COMPARATIVE STUDY OF POPULATIONS OF THE STRIPED BASS

SPECIAL SCIENTIFIC REPORT-FISHERIES No. 204

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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United States Department of the Interior, Fred A. Seaton, Secretary
U. S. Fish and Wildlife Service

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Special Scientific Report--Fisheries No. 204.

Washington, D. C.

June 1957

ABSTRACT

This study was undertaken in an effort to determine the value of gill raker counts as a taxonomic tool in classifying populations of striped bass, Roccus saxatilis. The possibility of a change with age and a difference between sexes in the number of gill rakers was investigated. Specimens were available from Philip River, Miramichi River, St. Lawrence River, coastal Rhode Island, Long Island Sound, Hudson River, Mullica River, Delaware River, Chesapeake Bay, Albemarle Sound, Pamlico River, Cape Fear River, Santee-Cooper River System, Gulf of Mexico and California. Gill raker counts were subjected to the following statistical procedures: t-test, analysis of variance, analysis of co-variance, chi-square and regression. The tests showed that there was no change in the number of gill rakers in the first two years of growth and that there was no significant difference in the number of gill rakers between males and females. On the basis of gill raker counts only, specimens from the Santee-Cooper River System, South Carolina were considered as one population; this was also true for specimens from the Hudson River, New York. The Chesapeake Bay population was divided into three main subpopulations. Samples from Long Island Sound were intermediate between those of Chesapeake Bay and the Hudson River. Specimens from California and the Hudson River had high counts and those from the Delaware River approached those from the James River in the Chesapeake Bay. It was shown that gill raker counts could be used to separate populations of striped bass.

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COMPARATIVE STUDY OF POPULATIONS OF THE STRIPED BASS[1/]

This study was instituted to determine whether gill rakers were a valid taxonomic tool that could be used along with other meristic characters to classify populations of striped bass, Roccus saxatilis (Walbaum). Racial studies of the striped bass have been made by Merriman (1937 and 1941), Vladykov and Wallace (1952), Raney and de Sylva (1953), Raney, Woolcott, and Mehring (1954), Raney and Woolcott (1955), and Raney (ms.).

The striped bass is found along the Atlantic coast from the St. Lawrence River to the northern part of Florida. It also occurs in the Gulf of Mexico from the west coast of Florida to Louisiana. Striped bass from northern New Jersey were shipped to California in 1879 and 1881 and are now well established there.

The striped bass is economically important in most parts of its range. It is therefore necessary, as an aid to management of this species, to know where populations occur and how to separate them from other populations that exist in close proximity. This gill-raker study was conducted, along with many other past and present racial studies, to help achieve this end.

The writer wishes to express his appreciation to Dr. Edward C. Raney of the Department of Conservation for his guidance during the course of this study. He also wishes to thank Dr. Clifford O. Berg of the Department of Entomology and Limnology for his criticism of the manuscript. Dr. R.G.D. Steel and Dr. Douglas Robson gave valuable statistical advice.

LITERATURE REVIEW

Gill rakers have been used as a taxonomic character at all levels of differentiation, generic, specific, subspecific, and race.

Vladykov and Wallace (1952) working with the striped bass from the Atlantic coast, maintained that gill rakers were not a useful character for racial determination because they thought they varied with age. Other workers have used gill-raker counts in taxonomic studies. Vladykov and Beaulieu (1951), working with the sturgeon in the Province of Quebec, found that the young of Acipenser fulvescens have their gill rakers closer together than the adults. This is explained by the fact that the development of the gill rakers is already completed in the case of the young, while growth of the gill arch continues through the rest of the life of the fish. They worked with three species of Eastern North American sturgeon and concluded that the number of gill rakers on the first branchial arch is a very important taxonomic character.

Suärdson (1952), studying coregonid fishes in Sweden, considered that environment affects the number of gill rakers very slightly or not at all. Hildebrand and Schroeder (1928) found that the number of gill rakers of Alosa sapidissima change with age. Vladykov (1954) thought that the number of gill rakers were of very little value as a character for chars (Salvelinus). Working with the berycoid fish family Polymixiidae, Lachner (1955), found that the number of dorsal fin rays and the total number of gill rakers were the most critical characters in the separation of the species. Ginsburg (1955), in his study of the genus Bembrops, also used gill rakers as an important meristic character. McGregor (1924) used a combination of gill rakers, pyloric caeca, branchiostegals, ova, and vertebrae to separate races of king salmon from the Klamath and Sacramento Rivers in California.

McHugh's (1951) study of the meristic variations of Engraulis mordax mordax showed a gradual increase in the number of gill rakers in larger fish. He was able to demonstrate by statistical treatment among three localities, that ranged from British Columbia to Baja California, that there were highly significant differences among localities and between sexes within each locality.

1/ A thesis presented to the faculty of the Graduate School of Cornell University for the degree of Master of Science.

MATERIAL EXAMINED

The collections examined are listed from north to south along the Atlantic Coast; California specimens are listed at the end. The abbreviations used are C.U., Cornell University; U.S.N.M., United States National Museum; U. Md., University of Maryland; N.C.S.C., North Carolina State College; U.M., University of Michigan. The 1954 collections from the Hudson River were made by Warren F. Rathjen and Lewis C. Miller (RM) of the New York State Conservation Department. The mileage from the mouth of a river is sometimes given. Thus PX40 denotes a distance of 40 miles from the mouth of the Patuxent River. Mileage in the Pamunkey and Mattaponi Rivers is from the mouth of the York River. In the case of the Chickahominy River, its mileage is measured from the mouth of the James River. Standard geographical abbreviations are used. For each collection the following data are given: Location, date of collection, number of specimens counted, in parenthesis, and catalog number.

Quebec: St. Lawrence R. at Chateau-Richer Village about 20 mi. west of Quebec City, Oct. 22, 1944, (62), C.U. 29605.

New Brunswick, Miramichi R.: Vicinity of Chatham, Dec. 7-21, 1952, (50), C.U.22135; Dec. 1953, (28), C.U. 28376; Loggieville to New Castle, Nov. 15-Dec. 15, 1955, (55), C.U. 29727.

Nova Scotia, Philip R.: 5 miles above Moater, Nov. 1955, (7), not catalogued; Ph5, Dec. 1955, (60), not catalogued.

Rhode Island: Pt. Saconnet, May 11, 1953, (37), C.U. 20641; Newport, May 24, 1955, (21), C.U. 29091.

Connecticut, Cos Cob Power Plant: Jan. 1953, (6), C.U. 21709; Jan.-Feb. 1953, (22), C.U. 20640; Oct. 1953, (21), C.U. 28377; Darien, L.I. Sd., Oct. 30, 1954, (1), C.U.28341; Greenwich, L.I. Sd., Nov. 11, 1954, (1), C.U. 28342; Darien, L.I. Sd., Oct. 30, 1954, (1), C.U. 28343; Greenwich, L.I. Sd., Oct. 19, 1954, (5), C.U. 28344; Fairfield, L.I. Sd., Aug.-Nov. 1954, (14), C.U. 28267.

New York, Hudson River:

1936: Haverstraw, Aug. 25, (27), C.U. 5180; Nyack, Sept. 1, (10), C.U. 27063.

1949: Port Ewen, Aug. 26, (12), C.U. 18215; Haverstraw and Stoney Pt., Aug. 5, (36), C.U. 15463; Haverstraw and Stoney Pt., Sept. 13, (13), C.U. 18219; Stoney Pt., Aug. 26, (21), C.U. 18221.

1950: Catskill to Piermont, Sept. 4-9, (36), C.U. 21070.

1952: Kingston, Oct. 9, (2), C.U. 22714; Fishkill, Aug. 21, (3), C.U. 22715; Fishkill, Oct. 9, (2), C.U. 22716; Haverstraw, Aug. 7, (2), C.U. 22717; Haverstraw, Aug. 15, (7), C.U. 22718; Haverstraw, Oct. 9, (3), C.U. 22719.

1953: Coxsackie, Sept. 10, (50), C.U. 24028; Beacon, Sept. 11, (12), C.U. 24037; Haverstraw, Sept. 11, (55), C.U. 24043.

1954: Coxsackie, Aug. 4, (50), C.U. 27128; Coxsackie, July 26, (23), RM 116; Coxsackie, Oct. 14, (9), RM 190; Coxsackie, June 23, (54), C.U. 26281; Coxsacki, July 13, (16), C.U. 26380; Middle Ground Is., July 8, (8), RM 89A; Haverstraw, Sept. 30, (34), RM 184; Haverstraw, Aug. 9, (9), RM 151; Haverstraw, Aug. 13, (6), RM 143; Haverstraw, July 29, (40), RM 126; Haverstraw, Sept. 21, (23), RM 175; Haverstraw, Oct. 20, (30), RM 192; Haverstraw, July-Aug. (12), RM 1-12; Harmon, Aug. 27, (20), RM 155; Harmon, Sept. 21, (27), RM 174; Croton, Nov. 4, (19), RM 194; Nyack, Aug. 19, (31), RM 152; Nyack, Aug. 4, (50), C.U. 27037; Palisade State Park, Sept. 10, (14), RM 168; Palisade State Park, Sept. 30, (34), RM 185; Palisade State Park, Oct. 20, (20), RM 193.

New Jersey: Mullica R., at Lower Bank, Feb. 16, 1954, (45), C.U. 25779; Delaware R. at Deepwater: Oct. 9, 1952 (83), C.U. 22004 and Aug. 26, 1953, (39), C.U. 23755; Maurice R., Yaup Shore Station, Sept. 8, 1954, (16), C.U.28453.

Chesapeake Bay and tributary rivers:

Susquehanna R. at B. and O. R.R. Bridge: Sept. 14, 1955, (14), C.U. 29724; Sept. 27, 1955, (46), C.U. 29675.

Elk R.: Aug. 4, 1955, (49), C.U.29098.

Sassafras R.: Buoy #6, Sept. 15, 1955, (15), C.U. 29718; Ordinary Pt., Sept. 15, 1955, (48), C.U. 29690.

Middle. R.: Piney Pt. Bar, Sept. 28, 1955, (15), C.U. 29697.

Back R.: Back R. Bridge, Sept. 28, 1955, (19), C.U. 29674; Witchcoat Rt., Sept. 28, 1955, (22), C.U. 29677.

Patapsco R. System: Curtis Cr., Sept. 26, 1955, (4), C.U. 29722; Stoney Cr., Sept.22, 1955, (8), C.U. 29686; Stoney Cr., Sept. 22, 1955, (2), C.U. 29701; Curtis Cr., Sept. 26, 1955, (1), C.U. 29684; Marley Cr., Sept. 26, (3), C.U. 29688; Curtis Bay, Sledds Pt., Sept. 26, 1955, (2), C.U. 29700; Stoney Cr., Sept. 22, (29), C.U. 29717.

Chester R., 1955: 2-1/2 miles below Chestertown, Aug. 4, (34), C.U. 28812; Hail Pt., Sept. 6, (16), C.U. 29709; Near Bay #35, Sept. 16, (2), C.U. 29693; Wilner Pt., Sept. 16, (1), C.U. 29720; Below Chestertown Yacht Club, Sept. 16, (2), C.U. 29706; Piney Pt., Sept. 16, (3), C.U. 29708; Milton Pt., Sept. 16, (8), C.U. 29719.

Severn River System, 1955: Old Hatchery, July 17, (5), C.U. 29771; Long Pt., July 28, (1), C.U. 29793; Epping Forest, July 28 (3), C.U. 29776; Mathews Pt., July 27, (6), C.U. 29784; Little Round Bay Cr., July 28, (1), C.U. 29765; Spring Cr., July 20, (4), C.U. 29779; 1 mi. above Old Hatchery, July 27, (3), C. U. 29764; Saltwater Cr., July 28, (1), C. U.29780; Valentine Cr., July 27, (4), C.U. 29774; Severnside, July 29, (1), C.U. 29790; Sherwood Forest, July 29, (2), C.U. 29777; Rt. 301 bridge, Aug.9, (1), C.U. 29767; Poosey Cr., July 29, (1), C.U. 29766; Rock Cove, July 27, (2), C.U. 29768.

Miles R., 1955: Miles R. Bridge, Aug. 25, (3), C.U. 29685; Mouth Royal Oak Cr., Aug. 25, (3), C.U. 29682; Yacht Club, Aug. 25, (5), C.U. 29704; Miles R. Bridge, Aug. 26, (7), C.U. 29672; Miles R. Bridge, Aug. 26, (7), C.U. 29687; Miles R. Bridge, Aug. 26, (13), C.U. 29696.

Choptank R.: 1 mi. below Ganey Wharf, Aug. 3, 1955, (44), C. U. 28756.

Patuxent R. System: Prince Frederick, Aug. 27, 1953, (36), C.U. 23507; 1955: St. Leonard Cr., Aug. 5, (3), C.U. 29769; PX40, July 22, (1), C.U. 29770; Below first bend, July 13, (2), C.U. 29773; PX21, Sept. 16, (2), C.U. 29772; Battle Cr. at Resthaven, Aug. 10, (1), C.U. 29783; Kaylor's Landing, Sept. 15, (1), C. U. 29792; Battle Cr., Aug. 10, (8), C.U. 29778; PX21, June 17, (1), C.U. 29788; PX22, June 17, (1), C.U. 29786; Mill Cr., Aug. 4, (1), C. U. 29775; Nottinghan, Sept. 15, (1), C.U. 29791; PX40, July 13, (1), C.U. 29787; Holland Pt., Sept. 16, (1), C.U. 29789; Holland Beach, Aug. 8, (3), C.U. 29785; PX40, July 22, (12), C.U.29781; PX34, July 26, (17), C.U. 29782.

Nanticoke R., 1955: Sandy Hill Beach, Aug. 2, (16), C.U. 28712; Lewis Wharf, Aug. 2, (11), C.U. 28724; Sharptown, Aug. 3, (50), C.U. 28751.

Wicomico R., 1955: Greenhill Church, Aug. 2, (50), C.U. 29096.

Potomac R. System: Fort Belvoir, Oct. 13, 1948, (18), C.U. 28996; Toll Bridge on Rt. 301, Oct. 30, 1953, (12), C.U. 25568; 1955: Liverpool Pt., Oct. 18, (13), C.U. 29687; Quantico, Oct. 18, (22), C.U. 29723; Wicomico R. Oct. 18, (29), C.U. 29680; Wicomico R. at Rock Pt., Oct. 18, (27), C.U. 29676; Morgan Haven, Oct. 18, (31), C.U. 29679; St. Georges Cr., Oct. 19, (33), C.U. 29673; Fenwick, Oct. 19, (12), C.U. 29681.

Crisfield, Md.: Aug. 10-11, 1948, (7), U. Md. 2128; Aug. 10-11, 1949, (39), U. Md. 3055; July 12-14, 1949, (11), U. Md. 2934; Sept. 12, 1949, (1), U. Md. 3108; July 26, 1949, (11), U. Md. 2961; 1951: Oct. 5, (1), U. Md. 3931; Aug. 8 (6), U. Md. 3755; Aug. 30, (2), U. Md. 3794; Aug. 29, (3), U. Md. 3703; July 11, (11), U. Md. 3609; July 10, (9), U. Md. 3588; July 10, (2), U. Md. 3377; July 9, 1952, (23), U. Md. 3658.

Rappahannock R. System, Va.: Betw. Tappahannock and Fredricksburg, Aug. 23-25, 1951, (10), not catalogued; Saunders Wharf, Aug. 30, 1953, (50), C.U. 23672; R38, Mar.-April 1954, (23), C.U. 26149; July 22, 1954, (12), C.U. 28056; Tappahannock, Aug. 29, 1954, (26), C.U. 28317; Layton's Landing, July 18, 1955, (50), C.U. 28894.

York River System, Va.:

York R.: Almondsville to West Point, Mar.-April 1954, (79), C.U. 26150; Pages Rock Y10, Mar.-April 1954, (7), C.U. 26151; West Point, July 1955, (52), C.U. 29089.

Pamunkey R.: Mussel Pond Beach, Aug. 4, 1949, (11), C.U. 14666; Sweet Hall Landing, Aug. 11, 1949, (8), C.U. 14466; Hill Reach, Aug. 21, 1949, (1), C.U. 14383; Sweet Hall Landing Pocket, Aug. 11, 1949, (1), C.U. 14455; Sweet Hall Landing, Aug. 31, 1949, (7), C.U. 14579; Hillis Reach, Sept. 29, 1949, (6), C.U. 14601; Hillis Reach, Station #12, July 28, 1949, (13), C. U. 14856; P40 to P65, Aug. 4-29, 1953, (16), C.U. 23581; West Point to Lestor Manor, Aug. 12-22, 1952, (35), C.U. 21941; P48, July 21, 1954, (50), C.U. 26561; P43, July 19, 1955, (50), C.U. 28613.

Mattaponi R.: West Point to Aylett, Aug. 25-28, 1952, (15), not catalogued; M45 to M55, Summer 1955, (16) C.U. 23933.

James River System, Va.:

James R.: Jamestown Island to Hopewell, Sept. 3-10, 1952, (9), not catalogued; Sandy Pt., Aug. 30, 1953, (4), C.U. 23468; Hopewell, Mar.-April 1954, (58), C.U. 26147; J42, July 21, 1955, (7), C.U. 28743; J35, July 21, 1955, (58), C.U. 28646; Hopewell, July-Aug. 1955, (44), C.U. 29090.

Chickahominy R.: Richmonds Farm, June 26, 1949, (18), C.U. 16747; C55, July 23, 1954, (41), C.U. 26642; C43, July 21, 1955, (27), C.U. 28639.

Norfolk, Va.: April 13, 1953, (15), C.U. 20627.

Albemarle Sound, N.C.: 1 mi east Rt. 37 crossing, April 15, 1953, (26), C.U. 20626; N. end Rt. 32 bridge, Aug. 28-29, 1953, (34), C.U. 23541; Mouth North River, Mar. 29, 1954, (17), C. U. 25842; North side bridge, Aug. 30, 1954, (16), C.U. 28322; The following N.C.S.C. collections have no catalog numbers: Albemarle Sd., July-Sept., 1946, (23); Albemarle Bridge southside, July 26, 1946, (9); Albemarle Sd., northside, Sept. 28, 1945, (3); Albemarle Sd., July 1945, (2); Albemarle Sd., 1955, (41); Little R., Summer 1954, (27), C.U. 28337; Roanoke R., April 1954, (5), C.U. 28336; Chowan R., Aug. 30, 1954, (44), C.U. 28161.

Pamlico R., N.C.: Washington Bridge to 5 mi. downstream, Oct. 27, 1954, (25), C.U. 28455.

Cape Fear, N.C.: Collections of N.C.S.C. with no catalog numbers; 1951, (7); Cape Fear River, Aug. 2, 1952, (2); 1953, (17); 1954 (2).

Santee-Cooper River System, S.C.: Lake Moultrie, Oct. 28, 1952, (2), C.U. 22073; Pinopolis Dam, April 2-May 5, 1954, (49), C.U. 26148; Lake Marion, Sept. 10, 1954, (50), C.U. 28225; Pinopolis Dam, Mar. 31, 1955, (9), C.U. 28520; Below Lake Moultrie Dam, Mar. 31, 1954, (6), C.U. 25993; Tailrace Canal, Mar. 31, 1955, (4), C.U. 28518; Pinopolis Dam, Mar. 29, 1955, (10), C.U. 28511; Tailrace Canal, April 20, 1955, (7), C.U. 28519; Diversion Canal, June 30, 1955, (55), C.U. 29017; Tailrace Canal, Sept. 1, 1955, (16), C.U. 29088; Pinopolis Dam, Sept. 1955, (14), C.U. 29670; Pinopolis Dam, Nov. 7, 1955, (19), C.U. 29671.

Ashley River, S. C.: Runney Meade Plantation, Nov. 22, 1953, (3), C.U. 24984.

Broad R., S.C.: Columbia, April 9, 1955, (17), C. U. 28521.

Gulf of Mexico: West Florida, (4), U.S. N.M. 35144, 126060, 126061, and 21312; Alabama R., mouth of Autauga Cr., June 1955, (2), C.U. 29628; Alabama, June 1955 (4), Ala. Poly. Inst.

California: Sacramento R., 7 mi. n. Antioch Bridge, Aug.-Sept. 1945, (50), C.U. 28573; Sacramento R., near Three Mile Slough Bridge, Aug.-Sept. 1945, (73), C.U. 28574; Sacramento R. at Rio Vista, Aug.-Sept. 1945, (62), C.U. 28575; Delta Area, San Francisco, 1951, (43), C.U. 20724; Carquinez Straits, Aug. 18, 1943, (20), U.M. 142369; Carquinez Straits, Sept. 11, 1946, (16), C.U. 28576.

METHODS

The specimens that were examined ranged from 26 to 489 mm. in standard length; the majority were either 0 (young) or I (yearling) in age. In order to count the number of gill rakers present on the first left branchial arch, it was necessary to remove the arch from the fish. Gill rakers were counted using a binocular microscope; they were tabulated as follows: the number present on the upper arm plus one at the angle of the arch plus the number on the lower arm. All developed gill rakers were counted. At the extreme ends of the arch, tubercles sometimes occurred. If higher than the diameter of their base they were counted; if not, they were considered as rudiments and not counted.

Some of the specimens had been put in a deep freeze and later were transferred to formalin. In these cases mucus had built up on the gill arches and it was necessary to scrape it off before counts could be made. The same situation existed when specimens had been poorly preserved. Gill raker counts were not made on fish below 26 mm. due to the difficulty of removing the entire gill arch.

Comparisons between samples were made by the following statistical procedures: analysis of variance, analysis of covariance, t - test and chi-square test and were in accordance with the methods followed by Snedecor (1946) and Steel and Torrie (ms.). Chi-square tests were run on samples that had a binomial distribution and on distributions that approached normality but the resulting level of significance was the same as when an analysis of variance was used.

Statistical significance is designated in the tables as follows: N.S. - not significant; * - significant at the five percent level; ** - significant at the one percent level. If the age of specimens in the sample is not stated in the table title, it is designated after the individual sample as: yg. - young or yr. - yearling.

Owing to environmental variation Rounsefell and Everhart (1953) considered it advisable to use the same year class in comparing samples of fish. In this study of gill-raker counts of striped bass, the same year classes are not always available from all the areas studied. Therefore, when several year classes from one river or area were compared and the differences found to be non-significant, these samples were combined and used to make comparisons with other areas.

When the term "by observation" is used it indicates that a previous t - test with less divergence between the means had been made and the results were significant.

In this paper a population is considered in the same sense as Mayr, Lindsley and Usinger (1953:308) use the term local population, that is, "the individuals of a given locality which potentially form a single interbreeding community." The term subpopulation is used to denote the specimens from the James, York-Rappahannock and Upper Bay Rivers in the Chesapeake Bay following the findings of Raney (ms.).

RESULTS

Variation in the number of gill rakers with age.--In order to determine if the number of gill rakers changes with age, a study was made of counts from localities where young of the year and older fish were available. The results are based on fish classified as O, I and a few II.

The best way to determine if there is a change with size or age is by use of statistical regression. A plot of the data was made on a graph and from this it was ascertained that the regression was linear. Therefore using the formula $\hat{Y} = \bar{y} + b\,(X - \bar{x})$, a linear regression line was calculated (Snedecor, 1946).

To get a clear picture of any possible change in gill raker number, fish from one year class and one locality were selected. One of the underlying assumptions of a regression, which is a moving average, is that the variances of the individual samples be homogeneous. This was verified by Bartlett's test of homogeneity of variance.

The results of several samples and combinations of samples are shown in table 1. First a regression on the individual samples was run. In all the rivers or river systems (Rappahannock, York, James, Albemarle Sound, and Santee-Cooper) the slope of the regression line fell very close to the abscissa. This was true whether the samples were just 0, I, II or any combination of these. The same held true if the counts were from the total number of gill rakers on the first left branchial arch or just the number of gill rakers from the upper arm of the same branchial arch. From observation of table 1 it seems that the (plus) or (minus) slopes are just random variations and if a large number of samples were taken the total population would have a slope of zero.

The above results indicate that there is no change in the number of gill rakers from O to I. We do not have adequate collections of III and older age groups to determine if the number of gill rakers change with these ages.

Variation in number of gill rakers with sex.--A study was made of striped bass, that were collected from the Delaware River in 1952, to determine if the number of gill rakers varied with sex. Specimens were immature and ranged in standard length from 72 to 198 mm. As there is no known way of determining the sex from external characters, a dissection was made. A section of the gonad was removed and a smear was examined using a compound microscope.

A t - test was used to compare the number of gill rakers in the sexes (table 2) and proved not to be significantly different. Therefore, it is concluded that there is no sexual difference as far as gill rakers are concerned.

Populations.

The Chesapeake Bay.--The 1955 year class and the 0 age group are available from the majority of the river systems in the Chesapeake Bay region. An analysis of variance was run on this group using the total number of gill rakers (table 3) and the F - value was highly significant. This same high significance also occurred when the number of gill rakers on the upper arm of the first branchial arch was used as the test criterion (table 4). For these data, the analysis of variance shows that more than one population exists in the Chesapeake Bay.

In order to determine where similarities and differences occurred, meaningful comparisons were carried out based on geographical locations. Therefore, an analysis of variance using the total number of gill rakers was performed on samples from the Chesapeake area, excluding those from the Rappahannock, York and James River Systems. The resulting F - value was significant at the one percent level but with a much lower magnitude than when these river systems were included (table 5A).

As the mean of the Patuxent River sample was the lowest value of any in the Upper Bay area it was deleted in the next test. The resulting F - value proved to be significant at the 5 percent level (table 5B). Still another analysis of variance was carried out with the Wicomico River sample dropped from the above grouping. The mean of the latter was the highest except for that of the Choptank, but due to its more southern location on the eastern shore it was more meaningful to omit it. The F - value from this test was not significant (table 5C).

A similar series of analyses of variances was worked out using the number of gill rakers on the upper arm of the gill arch. The F - value was highly significant when the whole bay area was included (table 4). When samples from the Rappahannock, York and James were excluded the resulting F was highly significant, but the magnitude was less (table 6A). Omitting the Patuxent sample from the Upper Chesapeake Bay area, F became non-significant (table 6B).

T - tests were executed for the 1955 year class and 0 age based on total numbers of gill rakers with the following results: A test between the Rappahannock and York River System samples was not significant (table 7A). However, when those of the York and Rappahannock Systems were tested against the James River sample, there was significance at the one percent level (table 7B). Also there was found to be no significant difference between upstream and downstream samples from the James River (table 7C). When the samples from the west shore of Chesapeake Bay (excluding Rappahannock, York, and James) were lumped and compared with the combined east shore samples, the result was just significant at the 5 percent level (table 8A). A similar comparison using the number of gill rakers on the upper arm of the arch showed no significant difference (table 8B).

For the 1954 year class, no significant differences in total numbers of gill rakers were found between upstream and downstream samples from the York and James River Systems. This involved a comparison between 0 and I in both cases (tables 9A and 9B).

When total gill raker counts of 0 and I samples of the Rappahannock 1953 year class were compared, t was found to be significant at the 5 percent level (table 10A). However, using the counts of the upper arm there was no significance (table 10B).

A t-test was also run on the samples of the 1953 year class from the York River System. Using the count on the upper arm there was no significant difference between the Mattaponi 0 and the York I (table 10C), but when using the total number of gill rakers, the difference proved to be significant at the one percent level (table 11A). When a covariance was run to adjust the fish to a common standard length the F - value was not significant (table 12).

A comparison of Rappahannock and York samples was made by use of a t - test for the above data. For the total number of gill rakers of the I specimens there was no significant difference (table 11B). By observation, the mean of the Rappahannock (24.68) versus the mean of the York (24.69) was not considered to be significantly different for the 0 age group either.

An analysis of variance of 0, I and II age groups of the 1952 year class in the York River System proved not significant (table 13). Also an analysis of variance was carried out for the 0 age group of the 1949 year class from Crisfield, Maryland and there was no significance (table 14). Samples of 5 year classes (1949, 1952, 1953, 1954 and 1955) from the James River were compared by an analysis of variance. It was found that there was a significant difference (table 15).

The mean value of the gill raker count on the first branchial arch and those from the upper arm of the same arch of samples of young of the 1955 year class from 17 rivers were ranked from the lowest to the highest under the two categories. The resulting correlation coefficient (r = .806) indicates a good correlation.

In summarizing the results given above, a biological difference was considered to exist only if the statistical differences were of a large magnitude when using both the count on the upper arm and the total number of gill rakers. The results seem to indicate that several subpopulations of striped bass exist in the Chesapeake Bay. The first subpopulation is in the Upper Bay; this includes the rivers north of the Rappahannock on the west shore and all the east shore rivers covered in this study. The Patuxent River sample has a lower gill raker count than the other rivers in the Upper Bay but perhaps this is not of biological significance and may be due to random variation or other sampling procedures. However, until stronger evidence is presented that the Patuxent River is biologically different, it should be considered as belonging to the homogeneous subpopulation from the Upper Chesapeake Bay.

The Rappahannock and York striped bass belong to another subpopulation, while the James is the third subpopulation. There doesn't seem to be any upstream - downstream difference in any of the rivers that can be deemed biologically significant.

Enough statistical difference exists among year classes from the same locality so that it seems unwise to lump year classes in making comparisons between localities. Study of additional year classes from throughout the Chesapeake Bay region may modify these conclusions.

<u>Comparison of populations above and below Pinopolis Dam, South Carolina</u>.--A unique situation exists in the Santee-Cooper Reservoir System of South Carolina. With the completion of Pinopolis Dam in 1942, water was impounded in Lake Moultrie and Lake Marion. This provided a fairly effective separation for striped bass above and below the dam. Scruggs and Fuller (1955) found that there is slight recruitment of fish from the Cooper River to the reservoir population during the operation of the locks; they also found that adequate spawning occurred above and below the dam.

Specimens of age group 0 were obtained above the dam, while I, and II were found below. An analysis of variance, using the 1953, 1954 and 1955 year classes and the three age groups, was run to determine if these specimens could be considered to be from the same population. The resulting F - value based on the total number of gill rakers was highly significant and is probably due to the variation among year classes and age groups (table 16).

The best way to compare fish having different standard lengths is by use of the analysis of covariance (Marr 1955). In order to use this test the regression slopes of the samples must belong to the same population. The F - value, for the "homogeneity of within sample regression" based on the total number of gill rakers was just significant at the 5 percent level (table 17). A test of adjusted sample means made using the total number of gill rakers (table 18) gave an F value which was just significant at the 5 percent level. When dealing with wild populations, it is difficult to know just where to draw the line for significance due to factors that may cause the data to be non-random.

Similar covariance tests were also run, using the number of gill rakers on the upper arm of the first branchial arch. The test determining the homogeneity of the slopes proved to be barely significant (table 19), while the test of adjusted sample means was not significant (table 20). As the above values were not highly significant, indications from the gill raker data are that the Santee-Cooper River System specimens belong to one population.

<u>The Hudson River population</u>.--The most numerous Hudson River collections available are from the 1954 year class and the 0 age group. Specimens are available from Palisades State Park to Coxsackie, New York. When an analysis of variance using the total number of gill rakers was run on these samples, the resulting F value proved to be highly significant (table 21). A similar test, based on the number of gill rakers on the upper arm, was also highly significant but with a lower magnitude (table 22).

Based on a purely statistical outlook, the results of these tests indicate that some heterogeneity of samples exists in the Hudson River. However, looking at it from a biological point of view, the magnitude of these differences doesn't seem to indicate more than one population. A chi-square test was performed on the same data from the total number of gill rakers. The total chi-square value was 42.75, which was significant at the 5 percent level. Bartlett's test for homogeneity of variances was also worked out for the above samples. The resulting value of chi-square (1.01 with 5 degrees of freedom) was not significant. By deleting the Coxsackie sample from the hudson samples and running a chi-square test (X^2 = 28.08, with 20 degrees of freedom), the results indicated that these (lower river) samples were homogeneous

A test was run to compare the samples from Haverstraw to Palisades State Park with Coxsackie, New York; t proved to be just above the 5 percent level of significance (table 23). This difference was not enough to consider the divergence between upstream and downstream to be biologically significant.

A test using the total number of gill rakers was run for samples of the 1953 year class from Coxsackie and Haverstraw and t was not significant (table 24). An analysis of variance was worked out for the 1949 year class with samples from Port Ewen, Stoney Point and Haverstraw; the F-value was not significant. The same was true when a sample from Port Ewen was compared with those from Stoney Point to Haverstraw (table 25).

An analysis of variance was conducted among six year classes (1936, 1949, 1950, 1952, 1953, 1954) from the Hudson River and was not significant (table 26).

A correlation coefficient was determined between the upper arm and the total number of gill rakers on the first arch for the samples from 1954 year class from Hudson River. The resulting value (r = .885) indicates a good correlation.

In summary, even though some significant differences were found between samples within the Hudson River, biologically it should be considered as one population. There is an overall homogeneity among the several year classes studied from the Hudson River. The samples from the Hudson River had the highest gill raker counts of any populations along the Atlantic Coast (tables 42 and 43).

A comparison of the James and Hudson populations.--Raney (ms.) found that within the Chesapeake Bay the James River subpopulation is the best defined; the other two are the York-Rappahannock and the Upper Bay. Therefore it is meaningful to make a comparison of the number of gill rakers of samples from the James and Hudson Rivers. A highly significant t-value was indicated by a t - test of the 1954 year class (table 27A) and the 1953 year class table 27B).

Gill raker counts from the James River are high and approach those from the Hudson River closer than do other samples of striped bass from the Chesapeake Bay. Due to the high magnitude of the t - values, indications seem to point to the fact that the Hudson and James River samples belong to separate populations.

The Long Island Sound population.-- Raney, Woolcott and Mehring (1954:394) have shown that there are movements of striped bass between the western end of Long Island Sound and the Hudson River. Merriman (1941:38-49) found that migratory schools of the Chesapeake Bay population cross the eastern end of Long Island Sound during the fall and spring. Therefore it was of interest to note how the samples from the western quarter of Long Island Sound compare to those of the Chesapeake Bay and Hudson River populations.

Collections from the western end of Long Island Sound were divided into year classes (1949, 1950, 1951, 1952 and 1953) and an analysis of variance was run. The result was not significant (table 28), so that it is valid statistically to lump these year classes together as a composite sample to get a general mean based on the total number of gill rakers. In the Hudson River, homogeneity of gill raker numbers exists among the 6 year classes studied as demonstrated above. Therefore, in order to make the comparison among fish from the 3 areas, the mean of the 1954 year class from the Hudson was compared with the general mean of 5 year classes from the western end of Long Island Sound and the mean of the 1955 year class from all the tributaries that were sampled from the Chesapeake Bay. Striped bass from the western end of Long Island Sound were found to be intermediate between the Chesapeake Bay and Hudson River populations (table 29). Similar comparisons were made for other year classes that had smaller samples and in all cases the relationship was the same as that stated above.

A comparison of populations from California with those from the Chesapeake Bay and Hudson River.-- In order to make comparisons with other localities it was necessary to find samples from several year classes from the Chesapeake Bay that were homogeneous. For the total number of gill rakers, samples from the Upper Chesapeake Bay were tested using an analysis of variance and the F - value was just significant at the 5 percent level (table 30). A similar test using the number of gill rakers on the upper arm gave an F - value which was not significant (table 31). It is concluded that the samples from the Upper Bay are biologically homogeneous and therefore can be used to make comparisons with other areas. Additional analyses of variance were run between samples from several year classes of the James River and samples from the York-Rappahannock Rivers. In all cases the F - values were highly significant indicating that they were not homogeneous among year classes.

An analysis of variance based on the total number of gill rakers was conducted for the samples from California, which included the 1943, 1945 and 1951 year classes and F was significant at the one percent level (table 32). A chi-square test was run on the same samples using the number of gill rakers on the upper arm and was significant at the one percent level (table 33). Due to the heterogeneity existing among year classes in California, an analysis of variance was carried out for samples of the 1945 year class; the F was not significant in this case (table 34).

A t - test using the total number of gill rakers was worked out between the Upper Chesapeake Bay composite sample and a sample from the California 1945 year class; t was highly significant and had a considerable magnitude (table 35A). The 1945 year class from California was used because of the larger number of specimens available. The 1945 year class from California was also compared with the composite sample of year classes from the Hudson River; t was significant at the 5 percent level (table 35B).

Results from the above tests of gill raker counts point to a wide difference between the Upper Chesapeake Bay and California population at the present time. The latter is much more closely related to the Hudson River population on the basis of this character.

A comparison within populations from Canada, Delaware River and Albemarle Sound.-- Samples are available from the St. Lawrence River, the Miramichi River in New Brunswick and the Philip River in Nova Scotia. A comparison of the samples collected from the Miramichi River in 1952, 1953, and 1955, was made using chi-square as the test criterion; the result based on the total number of gill rakers was significant at the 5 percent level (table 36A). However, no significant difference was found when the same test was run based on the number of gill rakers on the upper arm (table 36B). This indicates that there was little difference among these year classes.

Samples collected in 1955 from the Miramichi and Philip Rivers were compared by a t - test; the result using the total number of gill rakers was not significant (table 37A). A t - test using the number of gill rakers on the upper arm was run comparing the collections of 1952, 1953 and 1955 of the Miramichi with the 1944 collection from the St. Lawrence River; t was highly significant (table 37B). A t - test based on the total number of gill rakers was run comparing samples of the three year classes from the Miramichi River with those from the Philip River; t was not significant (table 37C). The results indicate that there is a difference between the St. Lawrence River and the other two rivers, the Philip and the Miramichi.

An analysis of variance using the total number of gill rakers was conducted for three different year classes of specimens collected from the Delaware River; the resulting F - value was not significant (table 38) and indicates that the samples studied are homogeneous.

In the Albemarle Sound, gill raker counts were made on several year classes and age groups. An analysis of variance using the total number of gill rakers was run on these samples and F proved to be highly significant (table 39). A chi-square test was run on the same data based on the number of gill rakers on the upper arm; it also was significant at the one percent level (table 40). Samples from the 1953 year class were compared by an analysis of variance; the F was highly significant (table 41). The results indicate that in the Albemarle Sound differences exist among and within year classes.

An overall comparison of several populations.-- In order to get an overall picture of the populations based on gill raker counts, the means of the total number of gill rakers on the first left branchial arch are shown in table 42. The locations are given from north to south along the Atlantic Coast. A similar table was made for the number of gill rakers on the upper arm of the first left branchial arch (table 43). The means shown in these tables include different year classes and age groups and present a graphical comparison of the areas studied.

A series of t - tests based on the total number of gill rakers (unless otherwise indicated) were carried out from observations of tables 42 and 43. The following comparisons were made in order to determine the relationship of samples from different localities along the Atlantic Coast. A sample from the Miramichi River in New Brunswick was compared with the Santee-Cooper River System sample for the 1953 year class; no significance resulted (table 44A). A test between the Miramichi River sample versus the Upper Chesapeake Bay subpopulation for the 1955 year class was highly significant (table 44B). By observation, there is a significant difference between the samples from the James and Miramichi Rivers for the 1955 year class. The result of a t - test between the York-Rappahannock subpopulation and the Miramichi River sample for the 1955 year class was not significant (table 44C). A comparison between the York-Rappahannock subpopulation versus the Santee-Cooper River System sample for the 1955 year class was significant at the 5 percent level (table 45A). However, a similar test based on the number of gill rakers on the upper arm was not significant (table 45B). Table 45C shows that heterogeneity exists between the Chesapeake Upper Bay subpopulation and the Santee-Cooper River System sample for the 1955 year class. Also by observation, there is a significant difference between the James River and Santee-Cooper River System samples for the 1955 year class.

In order to determine the relationship between the Chesapeake Bay and the Albemarle Sound, a comparison was made between the York-Rappahannock sample and the Albemarle Sound sample for the 1955 year class. It was just above the line for the one percent level of significance (table 46A). A t - test of the samples of the 1955 year class from the James River and Albemarle Sound was highly significant (table 46B). A similar test using the number of gill rakers on the upper arm was significant at the one percent level, but at a lower magnitude (table 46C). However, in comparing the Upper Chesapeake Bay subpopulation with the Albemarle Sound sample for the 1955 year class, there was no significance (table 47A). In a comparison between Albemarle Sound sample and the Santee-Cooper River System sample for the 1955 year class, t was significant at the one percent level (table 47B).

Indications of the relation of the Delaware River population to that of the Chesapeake Bay were determined by comparing three homogeneous year classes from the Delaware River with the York -Rappahannock sample of 1955; t in this case was significant at the one percent level (table 48A). The same level of significance resulted also when the Upper Chesapeake Bay subpopulation for the 1955 year class was compared with the homogeneous sample from the Delaware River (table 48B). However, when the James River sample of the 1955 year class was compared with that of the Delaware River sample there was no significance (table 48C).

A homogeneous sample of six year classes from the Hudson River, when compared with a homogeneous sample from the Delaware River was highly significant (table 49).

A few specimens were available from the Gulf of Mexico. Table 42 shows that the means of the total number of gill rakers of striped bass from the Gulf of Mexico fall in the same range as those from the Santee-Cooper River System, South Carolina. When the same fish are considered on the basis of the number of gill rakers on the upper arm, the means then fall in line with the Chesapeake population (table 43).

DISCUSSION

Important sources of the striped bass are Albemarle Sound, Chesapeake Bay, Delaware River and Hudson River. Merriman (1941:42) considered the Middle Atlantic area from Cape Hatteras to Cape Cod as the center of abundance for striped bass and tagging experiments indicated that there was comparatively little encroachment by this stock on the populations to the north and the south. Merriman (1941:36-38) tagged 2,573 fish at Montauk, Long Island and in the Niantic and Thames Rivers, Connecticut, between April 1936 and June 1938. Returns from fish tagged in this region reached 544 by July 1938 and gave abundant proof of a coastwise northern migration in the spring, a relatively stable population showing no movement of any consequence in the summer and a southern migration in the fall and early winter. Scattered returns, based on the above tagging experiment, from New Jersey, Delaware, the entrance to Chesapeake Bay and North Carolina show that striped bass may travel great distances in their southern migration. Vladykov and Wallace (1952:174-175) showed by tagging experiments in the Chesapeake Bay and Albemarle Sound, North Carolina that there was little exchange between the two areas. However, it is clear that some striped bass migrate out of the mid Chesapeake Bay area. Vladykov and Wallace (1952:174) tagged 1,869 fish during 1936 and 1937 in the middle Chesapeake Bay, and 28 (1.5 percent) were later captured along the Atlantic coast; of the 662 bass marked in the Potomac River, only two (0.3 percent) were taken outside the Bay. The James River population did not contribute to the stragglers along the Atlantic Coast north of the Chesapeake area. Raney, Woolcott and Mehring (1954:395) show that a sample of striped bass taken at Point Saconnet, Rhode Island was probably of Chesapeake or Delaware rather than Hudson stock. This is in agreement with the results from the above-cited tagging experiments which demonstrated a northward movement from the Chesapeake Bay.

Evidence of movement within the Chesapeake Bay was presented by Pearson (1938:843-845) in a tagging experiment conducted off Annapolis, Maryland in July and August 1931. Out of a total of 305 fish tagged, 9 were recaptured south of the point of release in the Bay and 80 were recovered north of the point of release. Pearson concluded that there was little movement from the Upper to the Lower Bay. Vladykov and Wallace (1952:165-172) found that specimens tagged in the middle Chesapeake Bay during the summer and fall remained where they had been released during the summer but in October moved slowly southward, mainly along the west shore of the Bay. They also found that the populations in the James and Potomac Rivers were relatively stationary. Raney (ms.) concluded on the basis of counts of spines in the first dorsal fin and the soft rays of the dorsal and anal fins that three subpopulations are present in the tributaries of the Chesapeake Bay, namely those of the James River, the York-Rappahannock and the Upper Bay Rivers. Gill raker counts also support this view. Using a series of statistical tests for samples from the 1955 year class based on the number of gill rakers on the upper arm and also the total number of gill rakers, the samples from the James River were separated from samples of all other rivers in the Chesapeake Bay that were studied. By the same procedure the York-Rappahannock River subpopulation was found to be significantly different from the James and Upper Bay River subpopulations. All the rivers on the west shore north of the Rappahannock River and all the east shore rivers that were sampled were considered to belong to a homogeneous Upper Bay subpopulation as the statistical tests did not show that there were any highly significant differences among these rivers. Evidence of these three subpopulations was supported by the samples from the older year classes also.

Merriman (1941:44-46) and Vladykov and Wallace (1952:172) indicated that there was insignificant movement of bass between the Chesapeake Bay and Albemarle Sound. Tables 42 and 43 give a general overall relationship between the sample means and show gill raker counts to be similar for the two areas. Comparisons, using t - tests, between the Albemarle Sound and the Chesapeake Bay populations showed that the Upper Chesapeake Bay subpopulation was more closely related to the population from Albemarle Sound than were the James and York-Rappahannock subpopulations.

Raney (1954:383 and 396) indicated that the populations from the Delaware River and from the coastal rivers of New Jersey are closely related to the Chesapeake race. Gill raker counts point to the close relationship between the populations from the Delaware River and the Chesapeake Bay.

The next most important source of striped bass north of the Delaware River is that of the Hudson River population. Raney, Woolcott and Mehring (1954:394), reporting on the results of a tagging program, found that the Hudson River population seldom migrates eastward beyond Fairfield, Connecticut or Northport, Long Island in the western quarter of Long Island Sound; on the southside of Long Island the eastern limit was the area of Jones Beach. They concluded from fin ray counts that there is an upstream population in the Hudson River above Haverstraw and that in some years below Haverstraw there existed a population derived from the Chesapeake Bay population or one that had similar characters. Raney (ms.) has modified this earlier view and considers the Hudson River samples as one population. Evidence for this is that the first dorsal spines are relatively constant throughout a wide range in the Hudson River and the soft dorsal and anal rays, even though there was a significant increase in downstream samples, were considered relatively small compared to differences that would indicate a racial separation. Gill raker counts also support the view that one population exists in the Hudson River.

The Hudson River population has the highest gill raker counts of any population samples in this study. Ancestors of the striped bass now found in California were collected from northern New Jersey in 1879 and 1881. Gill raker counts of recent samples from California approach those from the Hudson River and indicate a close relationship between the two.

Results of gill raker counts of samples from the western end of Long Island Sound are between those from the Hudson River and Chesapeake Bay populations. This may be due to the presence of some stock of Chesapeake origin that have intermingled with those from the Hudson River population. Raney, Woolcott and Mehring

(1954:385-387) reporting on a tagging program, have shown that some specimens that were tagged in the western quarter of Long Island were later recovered in the Chesapeake Bay.

Tables 42 and 43 show that the means of the Canadian samples are similar to those of the Chesapeake area. Merriman (1941:41-42) thought that there were two possibilities for the presence of striped bass in Nova Scotia: first, that these fish are of northern origin and are completely separated from the populations farther south; and second, that they are of mixed origin from both north and south. Raney (1952: 21) speculates that striped bass migrating northeastward from their wintering areas in the Chesapeake Bay and other more limited areas in New Jersey and New York probably travel to Canadian shores in some years. Raney (personal communication) considers that stocks in Nova Scotia, New Brunswick and the St. Lawrence River seem to be semi-endemic but were obviously drawn from post Pleistocene northward migrants of the Chesapeake race. The close relationship between the Canadian samples and the Chesapeake Bay samples is upheld by the non-significant result of a t -test between the Miramichi River sample and the York-Rappahannock samples for the 1955 year class, the only year class from which samples are available from both areas.

Merriman (1941:42) considered that striped bass from the area north and south of Cape Hatteras as separate populations based on absence of returns from tagged fish. Raney and Woolcott (1954:449), working with samples of striped bass from the Santee-Cooper River System, South Carolina, found an increase in lateral line scales and a slight increase in fin ray counts in an upstream direction. They tentatively concluded that the South Carolina stock was an endemic race which in turn is differentiated into upstream and downstream forms. Scruggs and Fuller (1955) studied samples in the Santee-Cooper River System and found that opportunity of exchange between the reservoir and Cooper River populations is restricted to the operating schedule of the navigation lock at Pinopolis Dam and that little transfer takes place; also spawning occurs above and below the dam. They found that the population in the Cooper River migrated within the river on a seasonal basis but none were found to move into salt water. No highly significant differences in gill raker counts were found in samples from above and below Pinopolis Dam.

Vladykov and Wallace (1952:148) thought that the number of gill rakers of striped bass varied inversely with length and presumably with the age of the fish and thus felt that this character was not helpful in separating races. They presented a table which showed counts of gill rakers from samples from Potomac River, James River, middle Chesapeake Bay and North Carolina. Their counts of the number of gill rakers on the upper arm of the first branchial arch were comparable with the counts made in this present paper. However, their counts for the total number of gill rakers were consistantly lower by approximately one gill raker on the average. It is possible that they did not define a gill raker in the same way, especially in reference to the smaller gill rakers at the end of the lower arm. In this study almost all the specimens counted were less than 300 mm. in standard length; these showed no change with length. Vladykov and Wallace (1952) used specimens mostly larger than 300 mm. and most of the counts were made in the field. Since the point of origin was not known it seems that some differences recorded by them may be populational differences.

Tables 42 and 43 show that there is little variation in the sample means from Cape Fear, North Carolina to those from the Susquehanna River in the northern Chesapeake Bay. Within this range environmental differences occur and it seems likely that if the number of gill rakers was not genetically fixed that greater variation between different localities would occur.

SUMMARY AND CONCLUSIONS

1. There is only random change in the number of gill rakers for specimens of the 0 and I age groups.

2. The number of gill rakers does not vary between the sexes.

3. It was not deemed that there was any biological differences in the number of gill rakers

counted between upstream and downstream areas in the Santee-Cooper, James, York and Hudson Rivers.

4. Samples from above and below Pinopolis Dam in the Santee-Cooper River System in South Carolina belong to one population in regard to gill raker counts.

5. The Hudson River population is homogeneous among year classes and indications are that there is only one population.

6. The Chesapeake Bay population is divided into three main subpopulations. They are the James, with the highest gill raker counts, the York-Rappahannock, with the lowest counts, and the Upper Bay, which has intermediate counts.

7. The gill raker counts of samples from the western end of Long Island Sound were intermediate between those of Chesapeake Bay and those of the Hudson River.

8. California and Hudson River specimens both have high gill raker counts.

9. The Delaware River population is approached most closely by the James River subpopulation from Chesapeake Bay.

10. Samples from the Santee-Cooper River System, South Carolina have the lowest mean gill raker counts, while those from the Hudson River have the highest counts along the Atlantic Coast.

11. It is shown that gill raker counts can be used to separate populations of striped bass.

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Table 1.—Relation between age of striped bass and calculated regression formula based on gill raker counts for samples from several river systems.

Location	Age	Mean-Gill Rakers	Upper Arm-U Total-T	Regression formula $\hat{Y} = \bar{y} + b(X - \bar{x})$
1952 yr. class				
York R.	0, I, II	24.466	T	=24.633 - 0.002X
York R.	0, I, II	9.548	U	= 9.474 + 0.001X
1953 yr. class				
Rappahannock R.	I	9.750	U	= 4.976 + 0.022X
Rappahannock R.	0	9.780	U	= 9.656 + 0.002X
Rappahannock R.	I	9.368	U	= 7.976 + 0.006X
Rappahannock R.	0, I	9.679	U	= 9.839 - 0.001X
Rappahannock R.	I	24.833	T	=20.493 + 0.020X
Rappahannock R.	0	24.680	T	=23.335 + 0.026X
Rappahannock R.	I	23.789	T	=18.651 + 0.024X
Rappahannock R.	0, I	24.494	T	=24.757 + 0.002X
Albemarle Sd.	0, I	24.824	T	=24.938 - 0.001X
Santee-Cooper	II	22.421	T	=26.634 - 0.015X
Santee-Cooper	I	23.326	T	=25.081 - 0.013X
Santee-Cooper	I, II	23.074	T	=24.252 - 0.007X
Santee-Cooper	I	9.184	U	= 8.576 + 0.004X
Santee-Cooper	II	8.789	U	=12.441 - 0.013X
Santee-Cooper	I, II	9.074	U	=13.820 - 0.003X
1954 yr. class				
Pamunkey R.	0	9.020	U	= 8.416 + 0.012X
York R.	I	9.039	U	= 9.287 + 0.001X
York & Pamunkey	0, I	9.030	U	= 9.000 + 0.0002X
Pamunkey R.	0	23.940	T	=22.581 + 0.027X
York R.	I	23.745	T	=26.033 - 0.012X
York & Pamunkey	0, I	23.842	T	=24.000 - 0.001X
James R.	I	24.432	T	=23.127 + 0.007X
Chickahominy	0	24.439	T	=24.250 + 0.004X
James & Chickahominy	0, I	24.435	T	=24.419 + 0.0001X

Table 2.—The total number of gill rakers in the sexes in a sample from 72 to 198 mm. S.L. taken in the Delaware River, New Jersey on October 9, 1952.

	Total No. Gill Rakers							
Sex	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
Male	3	17	13	13	3	49	24.918	[illegible]
Female	6	6	12	7	-	31	[illegible]	33.097

t = 1.13, N.S.

Table 3.—Total number of gill rakers of young striped bass of the 1955 year class from the tributaries of the Chesapeake Bay

River	Total No. Gill Rakers								No.	Mean	$S(X - \bar{x})^2$
	21	22	23	24	25	26	27	28			
Susquehanna	-	1	10	27	15	7	-	-	60	24.283	52.183
Elk	-	-	3	20	21	4	1	-	49	24.592	31.837
Sassafras	-	-	11	22	26	4	-	-	63	24.365	44.603
Middle	-	-	1	8	5	1	-	-	15	24.400	7.600
Back	-	-	7	17	16	1	-	-	41	24.268	24.049
Patapsco	-	2	8	12	17	9	-	-	48	24.479	57.979
Chester	-	1	5	29	22	7	1	-	65	24.492	52.246
Severn	-	-	2	12	19	2	-	-	35	24.600	16.400
Miles	-	-	8	13	12	5	-	-	38	24.368	34.842
Choptank	-	-	1	14	21	7	1	-	44	24.841	27.886
Patuxent	-	1	11	30	10	1	-	-	53	23.981	28.981
Nanticoke	1	-	17	24	29	5	1	-	77	24.286	77.714
Wicomico	-	1	3	14	23	9	-	-	50	24.720	40.080
Potomac	-	2	19	81	61	14	1	-	178	24.388	126.253
Rappahannock	-	2	9	20	18	1	-	-	50	24.140	38.020
Pamunkey	-	7	11	16	12	4	-	-	50	23.900	66.500
James	-	1	2	11	42	23	4	2	85	25.224	80.753

Analysis of Variance

Source	d.f.	S.S.	M.S.	F
Among Rivers	16	101.247	6.3279	7.71**
Error	984	807.926	0.8211	

Table 4.—Number of gill rakers on the upper arm of young striped bass of the 1955 year class from the tributaries of the Chesapeake Bay

River	Upper Arm 6	7	8	9	10	11	12	No.	Mean	$S(X - \bar{x})^2$
Susquehanna	-	-	1	30	23	6	-	60	9.567	28.733
Elk	-	-	1	22	25	1	-	49	9.531	16.204
Sassafras	-	-	1	26	35	1	-	63	9.571	19.429
Middle	-	-	-	8	7	-	-	15	9.467	3.733
Back	-	-	1	20	18	2	-	41	9.512	16.244
Patapsco	-	-	-	16	27	5	-	48	9.771	18.479
Chester	-	-	1	31	31	2	-	65	9.523	22.215
Severn	-	-	-	14	21	-	-	35	9.600	8.400
Miles	-	-	-	22	14	2	-	38	9.474	13.474
Choptank	-	-	1	15	27	1	-	44	9.636	14.182
Patuxent	-	-	2	41	10	-	-	53	9.151	10.792
Nanticoke	1	-	1	42	32	1	-	77	9.390	34.[illegible]
Wicomico	-	-	1	16	31	2	-	50	9.580	16.580
Potomac	-	-	2	84	88	4	-	178	9.528	56.360
Rappahannock	-	-	5	23	22	-	-	50	9.340	21.220
Pamunkey	-	4	10	28	8	-	-	50	8.800	32.000
James	-	-	1	12	50	21	1	85	10.106	40.047

Analysis of Variance

Source	d.f.	S.S.	M.S.	F.
Among Rivers	16	70.735	4.4209	11.67**
Error	984	372.704	0.3788	

Table 5.—Analyses of variance of total number of gill rakers of young striped bass of the 1955 year class from the tributaries of the Chesapeake Bay (see Table 3)

A Excluding the Rappahannock, York, and James River Systems

Source	d.f.	S.S.	M.S.	F
Among Rivers	13	29.513	2.2702	2.92**
Error	802	622.653	0.7764	

B Excluding the Patuxent, Rappahannock, York and James River Systems

Source	d.f.	S.S.	M.S.	F
Among Rivers	12	18.821	1.5684	1.98*
Error	750	593.672	0.7916	

C Excluding the Wicomico, Patuxent, Rappahannock, York and James River Systems

Source	d.f.	S.S.	M.S.	F
Among Rivers	11	14.792	1.3447	1.70 N.S.
Error	701	553.592	0.7897	

Table 6.—Analyses of variance of the number of gill rakers on the upper arm of young striped bass of the 1955 year class from the tributaries of the Chesapeake Bay (Table 4)

A Excluding the Rappahannock, York, and James River Systems

Source	d.f.	S.S.	M.S.	F
Among Rivers	13	14.073	1.0825	3.10**
Error	802	279.437	0.3484	

B Excluding the Patuxent, Rappahannock, York and James River Systems

Source	d.f.	S.S.	M.S.	F
Among Rivers	12	6.162	0.5153	1.43 N.S.
Error	750	268.645	0.3582	

Table 7.—Total number of gill rakers of young striped bass of the 1955 year class from the tributaries of the Chesapeake Bay

A	Total No. Gill Rakers							
River	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
Rappahannock	2	9	20	18	1	50	24.140	38.020
Pamunkey	7	11	16	12	4	50	23.900	66.500

$t = 1.16$ N.S.

B	Total No. Gill Rakers									
River	22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
Rappahannock and Pamunkey	9	20	36	30	5	-	-	100	24.020	105.960
James	1	2	11	42	23	4	2	85	25.224	80.753

$t = 8.08$**

C	Total No. Gill Rakers									
River	22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
Chickahominy	-	1	2	11	9	3	1	27	25.518	28.741
James	1	1	9	31	14	1	1	58	25.086	48.569

$t = 1.92$ N.S.

Table 8.—A comparison between samples from the east and west shore (excluding the York, Rappahannock, and James River Systems) tributaries of the Chesapeake Bay of young striped bass of the 1955 year class

A

	Total No. Gill Rakers									
Rivers	21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
West Shore	--	6	58	187	143	35	1	430	24.340	324.428
East Shore	1	2	48	136	154	41	4	386	24.500	322.500

t = 2.56*

B

	Upper Arm								
Rivers	6	7	8	9	10	11	No.	Mean	$S(X - \bar{x})^2$
West Shore	-	-	6	213	194	17	430	9.516	153.386
East Shore	1	-	6	174	195	10	386	9.534	140.062

t = 0.43 N.S.

Table 9.—A comparison of the total number of gill rakers between samples from up- and downstream areas of the York and James River Systems for the 1954 year class

A	Total No. Gill Rakers								
River	21	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
York - yr.	-	5	18	16	9	3	51	23.745	55.686
Pamunkey - yg.	1	3	15	16	9	6	50	23.940	68.820
t = 0.87 N.S.									

B	Total No. Gill Rakers									
River	21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
James - yr.	1	3	5	11	24	7	-	51	24.470	66.706
Chickahominy- yg.	-	1	3	17	18	1	1	41	24.439	30.098
t = 0.14 N.S.										

Table 10.—A comparison of samples of the 1953 year class within the same river system.

A		Total No. Gill Rakers						
Rappahannock	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
Yearling	1	9	11	10	4	35	24.200	37.600
Young	-	6	10	28	6	50	24.680	34.880

t = 2.33*

B		Upper Arm					
Rappahannock	8	9	10	11	No.	Mean	$S(X - \bar{x})^2$
Yearling	1	14	20	-	35	9.543	10.686
Young	-	14	33	3	50	9.780	14.580

t = 1.95 N.S.

C		Upper Arm						
River	7	8	9	10	11	No.	Mean	$S(X - \bar{x})^2$
York - yr.	3	4	45	25	2	79	9.240	44.430
Mattaponi - yg.	-	-	7	9	-	16	9.562	3.938

t = 1.63 N.S.

Table 11.—Total number of gill rakers from samples of striped bass of the 1953 year class from the tributaries of the Chesapeake Bay

A	Total No. Gill Rakers								
River	21	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
York - yr.	4	9	17	25	19	5	79	23.772	123.899
Mattaponi - yg.	-	-	-	6	9	1	16	24.688	5.438
t = 2.83**									

B	Total No. Gill Rakers								
River	21	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
York - yr.	4	9	17	25	19	5	79	23.772	123.899
Rappahannock- yr.	-	1	9	11	10	4	35	24.200	37.600
t = 1.75 N.S.									

Table 12.—An analysis of covariance of the total number of gill rakers for samples of the 1953 year class from the York River System

					Y adjusted for X		
Source	d.f.	Sx^2	Sxy	Sy^2	d.f.	S.S.	M.S.
Total	94	233574.358	-1813.453	140.484			
Samples	1	201292.736	-1498.002	11.147			
Error	93	32281.622	- 315.451	129.337	92	126.255	1.3723
Samples + Error	94	233574.358	-1813.453	140.484	93	126.404	
Samples adjusted					1	0.149	0.149
F = 0.11 N.S.							

Table 13.—An analysis of variance of the total number of gill rakers for samples of striped bass from the 1952 year class from the York River System

River	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
	Total No. Gill Rakers								
York - yr.	-	2	2	3	-	-	7	24.143	4.857
York + Pamunkey - yg.	-	9	16	14	9	2	50	24.580	60.180
Pamunkey - yr.	1	1	8	5	1	-	16	24.250	13.000

Source	d.f.	S.S.	M.S.	F
Among Samples	2	2.127	1.0635	0.95 N.S.
Error	70	78.037	1.1148	

Table 14.—An analysis of variance of the total number of gill rakers for samples of the 1949 year class of striped bass from the Chesapeake Bay at Crisfield, Maryland

Sample	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
	Total No. Gill Rakers							
A - yg.	-	5	5	2	-	12	24.750	6.250
B - yg.	2	3	3	3	-	11	24.636	12.546
C - yg.	3	7	21	7	1	39	24.897	29.590

Source	d.f.	S.S.	M.S.	F
Among Samples	2	0.662	0.3310	0.40 N.S.
Error	59	48.386	0.8201	

Table 15.—An analysis of variance of the total number of gill rakers for samples of striped bass from the James River, Virginia

	Total No. Gill Rakers											
Year Class	20	21	22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
1949 - yg.	-	-	2	2	8	5	1	-	-	18	24.056	18.944
1952 - yr.	-	-	-	1	4	11	1	-	-	17	24.706	7.530
1953 - yr.	1	1	3	12	18	17	2	-	-	54	23.926	73.704
1954 - yg.-yr.	-	1	4	8	28	42	8	1	-	92	24.456	96.826
1955 - yg.	-	-	1	2	11	42	23	4	2	85	25.224	80.753

Source	d.f.	S.S.	M.S.	F
Among year classes	4	64.923	16.2308	15.25**
Error	261	277.757	1.0642	

Table 16.—An analysis of variance of the total number of gill rakers for samples of striped bass from the Santee-Cooper River System, South Carolina

	Total No. Gill Rakers								
Year Class	21	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
1953 - yr.	-	8	20	18	3	-	49	23.326	32.776
1953 - yr.	3	6	9	1	-	-	19	22.421	12.632
1954 - yg.	-	3	8	25	12	2	50	24.040	39.920
1954 - yr.	1	3	6	3	1	-	14	23.000	14.000
1955 - yg.	-	5	20	22	7	1	55	23.618	42.982

Source	d.f.	S.S.	M.S.	F
Among year classes	4	42.407	10.6018	13.56**
Error	182	142.310	0.7819	

Table 17.—A "Homogeneity of Within Sample Regression" of the total number of gill rakers for samples of striped bass from the Santee-Cooper River System, South Carolina

Year Class	d.f.	Sx^2	Sxy	Sy^2	d.f.	Reduced S.S.
1953 - yr.	48	12774.980	-163.326	32.776	47	30.688
1953 - yr.	18	7831.790	-116.158	12.632	17	10.909
1954 - yg.	49	6530.420	85.920	39.920	48	38.790
1954 - yr.	13	4157.214	105.000	14.000	12	11.348
1955 - yg.	54	6004.727	96.636	42.982	53	41.427
Residuals from individual regressions					177	133.162
Totals for single regression	182	37299.131	8.072	142.310	181	142.308
Difference for homogeneity of regressions					4	9.146

$$F = \frac{9.146/4}{133.162/177} = 3.03*$$

Table 18.—An analysis of covariance of the total number of gill rakers for adjusted sample means of striped bass from the Santee-Cooper River System

					Y adjusted for X		
Source	d.f.	Sx^2	Sxy	Sy^2	d.f.	S.S.	M.S.
Total	186	993175.658	-5832.166	184.717			
Samples	4	955876.527	-5840.238	42.407			
Error	182	37299.131	8.072	142.310	181	142.308	0.786
Samples + Error	186	993175.658	-5832.166	184.717	185	150.469	
Samples adjusted					4	8.161	2.040

F = 2.60*

Table 19.—A "Homogeneity of Within Sample Regression" of the number of gill rakers on the upper arm for samples of striped bass from the Santee-Cooper River System

Year Class	d.f.	Sx^2	Sxy	Sy^2	d.f.	Reduced S.S.
1953 - yr.	48	12774.980	57.816	15.347	47	15.085
1953 - yr.	18	7831.790	-102.421	15.158	17	13.819
1954 - yg.	49	6530.420	55.900	18.500	48	18.022
1954 - yr.	13	4157.214	94.072	8.357	12	6.228
1955 - yg.	54	6004.727	57.818	19.746	53	19.189
Residuals from individual regressions					177	72.343
Totals for single regression	182	37299.131	163.185	77.108	181	76.394
Difference for homogeneity of regressions					4	4.051

$$F = \frac{4.051/4}{72.353/177} = 2.48^{*} \quad \text{(Tabulated .05 = 2.42)}$$

Table 20.—An analysis of covariance of the number of gill rakers on the upper arm for adjusted sample means of striped bass from the Santee-Cooper River System.

					Y adjusted for X		
Source	d.f.	Sx^2	Sxy	Sy^2	d.f.	S.S.	M.S.
Total	186	993175.658	-2272.545	83.818			
Samples	4	955876.527	-2435.730	6.710			
Error	182	37299.131	163.185	77.108	181	76.394	0.422
Samples + Error	186	993175.658	-2272.545	83.818	185	78.618	
Samples adjusted					4	2.224	0.556

F = 1.32 N.S.

Table 21.—Total number of gill rakers of young striped bass of the 1954 year class from the Hudson River, New York

	Total No. Gill Rakers									
Locality	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
Coxsackie	1	7	38	72	22	12	-	152	25.941	144.467
Haverstraw	2	13	31	45	18	3	-	112	25.652	117.420
Harmon	-	4	13	18	11	2	-	48	25.875	47.250
Croton Pt.	-	2	10	5	2	-	-	19	25.368	12.421
Nyack	1	1	19	35	20	4	1	81	26.086	76.395
Palisades State Park	1	6	31	20	7	3	-	68	25.515	66.985

Analysis of Variance

Source	d.f.	S.S.	M.S.	F
Among localities	5	21.429	4.2858	4.33**
Error	474	464.938	0.9809	

Table 22.—The number of gill rakers on the upper arm of young striped bass of the 1954 year class from the Hudson River, New York

	Upper Arm							
Locality	8	9	10	11	12	No.	Mean	$S(X - \bar{x})^2$
Coxsackie	1	8	55	76	12	152	10.592	82.711
Haverstraw	-	11	48	49	4	112	10.411	57.107
Harmon	-	2	17	19	10	48	10.771	32.479
Croton Pt.	-	2	12	5	-	19	10.158	6.526
Nyack	-	1	29	49	2	81	10.642	24.617
Palisades State Park	1	5	33	25	4	68	10.382	40.059

Analysis of Variance

Source	d.f.	S.S.	M.S.	F
Among localities	5	10.093	2.0186	3.92**
Error	474	243.499	0.5137	

Table 23.—Total number of gill rakers of young striped bass of the 1954 year class from the Hudson River, New York

	Total No. Gill Rakers									
Locality	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
A	1	7	38	72	22	12	-	152	25.941	144.467
B	4	26	104	123	58	12	1	328	25.747	337.997

t = 1.968 (tabulated value at .05 = 1.965)

Locality A - Coxsackie

Locality B - Haverstraw, Harmon, Croton Pt., Nyack and Palisades State Park

Table 24.—Total number of gill rakers of young striped bass of the 1953 year class from the Hudson River, New York

Locality	Total No. Gill Rakers 22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
Coxsackie	-	1	1	10	21	15	2	50	26.080	45.680
Haverstraw	1	-	1	19	20	13	1	55	25.818	54.182

t = 1.36 N.S.

Table 25.—An analysis of variance of the total number of gill rakers of young striped bass of the 1949 year class from the Hudson River, New York

Locality	Total No. Gill Rakers 24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
1) Port Ewen	-	5	4	3	-	12	25.833	7.667
2) Stony Point and Haverstraw	1	5	5	2	-	13	25.615	9.077
3) Stony Cove and Haverstraw	2	14	14	3	1	34	25.618	24.030
4) Stony Point	-	6	7	8	-	21	26.095	13.810

Source	d.f.	S.S.	M.S.	F
Among localities	3	3.366	1.122	1.56 N.S.
1 vs. 2, 3, 4	1	0.048	0.048	0.07 N.S.
Error	76	54.584	0.718	

Table 26.—An analysis of variance of the total number of gill rakers for samples from six year classes of young striped bass from the Hudson River, New York

	Total No. Gill Rakers										
Year Class	22	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
1936	-	-	1	15	18	2	-	1	37	25.676	26.108
1949	-	-	3	30	30	16	1	-	80	25.775	57.950
1950	-	1	1	13	16	4	1	-	36	25.667	30.000
1952	-	1	3	6	9	-	-	-	19	25.210	15.158
1953	1	1	9	42	49	32	3	1	137	25.788	140.861
1954	-	5	33	142	195	80	24	1	480	25.808	486.367

Source	d.f.	S.S.	M.S.	F
Among year classes	5	7.399	1.4798	1.53 N.S.
Error	783	756.444	0.9661	

Table 27.—A comparison of the total number of gill rakers between samples of striped bass from the James River, Virginia with those from the Hudson River, New York

A	Total No. Gill Rakers											
1954 Year Class	21	22	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
James R.- yg.-yr.	1	4	7	28	39	5	1	-	-	85	24.400	86.400
Hudson R. - yg.	-	-	5	33	142	195	80	24	1	480	25.808	486.367
t = 11.87**												

B	Total No. Gill Rakers											
1953 Year Class	20	21	22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
James R. - yr.	1	1	3	12	18	14	1	-	-	50	23.820	65.380
Hudson R. - yg.	-	-	1	1	9	42	49	32	3	137	25.788	140.861
t = 11.28**												

Table 28.—An analysis of variance of the total number of gill rakers of yearling striped bass from five year classes from the western end of Long Island Sound

	Total No. Gill Rakers								
Year Class	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
1949	2	5	7	2	1	-	17	24.706	17.530
1950	-	1	6	3	-	-	10	25.200	3.600
1951	1	4	4	2	-	-	11	24.636	8.546
1952	1	1	4	1	-	1	8	25.125	14.875
1953	1	4	12	8	-	-	25	25.080	15.160

Source	d.f.	S.S.	M.S.	F
Among year classes	4	3.384	0.8460	0.94 N.S.
Error	66	59.711	0.9047	

Table 29.—A comparison of the mean values of total gill rakers for seven year classes of striped bass from the Hudson River, western Long Island Sound and the Chesapeake Bay

Year Class	Hudson R.	Year Class	Long Island Sd.	Year Class	Chesapeake Bay
1954	25.808	'49-'53	24.944	1955	24.444
1953	26.080	1953	25.080	1953	24.241
1952	25.210	1952	25.125	1952	24.381
1951	-	1951	24.636	1951	23.400
1950	25.667	1950	25.200	1950	-
1949	26.095	1949	24.706	1949	24.256

Table 30.—An analysis of variance of the total number of gill rakers of young striped bass of five year classes from the upper Chesapeake Bay

Locality	Total No. Gill Rakers 21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
A	1	7	95	293	287	75	5	763	24.446	612.493
B	-	1	2	2	11	1	1	18	24.667	22.000
C	-	-	5	15	29	12	1	62	24.822	49.048
D	-	1	5	12	12	3	1	34	24.412	36.235
E	-	-	3	6	7	6	-	22	24.727	22.364

Source	d.f.	S.S.	M.S.	F
Among localities	4	10.307	2.5768	3.10*
Error	894	742.140	0.8301	

A - Upper Chesapeake Bay population not including the Patuxent River; 1955 year class

B - Potomac River 1948 year class

C - Crisfield, Maryland 1949 year class

D - Crisfield, Maryland 1951 year class

E - Crisfield, Maryland 1952 year class

Table 31.—An analysis of variance of the number of gill rakers on the upper arm of young striped bass of five year classes from the upper Chesapeake Bay

	Upper Arm								
Locality*	6	7	8	9	10	11	No.	Mean	$S(X - \bar{x})^2$
A	1	-	10	346	379	27	763	9.550	274.807
B	-	-	1	4	12	1	18	9.722	7.611
C	-	-	-	25	35	2	62	9.629	18.468
D	-	-	1	17	14	2	34	9.500	14.500
E	-	-	-	9	11	2	22	9.682	8.773

Source	d.f.	S.S.	M.S.	F
Among localities	4	1.287	0.3218	0.89 N.S.
Error	894	324.159	0.3626	

* Locality designations are the same as in table 30.

Table 32.—An analysis of variance of the total number of gill rakers of young striped bass from three year classes from California

Year Class	Total No. Gill Rakers 23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
1943	-	2	11	5	2	-	-	20	25.350	12.550
1945	1	1	16	33	17	4	1	73	26.096	70.329
1945	2	3	19	20	15	3	-	62	25.839	74.387
1945	-	2	16	14	15	3	-	50	26.020	50.980
1945	-	-	7	5	4	-	-	16	25.812	10.438
1951	2	6	23	9	3	-	-	43	25.116	34.419

Source	d.f.	S.S.	M.S.	F
Among year classes	5	33.018	6.6036	6.73**
Error	258	253.103	0.9810	

Table 33.—A chi-square test of the number of gill rakers on the upper arm for samples of young striped bass from three year classes from California

	Upper Arm						
Year Class	8	9	10	11	12	No.	Mean
1943	-	1	14	5	-	20	10.200
1945	-	3	31	34	5	73	10.562
1945	1	3	36	21	1	62	10.290
1945	-	-	26	24	-	50	10.480
1945	-	1	5	10	-	16	10.562
1951	1	2	34	6	-	43	10.046

$X^2 = 27.43^{**}$

Table 34.—An analysis of variance of the total number of gill rakers of young striped bass of the 1945 year class from California

	Total No. Gill Rakers									
Sample	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
A	1	1	16	33	17	4	1	73	26.096	70.329
B	2	3	19	20	15	3	-	62	25.839	74.387
C	-	2	16	14	15	3	-	50	26.020	50.980
D	-	-	7	5	4	-	-	16	25.812	10.438

Source	d.f.	S.S.	M.S.	F
Among samples	3	2.742	0.9140	0.87 N.S.
Error	197	206.134	1.0464	

Table 35.—A comparison of total number of gill rakers of young striped bass from California with those from the upper Chesapeake Bay and Hudson River

A	Total No. Gill Rakers											
Locality	21	22	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
Chesapeake Bay	1	9	110	328	346	97	8	-	-	899	24.482	752.447
California	-	-	3	6	58	72	51	10	1	201	25.975	208.876
t = 20.45**												

B	Total No. Gill Rakers										
Locality	22	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
Hudson R.	1	8	50	248	317	134	29	2	789	25.774	765.110
California	-	3	6	58	72	51	10	1	201	25.975	208.876
t = 2.56*											

Table 36.—A comparison among samples of three year classes of yearling striped bass from the Miramichi River, New Brunswick

A	Total No. Gill Rakers							
Year Class	21	22	23	24	25	26	No.	Mean
1952	1	4	29	14	2	-	50	23.240
1953	-	3	8	11	6	-	28	23.714
1955	-	1	26	17	10	1	55	23.709
X^2 = 13.40*								

B	Upper Arm					
Year Class	8	9	10	11	No.	Mean
1952	3	24	22	1	50	9.420
1953	2	12	14	-	28	9.428
1955	2	31	20	2	55	9.400
X^2 = 1.75 N.S.						

Table 37.—A comparison of striped bass from the Miramichi River with those from the Philip and St. Lawrence Rivers

A

River	Total No. Gill Rakers 22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
Miramichi	1	26	17	10	1	55	23.709	39.346
Philip	6	26	22	4	2	60	23.500	47.000

t = 1.28 N.S.

B

River	Upper Arm 8	9	10	11	No.	Mean	$S(X - \bar{x})^2$
Miramichi	7	67	56	13	143	9.524	75.664
St. Lawrence	1	13	38	10	62	9.919	26.597

t = 3.66**

C

River	Total No. Gill Rakers 21	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
Miramichi	1	8	63	42	18	1	133	23.534	97.098
Philip	-	6	26	22	4	2	60	23.500	47.000

t = 0.25 N.S.

Table 38.—An analysis of variance of the total number of gill rakers of striped bass of several year classes from the Delaware and Maurice Rivers, New Jersey

Year Class and River	Total No. Gill Rakers					No.	Mean	$S(X - \bar{x})^2$
	23	24	25	26	27			
1952 Delaware - yr.	2	8	10	17	2	39	25.231	38.923
1951 Delaware - yr.	9	24	25	22	3	83	24.831	91.639
1954 Maurice - yg.	-	2	9	5	-	16	25.188	6.438

Source	d.f.	S.S.	M.S.	F
Among samples	2	4.971	2.4855	2.45 N.S.
Error	135	137.000	1.0148	

Table 39.—An analysis of variance of the total number of gill rakers of striped bass from the Albemarle Sound

	Total No. Gill Rakers											
Year Class	19	20	21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
1953 - yg.	-	-	-	-	1	9	17	7	-	34	24.882	19.530
1954 - yg.	-	-	-	-	1	2	8	2	3	16	25.250	19.000
1951 - yr.	1	-	-	4	11	7	2	1	-	26	23.231	42.615
1953 - yr.	-	-	-	-	1	5	9	2	-	17	24.706	9.530
1946 - yg.	-	-	-	2	-	8	14	1	-	25	24.480	20.240
1946 - yg.	-	-	-	1	3	8	7	1	-	20	24.200	17.200
1952 - yr.	-	-	-	-	4	11	11	1	-	27	24.333	16.000
1955 - yg.	-	-	-	1	4	14	18	3	1	41	24.512	36.244
1953 - yr.	-	-	-	-	9	15	18	2	-	44	24.295	31.159

Source	d.f.	S.S.	M.S.	F
Among samples	8	58.678	7.3348	8.36**
Error	241	211.518	0.8777	

Table 40.—A chi-square test of the number of gill rakers on the upper arm of striped bass collected from the Albemarle Sound

Year Class	Upper Arm 8	9	10	11	No.	Mean
1953 - yg.	-	2	28	4	34	10.059
1954 - yg.	-	1	11	4	16	10.188
1951 - yr.	1	15	8	2	26	9.423
1953 - yr.	-	3	13	1	17	9.882
1946 - yg.	2	3	18	2	25	9.800
1946 - yg.	-	8	11	1	20	9.650
1952 - yr.	-	5	18	4	27	9.963
1955 - yg.	1	12	25	3	41	9.732
1953 - yr.	-	18	24	2	44	9.636

$X^2 = 50.95$**

Table 41.—An analysis of variance of the total number of gill rakers of striped bass of the 1953 year class from the Albemarle Sound

1953 Year Class	Total No. Gill Rakers 23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
A - yg.	1	9	17	7	34	24.882	19.530
B - yr.	1	5	9	2	17	24.706	9.530
C - yr.	9	15	18	2	44	24.295	31.159

Source	d.f.	S.S.	M.S.	F
Among samples	2	6.939	3.4695	5.30**
Error	92	60.219	0.6546	

Table 42.—An overall relationship between the sample means of the total number of gill rakers of striped bass and their geographical location

	Class Means* of the Total No. Gill Rakers													
	22		23			24				25			26	
Locality	.5	.8	.1	.4	.7	.0	.3	.6	.9	.2	.5	.8	.1	.4
St. Lawrence R.									1					
Miramichi R.			1		2									
Philip R.				1	1									
Rhode Island					1		1							
Western L.I. Sd.							1		2	1	1			
Hudson R.									1	2	11	8	7	2
Mullica R.							1							
Delaware R.									1	1				
Maurice R.										1				
Chesapeake Bay														
Susquehanna R.							2							
Elk R.								1						
Sassafras R.							2							
Middle R.							1							
Back R.							2							
Patapsco R.							1	1						
Chester R.						1		2						
Severn R.								1						
Miles R.							2							
Choptank R.									1					
Patuxent R.					1	2			1					
Nanticoke R.						1		1						
Wicomico R.								1						
Potomac R.					1	1	3	3	1					
Crisfield, Md.							1	2	3					
Rappahannock R.				1		2		2	1					
York R. System					1	4	3	1						
James R. System					1	1	3		1	3	1			
Norfolk, Va.									1					
Albemarle Sd.			1				2	3	1	1				
Little R.							1							
Roanoke R.					1			1						
Chowan R.							1							
Pamlico R.						1								
Cape Fear, N. C.							2							
Santee-Cooper R.	1	2	3	2	3	1								
Ashley R.							1							
Broad R.					1									
Gulf of Mexico			1	1										
California											1	2	3	

*Example - Class Mean 24.3 includes means 24.2 to 24.4

Numbers in the body of the table refer to the number of samples counted

Table 43.—An overall relationship between the sample means of the number of gill rakers on the upper arm of striped bass and their geographical location

	Class Means* of the No. Gill Rakers on Upper Arms											
	8	9					10					11
Locality	.85	.05	.25	.45	.65	.85	.05	.25	.45	.65	.85	.05
St. Lawrence R.			1									
Miramichi R.				3								
Philip R.			2									
Rhode Island				1		1						
Western L.I. Sd.							2		2	1		
Hudson R.								5	10	14	1	1
Mullica R.						1						
Delaware R.									2			
Maurice R.								1				
Chesapeake Bay												
Susquehanna R.					2							
Elk R.				1								
Sassafras R.					2							
Middle R.				1								
Back R.				1	1							
Patapsco R.					1	1						
Chester R.			1		2							
Severn R.					1							
Miles R.				2								
Choptank R.					1							
Patuxent R.		1	2		1							
Nanticoke R.			1		1							
Wicomico R.					1							
Potomac R.			3		4	1	1					
Crisfield, Md.				3	2		1					
Rappahannock R.			2	1		3						
York R. System	1	2	2	1	3							
James R. System			1	1	2	1	3	2				
Norfolk, Va.					1							
Albemarle Sd.				1	2	3	2					
Little R.							1					
Roanoke R.					1	1						
Chowan R.					1							
Pamlico R.						1						
Cape Fear, N.C.					1	1						
Santee-Cooper R.	2	3	4	2	1							
Ashley R.					1							
Broad R.			1									
Gulf of Mexico				1	1							
California							1	2	1	2		

* Example - Class Mean 9.85 includes means 9.8 to 9.9

Numbers in the body of the table refer to the number of samples counted

Table 44.—Comparisons of the total number of gill rakers of striped bass from the Miramichi River, New Brunswick with those from the Santee-Cooper River System, upper Chesapeake Bay and York-Rappahannock populations

A	Total No. Gill Rakers						
1953 Year Class	22	23	24	25	No.	Mean	$S(X - \bar{x})^2$
Miramichi - yr.	3	8	11	6	28	23.714	23.714
Santee-Cooper - yr.	8	20	18	3	49	23.326	32.776
t = 1.89 N.S.							

B	Total No. Gill Rakers									
1955 Year Class	21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
Upper Chesapeake Bay - yg.	1	7	78	293	287	75	5	746	24.478	576.157
Miramichi R. - yr.	-	1	26	17	10	1	-	55	23.709	39.346
t = 6.27**										

C	Total No. Gill Rakers							
1955 Year Class	22	23	24	25	26	No.	Mean	$S(X - \bar{x})^2$
York-Rappahannock - yg.	9	20	36	30	5	100	24.020	105.960
Miramichi - yr.	1	26	17	10	1	55	23.709	39.346
t = 1.90 N.S.								

Table 45.—Comparisons of young striped bass of the 1955 year class from the Santee-Cooper River System with those from the York-Rappahannock population and the upper Chesapeake Bay population

A	Total No. Gill Rakers							
River	22	23	24	25	26	No.	Mean	$S(X-\bar{x})^2$
York-Rappahannock	9	20	36	30	5	100	24.020	105.960
Santee-Cooper	5	20	22	7	1	55	23.618	42.982
t = 2.43*								

B	Upper Arm						
River	7	8	9	10	No.	Mean	$S(X-\bar{x})^2$
York-Rappahannock	4	15	51	30	100	9.070	60.510
Santee-Cooper	-	4	30	21	55	9.309	19.746
t = 1.965 (tabulated .05 = 1.976)							

C	Total No. Gill Rakers									
Locality	21	22	23	24	25	26	27	No.	Mean	$S(X-\bar{x})^2$
Upper Chesapeake Bay	1	7	78	293	287	75	5	746	24.478	576.157
Santee-Cooper	-	5	20	22	7	1	-	55	23.618	42.982
t = 6.99**										

Table 46.—Comparisons of young striped bass of the 1955 year class from the Chesapeake Bay and Albemarle Sound

A	Total No. Gill Rakers								
Locality	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
York-Rappahannock	9	20	36	30	5	-	100	24.020	105.960
Albemarle Sd.	1	4	14	18	3	1	41	24.512	36.244
t = 2.623 (tabulated .01 = 2.612)									

B	Total No. Gill Rakers									
Locality	22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
James R.	1	2	11	42	23	4	2	85	25.224	80.753
Albemarle Sd.	1	4	14	18	3	1	-	41	24.512	36.244
t = 3.86**										

C	Upper Arm							
Locality	8	9	10	11	12	No.	Mean	$S(X - \bar{x})^2$
James R.	1	12	50	21	1	85	10.106	40.047
Albemarle Sd.	1	12	25	3	-	41	9.732	16.049
t = 2.92**								

Table 47.—A comparison of the total number of gill rakers of young striped bass of the 1955 year class from the Albemarle Sound with those from the upper Chesapeake Bay and the Santee-Cooper River System

A	Total No. Gill Rakers									
Locality	21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
Upper Chesapeake Bay	1	7	78	293	287	75	5	746	24.478	576.157
Albemarle Sound	-	1	4	14	18	3	1	41	24.512	36.244
t = 0.24 N.S.										

B	Total No. Gill Rakers								
Locality	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
Albemarle Sound	1	4	14	18	3	1	41	24.512	36.244
Santee-Cooper	5	20	22	7	1	-	55	23.618	42.982
t = 4.72**									

Table 48.—Comparisons of the total number of gill rakers of striped bass from the Chesapeake Bay and the Delaware River [1]

A	Total No. Gill Rakers								
Locality	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
York-Rappahannock	9	20	36	30	5	-	100	24.020	105.960
Delaware	-	11	34	44	44	5	138	24.986	141.971
t = 7.18**									

B	Total No. Gill Rakers									
Locality	21	22	23	24	25	26	27	No.	Mean	$S(X - \bar{x})^2$
Upper Chesapeake Bay	1	7	78	293	287	75	5	746	24.478	576.157
Delaware	-	-	11	34	44	44	5	138	24.986	141.971
t = 6.08**										

C	Total No. Gill Rakers									
Locality	22	23	24	25	26	27	28	No.	Mean	$S(X - \bar{x})^2$
James	1	2	11	42	23	4	2	85	25.224	80.753
Delaware	-	11	34	44	44	5	-	138	24.986	141.971
t = 1.72 N.S.										

[1] Delaware River sample included young and yearling specimens of the 1951, 1952 and 1954 year classes. Chesapeake Bay samples are young striped bass of the 1955 year class.

Table 49.—A comparison of the total number of gill rakers of striped bass from the Hudson and Delaware [1] Rivers

	Total No. Gill Rakers										
River	22	23	24	25	26	27	28	29	No.	Mean	$S(X - \bar{x})^2$
Delaware	-	11	34	44	44	5	-	-	138	24.986	141.971
Hudson	1	8	50	248	317	134	29	2	789	25.774	763.843

t = 8.63**

[1] Delaware River samples included young and yearling specimens of the 1951, 1952 and 1954 year classes.

INT.-DUP. SEC., WASH., D.C 20157