DIFFERENCE IN SEX RATIOS OF THE ANADROMOUS ALEWIFE, *ALOSA PSEUDOHARENGUS*, BETWEEN THE TOP AND BOTTOM OF A FISHWAY AT DAMARISCOTTA LAKE, MAINE[1]

The Damariscotta River alewife, *Alosa pseudoharengus*, fishery has been monitored by the Maine Department of Marine Resources every year since 1971 for abundance of fish, length and weight frequencies, age distribution, and sex ratios. From 1977 through 1979, sampling plans were also devised to estimate numbers, size, and sex composition of ripe alewives escaping the fishery and entering the lake to spawn. (Throughout this paper they will be collectively referred to as escapements.)

While sampling the 1977 escapement run it became evident that a greater number of males than females were entering the lake to spawn. This male dominance was not unusual as it was reported in other alewife runs, as well. Bigelow and Schroeder (1953) stated that as a rule males greatly outnumber females on the spawning grounds. What prompted this investigation was the fact that while the escapement runs had significantly more males than females, the samples from the commercial catch revealed a consistent sex ratio of 1:1. Similar disproportionate ratios were observed in the 1978 and 1979 escapement runs, while the commercial catch ratios were 1:1 each year. In this paper I will examine these varying sex ratios and offer considerations for further investigation.

Study Area

The Damariscotta River fishery is located in the adjoining towns of Nobleboro and Newcastle and is one of the largest alewife fisheries in the state, composing about 30% of the annual total landings (Cating 1958). This area was selected for study because of the easy access to sampling both the commercial catch and the escapement run. The objectives of the study were: 1) to estimate the abundance of spawning adults, 2) to determine the escapement level which will maximize subsequent recruitment, and 3) to determine population characteristics of the Damariscotta River alewife stock such as stock size, age, distribution, and growth rates.

Damariscotta Lake, in Lincoln County, Maine, is a narrow, north-south oriented body of water 17 km long and 1,806 ha in area. There are three major outlets in a dam at the southeastern end of the lake: the first supplies water to a hydroelectric power station, the second is the main outflow controlled by two spillways, and the third is a man-made fishway. In 1803, the start of a commercial run was created (Atkins 1887), and a fishway made of stones set to form a series of irregular pools and raceways was constructed beside the main outflow. The fishway is about 150 m long with a 16 m vertical rise.

The spawning migration of this fishery's alewives consists of a 29 km swim up the Damariscotta River to head of tide at Great Salt Bay. The fish then enter the outflow of Damariscotta Lake via a tidal stream about 50 m long. The stream divides in two and the right branch becomes the entrance to the fishway. The left branch leads past two dipping bins used by the commercial fishery and then to the spillways. The spillways are opened to allow a sufficient amount of water into the stream to attract alewives into the bins. The alewives in this stream have a choice of swimming either into the left branch and the dipping bins or into the right branch and into Damariscotta Lake via the fishway.

Due to the type of construction and the lay of the embankment, the fishway is not consistent in its rise from pool to pool. The bottom and top sections are steepest, while the middle levels out, moderating the waterflow. The resting pools are of varying sizes and some of them appear to be too small, causing overcrowding of the alewives. Some of the connecting raceways are long and narrow, allowing for a faster current than is present in other raceways. The combination of a small pool and a difficult raceway lowers the efficiency of this fishway. From the appearance of alewives passing through the fishway, it is a difficult and exhausting run.

Methods

From 1977 to 1979, when escapement counts were made, a wood and wire mesh trap, 3 m long by 1.2 m wide by 0.8 m deep, was placed in the lake side of the dam at the top of the fishway. The trap's entrance covered the dam opening, where the es-

[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-18-(2,3) and AFC-21-1.

capement fish passed from the fishway into the lake. During 1977 and 1978, a stratified random sampling plan was used to estimate total numbers entering the lake. The total duration of the run was divided into successive 5-d strata with 2 d randomly selected out of each stratum. All fish entering the trap during a 24-h period were visually counted and released. During each day sampled, approximately 25 alewives were measured for total length and sex was determined by stripping.

In 1979 a Smith-Root[2] 602A electronic fish counter was installed in the trap. Saila et al. (1972) used the system 602 counter with two separate tunnels for counting direction movement, whereas the 602A has one tunnel for counting upstream and downstream passage. The tunnel was 20 cm in diameter and 35 cm long. During most of the run, alewives that passed through the tunnel were held in the trap and later counted to discover any errors and to make necessary adjustments to the instrument.

A separate sampling plan was used at the bottom of the fishway for the commercial catch. On randomly selected days during the run, 9 d in 1977 and 15 d in 1978, 50-100 fish were taken from the catch. In 1979 the number of days sampled was 31, with 50 fish taken each day. Total length, weight, sex, and scales were taken from these alewives. In 1979, otoliths were also removed for aging.

Mean lengths and weights were computed for each day sampled and for each sex. Length measurements were taken from the total length of the fish. Each mean length and weight was weighted by the number of fish caught or counted on that day for total mean length and weight results. The number of fish harvested each year was estimated by dividing total weight by the mean weight per fish.

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

Results

Each year the alewife run began in early May and ended in early June. The commercial harvest contained 1,277,642 fish in 1977, 999,484 in 1978, and 777,941 in 1979. The respective escapements into Damariscotta Lake (±SE) were 26,813±2,624, 53,180±9,147, and 20,313±4,145 ripe alewives. The resulting escapement was 2.0%, 5.0%, and 2.6% of the commercial catches for 1977, 1978,and 1979, respectively.

Sex ratios in the commercial catch samples showed no significant differences from the beginning of the run to the end in all but a few samples each season. The overall combined samples for each year showed no significant difference on χ^2 tests ($P \geq 0.05$) between numbers of males to females (Table 1).

Early immigrants into Damariscotta Lake had significantly different sex ratios in which males always outnumbered females and as the run progressed these ratios had a tendency toward a nonsignificant ratio of 1:1 (Figure 1). This persistency in male dominance was evidenced by significant (χ^2 $P < 0.05$) totals in the ratios of 2.1:1 for 1977, 1.9:1 for 1978, and 2.6:1 for 1979 (Table 1).

Age distribution of commercial and escapement runs ranged from 3 to 9 yr old. The age distribution for each sex in the commercial catch displayed greater percentages of younger males than younger females; conversely, there were greater percentages of females at older ages than males in

TABLE 1.—Sex ratios (M:F) and number of alewives sampled in 5-d consecutive periods for the commercial and escapement runs at the Damariscotta Lake fishway, Maine, 1977-79. The samples columns refer to the number of combined samples in the 5-d consecutive periods.

	1977						1978						1979					
	Commercial			Escapement			Commercial			Escapement			Commercial			Escapement		
	Samples	Ratio	*n*	Samples	Ratio	*n*	Samples	Ratio	*n*	Samples	Ratio	*n*	Samples	Ratio	*n*	Samples	Ratio	*n*
	1	2.7:1*	37	2	3.1:1*	111	3	1.1:1	300	2	3.4:1*	131	5	1.3:1*	247	3	3.0:1*	92
	1	1.1:1	19	2	3.3:1*	525	3	0.8:1*	300	2	2.1:1*	203	5	1.1:1	228	2	3.3:1*	113
	1	0.5:1	19	2	2.8:1*	569	3	0.7:1*	300	2	1.9:1*	280	5	1.0:1	252	1	4.1:1*	56
	3	1.2:1	128	3	1.2:1*	380	2	1.1:1	179	2	1.6:1*	118	5	0.9:1	251	1	3.2:1*	54
	1	0.8:1	54		—		2	1.2:1	223	2	1.3:1	155	5	1.1:1	243	1	1.7:1	30
	2	1.1:1	33	2	1.0:1	115	2	1.0:1	175	1	1.2:1	20	4	0.9:1	195	3	1.6:1	72
				1	1.1:1	66							2	1.1:1	100	2	1.1:1	44
				2	1.3:1	101												
				1	1.4:1	40												
Pooled samples		1.1:1			2.1:1*			1.1:1			1.9:1*			1.0:1			2.6:1*	

*χ^2 significance at $P \leq 0.05$.

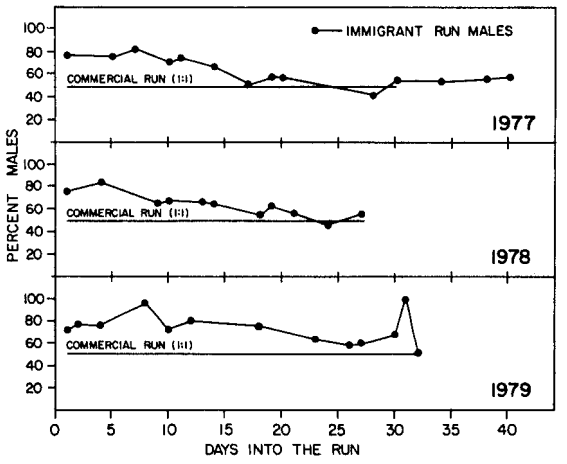

FIGURE 1.—Percentage of males from samples taken during the escapement run at Damariscotta Lake fishway, Maine, compared with the consistent (1:1) sex ratio of the commercial run, 1977-79.

each year. The greater proportion of ages III and IV were males, while ages V and VI were dominated by females in 1977 and 1979. In 1978 males dominated ages III through V. There is no evident trend in ages VII and older for either sex, probably due to the small sample sizes at these ages. The percentage at age of sexes in the escapement runs showed about the same distribution as was found in the commercial runs (Table 2). The trend in size and age at the Damariscotta Lake alewife run was larger and older fish arriving early and regressing to smaller and younger fish through time (Table 3).

Discussion

There have been other observations of early male alewife predominance in fishways and on spawning grounds. Dominy[3] showed a male predominance ratio of 2.4:1 at the start and a 0.7:1 ratio by the end of the run in the Gaspereau River, White Rock, Nova Scotia. Kissil (1974) at Bride Lake, Conn., observed more males during the early part of the run declining to an equal number with females for the remainder. Cooper (1961) reported that males gradually declined from 65% at the beginning to 35% at the end of the run at Pausacaco Pond, R. I. Rideout (1974) found a high percentage of males in most samples from the Parker River, Mass. Havey (1961) observed a 1.28:1

[3]Dominy, C. L. 1971. Evaluation of a pool and weir fishway for passage of alewives (*Alosa pseudoharengus*) at White Rock, Gaspereau River, Nova Scotia. Dep. Fish. For. Can. Resour. Dev. Branch, Halifax, Progr. Rep. 3:22.

TABLE 2.—Percentage of male and female alewives at age from the commercial and escapement runs at the Damariscotta Lake fishway, Maine, 1977-79.

		Commercial fishery								Escapement runs							
Year	Sex	III	IV	V	VI	VII	VIII	IX	Total	III	IV	V	VI	VII	VIII	IX	Total
1977	Males	0.3	34.6	13.8	1.6	0.7	0	—	51.1	0.5	37.4	26.0	1.8	0.9	0.1	—	66.6
	Females	.1	20.2	24.8	2.7	.7	.2	0.2	48.9	.2	14.4	15.5	2.9	0.3	.1	0	33.4
1978	Males	.1	14.1	28.1	6.6	2.0	.4	—	51.2	0	10.6	33.8	12.8	3.8	.8	—	61.9
	Females	.1	10.3	26.9	9.2	2.1	.2	—	48.8	.3	8.1	19.5	8.1	1.7	.4	0	38.1
1979	Males	.3	22.5	22.5	3.3	1.7	.2	—	50.4	.3	31.0	32.1	5.6	3.6	.1	—	72.7
	Females	.1	15.7	28.0	4.6	1.0	—	0.2	49.6	—	8.1	16.5	2.1	0.3	—	—	27.3

TABLE 3.—Age distribution (percent) and mean total length (millimeters) of alewives for three equal periods during the Damariscotta Lake, Maine, commercial run, 1977-79.

Date	Sex	III	IV	V	VI	VII	VIII	IX	Total	Mean length
4-13 May 1977	Males	—	22.0	28.1	5.4	3.1	0.9	—	59.6	304.0±2.0
	Females	—	10.3	25.3	4.9	—	—	—	40.4	309.4±2.0
14-23 May	Males	0.4	37.0	13.1	1.7	.9	—	—	53.1	292.6±1.4
	Females	.1	19.3	24.0	2.1	.9	.2	0.2	46.9	304.9±1.5
24 May-3 June	Males	.2	28.2	15.4	1.1	—	—	—	45.0	295.6±1.7
	Females	—	23.2	27.2	4.5	—	—	—	55.0	300.7±1.2
6-15 May 1978	Males	—	1.7	24.6	14.4	4.5	1.5	—	46.7	310.0±0.7
	Females	—	3.4	29.0	15.8	4.5	.6	—	53.3	317.5±0.7
16-25 May	Males	.1	11.2	29.3	6.9	2.5	.1	—	50.2	302.3±0.8
	Females	—	7.7	28.8	10.8	2.3	.3	—	49.8	313.7±0.8
26 May-3 June	Males	.3	22.5	27.3	3.7	.2	.4	—	54.4	295.7±0.8
	Females	.3	16.7	23.0	4.5	1.2	—	—	45.6	306.7±1.0
7-17 May 1979	Males	—	15.8	27.1	5.5	4.0	.5	—	52.9	299.6±1.0
	Females	—	9.3	29.4	6.6	1.3	—	.5	47.1	309.6±1.3
18-28 May	Males	.2	22.7	22.1	2.8	1.4	.1	—	49.2	292.1±0.8
	Females	—	16.4	28.9	4.0	1.2	—	.1	50.2	302.9±1.0
29 May-8 June	Males	.7	28.6	19.4	2.3	.4	—	—	51.3	288.3±1.0
	Females	.3	20.0	24.5	3.5	.4	—	—	48.7	299.5±1.2

(M:F) ratio at Long Pond, Maine, although this was not statistically significant.

Sex dominance in a species of fish that is assumed to have an equal sex ratio may be attributed to sampling and catch methods. For example, Casselman (1975) noted that the sex ratio of northern pike, *Esox lucius*, caught by anglers favored females because of their greater activity in foraging for food at the time of fishing. Early male alewife predominance is attributed to males maturing a year earlier than females (Havey 1961; Kissil 1974) and males ripening earlier in the season, thus beginning the spawning run sooner (Cooper 1961). Marcy (1969) at Bride Lake found that 68% of males were age IV and 68% of females were age V. The alewives in Damariscotta Lake have shown this same attribute of male dominance as in these other investigations. As fish begin entering the lake there were many more males present than females. The presence of significant heterogeneity revealed that this male dominance of early escapements into the lake is not consistent throughout the run. A comparison of percentage of males per sample in the fishway run to the hypothetical 1:1 ratio in the commercial catch showed a trend of diminishing male dominance.

The reasons cited earlier for male dominance in alewife runs do not explain the disproportionate ratio in these other runs or at Damariscotta Lake. The theory that earlier maturing or earlier ripening males in an alewife stock contribute to the greater male to female ratio does not correspond to the size and age trend of the Damariscotta spawning runs. As was shown, these runs had the largest fish arriving first. Other investigators have shown this to be the case in other alewife spawning migrations: Havey (1961) reported older fish running early; a decreasing trend in mean fork length for each sex during the spawning run was shown by Cooper (1961), Kissil (1974), and Rideout (1974). If larger alewives are the earliest to arrive, the greater proportion of males to females would not occur at the first of the run. The larger proportion of males would occur later or at the end of the run when the younger fish begin arriving. The main reason in searching for other explanations is the fact that the sex ratios in the commercial catch (located near the bottom of the fishway) had generally nonsignificant ratios throughout the run in each of the 3 yr. Age distribution of the commercial catches does show more younger males (III-IV), but the older ages contain more females (V-VII). The greatest proportion of the commercial catch (85-90%) is made up of 4- and 5-yr-old fish and they are always present throughout the run. This mixing of 4-yr-old males and 5-yr-old females caused the 1:1 sex ratio in the commercial catch.

The explanation for this abrupt change in the sex ratio from the tidal area to the lake appears to be an effect of the fishway. The greatest disproportionate ratio of male to female alewives occurred at the first part of the escapement run when the largest fish were in the fishway. It seemed that the construction of the fishway was selective against the largest or heaviest fish which were the females at that time. As the size of females tended to decrease, the male to female ratio became more equal.

Future investigations that deal with the sex ratio of alewives on the spawning grounds would do well to examine the alewife stock before it made any arduous runs through a difficult section of water or fishway. The reasons for a significantly different sex ratio on the spawning grounds could be from the physical aspects of the migration route rather than any biological factors of the alewife.

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PROXIMATE COMPOSITION AND NUTRITIVE VALUE OF SOME IMPORTANT FOOD FISHES FROM THE ARABIAN GULF

The unique value of fish for supplementing the nutritional qualities of man's diet, as also for animal feeding, is well recognized. Literature on the composition and calorie value of fish reported from various parts of the world is exhaustive. Love (1970), Sidwell et al. (1973, 1974), Bonnet et al. (1974), Stansby (1976), Sidwell, Loomis, Loomis, Foncannon, and Buzzell (1978), and Sidwell, Loomis, Foncannon, and Buzzell (1978) have provided good reviews on the subject.

The Arabian Gulf countries, including Kuwait, have rich fish faunas and Kuwait with a coastline of about 140 km, has at least 131 fish species in 64 families which are taken in commercial trawls (Kuronuma and Abe 1972). The total quantity of fish sold in Kuwait market in 1976 was 4,452 t as estimated by the Kuwait Ministry of Planning (Anonymous 1977). In a recent survey of the fish consumption of local populations in Kuwait, Afzal and Hayat (1977) reported that the consumption of fish in Kuwait is fairly high and that a majority of respondents had no clear idea about the nutritive value of fish. It was emphasized that a program was necessary to disseminate such information.

With the exception of the work of Das et al. (1976) on a few fishes from Shatt Al-Arab and the Arabian Gulf, nothing seems to have appeared on nutritional values of Arabian Gulf fishes. Here we report on the proximate composition and nutritive value of some of the important food fishes from Kuwait for use of consumers, dieticians, and the fishing industry.

Methods

The study was based on fish samples obtained from the local fish market. These are caught by shrimp trawlers and dhow boats operating in the Arabian Gulf. For each species, fresh specimens representing the common marketable size were selected (Table 1). Analysis used minced muscle from the trunk portion of each individual from which skin and all bony elements had been removed. Standard methods of chemical analysis were used (Horwitz 1975). Gross energy content was calculated from the mean values of fat, protein, and carbohydrate following equivalents as used by Jafri et al. (1964). All samples were taken during November and December 1978.

Results

Most of the fishes were found to be fairly high in protein content. The maximum value (22.6%) was observed in the barred Spanish mackerel whereas

TABLE 1.—Average proximate composition (± standard error of the mean) and energy content of some important food fishes sampled in November and December 1978 from the Arabian Gulf.

Species	No.	Total length (cm)	Protein (%)	Fat (%)	Moisture (%)	Ash (%)	Energy (cal/100 g)
Spotted Spanish mackerel, *Scomberomorus guttatus*	7	47.1±0.6	20.5±0.0	3.4±0.4	73.9±0.3	1.4±0.0	119.0
Barred Spanish mackerel, *S. commersoni*	5	103.5±7.2	22.6±0.6	1.8±0.2	73.5±0.1	1.5±0.0	111.7
Silvery croaker, *Otolithus argenteus*	5	33.4±1.1	21.8±0.3	1.1±0.3	74.5±0.4	1.3±0.0	104.8
Four-thread threadfin, *Eleutheronema tetradactylum*	5	53.0±0.6	20.7±0.2	5.3±1.1	72.1±0.7	1.3±0.0	136.6
Silvery grunt, *Pomadasys argenteus*	7	55.4±2.0	20.5±0.2	.5±0.1	77.6±0.3	1.2±0.0	89.4
Silvery pomfret, *Pampus argenteus*	5	30.4±6.4	18.5±0.3	1.4±0.3	78.3±0.3	1.3±0.0	91.0
Mullet, *Liza macrolepis*	12	17.5±0.2	17.2±0.2	1.1±0.0	79.6±0.2	1.3±0.0	83.9
Yellow finned black porgy, *Acanthopagrus latus*	5	31.2±0.8	19.7±0.3	.3±0.1	77.9±0.5	1.2±0.1	87.6
Crimson snapper, *Lutjanus coccineus*	5	64.0±1.4	19.1±0.3	.2±0.1	77.6±0.2	1.2±0.0	87.7
Brown-spotted grouper, *Epinephelus tauvina*	5	84.3±1.5	19.5±0.3	.5±0.0	74.1±0.1	1.2±0.0	104.1