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Comparative Study of Juvenile American Shad Populations by Fin Ray and Scute Counts

By

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By

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ABSTRACT

Forty-five juvenile American shad, Alosa sapidissima (Wilson), collections, from 10 major shad producing rivers along the Atlantic coast of North America, were examined to see if differences in meristic counts suggested evidence of discrete river populations. Four meristic characters--pectoral, dorsal, and anal fin rays and scutes--were used. The difference in the counts between locations and between years within rivers was small compared to that between rivers. The differences in counts between rivers indicated that discrete populations of juvenile shad occurred in rivers.

INTRODUCTION

In studies to discover causes of the decline in yield of American shad, Alosa sapidissima (Wilson), and to determine factors favoring recovery of the fishery, it was essential that the number and distribution of populations be known.

The shad is widely distributed along the Atlantic coast from the St. Lawrence River, Canada, to the St. Johns River, Fla. This species is anadromous, spending most of its life in the ocean, but ascending coastal rivers to spawn. The spawning migrations into the rivers begin earliest in the southern part of the range (November in St. Johns River, Fla.) and are progressively later northward (June in St. John River, Canada). A female spawns about 250,000 eggs, and hatching occurs in 6 to 8 days at a water temperature of 17° C. The young shad stay in the rivers until autumn, attaining a length ranging from 75 to 145mm., and then migrate to sea. After spending from 2 to 6 years in the ocean, shad return to the rivers to spawn. Those spawning in rivers south of Cape Hatteras, N.C., normally die after spawning, while north of Cape Hatteras the proportion of fish spawning for the second time or more progressively increases from about 15 to 25 percent in Chesapeake Bay tributaries to about 45 to 55 percent in the Connecticut River.

Several workers have reported evidence of different shad populations along the Atlantic coast. Differences between shad from different areas based on meristic counts (Fischler, 1959; Hildebrand and Schroeder, 1928; Hill, 1959; Vladykov and Wallace, 1938), growth rates (Hammer, 1942;[1] Hildebrand and Schroeder, 1928), and fecundity (Davis, 1957; Lehman, 1953) indicated the occurrence of different populations. Recapture on the spawning ground of shad tagged in prior seasons indicated that they returned to their native streams to spawn (Hollis, 1948; Nichols, 1960). Also, the fact that the runs in the northern rivers were self-perpetuating and fluctuated independently (Talbot and Sykes, 1958) suggested different populations.

The purpose of this study was to determine if discrete populations of shad could be identified on the basis of consistent differences in counts of meristic characters in juveniles from 10 rivers. As used in this report, a "population" is a group of fish having similar meristic characteristics, of which the nature of origin, genotypic and/or phenotypic, of the characteristics has not been determined.

MATERIALS AND METHODS

For this study, the Atlantic coast was divided into three geographical areas: North Atlantic (Maine to Virginia); Chesapeake Bay (Maryland and Virginia); and South Atlantic (North Carolina to Florida). In 10 major shad producing rivers within these areas, 45 collections of juvenile shad, from 43 to 146 mm. fork length, were taken near spawning and

[1]The homing instinct of the Chesapeake Bay shad, Alosa sapidissima (Wilson), as revealed by a study of their scales. Thesis (typewritten), 1942, University of Maryland, 45 p.

nursery areas (table 1). Fifty specimens were sampled at random from each collection, covering the size range in each, for the analysis.

Table 1.--Juvenile American shad collections, from 10 Atlantic coast rivers, examined in meristic studies

Area and river	Collecting gear	Locations	Collections	Specimens	Size range fork length
		Number	Number	Number	Mm.
North Atlantic:					
Connecticut...	Seine	2	6	300	55-146
Hudson.....	Seine	3	9	450	45- 82
Chesapeake Bay:					
Susquehanna...	Seine	1	1	50	48- 70
Rappahannock..	Trawl	2	2	100	64- 89
York.....	Trawl	2	6	300	54- 90
James.....	Trawl	2	3	150	55- 88
South Atlantic:					
Neuse.....	Seine	2	5	250	43-110
Edisto.....	Trawl	1	4	200	56- 83
Ogeechee.....	Trawl	2	4	200	54- 84
St. Johns.....	Trawl	3	5	250	46- 74
		Total...	45	2,250	

In the North Atlantic area, collections of juvenile shad were taken from the Connecticut and Hudson Rivers. From the Connecticut, collections were taken above South Hadley Falls Dam at Holyoke, Mass., about 85 miles from the river mouth, and at Enfield, Conn., about 15 miles downstream of South Hadley Falls Dam, in the fall of 1954, 1957, and 1958. The collections taken above South Hadley Falls Dam were considered as an introduced population, because the dam blocked upstream migrating fish from this area for more than 100 years until a fish-passage facility was installed in 1952. In the Hudson, collections were taken at Piermont, N.Y., in the brackish water section about 30 miles from the river mouth; at Kingston Point, N.Y., in the freshwater section about 50 miles upstream from Piermont; and at Catskill, N.Y., about 25 miles upstream from Kingston Point, in the autumn of 1950 and 1951. Additional collections were taken at Kingston Point in 1954, 1957, and 1958.

In the Chesapeake Bay area, collections of juvenile shad were taken from the Susquehanna, Rappahannock, York, and James Rivers. From the Susquehanna River, collections were taken below the Conowingo Dam in 1958; from the Rappahannock River, at Long Point in 1954 and in Batchelors Bay in 1958; from the York River, at the Pamunkey Indian Reservation in 1953, 1954, 1956, and 1958 and at the Mattaponi Indian Reservation in 1954 and 1958; and from the James River, at Walcot Wharf, Va., in 1954 and at Claremont Beach, Va., in 1954 and 1958.

In the South Atlantic area, collections of juvenile shad were taken from the Neuse, Edisto, Ogeechee, and St. Johns Rivers. From the Neuse River, collections were taken at Bridgeton, N.C., in 1950, 1954, 1957, and 1958 and at Streets Ferry, N.C., in 1954; collections from the Edisto River at Crosby Landing, S.C., were available for 1938 and 1939 and were taken in 1957 and 1958; collections from the Ogeechee River were available for 1938 and 1939 from Kings Ferry, Ga., and were taken in 1957 and 1958 at the State Park, near Richmond Hill, Ga.; and collections from the St. Johns River were taken at Mandarin, Fla., in 1954, in Lake Harney in 1954, and at Palatka, Fla., in 1954, 1957, and 1958.

Using a binocular microscope, counts were made of left pectoral, dorsal, and anal fin rays and total scutes. Fin ray counts included all rudiments, and the last elements in anal and dorsal fins, originating from the same base, were counted as one ray. The dorsal fin origin often required dissection to expose embedded rays. Scales occasionally had to be removed to expose enveloped scutes and anal fin rays. No attempt was made to separate scutes into anterior and posterior counts. Not a single abnormal fin or scute was encountered out of the 2,250 specimens examined.

Analysis of variance (Snedecor, 1956; Steel and Torrie, 1960) was used to test if meristic count means of specimens were statistically different at the 1 percent level (indicated by two asterisks in the tables) between rivers, locations within rivers, and years within rivers. Before comparing the means, group variances were tested for homogeneity.

ANALYSES OF MERISTIC COUNTS

Differences and similarities in meristic counts for samples of shad from within individual rivers and between rivers are discussed in the following sections by geographical area.

North Atlantic Area

Meristic counts were made of juvenile shad taken at each location in the Connecticut and Hudson Rivers (tables 2 and 3).

Connecticut River.--Mean meristic counts for the Holyoke samples (above Hadley Falls Dam) in most instances were slightly higher than those for Enfield samples (below Hadley Falls Dam). The difference in pectoral fin ray counts was significant between locations (table 4). The difference in each mean meristic count was nonsignificant between years for the Enfield samples. No analysis was made for differences between years in the meristic counts from above Hadley Falls Dam.

Hudson River.--Differences in meristic counts were not significant between locations (Piermont-Kingston-Catskill) for the years 1950 and 1951. Since Kingston Point was the

Table 2.--Frequencies of meristic counts from juvenile American shad in samples from the Connecticut River, Conn., and Mass.

Location	Year	Number of pectoral fin rays								Mean	Standard deviation
		13	14	15	16	17	18	19	20		
		Frequency									
Enfield, Conn.	1954	3	30	17	-	-				15.28	0.5729
Do.	1957	7	29	14	-	-				15.14	0.6392
Do.	1958	8	23	19	-	-				15.22	0.7083
Holyoke, Mass.	1954	-	12	33	4	1				15.88	0.6273
Do.	1957	-	16	28	6	-				15.80	0.6389
Do.	1958	-	13	33	4	-				15.82	0.5602
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Enfield, Conn.	1954	-	6	30	14	-				18.16	0.6181
Do.	1957	-	6	33	11	-				18.10	0.5803
Do.	1958	-	4	33	13	-				18.18	0.5602
Holyoke, Mass.	1954	-	4	34	11	-				18.18	0.5956
Do.	1957	-	1	31	18	-				18.34	0.5794
Do.	1958	2	10	20	17	-				18.10	0.8864
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Enfield, Conn.	1954	-	8	29	12	1	-			21.12	0.6893
Do.	1957	1	8	23	9	9	-			21.34	1.0224
Do.	1958	4	11	16	13	6	-			21.12	1.1364
Holyoke, Mass.	1954	1	6	25	18	-	-			21.20	0.7284
Do.	1957	1	5	27	16	1	-			21.22	0.7365
Do.	1958	2	10	19	16	2	1			21.18	1.0039
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Enfield, Conn.	1954	-	5	21	20	3	1			36.48	0.8389
Do.	1957	1	4	15	19	11	-			36.70	0.9742
Do.	1958	-	4	12	22	12	-			36.84	0.8889
Holyoke, Mass.	1954	1	2	15	23	8	1			36.76	0.9161
Do.	1957	-	3	18	21	8	-			36.68	0.8192
Do.	1958	-	6	10	16	16	2			36.96	1.0872

Table 3.--Frequencies of meristic counts from juvenile American shad in samples from the Hudson River, N. Y.

Location	Year	Number of pectoral fin rays									Mean	Standard deviation
		13	14	15	16	17	18	19	20	21		
		Frequency										
Piermont	1950	4	20	23	3						15.50	0.7354
Do.	1951	-	23	24	3						15.60	0.6061
Kingston Point	1950	2	15	28	5						15.72	0.7010
Do.	1951	-	19	29	2						15.66	0.5573
Do.	1954	1	19	28	2						15.62	0.6024
Do.	1957	-	10	34	6						15.92	0.5657
Do.	1958	1	6	36	7						15.98	0.5887
Catskill	1950	3	17	27	3						15.58	0.6999
Do.	1951	1	27	21	1						15.28	0.5771
		Number of dorsal fin rays										
		16	17	18	19	20	21	22	23	24		
		Frequency										
Piermont	1950	3	28	13	6						18.44	0.7866
Do.	1951	1	25	20	4						18.54	0.6764
Kingston Point	1950	2	24	20	4						18.52	0.7068
Do.	1951	4	18	27	1						18.50	0.6776
Do.	1954	3	27	20	-						18.34	0.5928
Do.	1957	3	24	22	1						18.42	0.6417
Do.	1958	3	24	21	2						18.44	0.6749
Catskill	1950	6	20	21	3						18.24	0.7440
Do.	1951	4	19	26	1						18.48	0.6773
		Number of anal fin rays										
		18	19	20	21	22	23	24	25	26		
		Frequency										
Piermont	1950	1	5	20	21	3	-				21.40	0.8330
Do.	1951	-	4	12	27	4	3				21.80	0.9258
Kingston Point	1950	-	7	21	16	4	2				21.46	0.9733
Do.	1951	-	6	19	17	7	1				21.56	0.9510
Do.	1954	-	10	21	13	6	-				21.30	0.9313
Do.	1957	2	12	26	8	2	-				20.92	0.8533
Do.	1958	-	10	29	9	2	-				21.06	0.7398
Catskill	1950	2	7	17	18	6	-				21.36	1.0079
Do.	1951	1	12	20	13	4	-				21.10	0.9478
		Number of scutes										
		33	34	35	36	37	38	39	40	41		
		Frequency										
Piermont	1950	-	3	4	17	19	6	1			37.50	1.0736
Do.	1951	1	1	7	21	11	9	-			37.34	1.1178
Kingston Point	1950	-	-	11	15	20	3	1			37.36	0.9638
Do.	1951	-	1	10	19	14	6	-			37.28	0.9906
Do.	1954	1	2	4	13	20	8	2			37.62	1.1952
Do.	1957	-	1	7	20	15	5	2			37.44	1.0529
Do.	1958	-	4	3	15	26	2	-			37.38	0.9666
Catskill	1950	-	1	5	16	20	7	1			37.58	0.9897
Do.	1951	-	3	7	25	10	5	-			37.00	0.8562

only location that had a sufficient number of data for comparing different young, samples taken at Kingston Point only were used to test for differences between years. There were no significant differences between years (1950, 1951, 1954, 1957, 1958) for these samples (table 4).

Comparison between Connecticut and Hudson Rivers.--Differences in the meristic counts for the Hudson and Connecticut Rivers samples were tested for significance only for the years for which collections were available from both rivers (1954, 1957, 1958). Therefore, only the collections taken at Kingston Point on the Hudson and at Enfield on the Connecticut were used in the comparisons. The Enfield samples were considered representative of the Connecticut River population, while the Kingston Point sample was considered representative of the Hudson River population.

The mean meristic counts for Hudson River shad generally were higher than those of Connecticut River fish. Significant differences were found between rivers for all meristic counts, except anal fin rays (table 4). The interaction between years and rivers was not significant. The significant difference in three of the four counts indicated that discrete populations occurred in each river.

Table 4.--Analysis of variance on meristic counts for differences between locations and between years within rivers, and differences between rivers, for samples of juvenile American shad from the Connecticut and Hudson Rivers

River	Component	Degrees of freedom (n_1,n_2)	F-value
Connecticut	Between locations:		
	Pectoral fin rays.....	1,296	73.923**
	Dorsal fin rays.....	1,296	0.680
	Anal fin rays.....	1,296	0.060
	Scutes.....	1,296	1.403
	Between years: (Enfield Dam only)		
	Pectoral fin rays.....	2,147	0.605
	Dorsal fin rays.....	2,147	0.291
	Anal fin rays.....	2,147	0.854
	Scutes.....	2,147	2.027
Hudson	Between locations:		
	Pectoral fin rays.....	2,296	1.955
	Dorsal fin rays.....	2,296	1.317
	Anal fin rays.....	2,296	3.455
	Scutes.....	2,296	0.262
	Between years: (Kingston Point only)		
	Pectoral fin rays.....	4,245	3.395
	Dorsal fin rays.....	4,245	0.496
	Anal fin rays.....	4,245	4.494
	Scutes.....	4,245	0.665
Connecticut and Hudson	Between rivers:		
	Pectoral fin rays.....	1,296	76.506**
	Dorsal fin rays.....	1,296	12.853**
	Anal fin rays.....	1,296	0.915
	Scutes.....	1,296	48.726**

** Statistically different at 1 percent level.

Chesapeake Bay Area

Frequencies of the meristic counts for the samples of juvenile shad from the Chesapeake Bay tributaries are given in tables 5, 6, 7, and 8.

Susquehanna River.--Only one sample of juvenile shad was available from the Susquehanna River, collected in 1958 below Conowingo Dam (table 5), so no comparisons could be made.

Rappahannock River.--Mean meristic counts for the Rappahannock River samples were similar, and tests for differences in the counts between years were not significant (table 6). No comparisons were made, because the only sample taken in each of the two years was taken at different locations.

York River.--Mean meristic counts for the York River samples were similar between years and locations (table 7). Based on the

Table 5.--Frequencies of meristic counts from juvenile American shad in samples from the Susquehanna River, Md.

Location	Year	Number of pectoral fin rays	Mean	Standard deviation
		12 13 14 15 16 17 18 19		
		Frequency		
Conowingo Dam	1958	- 4 36 10	16.12	0.5206
		Number of dorsal fin rays		
		15 16 17 18 19 20 21 22		
		Frequency		
Conowingo Dam	1958	- 33 17 -	18.34	0.4785
		Number of anal fin rays		
		18 19 20 21 22 23 24 25		
		Frequency		
Conowingo Dam	1958	- 8 21 20 1 -	21.28	0.7570
		Number of scutes		
		33 34 35 36 37 38 39 40		
		Frequency		
Conowingo Dam	1958	- - 7 26 16 1	37.22	0.7083

Table 6.--Frequencies of meristic counts from juvenile American shad in samples from the Rappahannock River, Va.

Location	Year	Number of pectoral fin rays	Mean	Standard deviation
		11 12 13 14 15 16 17 18 19 20		
		Frequency		
Long Point	1954	5 27 17 1	15.25	0.6713
Batchelors Bay	1958	1 22 26 1	15.54	0.5789
		Number of dorsal fin rays		
		14 15 16 17 18 19 20 21 22 23		
		Frequency		
Long Point	1954	3 20 24 3	18.54	0.7060
Batchelors Bay	1958	2 23 21 4	18.54	0.7060
		Number of anal fin rays		
		17 18 19 20 21 22 23 24 25 26		
		Frequency		
Long Point	1954	- 5 13 29 3 -	21.64	0.7559
Batchelors Bay	1958	1 8 16 20 3 2	21.38	0.9666
		Number of scutes		
		32 33 34 35 36 37 38 39 40 41		
		Frequency		
Long Point	1954	- 5 23 18 4 -	36.42	0.7848
Batchelors Bay	1958	4 8 22 10 6 -	36.12	1.0812

Table 7.--Frequencies of meristic counts from juvenile American shad in samples from the York River tributaries, Va.

Location	Year	Number of pectoral fin rays							Mean	Standard deviation
		12	13	14	15	16	17	18	19		
		Frequency									
Pamunkey River	1953			2	31	17	-			16.30	0.5440
Do.	1954			2	24	23	1			16.46	0.6131
Do.	1956			4	33	12	1			16.20	0.6061
Do.	1958			-	28	22	-			16.44	0.5014
Mattaponi River	1954			2	26	21	1			16.42	0.6091
Do.	1958			4	24	22	-			16.36	0.6312
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Pamunkey River	1953		-	24	25	1				18.54	0.5425
Do.	1954		-	26	22	2				18.52	0.5799
Do.	1956		1	21	25	3				18.60	0.6389
Do.	1958		3	15	27	5				18.68	0.7407
Mattaponi River	1954		1	18	21	10				18.52	0.5799
Do.	1958		-	26	22	2				18.80	0.7825
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Pamunkey River	1953	1	7	27	12	3				21.18	0.8254
Do.	1954	-	10	18	20	2				21.28	0.8340
Do.	1956	-	7	22	16	5				21.38	0.8545
Do.	1958	-	12	16	20	2				21.24	0.8404
Mattaponi River	1954	-	11	28	10	1				21.02	0.7140
Do.	1958	2	14	23	9	2				20.90	0.8864
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Pamunkey River	1953	1	3	14	21	10	1			36.78	0.9750
Do.	1954	-	3	14	21	9	3			36.94	0.9742
Do.	1956	2	3	8	18	16	3			37.04	1.1599
Do.	1958	-	1	9	28	11	1			37.04	0.7548
Mattaponi River	1954	2	1	12	22	11	2			36.90	1.0351
Do.	1958	-	2	11	22	13	2			37.04	0.9026

samples from 1954 and 1958 only, differences in the meristic counts were not significant between locations. Based on the Pamunkey River samples only, differences between years also were not significant (table 9).

James River.--Mean meristic counts for the James River samples were similar between years and between locations (table 8). Based on the 1954 samples, counts were not significant between the two locations, and for the

Table 8.--Frequencies of meristic counts from juvenile American shad in samples from the James River, Va.

Location	Year	Number of pectoral fin rays								Mean	Standard deviation
		12	13	14	15	16	17	18	19		
		Frequency									
Walcot Wharf	1954		-	21	28	1				15.60	0.5345
Claremont Beach	1954		1	19	27	3				15.64	0.6312
Do.	1958		-	12	34	4				15.84	0.5481
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Walcot Wharf	1954		1	29	20	-				18.38	0.5303
Claremont Beach	1954		5	29	16	-				18.22	0.6158
Do.	1958		5	32	11	2				18.22	0.7083
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Walcot Wharf	1954		17	21	9	3				20.70	0.8631
Claremont Beach	1954		24	21	5	-				20.62	0.6667
Do.	1958		13	25	11	1				21.00	0.7559
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Walcot Wharf	1954		2	6	27	12	2	1		36.18	0.9190
Claremont Beach	1954		1	8	20	14	7	-		36.36	0.9848
Do.	1958		2	6	20	18	4	-		36.32	0.9355

Claremont Beach samples the differences between years were not significant.

Comparison between Chesapeake Bay tributaries.--Data for all locations and all years for which collections were available were combined in testing for significant differences in meristic counts between two rivers. There was a significant difference in the meristic counts between the York and James fish in all instances; between the Rappahannock and James, the Rappahannock and York, and the James and Susquehanna in three instances; and between the Rappahannock and Susquehanna, and the York and Susquehanna in two instances (table 9). Where applicable, the interaction between years and rivers was not significant. The differences in meristic counts between rivers indicated that discrete populations of shad occurred in the Chesapeake Bay tributaries.

Table 9.--Analysis of variance on meristic counts for differences between locations and between years within rivers, and differences between rivers, for samples of juvenile American shad from Chesapeake Bay tributaries

River	Component	Degrees of freedom (n_1,n_2)	F-value
York	Between locations:		
	Pectoral fin rays.....	1,197	0.514
	Dorsal fin rays.....	1,197	0.391
	Anal fin rays.....	1,197	6.569
	Scutes.....	1,197	0.000
	Between years: (Pamunkey River only)		
	Pectoral fin rays.....	3,196	2.335
	Dorsal fin rays.....	3,196	0.651
	Anal fin rays.....	3,196	0.493
	Scutes.....	3,196	0.825
James	Between locations:		
	Pectoral fin rays.....	1, 98	0.117
	Dorsal fin rays.....	1, 98	1.938
	Anal fin rays.....	1, 98	0.269
	Scutes.....	1, 98	0.893
	Between years: (Claremont Beach only)		
	Pectoral fin rays.....	1, 98	4.914
	Dorsal fin rays.....	1, 98	1.635
	Anal fin rays.....	1, 98	3.419
	Scutes.....	1, 98	0.570
Rappahannock-James	Between rivers:		
	Pectoral fin rays.....	1,248	13.258**
	Dorsal fin rays.....	1,248	9.922**
	Anal fin rays.....	1,248	46.227**
	Scutes.....	1,248	0.011
Rappahannock-York	Between rivers:		
	Pectoral fin rays.....	1,398	188.925**
	Dorsal fin rays.....	1,398	0.835
	Anal fin rays.....	1,398	10.885**
	Scutes.....	1,398	37.095**
Rappahannock-Susquehanna	Between rivers:		
	Pectoral fin rays.....	1,148	46.512**
	Dorsal fin rays.....	1,148	3.287
	Anal fin rays.....	1,148	2.111
	Scutes.....	1,148	38.965**
James-York	Between rivers:		
	Pectoral fin rays.....	1,448	131.156**
	Dorsal fin rays.....	1,448	27.412**
	Anal fin rays.....	1,448	22.951**
	Scutes.....	1,448	47.494**
James-Susquehanna	Between rivers:		
	Pectoral fin rays.....	1,198	21.394**
	Dorsal fin rays.....	1,198	0.476
	Anal fin rays.....	1,198	16.101**
	Scutes.....	1,198	41.121**
York-Susquehanna	Between rivers:		
	Pectoral fin rays.....	1,348	7.570**
	Dorsal fin rays.....	1,348	7.859**
	Anal fin rays.....	1,348	0.798
	Scutes.....	1,348	3.550

** Statistically different at 1 percent level.

South Atlantic Area

Meristic counts were made of juvenile shad taken for certain years at locations in the Neuse, Edisto, Ogeechee, and St. Johns Rivers of the South Atlantic area (tables 10, 11, 12, and 13).

Neuse River.--Based on the 1954 samples (table 10), differences in the meristic counts were not significant between the Bridgeton and Streets Ferry samples. Differences in the meristic counts were not significant between years for the Bridgeton samples (table 14).

Table 10.--Frequencies of meristic counts from juvenile American shad in samples from the Neuse River, N. C.

Location	Year	Number of pectoral fin rays								Mean	Standard deviation
		12	13	14	15	16	17	18	19		
		Frequency									
Bridgeton	1950	-	9	36	5	-				15.92	0.5284
Do.	1954	-	12	31	6	1				15.92	0.6652
Do.	1957	1	7	28	14	-				16.14	0.7001
Do.	1958	-	7	25	18	-				16.22	0.6788
Streets Ferry	1954	1	14	29	6	-				15.80	0.6701
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Bridgeton	1950	3	17	26	4	-				18.56	0.7329
Do.	1954	-	10	33	7	-				18.92	0.5859
Do.	1957	-	16	28	6	-				18.80	0.6389
Do.	1958	-	21	25	3	1				18.68	0.6833
Streets Ferry	1954	-	10	33	7	-				18.74	0.8033
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Bridgeton	1950	2	8	22	16	2	-			21.56	0.8889
Do.	1954	-	4	15	20	10	1			21.58	0.9708
Do.	1957	2	6	15	21	6	-			21.46	0.9941
Do.	1958	2	5	20	18	5	-			21.38	0.9452
Streets Ferry	1954	-	6	14	21	9	-			21.78	0.9322
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Bridgeton	1950	1	7	17	15	7	3			36.58	1.1445
Do.	1954	2	8	20	16	4	-			35.24	0.9596
Do.	1957	-	17	18	8	7	-			36.10	1.0351
Do.	1958	-	3	27	14	5	1			36.48	0.8389
Streets Ferry	1954	4	5	17	18	6	-			36.04	1.0806

Edisto River.--Samples were collected from only one location in the Edisto River (table 11). The differences in the counts between years were not significant (table 14).

Ogeechee River.--Since samples were obtained in different years from the two locations in the Ogeechee River, each location was analyzed separately in testing for differences in meristic counts between years, and no comparisons were made between locations (table 12). The differences in the counts between years were not significant (table 14).

Table 11.--Frequencies of meristic counts from juvenile American shad in samples from the Edisto River, S. C.

Location	Year	Number of pectoral fin rays								Mean	Standard deviation
		12	13	14	15	16	17	18	19		
		Frequency									
Crosby Landing	1938		6	28	16	-				16.20	0.6389
Do.	1939		4	27	18	1				16.32	0.6528
Do.	1957		1	31	17	1				16.36	0.5628
Do.	1958		1	35	13	1				16.28	0.5360
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Crosby Landing	1938		2	20	25	3				18.58	0.6728
Do.	1939		2	24	22	2				18.48	0.6465
Do.	1957		1	23	24	2				18.54	0.6131
Do.	1958		-	20	28	2				18.64	0.5628
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Crosby Landing	1938		2	15	22	10	1			20.86	0.8574
Do.	1939		2	20	17	11	-			20.74	0.8526
Do.	1957		2	23	18	7	-			20.60	0.7825
Do.	1958		3	15	24	8	-			20.74	0.8033
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Crosby Landing	1938		1	3	22	17	6	1		36.54	0.9304
Do.	1939		-	4	24	17	3	2		36.50	0.8864
Do.	1957		-	7	24	15	2	2		36.36	0.9205
Do.	1958		1	7	20	18	4	-		36.34	0.8947

Table 12.--Frequencies of meristic counts from juvenile American shad in samples from the Ogeechee River, Ga.

Location	Year	Number of pectoral fin rays								Mean	Standard deviation
		12	13	14	15	16	17	18	19		
		Frequency									
Kings Ferry	1938		5	36	9	-				16.30	0.6145
Do.	1939		3	30	16	1				16.07	0.5284
State Park	1957		1	39	10	1				16.18	0.4375
Do.	1958		-	34	15	1				16.34	0.5194
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Kings Ferry	1938		13	34	3	-				18.86	0.6704
Do.	1939		15	27	8	-				19.00	0.5345
State Park	1957		13	32	4	1				18.86	0.6392
Do.	1958		13	30	6	1				18.90	0.6776
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Kings Ferry	1938		2	13	21	11	3			21.00	0.9476
Do.	1939		2	8	26	11	3			21.10	0.8864
State Park	1957		3	8	21	16	2			21.12	0.9398
Do.	1958		1	11	23	7	8			21.20	1.0302
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Kings Ferry	1938		2	2	24	17	5	-		36.64	1.1205
Do.	1939		-	9	13	18	7	3		36.43	1.0529
State Park	1957		-	9	17	18	6	-		36.42	0.9278
Do.	1958		-	6	19	17	8	-		36.54	0.9082

St. Johns River.--Based on the 1954 samples from the St. Johns River (table 13), differences in the meristic counts were not significant between the three locations. Differences between years were tested for the Palatka samples only and were not significant (table 14).

Comparison between South Atlantic coast rivers.--Data for all locations and all years for which collections were available were combined in testing for significant differences in meristic counts between two rivers. There was

Table 13.--Frequencies of meristic counts from juvenile American shad in samples from the St. Johns River, Fla.

Location	Year	Number of pectoral fin rays								Mean	Standard deviation
		12	13	14	15	16	17	18	19		
		Frequency									
Mandarin	1954		1	32	17					16.32	0.4518
Lake Harney	1954		7	28	15					16.16	0.6503
Palatka	1954		1	38	11					16.20	0.5127
Do.	1957		6	27	17					16.22	0.6481
Do.	1958		5	37	8					16.06	0.5115
		Number of dorsal fin rays									
		15	16	17	18	19	20	21	22		
		Frequency									
Mandarin	1954		12	29	9	-				18.94	0.6389
Lake Harney	1954		11	24	14	1				19.10	0.7626
Palatka	1954		10	30	10	-				19.00	0.6518
Do.	1957		10	33	7	-				18.94	0.5859
Do.	1958		11	29	10	-				18.94	0.6543
		Number of anal fin rays									
		18	19	20	21	22	23	24	25		
		Frequency									
Mandarin	1954		5	19	18	8	-			21.58	0.8053
Lake Harney	1954		2	21	21	5	1			21.64	0.8020
Palatka	1954		3	19	23	4	1			21.62	0.8827
Do.	1957		5	21	19	4	1			21.50	0.8631
Do.	1958		2	14	28	6	-			21.76	0.7160
		Number of scutes									
		33	34	35	36	37	38	39	40		
		Frequency									
Mandarin	1954		-	3	11	26	10	-		36.86	0.9313
Lake Harney	1954		-	6	11	15	14	4		36.98	1.1516
Palatka	1954		-	4	17	21	6	2		36.70	0.8084
Do.	1957		1	6	20	19	4	-		36.38	0.8781
Do.	1958		-	4	20	23	3	-		36.50	0.7354

a significant difference in the meristic counts between the Edisto and Neuse, the St. Johns and Neuse, and the St. Johns and Edisto in three instances; between the Ogeechee and Neuse, and the Ogeechee and Edisto in two instances; and between the St. Johns and Ogeechee in one instance (table 14). These differences indicated that discrete populations of shad occurred in the South Atlantic coast rivers.

Table 14.--Analysis of variance on meristic counts for differences between locations and between years within rivers, and differences between rivers, for samples of juvenile American shad from South Atlantic coast rivers

River	Component	Degrees of freedom (n_1, n_2)	F-value
Neuse	Between locations:		
	Pectoral fin rays.....	1, 98	0.808
	Dorsal fin rays.....	1, 98	2.023
	Anal fin rays.....	1, 98	1.104
	Scutes.....	1, 98	0.239
	Between years: (Bridgeton only)		
	Pectoral fin rays.....	3,196	2.822
	Dorsal fin rays.....	3,196	3.019
	Anal fin rays.....	3,196	1.732
	Scutes.....	3,196	2.403
Edisto	Between years:		
	Pectoral fin rays.....	3,196	0.649
	Dorsal fin rays.....	3,196	0.580
	Anal fin rays.....	3,196	0.831
	Scutes.....	3,196	0.606
Ogeechee	Between years: (State Park only)		
	Pectoral fin rays.....	1, 98	2.775
	Dorsal fin rays.....	1, 98	0.092
	Anal fin rays.....	1, 98	0.165
	Scutes.....	1, 98	0.427
	Between years: (Kings Ferry only)		
	Pectoral fin rays.....	1, 98	3.685
	Dorsal fin rays.....	1, 98	0.245
	Anal fin rays.....	1, 98	0.297
	Scutes.....	1, 98	0.846
St. Johns	Between locations:		
	Pectoral fin rays.....	2,147	1.170
	Dorsal fin rays.....	2,147	0.693
	Anal fin rays.....	2,147	0.068
	Scutes.....	2,147	1.043

Table 14.--Analysis of variance on meristic counts for differences between locations and between years within rivers, and differences between rivers, for samples of juvenile American shad from South Atlantic coast rivers--Continued

River	Component	Degrees of freedom (n_1,n_2)	F-value
	Between years: (Palatka only)		
	Pectoral fin rays.....	2,147	2.732
	Dorsal fin rays.....	2,147	0.068
	Anal fin rays.....	2,147	1.306
	Scutes.....	2,147	4.763
Edisto-Neuse	Between rivers:		
	Pectoral fin rays.....	1,448	23.119**
	Dorsal fin rays.....	1,448	8.469**
	Anal fin rays.....	1,448	74.019**
	Scutes.....	1,448	0.898
Ogeechee-Neuse	Between rivers:		
	Pectoral fin rays.....	1,448	15.087**
	Dorsal fin rays.....	1,448	3.040
	Anal fin rays.....	1,448	16.382**
	Scutes.....	1,448	2.839
Ogeechee-Edisto	Between rivers:		
	Pectoral fin rays.....	1,398	1.305
	Dorsal fin rays.....	1,398	22.185**
	Anal fin rays.....	1,398	17.366**
	Scutes.....	1,398	0.614
St. Johns-Neuse	Between rivers:		
	Pectoral fin rays.....	1,498	12.160**
	Dorsal fin rays.....	1,498	16.679**
	Anal fin rays.....	1,498	3.465
	Scutes.....	1,498	14.738**
St. Johns-Edisto	Between rivers:		
	Pectoral fin rays.....	1,448	3.196
	Dorsal fin rays.....	1,448	50.127**
	Anal fin rays.....	1,448	130.011**
	Scutes.....	1,448	8.140**
St. Johns-Ogeechee	Between rivers:		
	Pectoral fin rays.....	1,448	0.396
	Dorsal fin rays.....	1,448	5.013
	Anal fin rays.....	1,448	38.413**
	Scutes.....	1,448	3.640

** Statistically different at 1 percent level.

RELATION BETWEEN MERISTIC COUNTS AND OTHER FACTORS

In certain instances significant differences were found in meristic counts between young shad from neighboring streams and among streams within large geographical areas. Whether the cause of these differences was primarily genetic or was environmental variation under which the fish developed, or a combination of both, would not affect the findings. Physical and chemical data on the environment at spawning time were not available, so the relation between differences or shifts in meristic counts between two separate rivers and environmental factors was not known. Lindsey (1957), Raney and Woolcott (1955), and Tåning (1952), and others, although working on species other than shad, listed temperature as the obvious environmental factor that may produce differences at the time these characters are formed in the embryo. Although shad spawn earlier in southern rivers and progressively later in northern rivers, widely separated populations spawn and eggs and larvae develop under about the same water temperature range. Laboratory rearing of the species under controlled conditions would be needed to demonstrate clearly the relation between meristic counts and temperature.

There was no consistent latitudinal cline in the meristic counts examined over the entire geographic range sampled. Fin ray counts were higher in southern rivers and lower in northern rivers, with intermediate counts in between. Scute counts were higher in northern rivers and lower in southern rivers. The Connecticut River samples had the lowest mean count in pectoral and dorsal fin rays, and the St. Johns River samples had the highest mean counts in dorsal and anal fin rays. However, the mean scute counts, which showed the greatest difference, reversed this pattern with the high in the Hudson River being more than one unit larger than the low counts in the Neuse River.

There were slight variations in meristic counts on juvenile shad between years and locations within a river, but these were not significant and were small compared to the differences in the counts between rivers. The differences in meristic counts between rivers indicated that discrete juvenile populations exist. For a better understanding of shad populations, future work should include studies of the relation between the meristic counts of juvenile shad and environmental variations under which the fish developed.

SUMMARY

To test if shad populations in various rivers could be separated by differences in meristic count, collections of juvenile shad from 10 rivers along the Atlantic coast were compared by analysis of variance. Counts of pectoral, dorsal, and anal fin rays and scutes were used.

Differences in counts of meristic characteristics within individual rivers and between rivers within geographical areas were as follows:

1. Within individual rivers, no significant differences were found between locations and between years except between locations for pectoral fin rays in the Connecticut River.

2. In the North Atlantic area, significant differences were found between the Hudson and Connecticut Rivers for all counts except anal fin rays.

3. In Chesapeake Bay tributaries, significant differences were found between the York and James Rivers for all counts; between the Rappahannock and James Rivers, the Rappahannock and York Rivers, and the James and Susquehanna Rivers for three of the counts; and between the Rappahannock and Susquehanna, and the York and Susquehanna Rivers for two of the counts.

4. In the South Atlantic area, significant differences were found between the Neuse and Edisto Rivers, and the Neuse and St. Johns

Rivers for three of the counts; between the Neuse and Ogeechee Rivers, and the Ogeechee and Edisto Rivers for two of the counts; and between the Ogeechee and St. Johns Rivers for one of the counts.

These findings indicated that discrete populations of shad occurred in Atlantic coast rivers.

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