GRANT #
016/99A

ironmental Research and Education Technology for Conservation

Hudsonia

a non-profit institute

Alewives in Hudson River Tributaries, Two Years of Sampling

Final Report

to

The Hudson River Foundation

by

Robert E. Schmidt and Thomas R. Lake
Hudsonia Limited
Bard College, Annandale, NY 12504

April 3, 2000

ABSTRACT

The river herring observed in Hudson River tributaries in 1998 and 1999 were almost all alewives. We documented alewife runs in 18 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. The run of 1442 alewives in Coxsackie Creek occurred the same week as the previous in 1999. The small run (217) in Lattintown Creek was bimodal which may be related to a dip intributary water temperature.

Gender ratios were very different among the tributaries examined; Canterbury Brook had 55% females, the Moordener Kill had 23% females, Lattintown Creek had 37%, and Coxsackie Creek had 18.4%.

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. Lattintown Creek had numbers similar to the Moordener Kill with 46.1% second spawners and 46.2% of the famales being spent. Coxsackie Creek had the fewest spawning females (18.2% were second spawners) and the remainder were spent (81.8%).

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%. Estimates of egg deposition in Lattintown Creek and Coxsackie Creek were also very similar ($2.3X10^6$ and $2.6X10^6$, respectively) and an order of magnitude lower than the tributaries sampled in 1998. This may be a result of a generally poor alewife year in 1999.

In 1999, our estimates of mortality varied widely from 98.6% in Lattitown Creek to having estimated more eggs and larvae in the drift than were spawned in Coxsackie Creek. We have felt that our estimates of the numbers of adults were conservative and we think that our observations in 1999 confirm that netting adults is inefficient.

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.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

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 and 2) 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 and 2). 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 in 1998. Lattintown Creek (Fig. 2) in Ulster County (RM 69) and Coxsackie Creek in Greene County (RM 127) were similarly sampled in 1999. One of the purposes for sampling these streams was to estimate the magnitude of the alewife run. The other tributaries (Fig. 1 and 2) 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- TL, to the nearest mm). Catch per unit effort (CPUE) was defined as the number of individuals caught per net hour. In Canterbury Brook and Lattintown Creek, 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. Coxsackie Creek was fished on Monday evenings during drift net sampling (see below) thus alternately sampling high and low tides and also was fished at a daytime high tide each week.

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. In 1998, 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, the Moordener Kill, Lattintown Creek, and Coxsackie Creek, we also, at least weekly, sampled the drift for early life stages of fishes. 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 retrieved 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 (Swoffer current meter), and took a depth and velocity transect over the width of the stream to estimate discharge. In the laboratory, fish eggs and larvae were sorted out of the samples, identified as

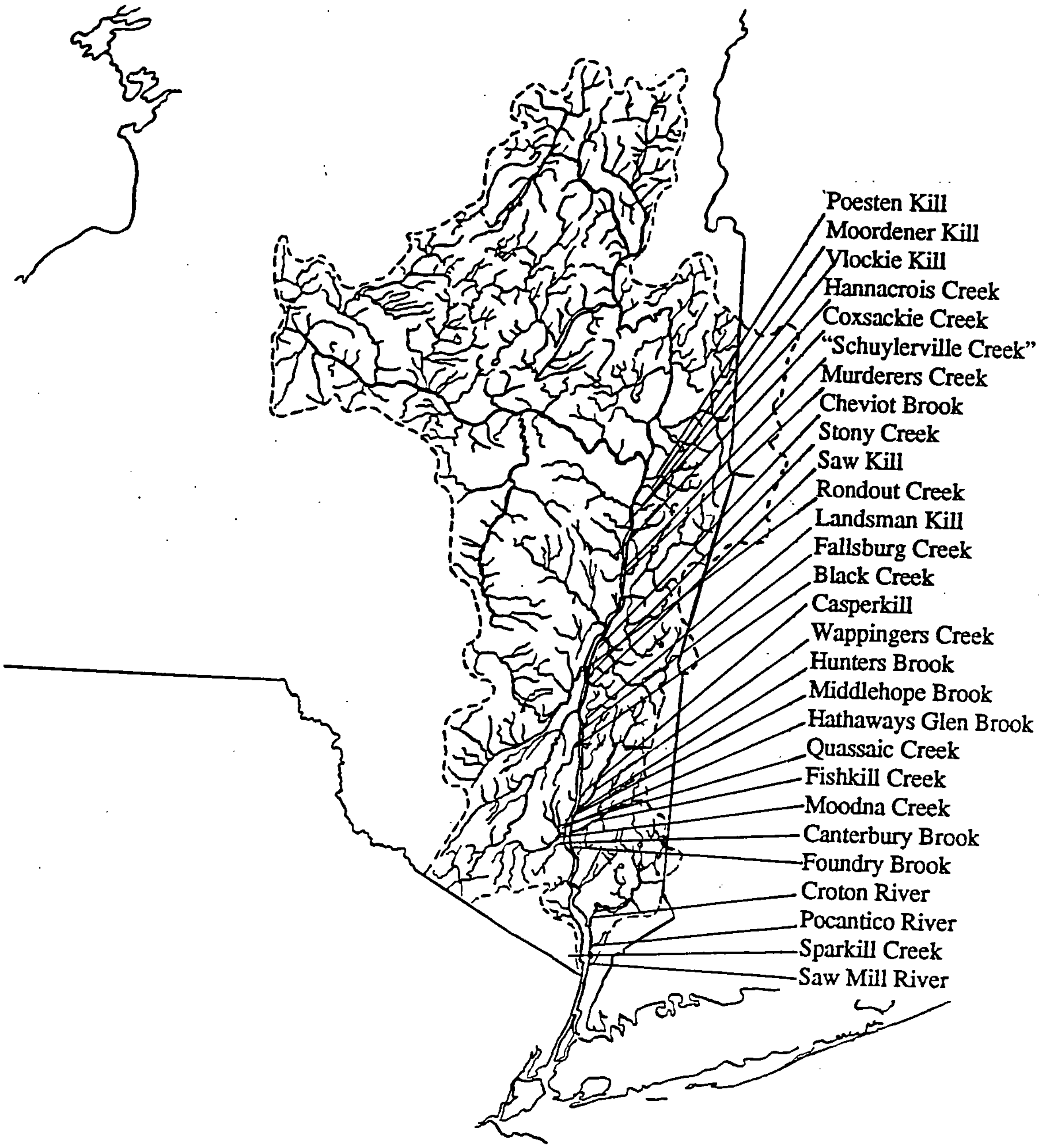


Figure 1. Map of the Hudson River estuary showing locations of tributaries sampled for river herring in 1998.

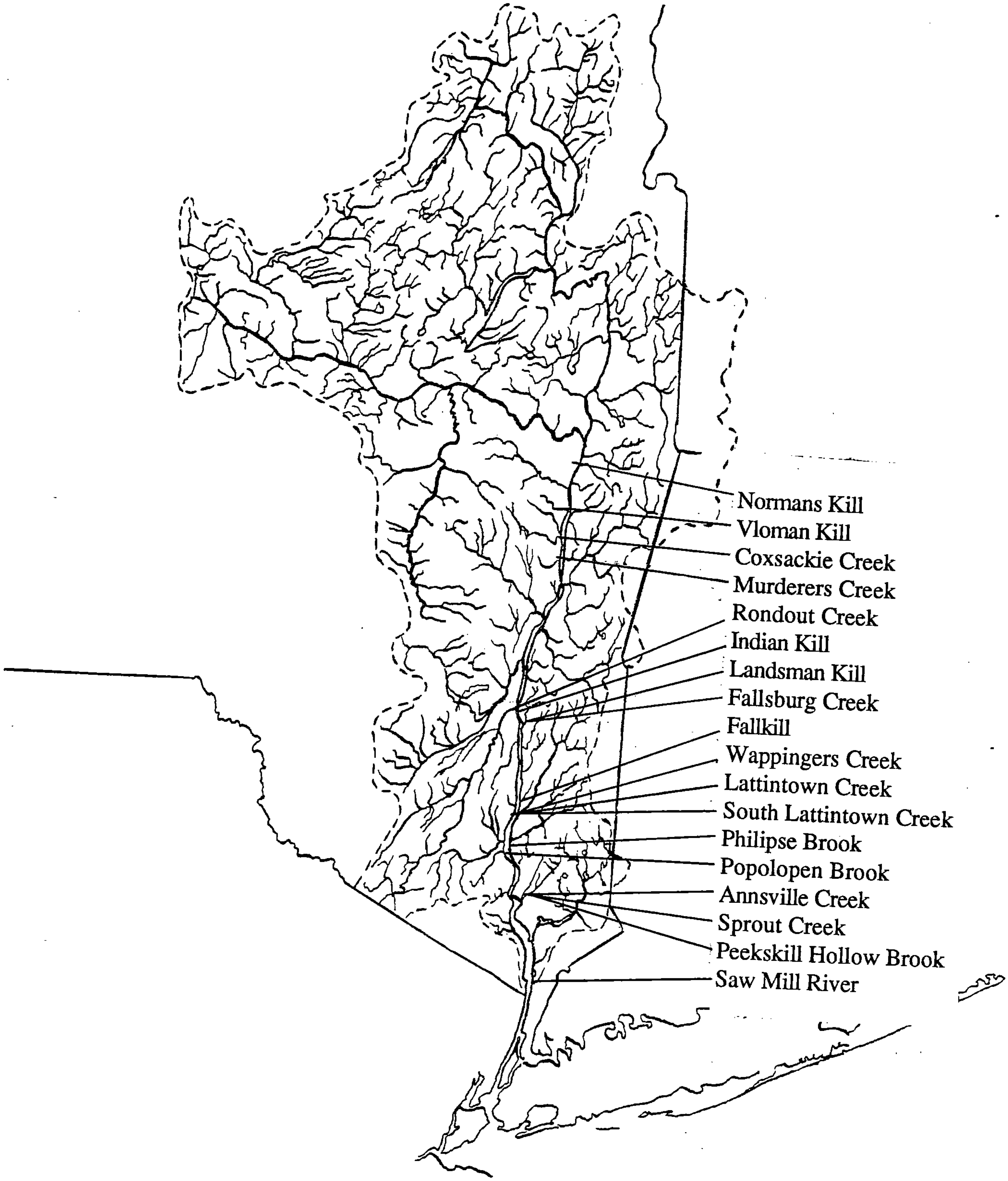


Figure 2. Map of the Hudson River estuary showing locations of tributaries sampled for river herring in 1999.

far as was practical, and counted.

The magnitude of the alewife runs was 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, on days we did not sample, could be predicted from the preceeding sample. CPUE was divided 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 from 1998 data 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 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 from 1998 fish 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 38 different tributaries of the Hudson River (Table 1). We collected river herring in 28 of these tributaries. Most of the river herring collected were alewives (*Alosa pseudoharengus*). Rondout Creek, the Poesten Kill, and the Normans Kill had the highest percentage of blueback herring (*Alosa aestivalis*) present (Table 1), but note that very few herring were seen in the latter tributary. Of the blueback herring we caught in the tributaries, few were females. Blueback herring probably are spawning in the Rondout, Catskill Creek (R. Simmons, Normandeau Inc., *pers. comm.*), and the Poesten Kill, but we suspect that their numbers are small. We conclude that virtually all of the reproducing river herring in Hudson River tributaries in general are alewives.

Fifteen of the tributaries sampled were either listed in Schmidt and Cooper (1996) as "herring runs not documented" (Normans Kill, Moordener Kill, Murderers Creek, Cheviot Brook, Fallkill, Lattintown Creek, South Lattintown Creek, Hunters Brook, and Middlehope Brook [listed as "Roseton Brook" in Schmidt and Cooper, 1996], Popolopen Brook, Sprout Brook, and Annsville Creek) 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 documented alewife runs in fifteen 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, Indian Kill, 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 1653 individuals of 28 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 and Lattintown Creek. A second potamodromous species, white sucker, was seen in greater abundance than alewives in Lattintown Creek. Thirteen species were seen in Canterbury Brook, eight in the Moordener Kill, 17 in Lattintown Creek, and 13 in Coxsackie Creek. 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.

Table 1. List of river herring catches in Hudson River tributaries, 1998-1999. River Mile (RM) is the number of miles north of the Battery in Manhattan. An asterisk (*) indicates tributaries that were sampled intensively.

Tributary		RM	# River Herring	% Alewives	CPUE
Saw Mill River	1998	18	0	-	-
	1999		0	-	-
Sparkill Creek	1998	24.5	0	-	-
Pocantico River	1998	28	0	-	-
Croton River	1998	34	0	-	-
Annsville Creek	1999	43.5	1	100.0	0.1
Peekskill Hollow	1999	43.5	1	100.0	0.2
Sprout Brook	1999	43.5	2	100.0	0.1
Popolopen Brook	1999	46.5	1	100.0	0.1
Philipse Brook	1999	51.5	0	-	-
Foundry Brook	1998	53	0	-	-
*Canterbury Brook	1998	58	200	99.5	1.3
Moodna Creek	1998	58	8	100.0	0.4
Fishkill Creek	1998	60	16	100.0	0.7
Quassaic Creek	1998	60	13	100.0	0.8
Hathaways Glen Brk	1998	63	20	100.0	0.7
Middlehope Brook	1998	65	25	100.0	7.1
Hunters Brook	1998	67.5	6	100.0	0.5
Wappingers Creek	1998	67.5	20	100.0	1.2
	1999		5	100.0	1.0
*Lattintown Creek	1999	68.5	48	100.0	<0.01
S. Lattintown Crk.	1999	68.5	3	100.0	0.1
Casperkill	1998	69	17	100.0	0.7
Fallkill	1999	75.5	11	100.0	4.4
Black Creek	1998	85	28	100.0	7.0
Indian Kill	1999	85	0	-	-
Fallsburg Creek	1998	87.5	0	-	-
	1999		0	-	-
Landsman Kill	1998	87.5	0	-	-
	1999		0	-	-
Rondout Creek	1998	92	37	75.7	2.5
	1999		57	82.4	8.1
Saw Kill	1998	98	1	100.0	0.7
Stony Creek	1998	99.5	0	-	-
Cheviot Brook	1998	106	9	100.0	1.3

Table 1. Continued.

Tributary		RM	# River Herring	% Alewives	CPUE
Murderers Creek	1998	118	0	-	-
	1999		5	100.0	2.0
"Schuylerville Crk"	1998	123	0	-	-
Coxsackie Creek	1998	127	37	100.0	9.2
	*1999		90	100.0	1.8
Hannacrois Creek	1998	132	0	-	-
Vlockie Kill	1998	136	0	-	-
Vloman Kill	1999	137	23	95.7	10.4
*Moordener Kill	1998	137.5	88	98.9	4.3
Normans Kill	1999	140	6	50.0	2.8
Poesten Kill	1998	159	21	80.9	6.5

Timing of the Alewife Runs

In 1998 and 1999, 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. 3). Our catches in Canterbury Brook, the Moordener Kill, and Coxsackie Creek described a single peak of abundance in mid-May in the same week each year (coincidentially? - Fig. 3). 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) which looks like the pattern we saw in Lattintown Creek in 1999 (Fig. 3). We caught few alewives (total of 48), however, in Lattintown Creek, so we are reluctant to interpret those data any further.

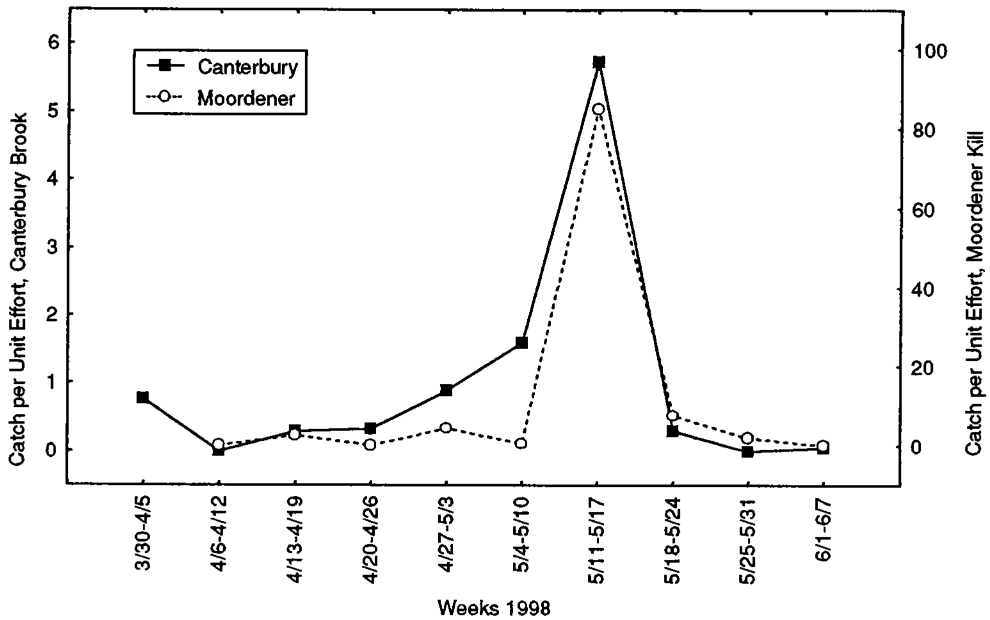
Alewife runs are reported to occur between 12-16°C (Pardue, 1983). Tributary water temperatures (Fig. 4) reached about 12°C at the end of April in 1998 and 1999 which generally coincided with an increase in catch per unit effort in our main tributaries. We did, however, see spawning (see the section on drift of eggs and larvae, below) at temperatures below the minimum (10.5°C) that was reported as 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. 3). This observation is similar to 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. In 1999, the highest catch rate in Lattintown Creek occurred two weeks prior to the highest catch in Coxsackie Creek, but, again, catches of alewives were generally low in Lattintown Creek.

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. 3). Catch rates in Coxsackie Creek were similar to those in Canterbury Brook and generally an order of magnitude higher than in Lattintown Creek (Fig. 3).

Table 2. List of species collected in gill nets in tributary mouths in 1998 and 1999. Numbers are number of individuals collected.

Species	Canterbury Brook	Moordener Kill	Lattintown Creek	Coxsackie Creek	Other Tributaries
Anguilla rostrata	-	1	-	-	6
Alosa mediocris	-	-	-	-	1
Dorosoma cepedianum	-	-	1	-	8
Carassius auratus	-	-	3	-	-
Cyprinus carpio	1	1	5	-	4
Notemigonus crysoleucas	7	2	11	21	57
Semotilus corporalis	-	-	-	-	1
Catostomus commersoni	37	2	109	27	120
Ameiurus catus	17	-	3	9	30
A. natalis	1	-	1	-	-
A. nebulosus	-	-	-	1	13
Ictalurus punctatus	-	-	-	-	1
Esox lucius	-	-	-	2	-
E. niger	4	-	1	-	2
Oncorhynchus mykiss	-	-	-	-	2
Salmo trutta	2	3	2	-	2
Fundulus heteroclitus	-	-	-	-	8
Ambloplites rupestris	-	1	6	-	24
Lepomis auritus	2	-	8	7	44
L. gibbosus	13	-	3	2	35
L. macrochirus	2	-	3	1	22
Micropterus dolomieu	-	-	-	1	6
M. salmoides	-	-	3	4	8
Pomoxis nigromaculatus	-	-	4	-	7
Morone americana	60	113	123	135	330
M. saxatilis	6	1	-	9	32
Perca flavescens	-	-	5	42	58
Stizostedion vitreum	-	-	-	-	4
Total	152	124	291	261	825



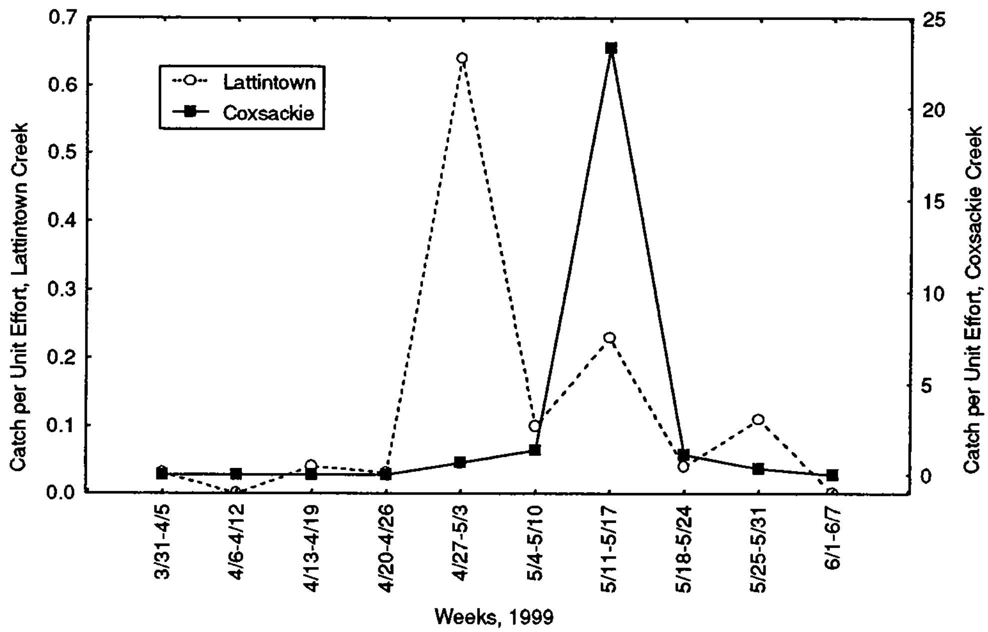
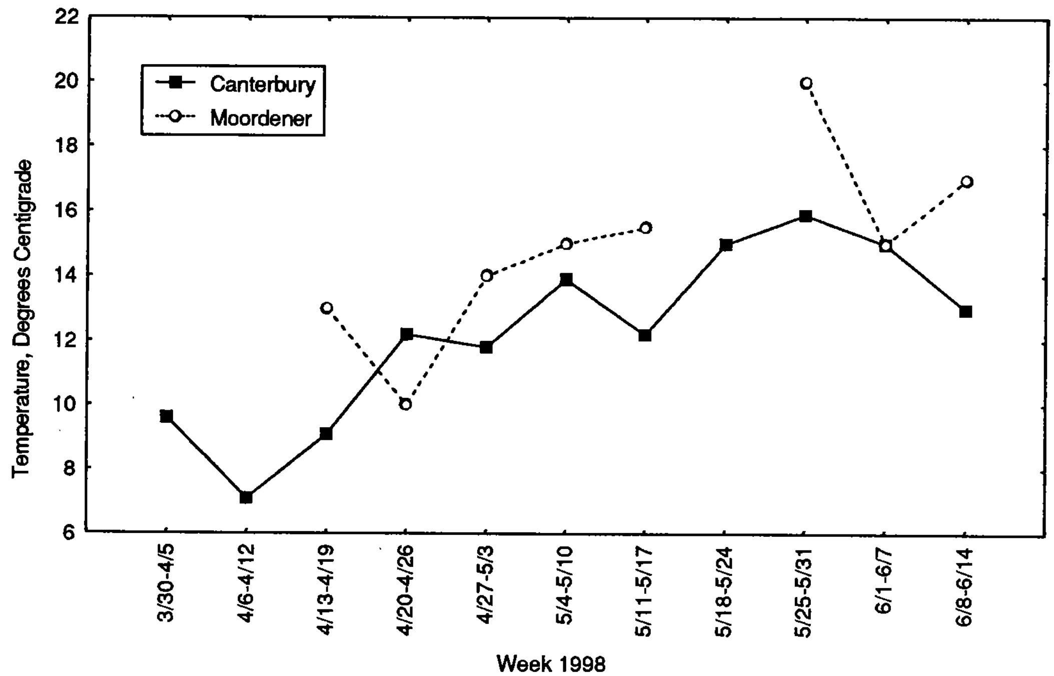


Figure 3. Upper Graph: Catch per net hour of alewives in Canterbury Brook (weekly means) and the Moordener Kill in 1998. Lower Graph: Weekly mean catch per net hour of alewives in Lattintown and Coxsackie Creeks in 1999. Note that the scales are different for each stream.



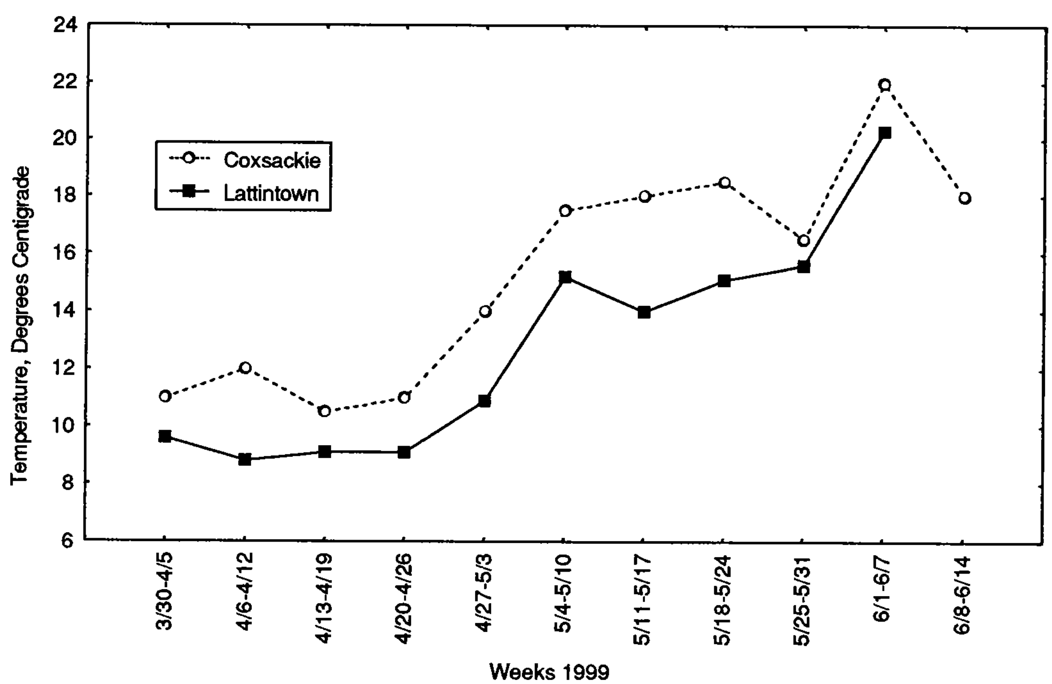


Figure 4. Water temperature in Hudson River tributaries during alewife sampling in 1998 (upper graph) and 1999 (lower graph).

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. In Lattintown Creek, catch rates were four times higher at night (0.17 alewives/net-h) than during the day (0.04 alewives/net-h) although total catches were not large in this tributary (6 and 42 alewives, respectively). In Coxsackie Creek, daytime catches (1.06 alewives/net-h) were higher than at night (0.57 alewives/net-h) but these differences were not significant (t_{12}=0.63, p=0.54).

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. 5), 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. In Coxsackie Creek, total catch rates at low tides (8.37 alewives/net-h at night) greatly exceeded catches at high tides, day or night (1.06 and 0.57 alewives/net-h, respectively). This is due to a single massive influx of alewives on May 11 during a nighttime low tide. If this single observation is ignored, low tide catches consist of a single alewife.

Characteristics of the Runs

Estimates of the size of the adult run were 1628 alewives in Canterbury Brook, 8604 alewives in the Moordener Kill, 217 in Lattintown Creek, and 1442 in Coxsackie Creek. The latter two estimates occurred in a low year for alewives.

One striking difference among the five tributaries for which we have substantial data are the gender ratios of the alewives. In Quassaic Creek and Canterbury Brook the gender ratio was 50 and 55% females, respectively. In Lattintown Creek, 37% of the alewives were females, 23% in the Moordener Kill, and 18.4% in Coxsackie Creek.

Canterbury Brook and Quassaic Creek are the only tributaries where we saw a 50:50 gender ratio. All other tributaries either had more females than males (Rondout Creek, Black Creek and Casperkill) or many more males than females. An even gender ratio appears to be anomalous in Hudson River tributaries, and most tributaries have more males than females. If male alewives enter tributaries first (Lake and Schmidt, 1997 and 1998; our observations in this study) and the males hang around a given tributary for some time (our subjective idea of what is occurring), a given sample should have more males than females.

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. In 1998, females averaged 26.8 cm TL (range, 24.3-30.2) and males averaged 26.4 cm TL (24.2-30.8). In 1999, females averaged 27.5 cm TL (24.8-32.1) and males averaged 26.4 cm TL (24.0-30.0). Females should weigh more for a given length than males, especially during spawning season. Comparison of length-weight regressions by gender (Figs. 6a and 6b) supports that idea. There appears to be more scatter in the female length-weight regression (and the correlation coefficient is lower) than in the male plot (Fig. 6b), especially among the larger females.

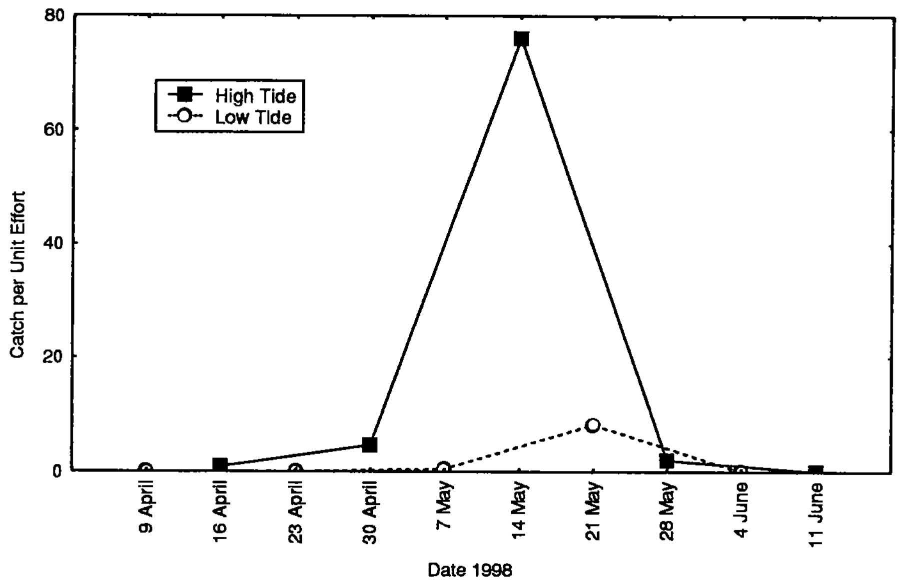


Figure 5. Alewife catch per net hour in the Moordener Kill comparing tidal stages.

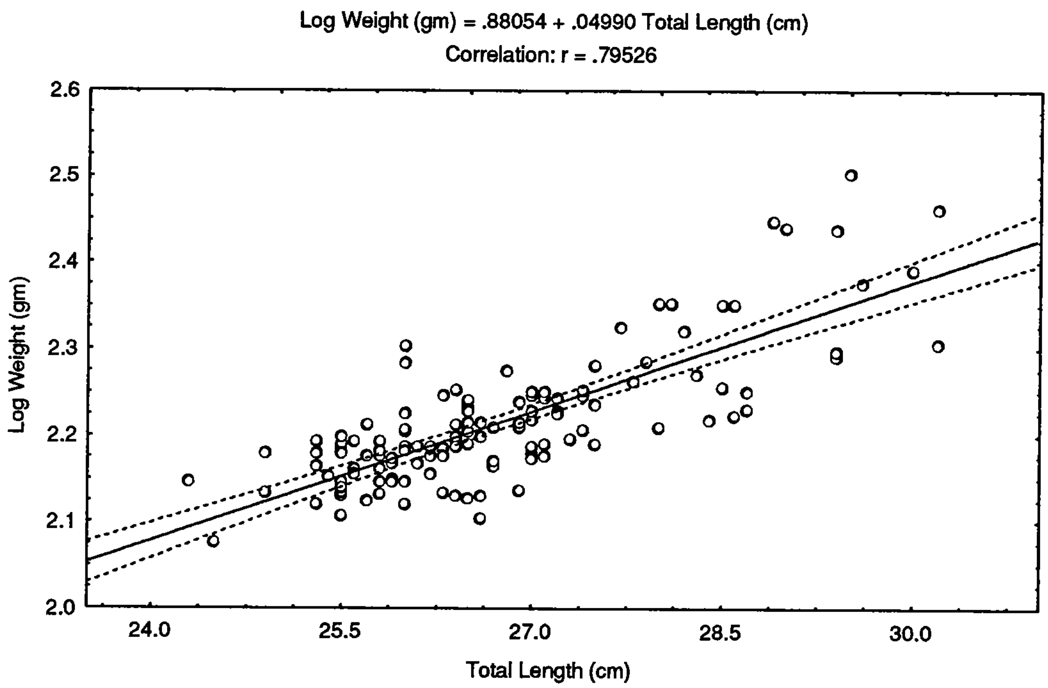


Figure 6a. Length-weight relationships of female alewives from the Hudson River,1998. The solid line is a regression fit to the data and the dashed lines are 95% confidence intervals.

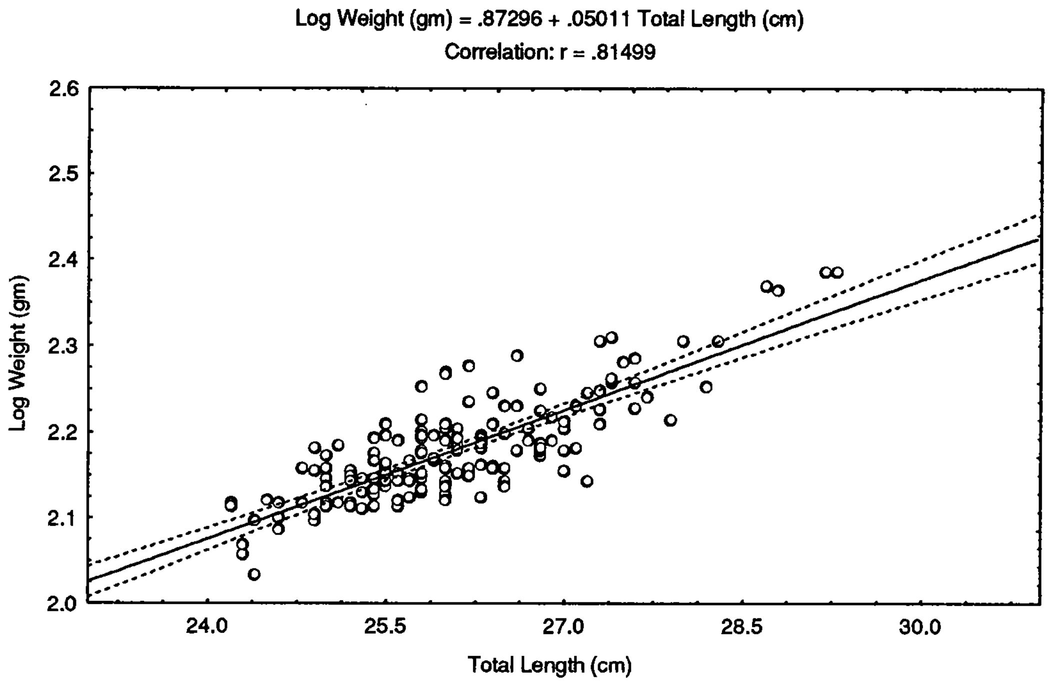


Figure 6b. Length-weight relationships of male alewives from the Hudson River,1998. The solid line is a regression fit to the data and the dashed lines are 95% confidence intervals.

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. 7) 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. 8); 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.

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

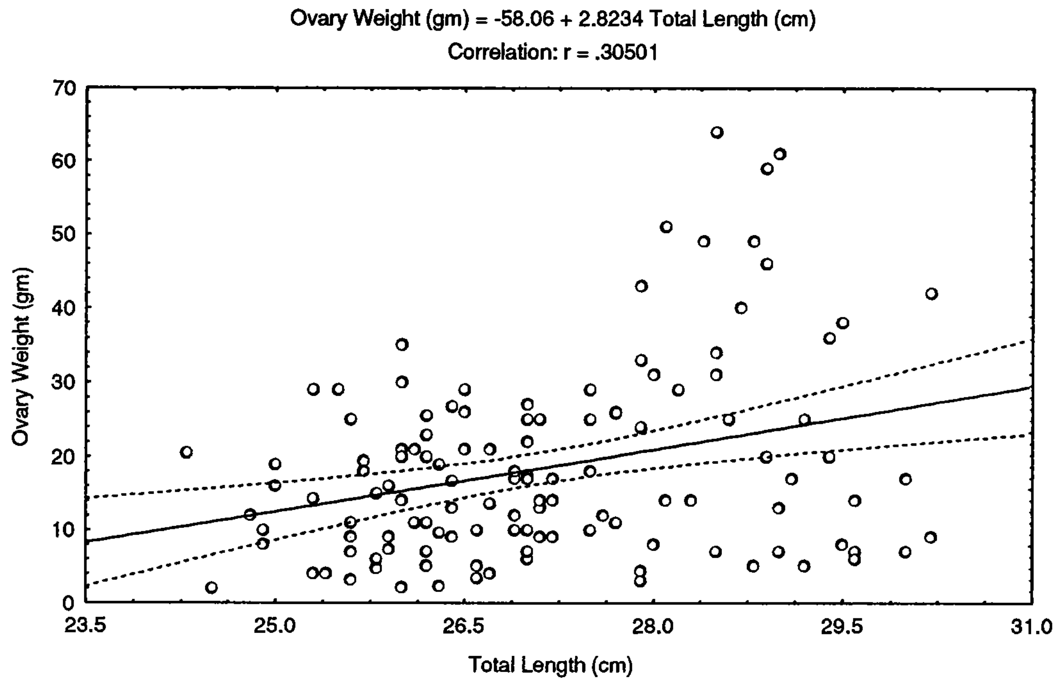


Figure 7. Ovary weight-total length relationship for female Hudson River alewives, 1998. The solid line is a regression fit to the data and the dashed lines indicate the 95% confidence interval.

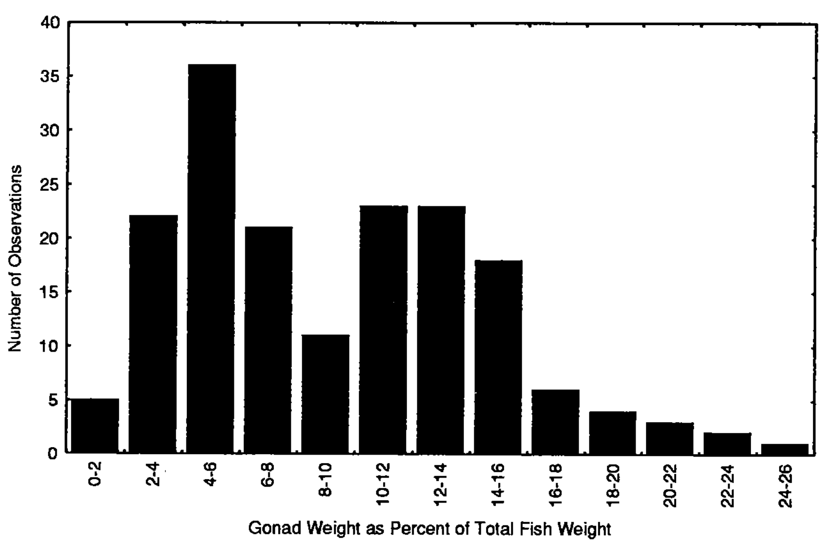


Figure 8. Frequency distribution of total ovary weight (expressed as percent of total body weight) for female alewives from the Hudson River, 1998 and 1999.

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. 9) 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. 9). 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. 9) 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 Hudson River tributaries could be categorized as spawning for the first time (Canterbury Brook- 14.0% of females, Lattintown Brook- 7.7%, and the other two tributaries had none). In fact, the majority of female alewives in the Moordener Kill (55.2%) and Coxsackie Creek (81.8%) were spent whereas 20.9% of the females in Canterbury Brook and 46.2% in Lattintown Brook were spent fish. This implies that most or all of the alewives entering these 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, 2641 in Canterbury Brook, 111 in Lattintown Brook, and 5440 in Coxsackie Creek (Tables 3-6). 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

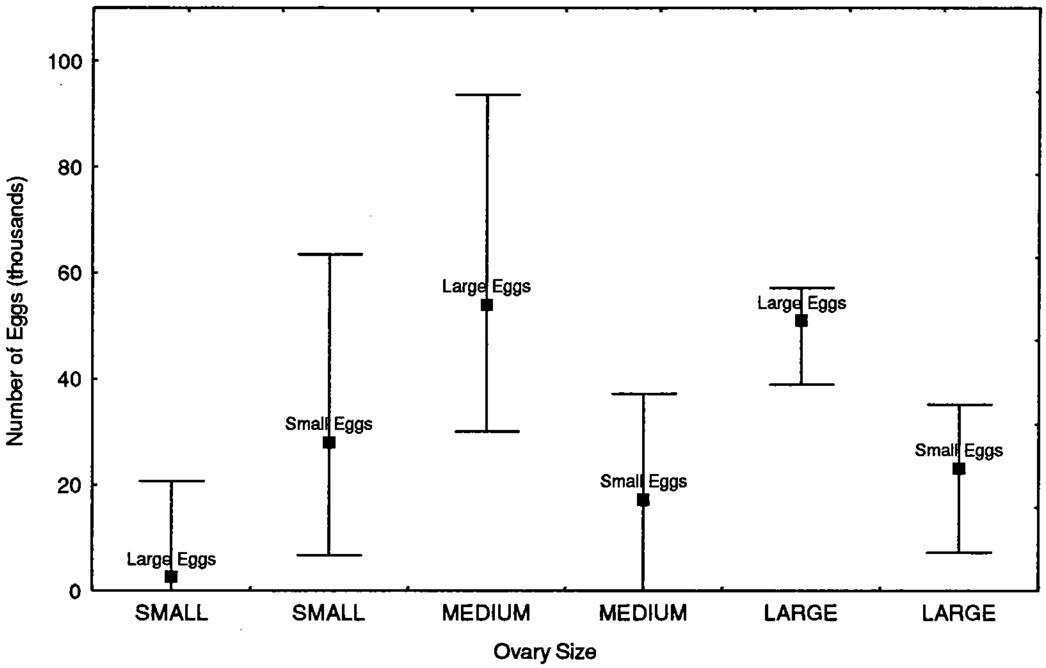


Figure 9. Mean (solid square) and range of number of eggs of two sizes present in three categories of alewife ovary size from the Hudson River, 1998.

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 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.

The presence of a substantial number of fathead minnow larvae in several of our tributaries reflects the growing distribution and abundance of this exotic species in the Hudson. The four-spine stickleback larvae collected in Canterbury Brook and Lattintown Brook are the first specimens 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 little about the distribution of spawning effort of this important potamodromous species.

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 Yolk	-	-	-	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*.

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

Table 4. Continued.

Species & Life Stage	Week, 1998 2	3	4	5	6	7	8	9	Total
Catostomus commersoni									
Egg	-	-	-	1	1	-	-	-	2
Post yolk	-	-	-	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

Table 5. List of species collected and numbers of individuals in drift nets from Lattintown Creek, Hudson River, 1999. Week 1 in this table was April 1-6.

Species & Life Stage	Week, 1999 1	2	3	4	5	6	7	8	9		Total
Alosa pseudoharengus											
Egg	-	-	-	-	-	-	5	-	-		5
Yolk sac	-	-	-	-	-	-	-	1	-		1
Notropis hudsonius											
Yolk sac	-	-	-	-	-	-	-	10	59		69
Post yolk	-	-	-	-	-	-	-	5	-		5
Etheostoma olmstedi											
Yolk sac	-	-	-	-	-	5	6	2	2		15
Pimephales promelas											
Yolk sac	-	-	-	-	-	-	8	-	3		11
Apeltes quadracus											
Post yolk	-	-	-	-	-	-	1	2	-		3
Anguilla rostrata											
Elver	-	-	-	-	-	1	-	1	-		2
Total	0	0	0	0	0	6	20	21	64	ns	111

Table 6. List of species collected and numbers of individuals in drift nets from Coxsackie Creek, Hudson River, 1999. Week 1 in this table was April 1-6.

Species & Life Stage	Week, 1999 1	2	3	4	5	6	7	8	9	10	Total
Alosa pseudoharengus											
Egg	-	-	-	22	359	488	101	104	226	-	1300
Yolk sac	-	-	-	2	20	1002	109	3	751	-	1887
Morone americana											
Egg	-	-	-	-	-	20	-	258	12	-	290
Yolk sac	-	-	-	-	-	538	18	-	224	-	780
Etheostoma olmstedi											
Egg	-	-	-	-	-	-	-	2	8	-	10
Yolk sac	-	-	-	-	94	171	10	1	13	37	326
Perca flavescens											
Egg	-	-	-	5	21	15	-	-	-	-	41
Yolk sac	-	-	-	80	81	66	19	-	-	-	246
Post yolk	-	-	-	-	-	2	-	-	-	-	2
Catostomus commersoni											
Egg	2	-	-	-	8	-	-	25	-	-	35
Yolk sac	-	-	-	1	35	89	-	-	-	-	125
Post yolk	-	-	-	-	45	-	1	-	-	-	46
Pimephales promelas											
Egg	-	-	-	-	-	-	-	-	50	-	50
Yolk sac	-	-	-	-	-	2	18	-	59	34	113
Post yolk	-	-	-	-	-	-	-	-	1	-	1
Unidentified											
Egg	-	-	-	-	41	33	-	4	1	1	80
Notropis hudsonius											
Yolk sac	-	-	-	-	-	1	15	1	8	13	38
Anguilla rostrata											
Elver	1	-	-	12	8	2	1	-	1	-	25
Juvenile	1	-	-	-	-	-	-	-	-	1	2
Semotilus corporalis											
Yolk sac	-	-	-	-	1	14	9	-	2	-	26
Cyprinus carpio											
Yolk sac	-	-	-	-	-	-	-	-	2	7	9
Notemigonus crysoleucas											
Post yolk	-	-	-	-	-	5	2	-	-	-	7
Fundulus diaphanus											
Yolk sac	-	-	-	-	-	-	-	-	-	1	1
Total	4	0	0	122	713	2448	303	398	1358	94	5440