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Alewives in Hudson River Tributaries

Final Report

to

The Hudson River Foundation

by

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ABSTRACT

The river herring observed in Hudson River tributaries in 1998 were almost all alewives. We documented alewife runs in seven tributaries for the first time.

The run in Canterbury Brook was estimated at 1600 alewives and the Moordener Kill at 8600 alewives. Despite being 80 miles apart, the runs were simultaneous in these two tributaries, peaking in mid-May. Gender ratios were very different with Canterbury Brook having 55% females and the Moordener Kill only 23% females.

Females apparently spawned twice each with the first spawning early in the season. Females entering tributaries wre mostly second spawners or completely spent. Second spawners made up 65.1% of the Canterbury Brook females and spent fish made up 20.9%. The Moordener Kill run was very different with 44.8% of the females second spawners and 55.2% were completely spent.

We estimated that $3.7X10^7$ alewife eggs were deposited in Canterbury Brook and about the same ($3.9X10^7$) were deposited in the Moordener Kill. Egg and larval mortality (comparing deposition to estimates of the drift), however, were very different with Canterbury Brook early life stages having a 61.5% mortality and the ones in the Moordener Kill at 38.5%.

Male and female alewives were the same size, and were much smaller than alewives in more northern populations. Only one female alewife attained the age of VIII+, all others were VII+ or younger. Only 8.2% of the alewives aged showed a spawning mark on their scales.

A synthesis of adult alewife behavior is presented. These hypotheses came from our observations and considerable previous work.

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INTRODUCTION

The anadromous fish populations in the Hudson River are widely perceived as significant economic and ecological resources (Schmidt 1996). Considerable research has been done on Hudson River striped bass (*Morone saxatilis*) from its early life stages (Limburg et al. 1997 and references therein) through the contribution of Hudson River adults to the Atlantic coastal stock (Waldman et al. 1997). American shad (*Alosa sapidissima*) adults are monitored by the NYS DEC tagging program and Limburg (1994) reported considerable information on larval and juvenile biology in the Hudson. Juvenile and adult sturgeon (*Acipenser* spp.) are currently being studied by M. Bain, Cornell University. A recent Master's thesis (Rose 1993) looked at larval distribution of rainbow smelt (*Osmerus mordax*) in the Hudson River.

The other two major anadromous species, alewife and blueback herring, perform a significant role in the Hudson estuary. They are forage for a variety of juvenile and adult game fishes (witness the sale of live herring for striped bass bait). The juveniles, by their abundance, are significant zooplankton feeders (Limburg and Strayer 1987). Distribution and abundance of the early life stages of river herring in the Hudson have been summarized (Schmidt et al. 1988) and similar ichthyoplankton data are annually presented in reports to the Hudson River Utilities.

River herring do spawn in Hudson River tributaries. Limburg and Schmidt (1990) proposed that watershed development affected the magnitude of river herring runs. Although it is not clearly known which Hudson River tributaries have river herring runs (Schmidt and Cooper 1996), Schmidt et al. (1994) were able to account for all of the alewife eggs produced in the Hudson Estuary by export from sixteen tributaries. The tributaries are, therefore, potentially very important spawning areas for the Hudson River populations.

All of the above information on river herring has come from sampling eggs through juveniles. Little work has been done on the adults of these species in the Hudson River. Lake and Schmidt (1997 and 1998) have made the only (very conservative) population estimates for a herring run in the Hudson that we know of. Quassaic Creek in Newburgh has a run of 4-5000 individuals and this tributary has suboptimal water quality (Stevens et al. 1994) and was not considered a major spawning tributary by Schmidt and Limburg (1989).

The purpose of this project was to turn our attention to the adult river herring as they enter Hudson River tributaries. Clearly, the title of this report has given away one of our observations, that these tributary spawners are mostly alewives. We present observations on size, timing, and gender composition of several runs. We document the presence of alewife runs in several tributaries. We have provided data on age, fecundity, and behavior of spawning alewives in the Hudson River.

METHODS

This study took place in streams tributary to the tidal Hudson River (Fig. 1) between Westchester County (Saw Mill River at River Mile 18) and Rensselaer County (Poesten Kill at RM 159). River Mile is a Hudson River convention defined as the distance (in miles) north of the Battery at the southern tip of Manhattan. Adult alewives were collected in monofilament gill nets (15.5 m X 1.8 m X 6.4 cm stretch mesh) set in or close to the tidal mouths of various tributaries (Fig. 1). A second, smaller mesh net (3.2 cm stretch mesh) was often set simultaneously to capture smaller potamodromous fishes, particularly rainbow smelt and spottail shiners.

There were two levels of sampling effort. Two tributaries (Fig. 1), Canterbury Brook in Orange County (RM 58) and the Moordener Kill in Rensselaer County (RM 137.5), were selected to be sampled at least weekly. One of the purposes for sampling these two streams was to estimate the magnitude of the alewife run. The other tributaries (Fig. 1) were sampled less frequently, the main purpose being to determine if an alewife run was present in these tributaries and one successful collection of alewives was deemed adequate to establish the presence of a run.

In either case, the percent of the width of the stream that the gill nets blocked was estimated visually, the length of time the net was fished was recorded, and all fishes collected were identified, counted, and measured (Total Length to the nearest mm). Catch per unit effort (CPUE) was defined as the number of alewives caught per net hour. In Canterbury Brook, nets were fished both day and night on incoming to high tides. In the Moordener Kill, partially because of other commitments, nets were fished in the evening, after sundown, once a week on the same day, thus we alternately sampled high and low tides.

River herring collected in gill nets were all returned to the laboratory. They were identified, measured (TL, nearest mm), weighed (nearest gr), and gender was determined. Ovaries from females were carefully removed and weighed. A subset of ovaries were preserved in 50% isopropanol for later fecundity analysis. Scales were removed from all river herring and, later in the study, otoliths were also removed from some specimens to provide an independent check on scale aging. Scales were stored dry in envelopes and otoliths were stored dry in small capped vials.

In Canterbury Brook and the Moordener Kill, we also, at least weekly, sampled the drift for fish early life stages. These samples were collected after sundown. Three standard rectangular drift nets (0.135 m^2 opening, 330 μm mesh) were deployed at regular intervals across the stream. Nets were fished for about 20 minutes (time was recorded) and were then retreived and the contents transferred into jars and preserved in the field with about 4% formalin. While nets were fishing, we measured water temperature (hand held thermometer), velocity of water in the mouth of each net (Swoffor current meter), and took a depth and velocity transect over the width of the stream to measure discharge. In the laboratory, fish eggs and larvae were sorted out of the samples, identified as far as was practical, and counted.

The magnitude of the alewife runs were calculated from the gill net CPUE data. We assumed that a given net intercepted all alewives entering that part of the stream that the net covered for the time a net was fished. We also assumed that the magnitude of the alewife run,

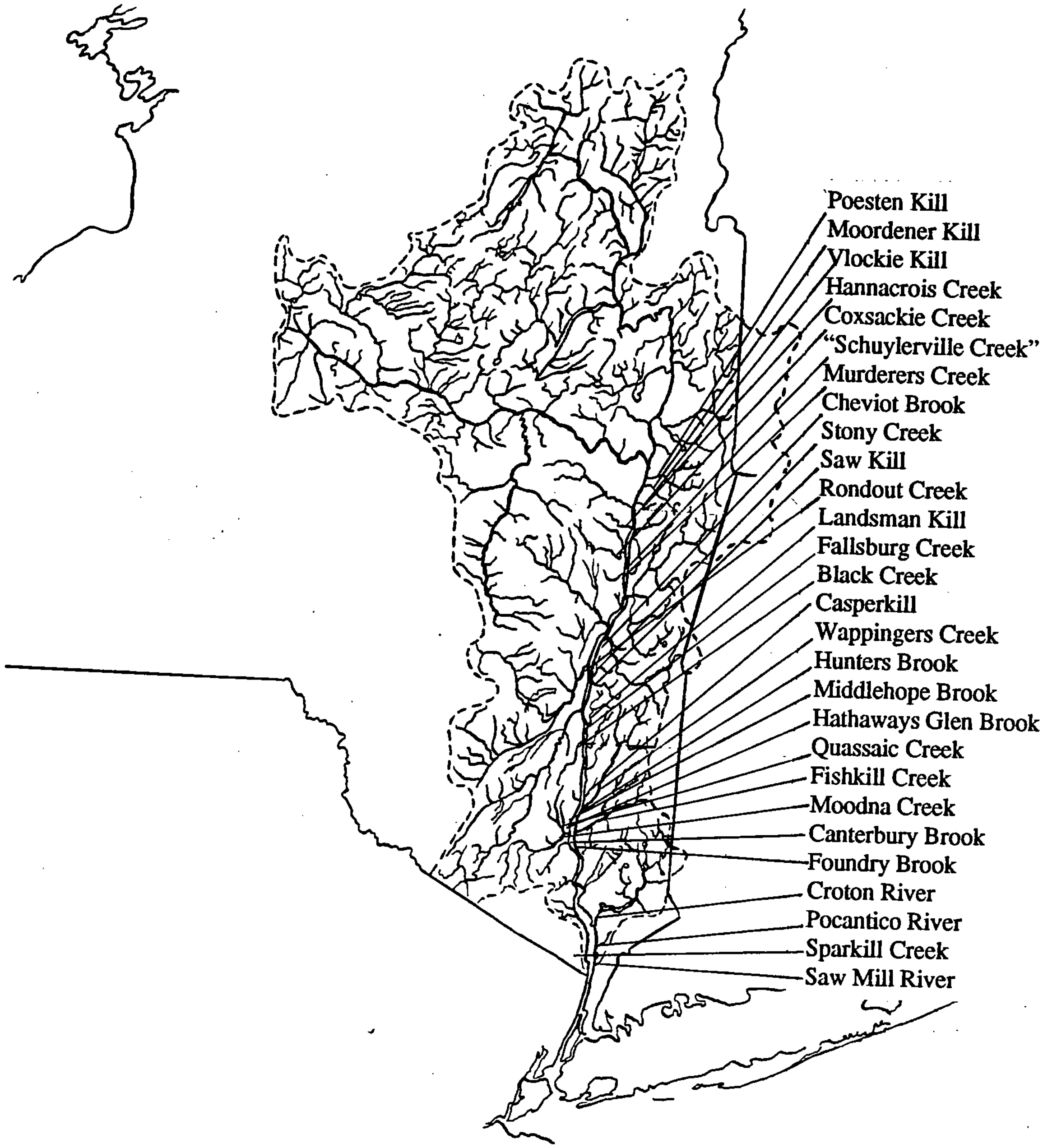


Figure 1. Map of the Hudson River estuary showing locations of tributaries sampled for river herring. Open circles indicate no herring were collected, closed circles indicate the presence of herring runs.

on days we did not sample, could be predicted from the preceeding sample. CPUE was diveded by the percent coverage of the tributary by the net and multiplied by the number of hours (incoming to high tides) of appropriate conditions for migration. These results were then multiplied by the number of unsampled days subsequent to each data point and finally summed.

The magnitude of the export of alewife eggs and larvae was calculated by first finding the density (#/m^3) of alewife eggs and larvae (separately) per drift net using the numbers counted, the water velocity in each net, and the area of the mouth of the net. The average densities of eggs and larvae were then calculated for each sampling night. Average densities were converted to numbers/second by calculating the flow of the stream from the depth and velocity transects and multiplying by the densities.

Total export of eggs was calculated by multiplying the instantaneous transport (#/s) by the number of seconds between a given sample and the next sample. This assumes that egg export is uniform over a 24 h period (Schmidt and Stillman, 1994) and that the amount of eggs exported did not change drastically between samples. Total export of yolk sac larvae was calculated somewhat differently because they tend to drift mostly after sunset (Schmidt and Stillman, 1994) and we adjusted the estimate of drift over 24 h based on those empirical observations. Total export of all life stages was the sum of export of eggs and export of yolk sac larvae.

Fecundity for a given female was estimated by first weighing the preserved ovaries. Three small subsamples were collected from the ovaries and also weighed (nearest 0.001 gr). Eggs were teased from the connective tissue in each subsample and were classified as either large or small (visually). Counts for large and small eggs were kept separately. Counts for each egg size for each subsample were averaged and the total number of large and small eggs per fish were estimated by proportion.

Total number of eggs imported into a tributary was estimated by first by determining how many females entered the tributary (total number of alewives times the gender ratio). The females were further classified as first spawning, second spawning, or spent (explained below in results) and the numbers in each category were determined by multiplying the total number of females in a tributary by the observed proportion of females in each category. Finally, the number of large (ripe) eggs per category was multiplied by the estimate of the number of females in each category and summed for a given tributary.

Scales were removed from envelopes, cleaned gently, and mounted between glass microscope slides. Images were projected on a white wall with a microprojector and annuli and spawning marks were determined following Marcy (1969). Ages were reported as observed, we did not add annuli to compensate for scale erosion. Otoliths were placed in a well slide in water and examined with transmitted light. We did not section or polish the otoliths.

RESULTS

River Herring

We deployed gill nets in 29 different tributaries of the Hudson River (Table 1). We collected river herring in 16 of these tributaries. Most of the river herring collected were alewives (*Alosa pseudoharengus*). Rondout Creek and the Poesten Kill had the highest percentage of blueback herring (*Alosa aestivalis*) present (Table 1), but female bluebacks were only seen in Rondout Creek. We conclude that virtually all of the reproducing river herring in Hudson River tributaries are alewives.

Seven of the tributaries sampled were either listed in Schmidt and Cooper (1996) as "herring runs not documented" (Moordener Kill, Cheviot Brook, Hunters Brook, and Middlehope Brook, the latter was listed as "Roseton Brook" in Schmidt and Cooper, 1996) or were not listed at all (Canterbury Brook, Casperkill, and Hathaways Glen Brook, the latter listed as "Unnamed-Newburgh" in Limburg and Schmidt, 1990). Therefore we added three tributaries that have alewife runs to the list of 66 tributaries in Schmidt and Cooper (1996) and we documentd alewife runs in four others.

Seven of the tributaries we sampled had no documented alewife runs and we were unable to catch alewives in this study (Foundry Brook, Sparkill Creek, Saw Mill River, Landsman Kill, Fallsburg Creek, Murderers Creek, and "Schuylerville Creek", the latter was not listed in Schmidt and Cooper, 1996). However, since we also failed to catch alewives in some tributaries where we know they exist (Croton River, Vlockie Kill, and Stony Creek), we don't feel that we have ruled out any of the above tributaries for having alewife runs. With a small amount of sampling effort, it is possible to miss a run.

Gill Net By-catch

Although not part of this study, our netting does document presence of other, possibly potamodromous, species in these tributaries (Table 2). Besides river herring, we collected 717 individuals of 25 species, mostly consisting of important game and forage fishes. The most abundant species in our collections was white perch, well documented as a potamodromous species in the Hudson River (Limburg and Schmidt, 1990; Lake and Schmidt, 1997 and 1998; Schmidt and Stillman, 1994). In fact, more white perch were collected than alewives in the Moordener Kill. Thirteen species were seen in Canterbury Brook whereas only eight were taken in the Moordener Kill. Comparing the lists in Table 2, it seems that there are substantial differences in species composition among Hudson River tributaries. These data do add further support to the hypothesis that tributaries are important to a wide variety of fishes, not just the anadromous alewife.

Timing of the 1998 Alewife Runs

In 1998, there was a period of one or two weeks where alewives were quite abundant in the tributaries with generally low abundance the rest of the spring (Fig. 2). Our catches in Canterbury Brook and the Moordener Kill described a single peak of abundance in mid-May (Fig. 2). Previous studies have shown a bimodal pattern with abundant alewives in late April followed by a (usually smaller) run in mid-May (Lake and Schmidt, 1997 and 1998; Schmidt and Stillman, 1994).

Table 1. List of river herring catches in Hudson River tributaries, 1998. River Mile (RM) is the number of miles north of the Battery in Manhattan. CPUE is the mean catch per net hour in standard gill nets. An asterisk (*) indicates two tributaries that were sampled intensively.

Tributary	RM	# River Herring	% Alewives	CPUE
Saw Mill River	18	0	-	-
Sparkill Creek	24.5	0	-	-
Pocantico River	28	0	-	-
Croton River	34	0	-	-
Foundry Brook	53	0	-	-
*Canterbury Brook	58	200	99.5	1.3
Moodna Creek	58	8	100.0	0.4
Fishkill Creek	60	16	100.0	0.7
Quassaic Creek	60	13	100.0	0.8
Hathaways Glen Brook	63	20	100.0	0.7
Middlehope Brook	65	25	100.0	7.1
Hunters Brook	67.5	6	100.0	0.5
Wappingers Creek	67.5	20	100.0	1.2
Casperkill	69	17	100.0	0.7
Black Creek	85	28	100.0	7.0
Fallsburg Creek	87.5	0	-	-
Landsman Kill	87.5	0	-	-
Rondout Creek	92	37	75.7	2.5
Saw Kill	98	1	100.0	0.7
Stony Creek	99.5	0	-	0
Cheviot Brook	106	9	100.0	1.3
Murderers Creek	118	0	-	-
"Schuylerville Creek"	123	0	-	-
Coxsackie Creek	127	37	100.0	9.2
Hannacrois Creek	132	0	-	-
Vlockie Kill	136	0	-	-
*Moordener Kill	137.5	88	98.9	4.3
Poesten Kill	159	21	80.9	6.5

Table 2. List of species collected in gill nets in tributary mouths in 1998. Numbers are number of individuals collected.

Species	Canterbury Brook	Moordener Kill	Other Tributaries
Anguilla rostrata	-	1	2
Alosa mediocris	-	-	1
Dorosoma cepedianum	-	-	4
Cyprinus carpio	1	1	11
Notemigonus crysoleucas	7	2	35
Semotilus corporalis	-	-	1
Catostomus commersoni	37	2	33
Ameiurus catus	17	-	23
A. natalis	1	-	-
A. nebulosus	-	-	10
Esox niger	4	-	1
Oncorhynchus mykiss	-	-	1
Salmo trutta	2	3	1
Fundulus heteroclitus	-	-	8
Ambloplites rupestris	-	1	20
Lepomis auritus	2	-	33
L. gibbosus	13	-	22
L. macrochirus	2	-	13
Micropterus dolomieu	-	-	3
M. salmoides	-	-	3
Pomoxis nigromaculatus	-	-	5
Morone americana	60	113	170
M. saxatilis	6	1	13
Perca flavescens	-	-	24
Stizostedion vitreum	-	-	4
Total	153	124	440

Alewife runs are reported to occur between 12-16°C (Pardue, 1983). Tributary water temperatures (Fig. 3) reached about 12°C at the end of April in 1998 which generally coincided with an increase in catch per unit effort in our two main tributaries. We did, however, see spawning (see the section on drift of eggs and larvae, below) at temperatures below the reported minimum (10.5°C) necessary for spawning (Pardue, 1983).

Despite the fact that Canterbury Brook and the Moordener Kill are about 80 miles apart, the alewife runs in both occurred simultaneously (Fig. 2). This observation is similar to

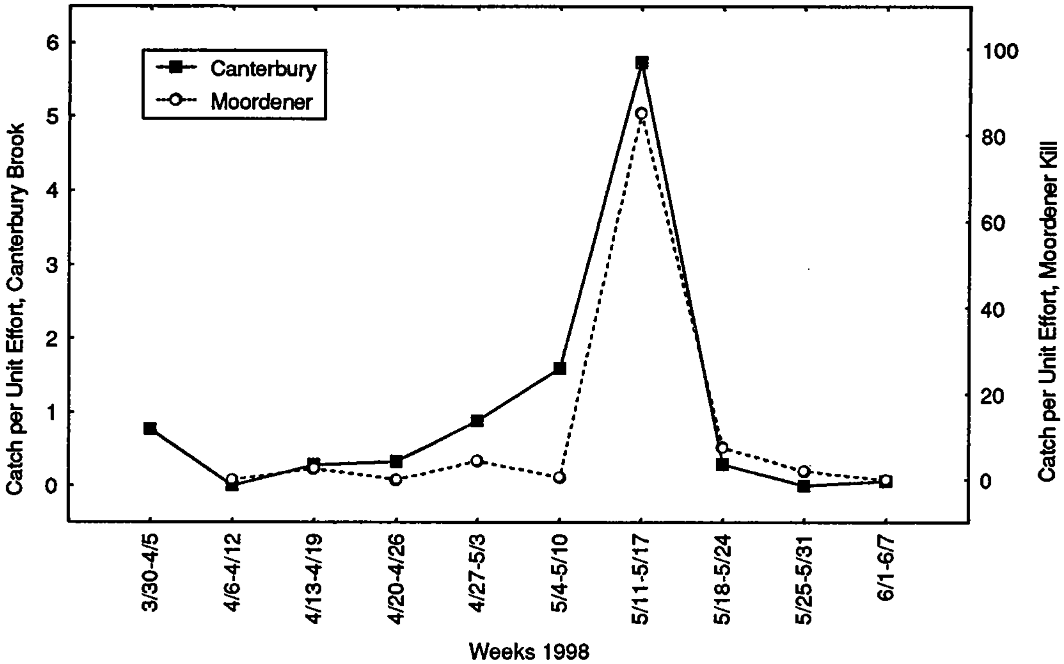


Figure 2. Catch per net hour of alewives in Canterbury Brook (weekly means) and the Moordener Kill in 1998. Note that the scales are different for the two streams.

Limburg and Schmidt (1990) where they reported that alewives appeared in all tributaries at about the same time regardless of the location of the tributary in the estuary. The magnitude of the run in the Moordener Kill was greater than in Canterbury Brook. The catch per net hour in the Moordener Kill was almost always an order of magnitude greater than in Canterbury Brook (Fig. 2).

Sampling for alewives in Canterbury Brook occurred on incoming tides, 17 during the day and 17 at night. Catch per net hour did not differ between day (mean= 1.09 alewives per net hour, range 0-10) and night (0.96, 0-10.1). This observation suggests that alewife runs can be sampled during the day and at night with equivalent results.

Tidal stage does make a large difference in catch rates of alewives, however. Samples in the Moordener Kill on high tides showed greater catches per net hour than samples taken on subsequent low tides (Fig. 4), frequently much greater. This observation suggests that alewives enter tributaries on incoming and high tides and sampling at other times will underrepresent the magnitude of the run.

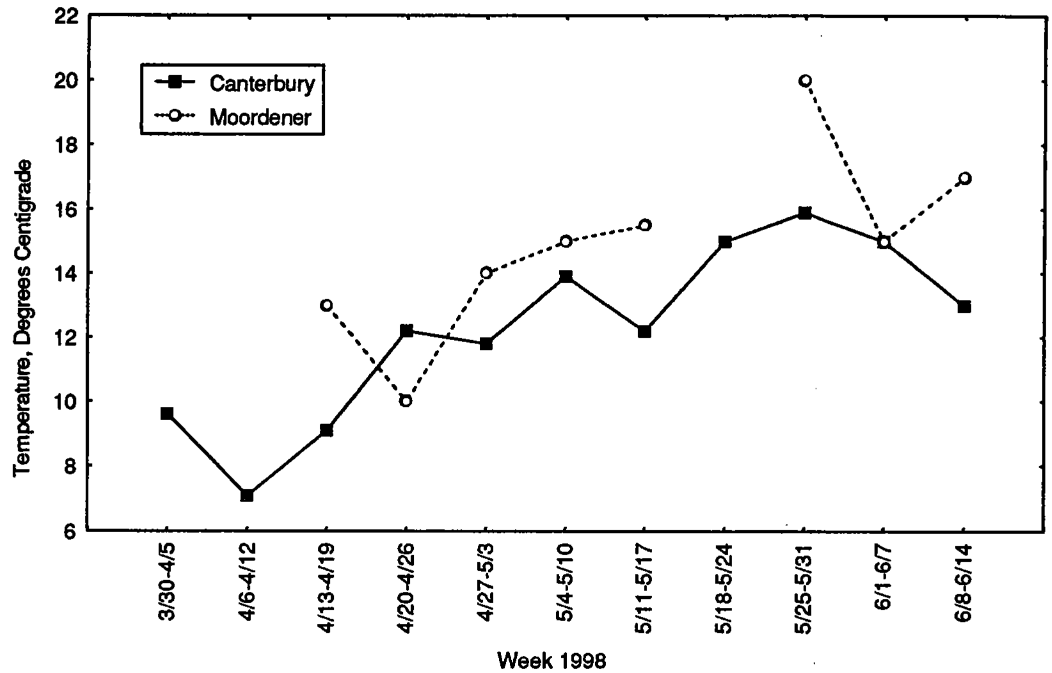


Figure 3. Water temperature in two tributaries during alewife sampling in 1998.

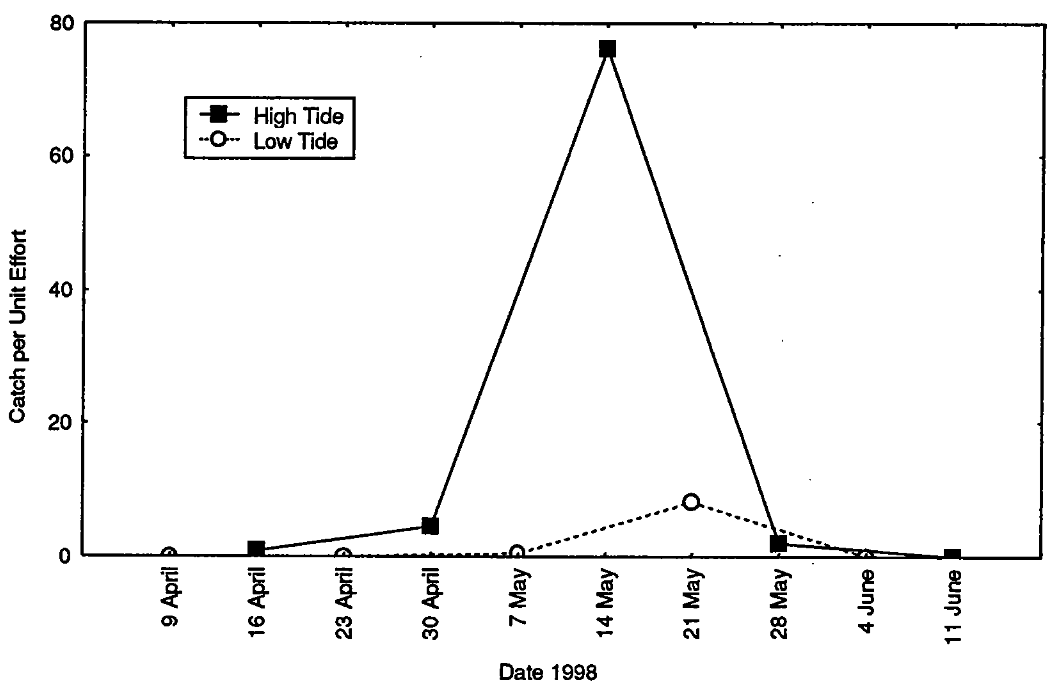


Figure 4. Alewife catch per net hour in the Moordener Kill comparing tidal stages.

Characteristics of the Runs

Estimates of the size of the adult run were 1628 alewives in Canterbury Brook and 8604 alewives in the Moordener Kill. When compared to our estimates of the alewife run in Quassaic Creek (Lake and Schmidt, 1997 and 1998), there seems to be a good correlation between number of alewives and tributary size. However, two of the largest runs we have seen are in tributaries smaller than Canterbury Brook (Crum Elbow Creek and Black Creek), so this correlation may be spurious.

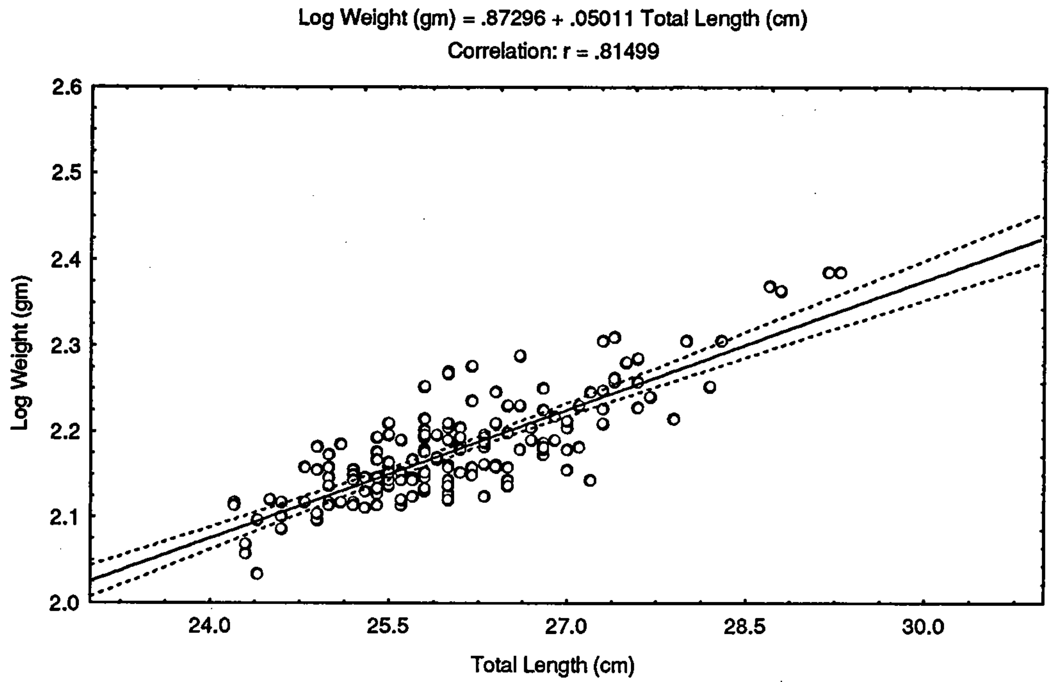
One striking difference among the three tributaries mentioned in the previous paragraph is the gender ratios of the alewives. In Quassaic Creek and Canterbury Brook the gender ratio was 50 and 55% females, respectively. In the Moordener Kill, 23% of the alewives collected were females. We sampled enough alewives in two other northern tributaries to get a reasonable estimate of gender ratios. Coxsackie Creek had 5.4% females (N = 37, but only one sample) and the Poesten Kill had 17.6% females (N = 17, 2 samples).

In the southern tributaries, Rondout Creek, Black Creek and Casperkill had more females than males in our samples but most of the rest had more males than females (Fishkill Creek, Wappingers Creek, Middlehope Brook, and Hunters Brook). If male alewives enter tributaries first (Lake and Schmidt, 1997 and 1998; our observations in Canterbury Brook and the Moordener Kill) and the males hang around the tributary for some time (our subjective idea of what is occurring), a given sample should have more males than females. In the Moordener Kill, no sample had more females than males or even approached a 50:50 gender ratio. The other tributaries were sampled too infrequently to determine if there was a temporal trend in gender ratios. Alewife behavior in the Moordener Kill appears to be different from alewives in Canterbury Creek or Quassaic Creek, but whether this is generally true for northern tributaries remains unknown.

Gender and Size of Alewives

Conventional wisdom says that male alewives are smaller than females, but our data showed no difference in total lengths between the genders. Females averaged 26.8 cm TL (range, 24.3-30.2) and males averaged 26.4 cm TL (24.2-30.8). Females should weigh more for a given length than males, especially during spawning season. Comparison of length-weight regressions by gender (Fig. 5) supports that idea. There appears to be more scatter in the female length-weight regression (and the correlation coeffecient is lower) than in the male plot (Fig. 5), especially among the larger females.

We guessed that the variation among females was due to variation in maturity and reproductive state of the ovaries. A regression of ovary weight and total length of females showed little correlation (r = 0.31, Fig. 6) with a large amount of variation in female alewives greater than 27.0 cm TL. Mean ovary weight was 18.5 g (range, 2-64 g). This wide range indicated that we had captured females that ranged from ripe to spent individuals (even though they were all caught coming upstream into tributaries). A size frequency showed that there were roughly three classes of females (Fig. 7); females with ovaries weighing <8% of total body weight, females with ovaries weighing 10-16% of total body weight, and females with ovaries weighing >16% of total body weight.



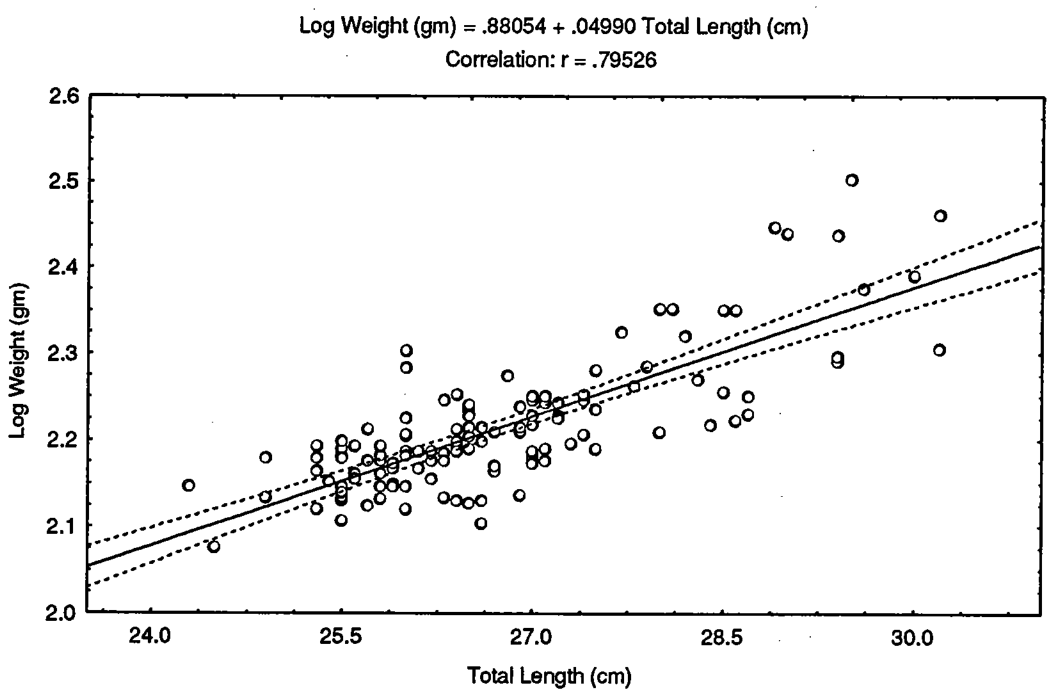


Figure 5. Length-weight relationships of male (upper graph) and female (lower) alewives from the Hudson River, 1998. The solid line is a regression fit to the data and the dashed lines are 95% confidence intervals.

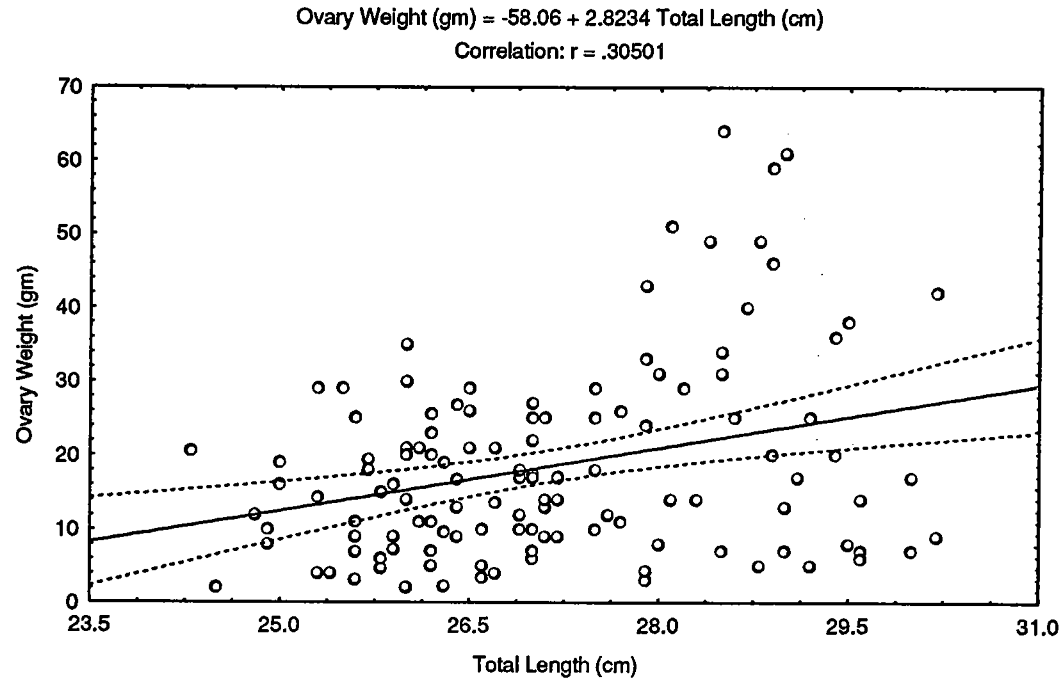


Figure 6. Ovary weight-total length relationship for female Hudson River alewives, 1998. The solid line is a regression fit to the data and the dashed lines indicate the 95% confidence interval.

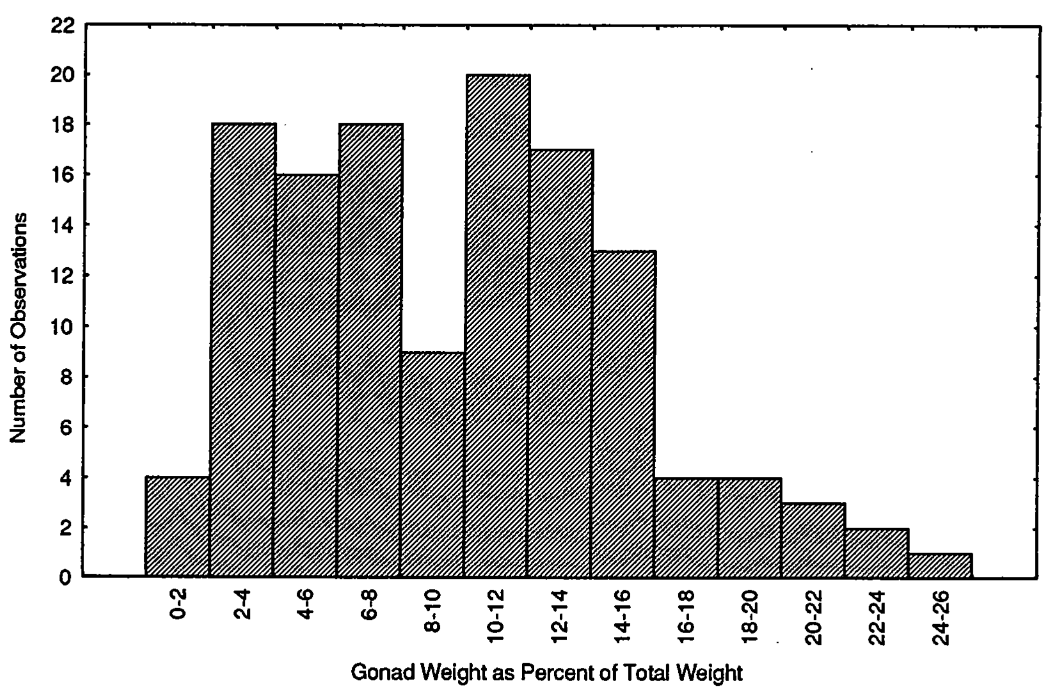


Figure 7. Frequency distribution of total ovary weight (expressed as percent of total body weight) for female alewives from the Hudson River, 1998.

Fecundity

Examination of alewife ovaries revealed the presence of two sizes of eggs in most females, an observation previously reported for the Hudson (Lake and Schmidt, 1998) and observed in many other populations (Jessop, 1993 and references therein). Larger eggs were about 0.96-1.1 mm diameter (after preservation in 50% isopropanol) and smaller eggs were about 0.6-0.8 mm. Larger eggs were often loose in the ovaries and were clearly ready to be spawned. These eggs were golden in color in living alewives and could easily be extruded with slight pressure on the abdomen ("running ripe" females). The smaller eggs were attached to membranes in the ovary, were whitish in living females and could only be extruded with substantial pressure ("green" females) and therefore we considered these smaller eggs as not ready for spawning at time of capture. Females with very small ovaries and small eggs could be considered "spent" by the same logic.

Categorizing females by using these standard terms, however, confounds understanding of the reproductive physiology of these fish. Estimates of fecundity for the three different size classes of ovaries (Fig. 7) showed that the number of large eggs in large ovaries (mean = 50,893) was the same as the number of large eggs in medium ovaries (mean = 53,951) but both had many more large eggs than alewives with small ovaries (mean = 2,615). Small eggs wre found in about equal numbers in all ovaries (Fig. 8). A 3X2 ANOVA showed significant differences in numbers of eggs in different size ovaries ($F_{2,32} = 6.299$, $p = 0.0049$) but no significant difference between number of large eggs vs number of small eggs ($F_{1,32} = 3.644$, $p = 0.0653$) although close to being significant. The interaction term, egg size by ovary size was significant ($F_{2,32} = 12.529$, $p = 0.0001$). This is due to the distribution of large eggs, alewives having comparatively few large eggs in small ovaries (Fig. 8).

These observations can be explained by assuming that alewives are iteroparous-spawning twice during a season. This has been hypothesized for other alewife populations (Kissel, 1974). In the Hudson, we interpret individuals with the largest ovaries as those that have not spawned yet that season. These individuals have a large number of ripe eggs (mean = 50,893, range 38,876-56,994) and were seen in this study throughout the spawning season.

Female alewives with medium size ovaries have a substantial number of ripe eggs (mean = 53,951, range 30,075-93,592). We interpret these mature eggs as probably a second batch recruited from the smaller size class of eggs originally present in the ovary. The small eggs present either did not mature or were, in turn, recruited from the microscopic previtellogenic oocytes present in clupeid ovaries, or probably both since the numbers of small eggs in large ovaries are less than the large eggs in medium ovaries.

Alewives with small ovaries have few large eggs (mean = 2,615, range 0-20,713, but see Fig. 8) but may have substantial numbers of small eggs (mean = 28,089, range 6,756-70,285). We interpret these individuals as having spawned probably twice already in the season. The small eggs will not mature until the next year when many of the females will have recruited more eggs from the previtellogenic oocytes. It is unclear why these females are found entering tributaries with more mature individuals, other than they may be schooling with the other alewives and are simply following the crowd.

Few females in either Canterbury Brook (14.0%) or the Moordener Kill (0%) could be categorized as spawning for the first time. In fact, the majority (55.2%) of female alewives in the Moordener Kill were spent whereas 20.9% of the females in Canterbury Brook were spent

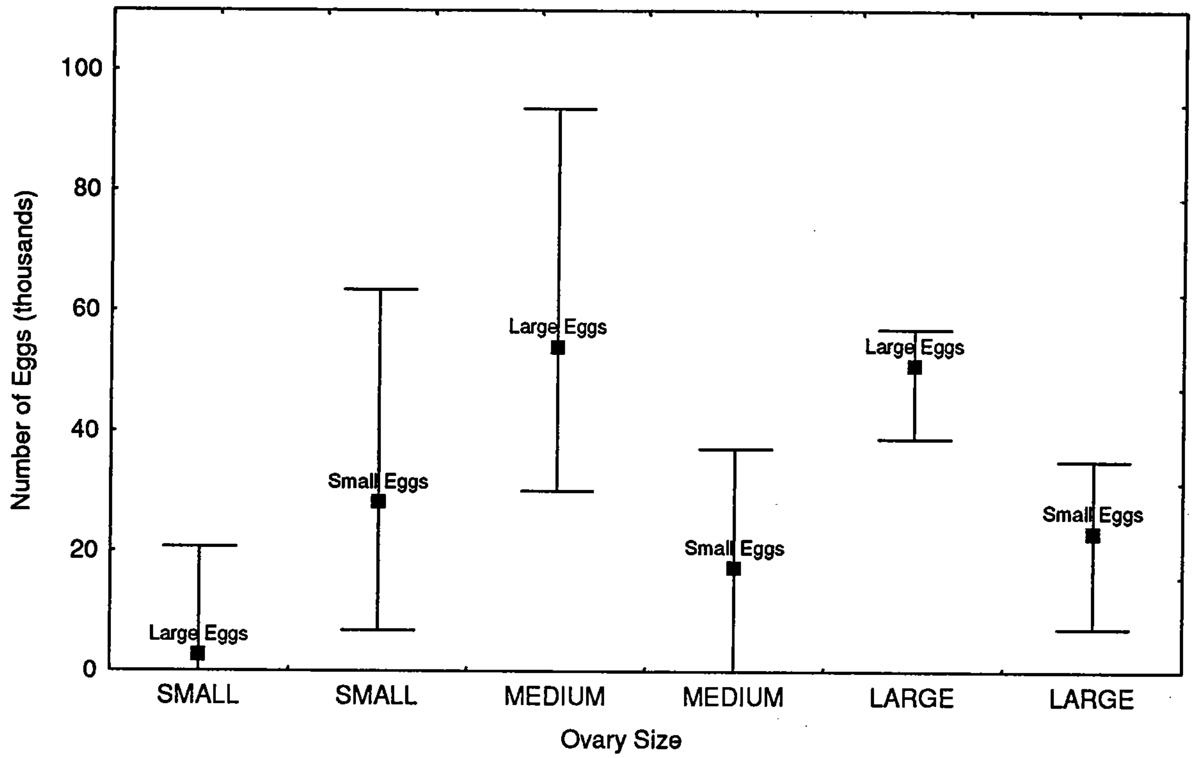


Figure 8. Mean (solid square) and range of number of eggs of two sizes present in three categories of alewife ovary size from the Hudson River, 1998.

fish. This implies that most or all of the alewives entering these two tributaries had spawned elsewhere already, and perhaps twice. They may have spawned in the main estuary or spawned earlier in tributaries further south (although we have no evidence of substantially earlier spawning in other tributaries). A second implication is that we need to adjust our calculations of egg import into tributaries based on the proportions of ovary sizes in the runs.

Larval Drift

We collected 9032 fish eggs and larvae in the Moordener Kill and 2641 fish eggs and larvae in Canterbury Brook (Tables 3 & 4). The species composition of the drift samples was generally similar to other studies (Limburg and Schmidt, 1990; Schmidt and Stillman, 1993; Lake and Schmidt, 1998) in that we collected alewife eggs and larvae as well as early life stages of common potamodromous species (white perch, white suckers, and smallmouth bass).

We collected a single smelt larva in the Moordener Kill. This anadromous species is rarely seen in Hudson River tributaries, although there were large runs historically in the system. We caught few spottail shiner larvae and neither of us saw any adults in our two study streams. This observation follows a current trend of observations (or rather the lack of observations) of spottail shiners in habitats where previously they were abundant.

Table 3. List of species collected and numbers of individuals in drift nets from the Moordener Kill, Hudson River, 1998. Week 1 in this table was April 6-12.

Species & Life Stage	Week, 1998 1	2	3	4	5	6	7	8	9	10	Total
Alosa pseudoharengus											
Egg	-	-	4	-	918	970	53	1	1	-	1947
Yolk sac	-	1	-	-	17	2	1213	28	-	-	1261
Morone americana											
Egg	-	-	-	-	1224	942	59	1	2	-	2228
Yolk sac	-	-	4	-	19	109	3081	1	9	-	3223
Pimephales promelas											
Yolk sac	-	-	-	-	1	2	165	29	2	1	200
Unidentified*											
Egg	1	-	5	-	11	79	5	3	-	-	104
Notropis hudsonius											
Yolk sac	-	-	-	-	-	-	-	28	-	2	30
Etheostoma olmstedi											
Yolk sac	-	-	-	-	7	8	3	5	-	-	23
Catostomus commersoni											
Post Yolksac	-	-	-	1	4	6	-	-	3	-	14
Osmerus mordax											
Yolk sac	-	-	1	-	-	-	-	-	-	-	1
Micropterus dolomieu											
Yolk sac	-	-	-	-	-	-	-	-	1	-	1
Total	1	1	14	1	2201	2118	4579	96	18	3	9032

*Most of these eggs were Cyprinidae and are probably *Pimephales promelas.*

The presence of a substantial number of fathead minnow larvae in the Moordener Kill reflects the growing distribution and abundance of this exotic species in the Hudson. The single four-spine stickleback larva collected in Canterbury Brook is the first specimen we have seen in the drift in the Hudson River.

White perch are frequently the second most abundant species in drift samples (Limburg and Schmidt, 1990; Lake and Schmidt, 1998). In Canterbury Brook, we caught surprisingly few white perch early life stages, in fact fewer than either white suckers or tessellated darters. The Moordener Kill showed the opposite pattern, our samples had almost twice as many white perch as alewives. White perch do not enter some tributaries because of barriers that alewives can pass (Schmidt and Stillman, 1993) but otherwise we know very

Table 4. List of species collected and numbers of individuals in drift nets from Canterbury Brook, Hudson River, 1998. Week 1 in this table was April 6-12.

Species & Life Stage	Week, 1998 2	3	4	5	6	7	8	9	Total
Alosa pseudoharengus									
Egg	4	14	-	634	78	947	28	-	1705
Yolk sac	-	-	-	-	-	1	802	8	811
Morone americana									
Egg	-	-	-	-	-	5	-	10	15
Yolk sac	-	1		-	-	-	-	-	1
Etheostoma olmstedi									
Yolk sac	-	-	-	1	-	11	1	37	50
Catostomus commersoni									
Egg	-	-	-	1	1	-	-	-	2
Post yolksac	-	-	-	2	-	-	1	21	24
Unidentified									
Egg	-	1	-	8	-	1	12	-	22
Notropis hudsonius									
Yolk sac	-	-	-	-	-	-	-	10	10
Apeltes quadracus									
Yolk sac	-	-	-	-	-	-	-	1	1
Total	4	16	0	646	79	965	844	87	2641

little about the distribution of spawning effort of this important potamodromous species.

In both tributaries, the peak of alewife egg and larval abundance correlated well with the peak catches of adult alewives (Fig. 2). Drift of alewife and white perch early life stages was highest in the three weeks of May 5 through May 25 in the Moordener Kill (Table 3) whereas the peak abundance of alewife early life stages in Canterbury Brook extended over four weeks and began the week of April 29 (Table 4).

Total export of alewife eggs and larvae from Canterbury Brook was calculated as $6.8X10^6$ individuals and export from the Moordener Kill was $2.4X10^7$ (Table 5). The numbers of alewives exported from these two tributaries are then in the middle and upper third, respectively, of tributaries thus far examined (Schmidt and Stillman, 1993; Lake and Schmidt, 1998).

Table 5. Estimated export of alewife early life stages in the Moordener Kill and Canterbury Brook, Hudson River, 1998. Week 1 was April 6-12, 1998.

	Moordener		Canterbury	
Week	Eggs	Yolk sac	Eggs	Yolk sac
1	$9.7X10^3$	-	No Sample	No Sample
2	-	$1.8X10^4$	$1.3X10^4$	-
3	$1.7X10^4$	-	$9.9X10^4$	-
4	-	-	-	-
5	$7.5X10^6$	$2.1X10^5$	$1.3X10^6$	-
6	$9.6X10^6$	$1.6X10^4$	$4.7X10^5$	-
7	$1.8X10^5$	$5.8X10^6$	$3.0X10^6$	$4.0X10^3$
8	$1.1X10^4$	$4.1X10^5$	$5.2X10^5$	$1.9X10^6$
9	$2.4X10^3$	-	-	$1.7X10^4$
Total	$1.7X10^7$	$6.4X10^6$	$4.9X10^6$	$1.9X10^6$
Grand Total	$2.4X10^7$		$6.8X10^6$	

Egg and Larval Mortality Rates

We estimated that $3.7X10^7$ alewife eggs were released into Canterbury Brook in 1998. Compared to our estimates of egg and larval export (Table 5), we could account for only 18.4% of the total eggs laid. If we assume that this difference is due to mortality of eggs, than mortality is 81.6% in Canterbury Brook, very similar to the mortality rate (77%) we saw in Quassaic Creek using the same methods (Lake and Schmidt, 1998).

In the Moordener Kill, we estimated egg deposition to be almost the same as in Canterbury Brook ($3.9X10^7$) despite a run estimated as 5 times as large in the Moordener Kill. The percentage of female alewives in the Moordener Kill was much lower than in Canterbury Brook and more than half of those females were completely spent. Comparing the estimated egg deposition to our catches in the drift nets (Table 5), we were able to account for 61.5% of the eggs deposited; a mortality rate of only 38.5%.

Examining the alewife runs from the three tributaries for which we have comparable data, Canterbury Brook and Quassaic Creek are very similar in gender ratios, amount of egg deposition, and estimated mortality rates. This is reasonable since the these two tributaries are within 2 miles of each other on the western shore of the estuary. The alewife run in the Moordener Kill differs greatly from these other two tributaries in gender ratio, degree of ripeness of the females, and estimated mortality rates of the eggs. Limited data from two other tributaries in the northern end of the estuary (Coxsackie Creek and the Poesten Kill) show characteristics similar to the Moordener Kill. More observations are necessary to make a hypothesis that northern tributaries differ significantly from those in the middle of the Hudson estuary.

Aging

We examined the scales of 110 alewives, 62 males (23.3-30.8 cm TL) and 48 females (24.3-30.3 cm TL). Ages ranged from III+ to VIII+, the latter being the largest female examined (Table 6). There was considerable overlap in size among age groups within genders (Table 6). Females were slightly larger on average than males within age groups, but there was no difference between genders in the maximum age attained (except the single large VIII+ female).

The modal age for males was V+ and females was IV+, but the individuals to be aged were not chosen at random and therefore these observations may not represent the structure of the population. We observed spawning marks on 9 individuals (8.2% of the alewives aged), 7 females (14.6% of the females aged) and 2 males (3.2%).

We examined otoliths from 21 alewives (17 males and 4 females) and compared ages derived from the otoliths to those derived from scales from the same individuals. There were only two instances where our otolith ages disagreed with the scale ages (better agreement than reported by Libby, 1985); one 27.0 cm female was aged at V+ by her scales and IV+ by the otolith and one 28.0 cm male was aged at V+ (with a spawning mark) by his scales and VI+ by his otolith. It appears that these two aging methods give the same results for Hudson River alewives.

Hudson River alewives appear to be smaller in general and smaller at a given age than alewives in more northern populations. Libby (1982), Kissel (1974), and Havey (1973) quoted average sizes of males bewtween 29-31 cm and females between 30-32 cm, sizes barely attained by a few Hudson River individuals. In Maine, a few individuals reach IX+ years (Libby, 1981 and Walton, 1983) whereas we saw only one fish at VIII+. Average size at age was higher for each age in Maine (Libby, 1981 and Walton, 1983) than in our data (Table 6).

Magnitude of the Alewife Runs in Hudson River Tributaries

Originally we had intended to try to compare alewife runs in lightly sampled tributaries to those we had sampled more thoroughly. One method we tried examining was to compare catch per unit effort at given times to similar measures in our thoroughly sampled tributaries. However, our catch per unit effort data don't seem to be adequate for making population estimates. Catches in lightly sampled tributaries appear to be very uniform among streams that subjectively we feel should have widely varying magnitudes of alewife runs.

We have a smaller data set of 17 tributaries where alewife early life stages were collected in drift nets (Limburg and Schmidt, 1990; Schmidt and Stillman, 1993; Lake and Schmidt, 1997). These tributaries could be compared with Canterbury Brook, the Moordener Kill, and Quassaic Creek (Lake and Schmidt, 1997) where independent estimates of the size of the run are also available.

Now that we have seen, however, that the gender ratios, proportion of spent females, and probably mortality rates vary considerably among tributaries, calculating population size without having good knowledge of these variables seems unrealistic. There are some

Table 6. Distribution of ages and mean and range of sizes at age by genders for Hudson River alewives, 1998.

Males			
Age	Average TL	Range TL	N
III+	25.0	23.3-26.8	16
IV+	26.0	24.2-27.6	18
V+	26.6	25.3-28.0	16
VI+	27.7	26.0-29.2	9
VII+	29.2	28.0-30.8	3

Females			
Age	Average TL	Range TL	N
III+	24.9	24.3-25.3	6
IV+	26.1	24.2-27.9	19
V+	27.2	26.0-28.6	13
VI+	28.6	27.2-29.5	4
VII+	29.7	29.4-30.2	5
VIII+	30.3	-	1

indications in our data that those variables may be consistent among subsets of Hudson River tributaries (northern vs more southern ones) so we have elected to wait to estimate run sizes from drift data to see if more observations might allow us to make subregional generalizations.

DISCUSSION

Our observations in spring 1998 coupled with other previous studies has allowed us to develop the following hypothesis(es) of the life history of alewives in the Hudson River estuary. Hopefully, studies that are proposed for the 1999 spring season will be able to test some of these ideas.

Adult alewives enter the Hudson River estuary in late March or early April. There is some evidence that a portion of the adult population is resident in the freshwater section of the estuary (Limburg, 1998). Individuals begin entering tributaries soon after they enter the estuary, but these are mostly males (Lake and Schmidt, 1997 and 1998). The largest tributary runs occur in mid-May. At that time, most of the females have already spawned once