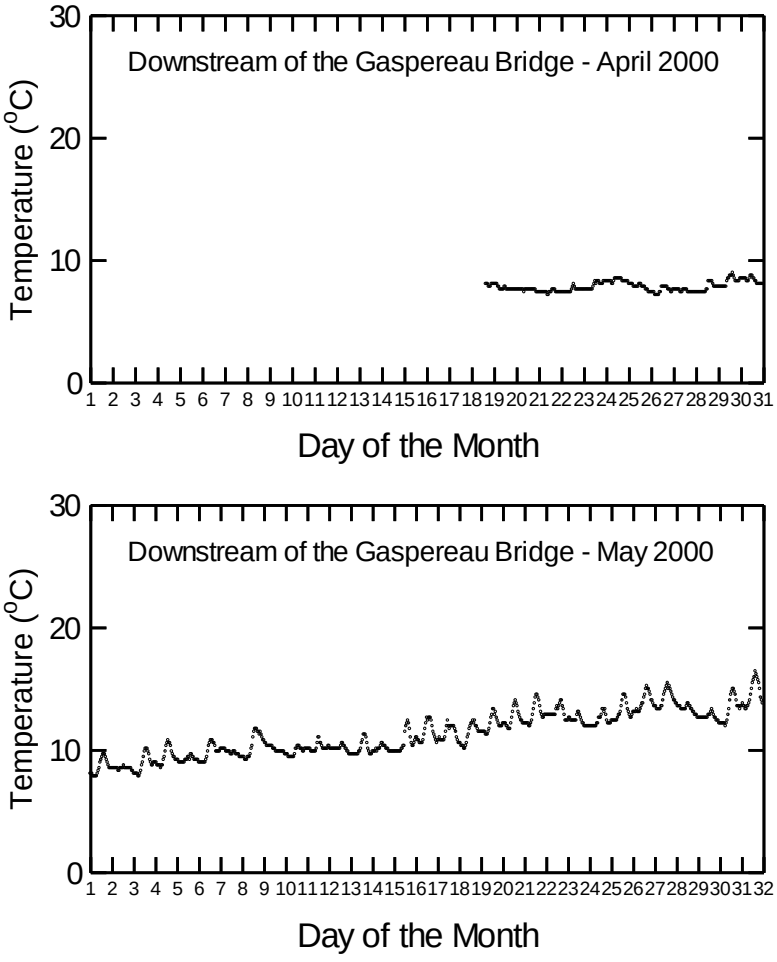

Figure 8. Water temperature in the Gaspereau River c.0.5 km downstream of the Gaspereau Bridge during April and May, 2000.

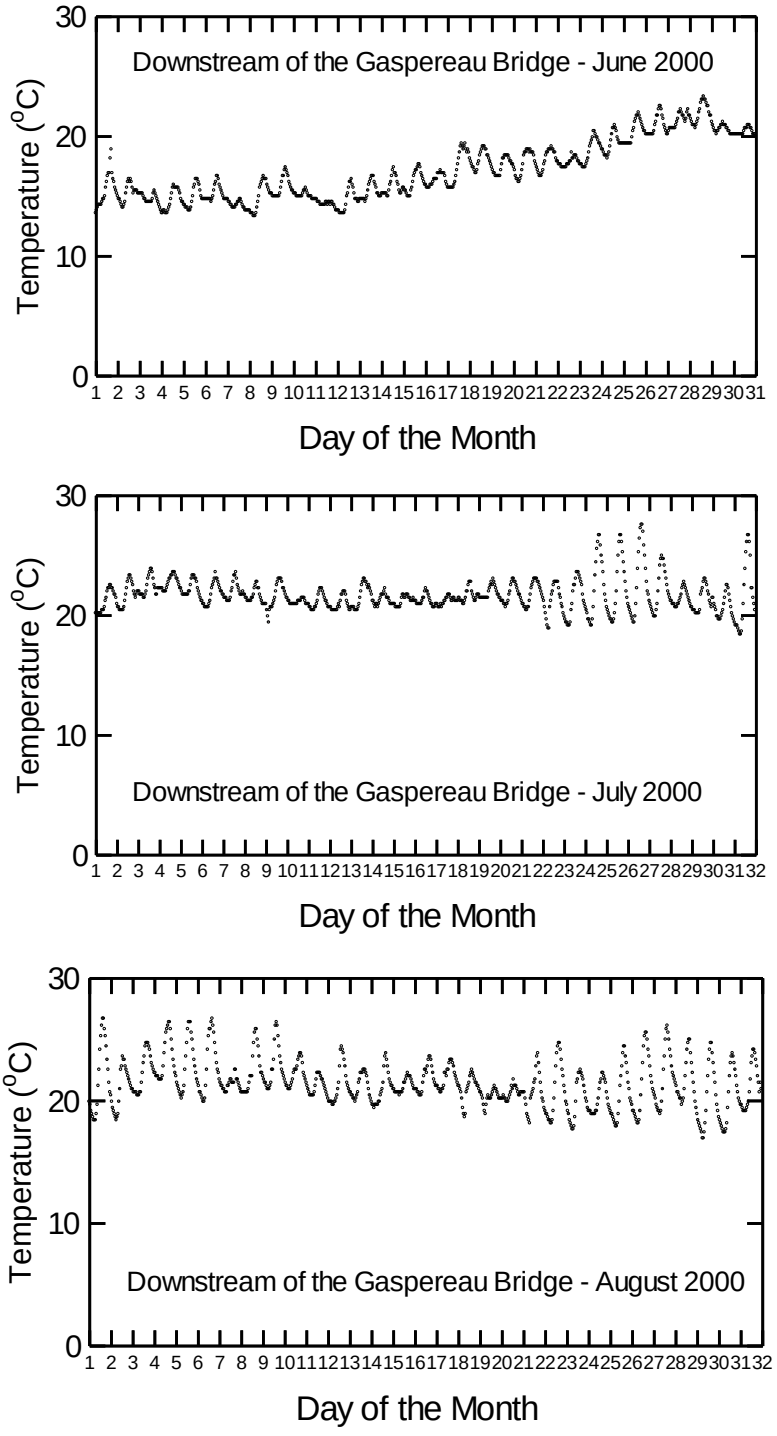

Figure 8 (con't). Water temperature in the Gaspereau River c.0.5 km downstream of the Gaspereau Bridge during June, July and August, 2000.

4. DISCUSSION

While the estimated stock size in 2000 (853,468 fish) was of the second highest of the 9 years for which counts are available, the Gaspereau River alewife stock continues to exhibit characteristics of a heavily impacted stock. Only 11.1% of males, and 7.4% of females in this run had previously spawned. This percentage can be over 50% in un-impacted stocks. As a result, the population relies primarily on only 2 year classes (94.5% of the spawning run belonged to the 1995 and 1996 year classes), instead of 6 or more year classes in an un-impacted stock. The large stock size in the year 2000 is the result of a comparatively high recruitment of 5 year old first time spawners combined with the recruitment of four year old fish.

Alewives in 2000 averaged slightly older and larger than 1998 or 1999. This increase was due to the relatively large recruitment of age five fish, not an increase in the number of age classes in the population.

Estimates of total annual mortality in 1999 and 2000 are slightly lower than estimates of the harvest rate (total mortality cannot be lower than the harvest rate because it includes mortality from all sources, including harvesting). This result supports observations in previous years that the estimates of the harvest rates are biased high because all fish that are not harvested to not subsequently take the ladder. Changes in the efficiency of the ladder from year to year, that result from changes to water management strategies, change the extent of this bias. Mortality calculated from the count-at-age data, from year to year are probably the better indicator of the impact imposed on this stock. As was the case in 1999, only about 10% (or less if a significant proportion of fish do not take the ladder) of the fish that entered the river to spawn succeeded in reaching the top of the White Rock ladder. While the biological limits are of the Gaspereau River alewife stock are currently unknown, 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 of 64.5% and 77.0% respectively. These estimates are based on the assumption that the remainder of the population has the opportunity to reproduce. The combined effect of the fishery and restriction to migration on the Gaspereau River is to reduce the fraction of the fish that are available to reproduce to 10% or less. Reproduction downstream of the White Rock dam probably does not contribute significantly to the resulting year class due to a parasitic bivalve in that area (Gibson and Daborn 1998).

YOY alewife emigration via Trout River Pond was different from other years. During 1996 and 1999 alewives moved downstream during mid-August when the gate was open, and during 1997 and 1998 alewives moved downstream via this route as soon as the gate was opened (late October in 1997 and late September in 1998). In 2000, the gate was opened on August 16th, but YOY alewives did not appear at the diversion screen until September 6th. Just over 116,000 alewives moved down the bypass stream on September 6th and 7th, a smaller number than observed at the onset of migration in other years. An unknown, but large number of YOY alewives were observed moving past the White Rock dam in early October, suggesting that large numbers of alewives remained in

Gaspereau Lake later into the fall. Emigrating YOY alewives on Sept. 6th and 7th averaged 57.5mm in fork length. These fish were smaller than those observed at similar times other years (Lumsdens Pond and Black River Lake, last week of August, 1996: 109 mm; Lanes Mill, first week of September, 1997: 81.5 mm; Lanes Mill, first week of September, 1998: 65.5 mm; Trout River Pond on August 16th, 1999: 72.4 mm).

As mentioned in previous reports, from a conservation perspective, water management in the Gaspereau River and management of the alewife fishery cannot be uncoupled. The most obvious reason for this is because water levels in the river downstream of the White Rock dam directly affect the efficiency of fishing gear in that area. A less obvious reason related to the timing of the gate closure gate at Forest Home in the spring, an event that places restrictions on water flow until the late summer and fall. Currently, the gate is closed shortly after adult alewives enter Gaspereau Lake to prevent alewife eggs and larvae from being transported downstream. Because Gaspereau Lake and Aylesford Lake are the primary storage basins in the watershed, this closure limits the amount of water available for salmon migration and maintenance of water levels downstream of the gate for most of the summer. When at equilibrium levels of abundance, alewife population size is thought to be regulated by high compensatory mortality in the larval and early juvenile life stages. Within limits, if spawner abundance is adequate, this protection of pre-compensation life stages probably has little effect on stock size, in comparison with the protection of post-compensation life stages such as emigrating young-of-the-year, adults returning to spawn, and post-spawning adults. Given the caveat that spawner abundance needs to be adequate before relaxing the restrictions on the Forest Home gate operation, it follows that the operation of the gate and the alewife catch are directly linked. As spawner abundance declines, in the importance of protecting pre-compensation life stages increases. Additionally, the importance of protecting these life stages increases throughout the summer, as compensation occurs. A biological model of these processes, and a field study to determine the rates of downstream egg and larval transport would be necessary to evaluate a plan to relax the restrictions on the operation of this gate.

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