AGING OF GULF MENHADEN, *BREVOORTIA PATRONUS*

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ABSTRACT

Length-frequency distributions, returns of tagged juveniles, and scale annuli indicate that over 97% of Gulf menhaden, *Brevoortia patronus,* caught in the purse seine fishery are ages 1 and 2. Few fish survive to age 3. About 50% of the fish examined for the years 1971-73 could be aged by scale annuli. Those with no scale annuli or with indistinct or false annuli could be assigned to age 1 or younger or age 2 or older on the basis of length.

When large numbers of fish are routinely sampled for age and size distributions, they must be aged by some technique that consumes relatively little time. One common method is to count scale annuli, another is to group the fish by length frequencies. Counting otolith rings usually is impractical because of the large amount of time and effort it takes to collect, prepare, and observe the otoliths.

As pointed out by Struhsaker and Uchiyama (1976), "Attempts to age tropical fishes by conventional methods have generally been thwarted by the absence of well-defined annuli in calcarious structures and protracted spawning periods which make length-frequency mode progression analysis difficult." In temperate regions where the winter water temperature may not fall low enough to cause a cessation of fish growth for an extended period, aging fish by counting scale annuli may also be difficult.

Gulf menhaden, *Brevoortia patronus,* range along the coasts of the United States and Mexico from Florida to Yucatan. They spawn offshore in the Gulf of Mexico from about October to April (Suttkus 1956; Turner 1969). The eggs hatch in about 48 h and the larvae are transported by onshore currents to estuaries, where they metamorphose into adult form (Fore and Baxter 1972). In late summer the juveniles, ranging from about 45 to 120 mm fork length (FL), congregate in the lower estuaries before moving to offshore waters (Kroger and Pristas 1975).

Gulf menhaden, the basic resource for a large meal and oil industry, are caught exclusively in a purse seine fishery extending from western Florida to eastern Texas. Processing plants, now operating only in Mississippi and Louisiana, formerly operated in Florida and Texas also. During routine sampling of the catch during the fishing season, usually lasting from late April to October, scales have been removed from, and weights and fork lengths recorded for, about 13,000 fish annually since 1964.

Aging these fish by conventional methods has been a problem. Although some fish had well-defined rings that appeared to be annuli, others had no rings, or rings that were unclear or oddly spaced. Length-frequency distributions indicated two major age-groups with overlapping lengths, and a third group that appeared in late summer.

Since neither length frequencies nor scale rings alone were satisfactory for aging all fish, ages subsequently were based on a combination of factors: appearance of scales, number and spacing of visible rings, and length of fish at the time it was caught. This method of aging could be criticized as being too subjective. But until returns of fish tagged at a known age, such as juveniles, were available there were no distributions of known ages to which distributions of estimated ages based on scale rings and lengths could be compared.

A study to resolve the problem was not begun until returns of juveniles tagged in late summer and early fall 1970-73 became available. In 1975 we began a study of fish collected from 1971 to 1973. We choose those years because returns of tagged juveniles of the 1970-73 year classes were available, and we limited our material to 3 yr to keep it manageable. Age-0 fish were defined as young-of-the-year that would have no scale ring, age 1 as those in their second year that should have one ring, and age 2 as those in their third year that should have two rings.

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Our primary objective was to determine if rings visible on some scales were true annuli. If they were, our second objective was to determine if fish that had scales with no visible rings or with a profusion of unclear rings could be aged on the basis of length; if the rings were not annuli, our second objective was to explore other methods of aging Gulf menhaden.

COLLECTION OF DATA

Samples of the catch are taken daily by field personnel stationed at four ports, each comprising two or three plants grouped in close proximity. After weighing and measuring a fish, samplers remove a cluster of scales from just above the lateral line below the dorsal fin and deposit them in a 0.1% phenol solution. Later, six scales from each fish are cleaned and mounted between two glass slides. Each fish and its scales are identified by port, collection, and scale number. From 1964 to 1971, two samples of 20 fish each were taken daily at each port. Since 1972, three samples of 10 fish each have been taken.

Juveniles ranging from about 80 to 120 mm FL were marked in late summer and early autumn with numbered internal ferro magnetic tags similar to, but smaller than, those used for adults (Pristas and Willis 1973). Tags were recovered on magnets in various parts of the processing plants (Parker 1973), although all tags passing through a plant were not retained.

To estimate the numbers of field tags not retained on magnets, batches of 100 fish marked with test tags were periodically planted in the catches. The percentage subsequently recovered was an estimate of the efficiency of the magents to recover field tags. The number of annual tests at each plant varied from 2 to 15 (200-1,500 tags). Annual recovery rates varied from 2 to 60%, but over one-half were between 15 and 40%.

Some test tags were not recovered until 1, 2, or even 3 yr after they had been placed in catches (Table 1). Delayed recoveries were caused by 1) tags lodging in various parts of a plant before later being dislodged, 2) tags remaining in fish scrap stored for long periods before being ground, 3) tags remaining in various scrap storage areas before being mixed with new scrap. The number varied by plant and year and amounted to about 1% or less of the number of test tags applied, although in 1972 it was 6% at plant 58 and 5% at plant 57.

TABLE 1.—Number of test tags applied and number recovered at Gulf menhaden processing plants, 1971-73.

Plant no.	Year tags applied	No. of tags	No. recovered 1971	1972	1973	1974
54	1971	900	28	0	([1])	([1])
	1972	1,300		703	([1])	([1])
55	1971	900	100	4	6	0
	1972	1,400		598	13	0
	1973	700			255	7
56	1971	900	448	0	1	1
	1972	1,300		617	2	0
	1973	600			199	2
57	1971	200	40	1	1	0
	1972	1,300		301	59	3
	1973	1,200			322	7
58	1971	300	43	5	0	0
	1972	1,500		425	93	0
	1973	1,200			396	3
62	1971	1,200	470	1	0	0
	1972	1,300		654	1	0
	1973	1,100			658	2
63	1971	1,000	203	12	0	0
	1972	1,000		379	8	0
	1973	1,200			217	13
64	1971	930	395	8	0	0
	1972	1,200		314	4	0
	1973	1,100			241	6
65	1971	800	399	([2])	([2])	([2])
68	1971	1,100	436	2	0	0
	1972	900		311	12	0
	1973	400			214	0
69	1971	1,000	163	1	0	0
	1972	1,100		265	3	0
	1973	1,300			273	1
71	1971	1,100	205	0	1	0
	1972	1,100		317	0	0
	1973	1,200			186	0

[1]Plant did not operate after 1972.
[2]Plant did not operate after 1971.

OBSERVATION OF SCALES

Scales were viewed on a scale projector at 48× magnification. If no rings were evident, or if no one ring could be considered as an annulus, no measurements were made. If rings were evident, the distances from the focus to each ring and to the scale edge of the projected image were measured. Each ring had to be discernable on three or more scales or it was not measured. Each fish was assigned an age corresponding to the number of rings on the scales except when the only ring visible was in the area of the scale usually occupied by the second ring. Then the fish was called age 2 rather than age 1. The decision to assign a ring the number one or two position was based on the distance of the ring from the scale focus.

VALIDITY OF RINGS AS YEAR MARKS

To determine if observed rings were true annuli, we examined three different sets of data: length-

frequency distributions of sampled fish, returns of tagged juvenile menhaden, and spacing of rings on the scales.

Length-Frequency Distributions

From the general shape and the number of modes of a length-frequency distribution curve, it is often possible to infer the number of age-groups represented. Length-frequency curves of Gulf menhaden sampled during 1964-73 fishing seasons had two distinct modes. Since distributions in all years were similar, we have shown only those for 1967-70 (Figure 1). A prominent mode, usually evident in May at around 135 to 150 mm, shifted progressively to the right during the season and by September varied from about 155 to 170 mm. A smaller mode at about 170 to 180 mm in May tended to shift farther right during the season and disappear by midsummer, so that the curve became unimodal and greatly skewed. This small mode apparent in May appeared to be a continuation of the mode that was prominant during the preceding September.

From the general shape of the length-frequency curves there appears to be only two dominant age-groups in the fishery. The younger and more numerous tends to dominate the fishery as the

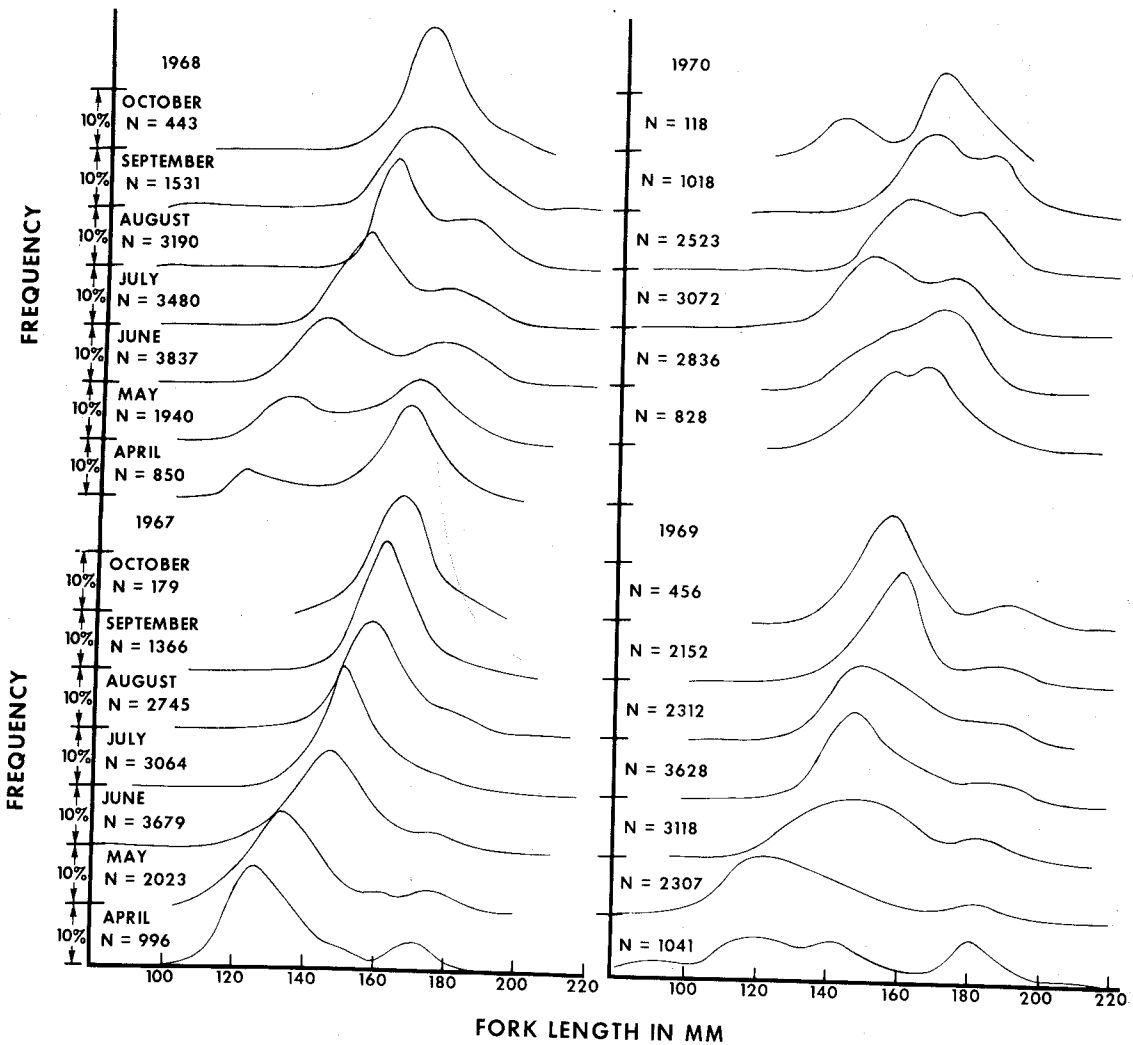

FIGURE 1.—Length-frequency distributions of Gulf menhaden in percent, by month, 1967-70.

season advances, so that by the end of the season the catch is composed almost entirely of this age-group. The considerable variation in the relative numbers of the two major age-groups from year to year is probably a reflection of the differences in the relative abundance of each year class. Small numbers of a third age-group of still younger fish may enter the fishery in some years in August or September.

Juvenile Tagging

An advantage of tagging juveniles is that the age of each fish is known when it is recaptured. Unfortunately, recovery of some tags a year or more after they had entered a plant caused some fish to appear older at the time of recapture than they actually were. Although the number was relatively small, it had an important bearing on inferences pertaining to longevity and the proportion of older fish in the catch.

By the end of the 1974 fishing season 1,137 field tags had been recovered (Table 2). Of these 1,069 (94.0%) were recovered in the 2 yr following tagging, 62 (5.5%) in the third year, and 6 (0.5%) in the fourth year. Only tags applied in 1970 had an opportunity to be recovered in the fourth year, and only tags applied in 1970 and 1971 had an opportunity to be recovered in the third year.

The tendency for test tags to remain in plants for one or more years leads us to believe that all field tags recovered in the fourth year and most of those recovered in the third year were holdovers from previous years. All of these tags were recovered at plants that had the highest percentage of test tag holdovers.

We conclude, therefore, that at least 97% of Gulf menhaden caught in the purse seine fishery are age 1 or age 2, and that very few, probably less than 1%—live to age 3. If ring marks are valid annuli, they also should indicate that the catch is composed primarily of age-1 and age-2 fish.

Incidence and Spacing of Scale Rings

The scale length-fish length relation for Gulf menhaden was linear. Correlation coefficients for 1971, 1972, and 1973, based on fish ranging from 95 to 225 mm FL, was 0.790, 0.765, and 0.768, respectively; for log transformed data the coefficients decreased to 0.729, 0.695, and 0.681. Sample sizes were 4,674, 4,457, and 4,902, respectively. The regression equation for the 3 yr combined was: Scale length = 5.392 + 0.865 Fish length.

TABLE 2.—Numbers of field tags of juvenile Gulf menhaden recovered from 10,458 fish tagged in 1970, 15,511 in 1971, 15,262 in 1972, by plant.

Plant no.	Year tagged	No. recovered 1971	1972	1973	1974
54	1970	2	30	(1)	(1)
	1971		5	(1)	(1)
55	1970	16	3	3	1
	1971		14	31	5
	1972			76	35
56	1970	29	30	3	2
	1971		10	33	7
	1972			54	30
57	1970	5	5	4	0
	1971		4	14	2
	1972			16	3
58	1970	2	19	18	1
	1971		2	24	6
	1972			6	12
62	1970	0	3	1	1
	1971		18	13	2
	1972			12	17
63	1970	3	2	0	0
	1971		49	2	1
	1972			28	4
64	1970	19	0	0	0
	1971		95	1	1
	1972			54	1
65	1970	7	(2)	(2)	(2)
68	1970	3	7	3	0
	1971		45	16	2
	1972			36	17
69	1970	1	7	2	1
	1971		5	7	1
	1972			9	6
71	1970	4	2	0	0
	1971		43	1	1
	1972			21	1

[1]Plant did not operate after 1972.
[2]Plant did not operate after 1971.

Not all fish had scales with clearly discernable rings. The percentage with no rings varied from 45.0 to 55.8. Of the fish considered as age 2, <2% had a ring in the number one position only and 25.1% in 1971, 39.1% in 1972, and 30.6% in 1973 had a ring in the second position only. A relatively small number of fish had scales with three clearly discernable rings.

The length frequencies from May to September of fish with one or two rings clearly indicated two distinct ages. In Tables 3-5 length groups below the first containing fish with both one and two rings have been lumped into one group. For one-ring fish the mode is the group, other than the lumped one, containing the most fish. The only exception is for May 1971 when the mode for fish with one ring was 155 mm. It is clear that the modes and means of one- and two-ring fish increased and that the distributions shifted toward larger sizes as the season progressed.

TABLE 3.—Length frequencies and mean lengths of Gulf Menhaden, by month and number of scale rings (0-3), 1971.

Fork length (mm)	May				June				July				August				September			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
<165	50	150			560	747			587	503			663	330			260	48		
165-169	1	14			31	99	3		36	80	1		74	61			55	17		
170-174	4	14	6		45	74	16		32	95	1		49	69	1		29	22		
175-179	14	6	9		67	42	56		41	69	27		28	76	2		19	18	4	
180-184	11		22		84	18	111		53	43	100		44	61	6		27	19	10	
185-189	12		26		78	2	134		56	14	108	1	36	32	32		15	5	15	
190-194	4		29		53		83	3	42		144	5	44	15	48	2	22	6	17	
195-199	3		10	1	30		49	7	29		68	2	28	1	52	3	10	2	9	1
200-204	3		4	2	18		14	3	14		35	17	16		35	5	11		4	1
205-209				1	1		6	1	2		11	7	4		6	4	1		4	2
210-214	1				2		1	4				8	5		3	5	2		1	3
215-219								1				2	1			2	1			2
220-224	1							1												
Total number	104	184	106	4	969	982	473	20	892	804	495	42	992	645	185	21	452	137	64	9
Mean length	—	148	187	202	—	154	186	202	—	160	189	203	—	165	194	204	—	169	191	209

TABLE 4.—Length frequencies and mean lengths of Gulf menhaden, by month and number of scale rings (0-3), 1972.

Fork length (mm)	May				June				July				August				September			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
<155	288	353			264	338			198	102			97	39			41	6		
155-159	64	79	3		158	134			204	107			136	51			14	7		
160-164	109	94	5		170	114	1		339	169			280	129			47	11		
165-169	109	75	12		192	88	3		236	126			347	134	1		33	19		
170-174	79	47	52		120	99	24		178	78	9		180	83	3		43	10		
175-179	53	5	71		86	48	42		136	64	39		118	54	7		57	14		
180-184	44	1	72		45	7	59		97	41	52		102	33	24		44	7	1	
185-189	20		55	1	36		72		70	6	102		78	8	74		28	1	1	
190-194	16		27	2	17		66	2	37	1	89	2	79	3	105		25	1	5	
195-199	7		13	7	15		31	3	42		79	3	65		77		17		8	
200-204	8		4	4	11		12	4	19		40	3	30		46	3	26		1	
205-209	2			2	4		3	4	16		20	4	19		10	4	10		1	
210-214				1	9		2	9	13		10	7	9		5	3	7			
215-219					3			4	5		1	3	7		1	3	1			
220-224				1	1				2		1	3	2		1	8	1			
225-229								1	1		1	1	1			1				
Total number	799	654	314	18	1,131	828	315	27	1,593	694	443	26	1,550	534	354	22	394	76	17	
Mean length	—	151	181	198	—	157	186	208	—	164	191	209	—	166	193	215	—	170	194	

TABLE 5.—Length frequencies and mean lengths of Gulf menhaden by month and scale rings (0-3), 1973.

Fork length (mm)	May				June				July				August				September			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
<155	162	55			265	109			181	41			171	10			49	2		
155-159	80	28	1		217	105			187	103			26	22			1			
160-164	94	17	13		151	117			229	190			77	71			2	1		
165-169	69	16	27		93	80	2		210	169			127	164			11	12		
170-174	44	16	45		96	79	14		204	207	2		138	295			16	26		
175-179	40	4	44		90	39	70		150	138	24		237	100	3		34	26	3	
180-184	21		42		68	11	169		95	89	73		143	71	32		31	28	7	
185-189	6		30		28	5	196		82	43	114		75	35	80		19	16	12	
190-194	7		26	1	16	1	119		34	19	117		50	12	88		15	3	28	
195-199	4		12		15		71	3	15	1	81		14	1	64		17	2	16	
200-204	1		12	1	10		46	6	10		49	4	14		42	6	8	1	16	2
205-209	1		4	2	2		28	2	7		26	3	8		28		5		5	1
210-214	3		4	4	8		13	8	5		12	5	5		8	6	9			
215-219				3	2		1	5	1		6	3	2		2	8	2			2
220-224					1			5	1		2	3	4		1	4	3			2
225-229								2	1			2	1			2	1			
Total number	532	136	260	11	1,062	546	729	31	1,412	1,000	506	20	1,092	781	348	26	223	117	87	7
Mean length	—	158	182	210	—	162	188	211	—	169	192	213	—	172	194	214	—	178	193	211

TABLE 6.—Mean distance from last ring to scale edge expressed as the percent of the distance from focus to scale edge for Gulf menhaden.

	1971			1972			1973		
Period	Age 1	Age 2	Age 3	Age 1	Age 2	Age 3	Age 1	Age 2	Age 3
1-15 May	36.7	9.9	5.0	24.6	11.6	—	29.6	13.3	6.7
16-31 May	37.0	10.6	—	35.8	12.5	5.2	32.6	15.2	7.3
1-15 June	40.1	12.4	7.7	39.1	13.8	5.7	34.8	17.4	8.8
16-30 June	42.1	12.6	7.3	39.9	15.6	5.8	38.0	18.9	8.7
1-15 July	43.2	13.0	7.4	42.1	15.7	6.7	40.4	20.7	8.6
16-31 July	43.5	12.7	7.4	41.6	15.0	6.7	41.1	19.6	8.8
1-15 Aug.	45.6	14.2	8.6	42.9	15.8	6.9	42.1	20.6	10.4
16-31 Aug.	47.5	13.4	8.9	44.9	14.1	7.5	43.7	19.6	11.0
1-15 Sept.	44.6	10.4	—	42.3	14.4	—	36.8	25.6	—
16-30 Sept.	45.2	13.8	8.7	47.3	15.0	—	40.3	21.8	8.7
1-15 Oct.	—	16.0	—	—	—	—	42.3	20.0	8.4

Fish with three rings were not clearly differentiated as a distinct age-group. Because of small numbers neither modes nor general shapes of the distributions could be clearly determined. Means tended to increase slightly as the season progressed. There was considerable overlap of the lower end of the length range with the upper end of the length range of two-ring fish.

If the rings we observed were true annuli, the distance from the last ring to the scale edge should have decreased as the number of rings increased, and should have increased throughout the season for fish having the same number of rings. Both of these trends were apparent (Table 6).

Mean lengths back-calculated to the age of annulus formation from fish with one, two, or three rings were similar, and the mean lengths at the time of first ring formation calculated from two-ring fish were slightly smaller than those calculated from one-ring fish, as would be expected (Table 7). This tendency for mean lengths back-calculated from successively older ages of the same year class to become progressively smaller is commonly known as Lee's phenomenon and may be caused by a variety of factors. Mean lengths calculated from three-ring fish, however, were slightly larger, rather than smaller, than mean lengths calculated from either one- or two-ring fish.

Frequency distributions of lengths back-calculated to the time of the first, second, and third ring formation were well separated from each other, with only a small overlap between one- and two-ring and two- and three-ring fish (Figure 2). Those at the time of the first ring formation were similar in shape, whether calculated from one-ring, two-ring, or three-ring fish. Those calculated from two-ring fish were shifted slightly farther to the left than those calculated from one-ring fish, as

TABLE 7.—Mean lengths (millimeters) of Gulf menhaden at the time of each ring formation calculated from one-, two-, and three-ring fish, 1968-72 year classes.

	First ring			Second ring		Third ring
Year class	1-ring fish	2-ring fish	3-ring fish	2-ring fish	3-ring fish	3-ring fish
1968	—	—	88.4	—	157.4	186.4
1969	—	95.2	96.6	164.5	166.1	195.1
1970	90.3	85.1	92.9	165.0	166.3	195.3
1971	95.0	86.3	—	158.9	—	—
1972	100.3	—	—	—	—	—

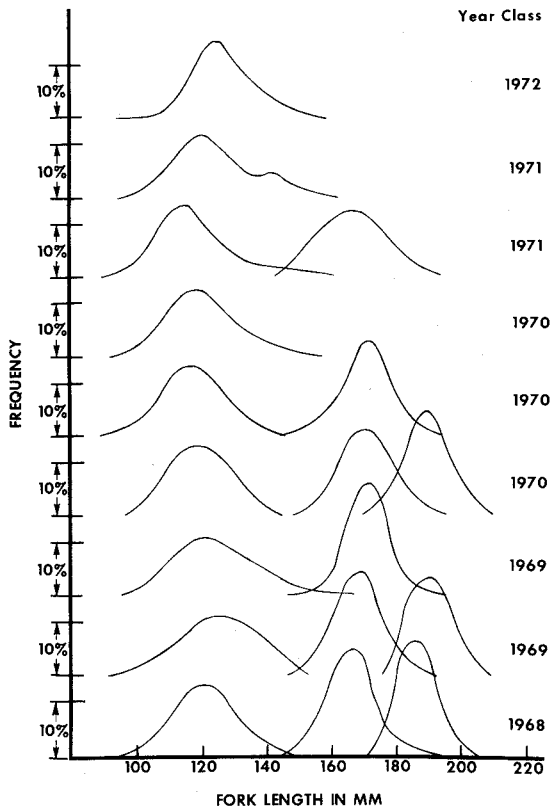

FIGURE 2.—Length-frequency distributions at time of first, second, and third ring formation, back-calculated from one-ring, two-ring, and three-ring Gulf menhaden, 1968-72 year classes.

would be expected. Those at the time of the second ring formation, whether calculated from fish with only a ring in the second position or from fish with both rings, were nearly identical and were shifted slightly to the right of distributions calculated from fish with three rings.

CONCLUSIONS

On scales of most Gulf menhaden with one or two rings, the rings appear to be true annuli. A relatively large number of fish that do not form a ring at the end of the first year form a ring at the end of the second year. A very small number that form a ring at the end of the first year do not form a ring at the end of the second year. It is possible, therefore, to separate age-2 from age-1 fish by the number of rings, or the location of the ring if only one is visible.

For fish having scales with more than two rings, or with two rings that are oddly spaced, it is difficult to differentiate between true and false annuli, or to determine to what year a particular ring should be assigned. On scales of some fish that could be age 3 on the basis of length, only two rings are visible, in what appears to be either the first and second or second and third positions. On some scales that have three well-defined rings, the spacing appears too unusual to be true annuli. For those fish that are called age 3, the lengths overlap those of age-2 fish, the mean lengths and ranges progress very little during the season, and the mean increments from the last annulus to the scale edge show little increase. We concluded that it is impossible to separate age-3 from age-2 fish with a high degree of certainty on the basis of the number or the location of scale rings.

From late August until October a small number of fish ranging from about 115 to 135 mm appear. We believe most of these fish, which have no scale rings, are age 0, but we cannot be certain because many of the fish in this size range of age-1 fish also have no scale rings.

The small number of tags recovered after 2 yr from fish tagged as juveniles, or age 0, the scarcity in the catch of fish larger than those with two rings, and the small numbers of fish with more than two rings, indicate that few Gulf menhaden live to be older than age 2. Since both age-0 and age-3 fish compose <2% of the catch, and since each age-group is either impossible or difficult to identify, we believe it is practical to recognize only two age-groups of Gulf menhaden: those age 1 or younger and those age 2 or older.

If only two ages are recognized, fish with no annuli can be aged by length. For each month, those below a certain fork length can be called age 1 or under, those above a certain length age 2 or older. Those in between cannot be individually aged, but the number in each length class can be apportioned to each age-group on the basis of the percentage of fish in each length class with one or two annuli. For example, in June 1971 (Table 3) all fish <165 mm may be called age 1, all >185 mm age 2. Of the 31 unaged fish 165-169 mm, 30 (97%) are age 1 and 1 (3%) is age 2; of the 45 between 170 and 174 mm, 37 (82%) are age 1 and 8 (18%) are age 2.

A question that may arise concerns the accuracy of previous aging methods. To shed some light on this question, we compared the percentages of fish at each age for methods 1 and 2. In method 1, fish ages had been based on a combination of factors: the general appearance of the scales, the number and location of rings, the fish length, and the time of year the fish was caught. In method 2, fish that had been aged by the number and location of scale rings, and fish that could not be aged, were grouped in 5-mm size classes. For each size class the number of unaged fish were apportioned to each age-group by the same percentage as fish that had been aged. We retained the age-3 group for comparative purposes, but could not differentiate between age-0 and age-1 fish.

The percentages at each age were remarkably similar, the differences between methods varying from only 0.1 to 2.7%. We concluded, therefore, that age compositions based on the previous method of aging are reliable and that valid inferences pertaining to population dynamics of Gulf menhaden can be based on them.

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