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DECREASE IN LENGTH AT PREDOMINANT AGES DURING A SPAWNING MIGRATION OF THE ALEWIFE, *ALOSA PSEUDOHARENGUS*[1]

The spawning migration of the anadromous alewife, *Alosa pseudoharengus*, has been characterized by a decreasing trend in size and age. Cooper (1961) reported a trend in decreasing size in Pausacaco Pond, R.I., and Kissil (1974) found this one year in a 2-yr study at Bride Lake, Conn. A trend of decreasing size and age composition was also found in the Damariscotta River, Maine, alewife migration for the years 1977 through 1979 (Libby 1981).

Since 1977, data have been collected for length, weight, sex, age, and daily catch from the Damariscotta River commercial fishery. Analysis resulted in length-weight relationships, length, sex and age compositions, and an overall view of the annual stock changes. Further analysis of the collected data revealed that as age of the alewives decreased during migration, lengths at age also decreased with time. The analysis was applied only to 1979 and 1980 because of insufficient data in the other years.

The intent of this paper is to show the analysis and explain in greater detail this trend in decreasing length at age of an alewife migration.

The Study Area

The Damariscotta River alewife fishery is located approximately 29 km from the mouth of the river at the head of tide (Fig. 1). The river terminates at Great Salt Bay where a small outflow stream connects it with Damariscotta Lake.

Alewives are harvested with traps consisting of moveable metal bins that are set into the stream. Alewives swim into these bins which are then hoisted out of the water and the fish are dumped into a holding trough. The alewives that escape capture may pass through a fishway and

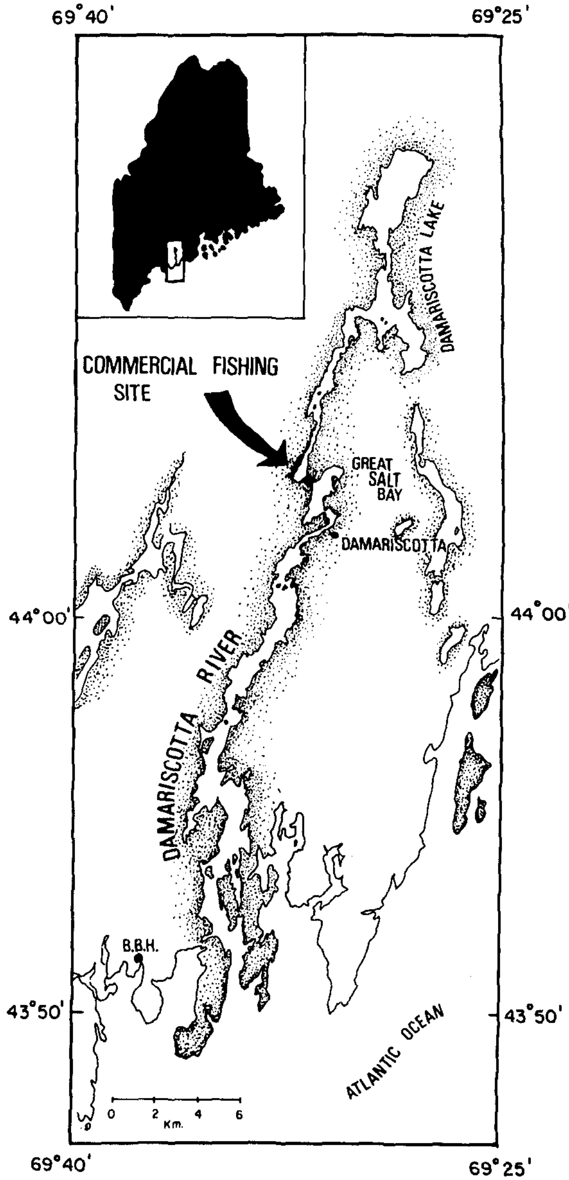

FIGURE 1.—Damariscotta River and site of the commercial alewife fishery.

[1]This study was conducted in cooperation with the U.S. Department of Commerce, National Marine Fisheries Service, under Public Law 89-304, as amended, Commercial Fisheries Research and Development Act, Projects AFC-21-1 and AFC-22-2.

into the lake to spawn. This particular fishery is one of about 30 commercially harvested alewife runs on the Maine coast and produces between 20 and 30% of the state's landings.

Materials and Methods

The method of harvesting was not considered selective of size, sex, or age of the alewives, and the catch presumably represented the true composition of the migrating stock. From previous work it was known that the size and age composition was not homogeneous throughout the run (Libby 1981), so a catch sample of fish was taken on alternate days to gain an equal representation of the total run.

Each sample consisted of 50 fish scooped from the catch in the holding trough. The sample was then brought to the laboratory and processed as soon as possible to minimize shrinkage or weight loss. Total length and weight were measured to the nearest millimeter and 0.1 g, respectively. The alewives were sexed by visual inspection of the gonads.

Otoliths were removed, cleaned, dried, and set into labeled black Plexiglas[2] trays. Watson (1965) described this procedure for mounting otoliths with the use of ethylene dichloride to fix the otoliths permanently in the trays. I prefer Permount, a histological medium that is poured over the otoliths and left to harden. If an otolith has to be repositioned, a drop of xylene will dissolve the Permount back to a liquid state. The otoliths were read with the use of a binocular microscope at a 30×-60× magnification.

Results and Discussion

The 1980 commercial harvest for the Damariscotta River lasted for 34 d, starting 4 May and ending 6 June. Fifteen daily samples were taken, each sample containing about 50 alewives totaling 365 males and 346 females. In each sample the sex ratio did not deviate significantly ($P>0.05$) based on a χ^2 test from a 1:1 ratio (Table 1). This ratio had been previously shown to be consistent from 1977 to 1979 in the Damariscotta River (Libby 1981).

In analyzing length with time, I was more concerned with similarities between the slopes of lines comparing males and females than in differences between mean lengths. Using the 1980 data as an example, females were shown to be larger than males at a given age (Table 1). A covariance analysis (Table 2) revealed no significant differences between slopes of the lines for the two sexes at the 5% level. Even though the mean length varied daily, the compared length distribution in each sample was less variable. Bartlett's test of homogeneity demonstrated no significant differences between the residual variances ($\chi^2 = 3.59$, df = 1, $P>0.05$). A t-test of significance of slope (t equals a ratio of the slope to its standard error) applied to the pooled regression coefficient showed that the slope (−0.36) was significantly different from zero ($t = 9.36$, df = 707, $P<0.05$). The influx of male and female alewives into the river follows a similar pattern regardless of their size differences. Ages throughout the 1979 and 1980 samples ranged from 3 to 8 yr for 234 males and 3 to 9 yr for 259 females and from 4 to 7 yr for 361 males and 3 to 7 yr for 344 females, respectively.

TABLE 1.—Sex ratios and mean length of 15 alewife samples taken from the 1980 Damariscotta River commercial fishery.

Date	Sex ratio M:F	No. sampled	Mean length Males	SE	Females	SE
5/6	1.3:1	50	305.0	1.7	316.2	2.2
5/8	1.0:1	50	300.4	1.8	316.6	1.6
5/12	1.1:1	50	305.2	1.7	310.2	2.0
5/14	1.2:1	50	304.1	1.6	315.4	2.3
5/16	0.9:1	37	304.4	1.6	312.9	2.2
5/18	0.6:1	50	301.6	1.8	308.5	1.6
5/20	1.2:1	50	299.9	1.5	311.0	1.4
5/22	1.4:1	50	302.0	1.4	309.0	1.8
5/24	0.8:1	50	292.7	1.8	302.0	1.7
5/26	0.9:1	50	299.3	1.5	308.3	1.8
5/28	1.3:1	50	296.3	1.7	305.9	2.5
5/30	0.9:1	50	295.7	1.7	304.2	1.8
6/1	1.1:1	45	298.0	1.9	307.7	2.2
6/3	1.2:1	44	293.4	2.2	307.2	2.3
6/5	1.5:1	35	299.0	2.7	305.3	2.4

TABLE 2.—Analysis of covariance of length by time regression for male and female alewives and test for nonzero pooled slope. Damariscotta River, 1980.

Treatment	Regression coefficient	df	Residual SS	Mean square
Males	−0.32	363	27,388.279	
Females	−0.40	344	31,754.933	
	within	707	59,143.212	83.65
Pooled	−0.36	708	59,217.604	
Difference between slopes		1	74.392	74.39
Comparison of slopes		[1]F = 0.89, df = 707	[2]P = 0.65	
Test of pooled slope coefficient		[3]B = −0.36 SE = 0.04		
		t = B/SE = 9.36		

[1]F test, ratio of mean square of difference between slopes to mean square of difference within slopes.
[2]Calculated probability, not significant at the 5% level.
[3]Pooled slope coefficient.

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Age distribution from the 1979 and 1980 samples

Age:	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Total*
1979								
Males	5	134	79	11	4	1	—	234
Females	1	115	116	22	3	1	1	259
1980								
Males	—	116	221	22	2	—	—	361
Females	2	93	211	32	6	—	—	344

Age by time regressions for the 1980 data were computed for each sex and an analysis of covariance (Table 3) revealed no significant differences between the slopes. The pooled regression like the pooled length by time regression, showed a significant slope (−0.02) at the 5% level. These two nonzero slopes (length by time and age by time) are evidence of changes in mean size and mean age throughout this alewife migration. The slope of the length trend (−0.36) is greater and significantly different from the age trend slope (−0.02) at the 5% level. The daily age composition of alewives moving to their spawning ground is a result of the fish schooling by size.

Lengths were separated into respective age categories for both years and regressions were computed of the age-length relation over time for each sex (Fig. 2). This was not done for ages three and seven through nine because of the small sample size. Ages four, five, and six were predominant, constituting over 95% of all the fish in the samples. All regressions produced negative slopes, although regressions A and B in 1979 and C and D in 1980 (Fig. 2) proved their slopes to be nonsignificant from a zero slope.

An analysis of covariance applied to all regressions in each year showed no significant differences between slopes (Tables 4, 5). Apparently

TABLE 3.—Analysis of covariance of age by time regressions for male and female alewives and test for nonzero pooled slope. Damariscotta River, 1980.

Treatment	Regression coefficient	df	Residual SS	Mean square
Males	−0.016	359	115.755	
Females	−0.021	342	137.007	
	within	701	252.872	0.36
Pooled	−0.019	702	253.127	
Difference between slopes		1	0.365	0.37
Comparison of slopes		[1]F =	1.01, df = 701	[2]P = 0.32
Test of pooled slope coefficient		[3]B =	−0.02 SE = 0.003	
			t = B/SE = 7.49	

[1]F test, ratio of mean square of difference between slopes to mean square of difference within slopes.
[2]Calculated probability, not significant at the 5% level.
[3]Pooled slope coefficient.

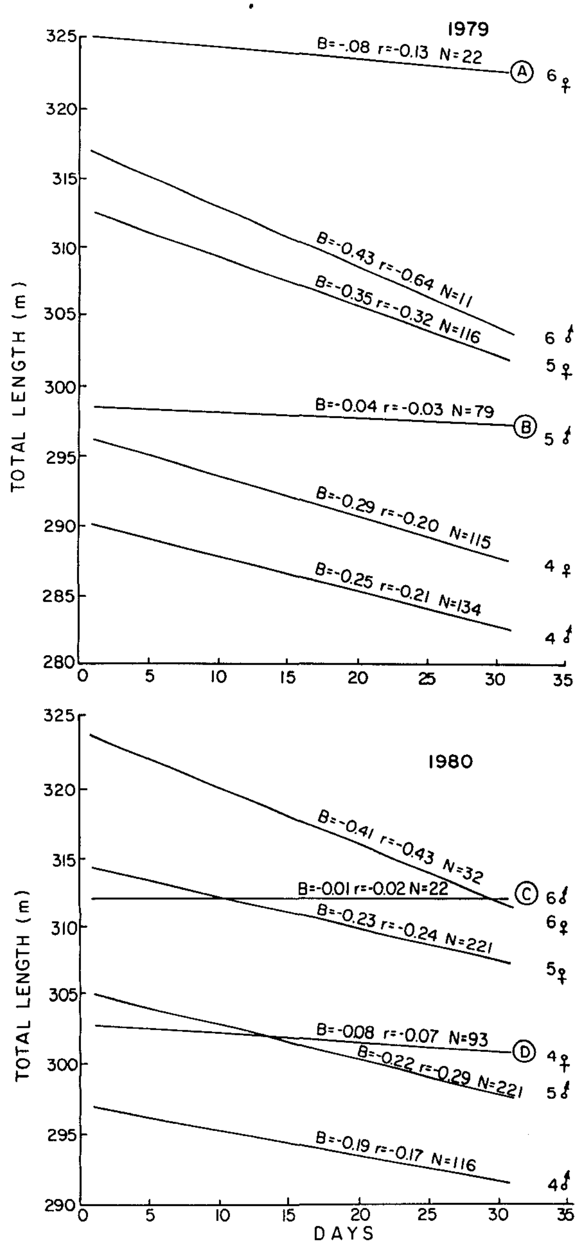

FIGURE 2.—Regressions of length at age with time from the 1979 and 1980 Damariscotta River alewife fishery.

the nonsignificant slopes still contributed to the homogeneity of the combined slopes producing significant 1979 and 1980 pooled regression slopes of −0.24 and −0.21, respectively. These results show, along with the previously observed decrease in length with time and age with time of this alewife migration, that the length of fish at age also decreases with time. The fish that arrive

TABLE 4.—Analysis of covariance of length by time regression by age and sex for alewives and test for nonzero pooled slope. Damariscotta River, 1979.

Treatment	Regression coefficient	df	Residual SS	Mean square
Male age				
4	−0.25	132	12,772.315	
5	−0.04	77	9,186.425	
6	−0.42	9	269.782	
Female age				
4	−0.29	113	11,810.600	
5	−0.35	114	11,923.360	
6	−0.08	20	996.642	
	within	465	46,959.124	100.10
Pooled	−0.24	470	47,503.000	
Difference between slopes		5	543.876	108.7
Comparison of slopes		^1F = 1.07, df = 465		^2P = 0.63
Test of pooled slope coefficient		^3B = −0.24 SE = 0.05		
		t = B/SE = 4.59		

[1]F test, ratio of mean square of difference between slopes to mean square of difference within slopes.
[2]Calculated probability, not significant at the 5% level.
[3]Pooled slope coefficient.

TABLE 5.—Analysis of covariance of length by time regressions by age and sex and test for nonzero pooled slope. Damariscotta River, 1980.

Treatment	Regression coefficient	df	Residual SS	Mean square
Male age				
4	−0.19	114	7,819.279	
5	−0.22	219	10,575.189	
6	−0.01	20	835.044	
Female age				
4	−0.08	91	5,926.716	
5	−0.24	210	14,708.805	
6	−0.41	30	1,699.554	
	within	683	41,564.587	60.86
Pooled	−0.21	688	41,824.344	
Difference between slopes		5	259.757	51.95
Comparison of slopes		^1F = 0.854, df = 683		^2P = 0.49
Test of pooled slope coefficient		^3B = −0.21 SE = 0.03		
		t = B/SE = 6.15		

[1]F test, ratio of mean square of difference between slopes to mean square of difference within slopes.
[2]Calculated probability, not significant at the 5% level.
[3]Pooled slope coefficient.

earliest are not only the largest of the migrating stock but also of the age groups.

The change in length at age is a source of bias in determining the age composition of the alewife harvest if a pooled age-length key were used. Westrheim and Ricker (1978) studied biases connected with application of an age-length key to stocks with different age compositions. Using an age-length key derived from pooled length subsamples will introduce bias in computing age composition of an anadromous alewife run. The pooled age-length key assumes homogeneity, but lengths at age change throughout the migration period. Such bias may, however, dwell within the range of acceptable error of 5% of the expected age frequencies. Chi square applied to each observed age frequency against the age-length key expected frequency, for each day sampled, indicated no significant differences between observed and expected age frequencies in the 1980 data. The magnitude of this decreasing trend in length at age may vary from year to year and stock to stock, but it is present and should be taken into account when investigating a migratory stock of alewives.

Acknowledgments

I thank David B. Sampson for his help and review of this paper, Sherry Collins for her assistance in data collecting, and James Rollins for drafting the figures.

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