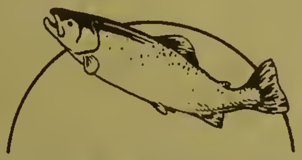
MORPHOMETRIC STUDY OF THE STRIPED BASS

Roccus saxatilis



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EXPLANATORY NOTE

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

MORPHOMETRIC STUDY OF THE STRIPED BASS, ROCCUS SAXATILIS

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ABSTRACT

Morphometric characters were found to be good indicators for separating populations of striped bass found along the Atlantic coast. Standard length, head length, predorsal distance, prepelvic distance, body depth, and caudal-peduncle depth were the characters used. The data were analyzed by appropriate F-tests in an analysis of covariance. Standard length was used as the independent variable in all comparisons, and all other characters were employed as dependent variables.

On the basis of this study, it is believed that there are at least four populations of striped bass in Chesapeake Bay and its tributaries. The data also revealed that the Hudson River and Albemarle Sound contain distinct populations. Specimens collected above Pinopolis Dam, in the Santee-Cooper River System in South Carolina were found to have a greater body depth and a thicker caudal peduncle than samples collected below the dam. The striped bass exhibited north-south clines with respect to body and caudal-peduncle depths.

CONTENTS

MORPHOMETRIC STUDY OF THE STRIPED BASS, ROCCUS SAXATILIS

The striped bass, Roccus saxatilis (Walbaum), is of great importance to both commercial and sport fishermen. Many workers have contributed to the knowledge of the basic biology of this species, and these various contributions are summarized by Raney (1952). Because of the great economic value of the striped bass, racial studies have been undertaken in the form of tagging experiments and investigations of meristic characters. The purpose of this present study was to determine whether morphometric data would help to verify past studies or would contribute new knowledge for a better understanding of the racial makeup of the striped bass along the Atlantic coast.

Ichthyologists and fishery biologists have widely used morphometric data in studying races of fish. The advantages of using some form of a regression analysis when comparing such data, and the disadvantages of using other techniques, have been pointed out by Marr (1955). Mottley (1941) introduced the use of a covariance procedure in comparing two populations of fish on the basis of morphometric data. Martin (1949) recognized the fact that the regressions may differ in one or two ways: the slopes may differ, and the intercepts may differ. Therefore, both components should be tested before one can state that the populations are homogeneous. Such a procedure was followed in this study.

ACKNOWLEDGMENTS

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MATERIALS

The specimens measured in this study are listed below under their respective river systems. The designations CU and RM stand for Cornell University and for Rathjen and Miller. The collections were made by Warren S. Rathjen and Lewis C. Miller on the Hudson River during 1954. The river mileage is given for some collections. The first letter of the river is used as an abbreviation; thus R-40 represents 40 miles from the mouth of the Rappahannock River. In the York River System all distances are measured from the mouth of the York River. Therefore, P-40 (Pamunkey River) and M-39 (Mattaponi River) are distances from the mouth of the York. The same is true in the James River System where C-55 (Chickahominy River) denotes 55 miles from the mouth of the James.

Each collection is designated as follows: the catalogue numbers listed in numerical order; in parenthesis, the number of fish examined in that sample; the locality within the system; the date of collection.

Hudson River--CU 15463 (33), Haverstraw and Stony Cove, August 5, 1949. CU 18221 (20), Stony Point Cove, Stony Point, New York, Aug. 26, 1949. CU 21070 (35), between Catskill and Piermont, Sept. 4-9, 1950. CU 24037 (10), Denning Point just south of Beacon, Sept. 11, 1953. CU 24043 (70), Haverstraw Beach, Sept. 11, 1953. CU 26370 (17), Coxsackie Beach, July 12, 1954. CU 26281 (48), Coxsackie Beach, June 23, 1954. CU 26380 (16), Coxsackie Beach, July 13, 1954. CU 27108 (44), Grassy Point, Aug. 4, 1954. CU 27128 (50), Coxsackie, Aug. 4, 1954. CU 29996 (41), two miles south of Sing Sing Prison, May 2, 1956. RM 89 and 91 (21), North of Middleground Island, July 8, 1954. RM 105 (15), Coxsackie Beach, Aug. 19, 1954. RM 116 (23), Coxsackie Beach, July 26, 1954. RM 150 (9), Coxsackie Beach, Aug. 4, 1954. RM 162 (23), Alsen, Silver Point, Aug. 31, 1954. RM 163 (28) Newburg, Aug. 31, 1954. RM 174 (23), Harmon, Sept. 21, 1954. RM 177 (21), Denning Point, Sept. 29, 1954. RM 184 (22), Haverstraw Bathing Beach, Sept. 30, 1954. RM 185 (32), Palisade Interstate Park, Sept. 30, 1954. RM 186 (7), Palisade Interstate Park, Sept. 30, 1954. RM 187 (24), Croton Park Bathing Beach, Oct. 8, 1954. RM 191 (41), Croton Park Bathing Beach, Oct. 20, 1954. RM 192 (19), Haverstraw, Oct. 20, 1954. RM 193 (16), Palisade State Park, Oct. 20, 1954. RM 89A, Middleground Island, July 8, 1954. RM 1-12 (9), Haverstraw, July-Aug. 1954. No cat. number (12), Coxsackie Beach, June 23, 1954.

Delaware River--CU 22004 (53), Deepwater, New Jersey at Atlantic City Electric Co., Oct. 9, 1952. CU 23755 (39), Deepwater, New Jersey at Atlantic City Electric Co., Aug. 26, 1955. CU 27165 (4), Deepwater, New Jersey at Atlantic City Electric Co., Aug. 3, 1954. CU 28453 (16), Maurice R., Yaup Shore Station, Sept. 8, 1954. CU 29625 (60), Deepwater, New Jersey at Atlantic City Electric Co., Oct. 3, 1955.

Potomac River--CU 25568 (11), Toll Bridge on Rt. 301, Oct. 30, 1953. CU 28996 (18), Fort Belvoir, Oct. 13, 1948. CU 29673 (32), St. Georges Creek, Oct. 19, 1955. CU 29676 (27), Wicomico River Rocky Point Bar at Rock Point, Md., Oct. 18, 1955. CU 29678 (13), Liverpool Point, Oct. 18, 1955. CU 29679 (41), Morgan Haven, Oct. 18, 1955. CU 29680 (29), Wicomico River, Rock Point Bar at Rock Point, Md., Oct. 18, 1955. CU 29723 (16), Sandy Point Old Pulpwood Dock opposite Quantico, Va., Oct. 18, 1955.

Rappahannock River--CU 26149 (23), R-38, Mar.-April 1954. CU 26514 (15), Layton's Landing, July 20, 1954. CU 28056 (12), July 22, 1954. CU 28317 (26), Tappahannock, Aug. 29, 1954. CU 28319 (24), Layton's Landing, Aug. 28, 1954. CU 28830 (14), Naylor's Point R-40, July 13, 1955. CU 28846 (13), Lowery Point R-35, July 14, 1955. CU 28894 (50), Layton's Landing, July 18, 1955.

York River System--CU 23581 (29), Pamunkey River Lowest stat. P-40 (White Oak Landing) near town of New Kent Court House, Aug. 4-24, 1953. CU 26150 (60), Almondsville to West Point, Mar.-April 1954. CU 26151 (7), Pages Rock Y-10, Mar.-April 1954. CU 28566 (42), Mattaponi River at Melrose E. side M-39, July 19, 1955. CU 28621 (34), Mattaponi River at Mantapike M-44.5, July 19, 1955. CU 29089 (46), West Point, July 1955. No cat. number (22), Pamunkey River, Aug. 25-28, 1952.

James River--CU 26147 (60), Hopewell vicinity, Mar.-April 1954. CU 26451 (18), below Hopewell J-56, 4th station E. side at Wilcox Wharf, July 24, 1954. CU 26622 (15), just off Back River J-35, July 23, 1954. CU 26642 (40), Chickahominy River at Shackelford Farm C-55, July 23, 1954. CU 28646 (59), island just E. of Swan Point, July 21, 1955. CU 28649 (39), tip of Hoy Island, July 22, 1955. CU 28693 (26), Chickahominy River N. Shore 1st point, July 21, 1955. CU 28743 (7), J-42 Dancing Point, July 21, 1955. CU 29090 (44), Hopewell, July-Aug. 1955.

Albemarle Sound--CU 20626 (24), 1 mi. east of route 37 crossing, Apr. 15, 1953. CU 23541 (34), north end bridge Rt. 32, Aug. 28-29, 1953. CU 25842 (8), off Powell's Point, mouth North River, Mar. 29, 1954. CU 28161 (5), Chowan River, North Carolina, Aug. 10, 1954. CU 28161 (39), Chowan River, North Carolina, Aug. 30, 1954. CU 28322 (16), north side bridge, Aug. 30, 1954. CU 28336 (2), Weldon, North Carolina, April 1954. CU 28337 (23), Little River, North Carolina, Summer 1954.

Santee-Cooper (below Pinopolis Dam)--CU 26148 (37), Pinopolis Dam, Apr. 2-May 5, 1954. CU 28518 (4), Tailrace Canal, Pinopolis Dam, Mar. 31, 1955. CU 28519 (6), Pinopolis Dam, Tailrace, Apr. 20, 1955. CU 28520 (8), Pinopolis Dam Tailrace, Apr. 25, 1955. CU 29088 (16), Tailrace Canal, Sept. 1, 1955. CU 29670 (14), Sept. 1955. CU 29671 (13), Nov. 7, 1955.

Santee-Cooper (above Pinopolis Dam)--CU 22073 (1), Lake Moultrie, Oct. 28, 1952. CU 28225 (68), Lake Marion near head of Diversion Canal, Sept. 10, 1954. CU 28348 (18), Lake Marion and Diversion Canal, Sept. 27, 1954. CU 28349 (2), Lake Moultrie near Diversion Canal, Dec. 5, 1954. CU 28513 (4), Lake Moultrie, Diversion Canal, May 6, 1955. CU 28514 (5), Wyboo Creek, Mar. 28, 1955. CU 29017 (55), lower end of Diversion Canal, June 30, 1955. CU 29018 (9), upper end Wilkinson's Landing, July 29, 1955. CU 29669 (14), Lake Marion, Oct. 1955. No cat. number (17), Wilkinson's Landing at head of Diversion Canal, March 1956.

METHODS

Measurements--Six characters were measured. Standard length, predorsal distance, head length, and caudal-peduncle depth conform to the descriptions of Hubbs and Lagler (1947). The following measurements were also made: body depth, the distance between the origin of the first dorsal fin and the origin of the pelvic fin; prepelvic distance, the distance between the anterior base of the pelvic fin and the most anterior tip of the lower jaw.

Measurements up to 150 mm. were made to 0.1 mm. with dial calipers. The larger specimens were measured to 0.1 mm. with trammel points (used in the carpentry trade) and the distances between the points were ascertained with a steel ruler.

Comparison of data--The standard length was used as the independent variable in all comparisons; all other characters measured were employed as dependent variables. Therefore, five regressions were determined for the specimens from each locality. Representative samples of the data were plotted for an indication of the relations of the various dependent variables on the independent. Throughout the size range investigated, all relations were found to be linear. It was also noted that the variances of the dependent variables increased as the standard length increased. The regression assumption of homogeneous variances was not justified and a transformation had to be performed. The correlation between means and variances was removed by transforming the original data into logarithms, as suggested by Mottley (1941). The transformations and the sums of squares were compiled on a Card Program Computer. Natural logarithms were used, since the machine performs this transformation more rapidly. A linear relation was still present after transformation.

The statistical procedure used in comparing the regression is similar to that employed by Martin (1949). Homogeneity of regression is posed as the null hypothesis and is tested by the appropriate F-test in an analysis of covariance. The regression coefficients are first tested for homogeneity, and if a nonsignificant "F" value is found the intercepts are subjected to analysis. When the slopes are found heterogeneous the intercepts are not tested for the populations have already been found different. Throughout the text, when reference is made to values being significant or not significant the 1-percent level is implied. The 5-percent level is not considered biologically significant, however, in the tables, "F" values found significant at that level are labelled as such. Unless specified otherwise, statistical significance is designated in the tables as follows: N.S. - not significant; * - significant at the 5-percent level; ** - significant at the 1-percent level. The statistical methods outlined in Snedecor (1946) were followed.

Individual comparisons among samples from nearby geographic areas were made in an attempt to find out whether the samples differed, and other comparisons were made to check differences found by other workers who used different characters. Therefore, all individual comparisons were meaningful and need not be orthogonal (independent).

The term "population", as used throughout the text, is employed in a restricted sense. Its meaning is synonomous with the definition that Mayr, Lindsley, and Usinger (1953; p.308) give to "local population". Since it is common practice to use the term "population" when referring to the results of statistical tests and in so doing imply a restricted meaning, the term was always employed in that way for the sake of consistency.

The locations studied were limited to areas from which large specimens were available. All specimens obtained in an area were assumed to have had their origin there. Different year classes were combined and the resulting regressions represent averages for that locality.

It was assumed that sexual dimorphism was not present.

RESULTS

Body Depth--Using body depth as the dependent variable and standard length as the independent, the covariance test for the homogeneity of regression coefficients over all areas studied (table 1) resulted in an "F" value that was significant at the 1-percent level. This indicates that the various samples were not all drawn from the same population. This heterogeneity of samples was further analyzed with meaningful comparisons between individual areas.

The samples secured in the Hudson River were compared, on the basis of body depth, with those taken in the Delaware River (table 2), the nearest geographic area studied. The covariance procedure testing the slopes resulted in nonsignificance. The intercepts when subjected to analysis yielded a value significant at the 1-percent level. It is therefore assumed that the body depth - standard length relation of the Hudson and Delaware populations increases at different rates from embryonic stage until approximately 32 mm., the minimum size studied (table 13); the two populations increase at the same rate from 32 mm. until at least 227 mm. Because of the existing linear relation between the two variables, this similarity undoubtedly holds true for larger size fish.

Raney (1957) studying meristic characters, found similarities between the James and Hudson populations. They were significantly different but, approached one another in high first dorsal spine counts, low second dorsal soft ray counts, and low anal soft ray counts. Thus, the Hudson River samples were compared with those collected in the James. The body depth - standard length relation of samples from these two river systems were compared for homogeneity and an "F' value significant at the 1-percent level resulted (table 3).

Within the Chesapeake Bay, when using the body depth - standard length relation as an index, most samples used in this study appear to have been drawn from different populations. The only populations found homogeneous in body depth were the James and Rappahannock. These two collections yielded nonsignificant results in both slope and intercept (table 4). The latter two tests proved that the samples were drawn from the same population or, and undoubtedly the case, that body depth cannot be used in separating the two populations. The James specimens were significantly different in body depth from the York (table 5) and Potomac samples (table 6), as well as those from Albemarle Sound (table 7), the nearest area to the south. The other collections from Chesapeake Bay differed in body depth - standard length relation. The York samples were significantly different from the Rappahannock's (table 9) and the latter were significant from specimens collected in the Potomac (table 8).

The upstream Santee-Cooper, S.C., samples were compared with those taken below the dam. The covariance test for the homogeneity of regression coefficients, for the regression of body depth on standard length, resulted in an "F" value that was significant at the 1-percent level (table 10). This indicates that the collections were not taken from the same population, unless an unusual sample was encountered. On the basis of body depth, the downstream Santee-Cooper samples were compared with those from Albemarle Sound, the nearest area to the north, and a highly significant "F" value resulted (table 11).

A north-south cline is noted in the column of body depths found in table 12. The northern samples (Hudson and Delaware) are seen to have the least body depth while those from the southernmost area Santee-Cooper, have the greatest body depth. The Chesapeake samples are intermediate and, with the exception of York River, there is an indication of a reverse trend within the Bay. The more southern Albemarle Sound specimens have a greater body depth than the collections within Chesapeake Bay, with the York River population once again proving to be an exception. The Santee-Cooper samples taken below the dam were deeper bodied than those taken above the dam.

Caudal-Peduncle Depth-- The overall "F" test for the homogeneity of the regression coefficients, for the regression of caudal peduncle on body depth, yielded a value that was significant at the 1-percent level (table 1). This indicates that the samples used for the test were not drawn from a homogeneous population.

Table 12 reveals that there is some correlation between caudal peduncle depth and body depth. There is only one marked divergence, that of the Potomac having a thicker peduncle than the downstream Santee-Cooper population. The Hudson and Delaware once again harbor the slimmest fish, with the James next in order.

In the caudal-peduncle character, the Hudson and Delaware samples proved to be similar in both slope and intercept (table 2). Therefore, least caudal-peduncle depth cannot be used as a criterion for separating the Hudson and Delaware populations. The Hudson and James collections were compared for homogeneity of slopes, and the resulting "F" value was not significant at the 1-percent level, but the intercepts were found to be highly significant (table 3).

The collections from the James River were significantly different in caudal peduncle - standard length relation from the Rappahannock (table 4), York (table 5), Potomac (table 6) and Albemarle Sound samples (table 7). Using the same relation the Potomac (table 8) and York (table 9) samples were found to be significant from the Rappahannock's. Therefore, when the regression of caudal peduncle on standard length is used as a criterion, Chesapeake Bay appears to be composed of heterogeneous populations.

In the Santee-Cooper System, the population below the dam is seen to be deeper in caudal peduncle depth than the upstream samples (table 12). The upstream-downstream comparison of this character resulted in an "F" value that was significant at the 1-percent level (table 10). A comparison of the Albemarle Sound collections with those of Santee-Cooper (below dam) showed that the two samples were not homogeneous in caudal peduncle - standard length relation (table 11).

In summary, the regression of caudal peduncle depth on standard length differs significantly between most areas; the homogeneity of the Hudson and Delaware collections was the only exception.

Prepelvic distance--The overall covariance procedure testing the homogeneity of regression coefficients, for the regression of prepelvic distance on standard length, resulted in a highly significant "F" value (table 1). This significant value points out that the samples used in this study do not belong to one homogeneous population.

Using the prepelvic distance - standard length relation as an index, the Hudson River samples were compared with both the Delaware and the James collections. Tables 2 and 3 show that these comparisons were highly significant.

With the exception of the James River samples, the prepelvic distance - standard length relation remained constant throughout the specimens studied from Chesapeake Bay. The James River collections diverged somewhat and were found to be highly significant from the York (table 5) and Rappahannock (table 4) samples. A similarity in both slope and intercept was found between the James and Potomac samples (table 6) as well as the James and Albemarle collections (table 7). No significance was encountered when the Potomac samples were compared with those of the Rappahannock (table 8) and also when the latter were compared with the York River specimens (table 9).

The Santee-Cooper collections proved to be homogeneous in the prepelvic distance - standard length relation as the upstream versus downstream comparison was not significant in either slope or intercept (table 10). The Santee-Cooper (below dam) samples were found to be similar in prepelvic distance with the Albemarle Sound collections (table 11).

In conclusion, the prepelvic distance - body depth relation remains relatively constant between areas of close geographic proximity. The ranking numbers of table 12 may lead to confusion because nonsignificance is present between some locations, however, the numbers do show a slight north-south trend.

Predorsal distance--The homogeneity of slopes within the nine location regressions, for the regression of predorsal distance on standard length, was tested by the appropriate covariance procedure. The resulting "F" value was found to be significant at the 1-percent level (table 1). Comparisons between individual locations were made to determine the cause of this heterogeneity.

The regression of predorsal distance on standard length for the Hudson and Delaware samples was homogeneous in slope, but significantly different in intercept (table 2); this is also true for the comparison involving the Hudson and James populations (table 3). Unless unusual samples were encountered, the Hudson River collections were not drawn from the same population as either the Delaware or James specimens.

The predorsal distance - standard length relations of the collections within Chesapeake Bay were compared for homogeneity. The James samples were significantly different in slope from the Rappahannock specimens (table 4) and the former were similar in slope but significantly different in intercept when compared with samples taken in the York River (table 5). The Potomac and James specimens were also found to be similar in slope but significantly different in intercept (table 6). The Rappahannock samples were significantly different in slope when compared with the Potomac (table 8) and York (table 9) specimens. The results of the comparison involving the James and Albemarle Sound samples indicate that both collections could have been taken from the same population (table 7).

The collections made above and below Pinopolis Dam (the Santee-Cooper River System) proved to be homogeneous in the regression of predorsal distance on standard length (table 10). Therefore, the two populations, if they do exist, cannot be separated on the basis of predorsal distance. An "F" value significant at the 1-percent level resulted when the downstream samples were compared with the Albemarle Sound collections for homogeneity of regression coefficients (table 11).

The regression of predorsal distance on standard length was homogeneous in two comparisons: the James samples with those from Albemarle Sound, and the Santee-Cooper upstream and downstream collections. All other comparisons between two locations resulted in the hypothesis that the samples were not drawn from the same population.

Head length--The assumption of homogeneity of the nine regression coefficients, for the regression of head length on standard length, was posed as the null hypothesis and tested by the appropriate "F" test in an analysis of covariance (table 1). The "F" value found was significant at the 1-percent level. The alternative hypothesis that of the regression coefficients not being homogeneous is therefore accepted.

The Hudson River samples possessed a head length - standard length relation that was significantly different from the relation found in both the Delaware and the James specimens (tables 1 and 2). The character head length shows that the Hudson River samples were not taken from the same population as the Delaware or James collections.

The regression of head length on standard length was compared among samples taken from the Chesapeake Bay area. The slope of the James River specimens was significantly different from that of the Rappahannock and York collections (tables 4 and 5). The regression coefficients of the James and Potomac samples were homogeneous but the regression differed significantly in intercept (table 6). When the James River collections were compared to samples taken from the nearest area studied outside the bay, Albemarle Sound, nonsignificance of both slope and intercept resulted (table 7). The Rappahannock River samples were found similar in slope but different in intercept when compared with the Potomac collections (table 8). The Rappahannock and York specimens differed significantly in slope (table 9). The samples secured in Chesapeake Bay do not appear to have been taken from a homogeneous population. Using the regression of head length on standard length as an index, the various river systems of Chesapeake Bay appear to have their own distinct populations.

The regression of head length on standard length was not statistically different between the Santee-Cooper upstream and downstream samples (table 10), or between the downstream samples and the Albemarle Sound collections (table 11). Therefore, head length indicates that both the upstream Santee-Cooper and the Albemarle Sound samples could have been taken from the same population as the downstream Santee-Cooper collections.

The regression of head length on standard length was significantly different for all comparisons made between samples taken from the James River northward. Comparisons made between samples taken from the James River and areas to the south yielded nonsignificant results in every case. Table 12 does not indicate the presence of a north-south cline, however, the Santee-Cooper samples are seen to have the longest heads.

Table 14 contains a summary of all comparisons made.

DISCUSSION

Migratory and racial studies of the striped bass along the Atlantic coast have been divided into two phases, tagging programs and investigations of meristic characters. The tagging programs were initiated in 1936. Basic knowledge of the seasonal coastwide migration was determined by Merriman (1937 and 1941). Between April and the end of October 1936, Merriman (1937, pp. 27-32) tagged and released 1,397 striped bass in the Niantic and Thames Rivers, Connecticut. Returns during the spring months gave proof of an eastward movement from Connecticut to Rhode Island believed to be part of a mass migration to the north. The populations of the Thames and Niantic Rivers remained static during the summer months, as the maximum distance traveled by an individual was 10 miles. In the fall, tagged fish were first caught at Montauk, Long Island, N. Y., and the south side of Long Island. As the season progressed, returns were received from more distant southern localities, and thus, a definite southern migration was shown. An additional tagging experiment was performed at Montauk, Long Island, and the results verified the initial study (Merriman 1941, p. 38). Results from the last two studies and an additional tagging program carried on in Albemarle Sound, led Merriman to the following conclusions: 1. The striped bass south of Cape Hatteras comprise a population that does not contribute to the coastwide northern migration; 2. The North Carolina fish only contribute a very small percentage to the summer population of the north; 3. Most of the northern migrants are from Chesapeake Bay. Merriman's findings suggest that various populations of striped bass exist along the Atlantic coast. These populations and the economic importance of each should be well defined so that, if necessary, sound management practices could be applied.

What actually caused the differences that were encountered in body form of the striped bass is subject to speculation. The north-south cline that is noted in body depth (table 12), and to a lesser extent in caudal-peduncle depth, may indicate that the differences are genetic. The presence of a cline in many instances is the result of selection (Huxley 1943, pp. 206-227), and the cline therefore tends to be parallel to the environment that influenced it. However, the differences found are not necessarily the result of selection; Martin (1949) showed that body form, at least in the Atlantic salmon, Salmo salar, and perhaps in most fishes, is influenced by five relative-growth stanzas, provided the body part under consideration does exhibit these growth inflections. These stanzas were represented by four inflections found at approximately the eyed-egg stage, hatching, ossification, and sexual maturity. Since the body size at these inflections is an influencing factor on the determination of the relative size of the body parts, it appears that the immediate environment can alter body proportions during a considerable length of time. It therefore seems likely that a combination of genetic factors due to selection and the effect of the immediate environment could be the cause of differences that were found. The other characters measured, predorsal distance, head length, and prepelvic distance, yielded Y-values (table 12) that appear to be more or less randomly distributed. However, nonsignificance is present between some samples, and consequently many of the ranking values are meaningless. The random distribution of the ranking values would seem to support the theory that the characters measured are genetically fixed. Even if these characters were not genetically fixed they could still be used as indicators for separating populations of striped bass. No taxonomic status can be assigned to the populations found different. Nevertheless, if all individuals of one sample are found to exhibit a certain characteristic that differs significantly from the same characteristic found in another sample, the populations are obviously not homogeneous.

The Hudson River samples were significantly different from the James population in all characters studied and different from the Delaware samples in all characters except caudal-peduncle depth. It is seen from table 12 that the Y-value for body depth of the Delaware samples approaches that of the Hudson closer than any of the other collections studied. On the basis of this visual observation, it may be said that the Hudson population is significantly different from all other areas studied, when body depth is used for the comparisons. It is concluded, on the basis of morphometric data, that the Hudson River contains a distinct population of striped bass.

This is in agreement with the findings of other workers. Raney and de Sylva (1953), studying dorsal, pectoral, and anal soft rays, conclude that the Hudson River striped bass perhaps constitute a separate race. Lewis (1957), on the basis of gill-raker counts, found that the Hudson River contains a homogeneous population of striped bass. Raney, Woolcott, and Mehring (1954, p. 394) studied the results of a tagging program and found that part of the Hudson River population moves in late spring to the western end of Long Island Sound, seldom going east farther than Fairport, Conn., or North Port, Long Island. Other individuals were found to move along the south shore of Long Island but not farther than Jones Beach. In the fall, the bass were found to migrate from the Sound into the Hudson River and as far upstream as Stony Point. Raney (1957) found significant differences between the Hudson population and samples secured in the Chesapeake Bay region. He assumed that only one population was present in the Hudson for the following reasons: the first-dorsal-spine counts remained rather constant in individuals taken throughout the Hudson River; the soft-dorsal and anal-ray counts were significantly different when upstream and downstream samples were compared, but the differences were not great enough to consider the possibility of two populations. The past studies and the results obtained using morphometric data are in agreement as all denote the Hudson River striped bass as a distinct population.

Within Chesapeake Bay, tagging studies have been carried out in an attempt to determine movements which in turn help solve the population problem. Pearson (1938, p.842) tagged 305 striped bass in upper Chesapeake Bay at Annapolis, Md. A total of 29.1 percent (89 specimens) of the number tagged were recaptured and of these only 9 returns were south of Annapolis. The majority of the tagged fish were taken in the area that extends from the Magothy River and Love Point north to the Susquehanna and Elk Rivers, with the greatest number centering around Rock Hall near the entrance to the Chester River. Over a 2-year period, the most distant points of recapture were off Maryland Point in the Potomac River and near Salisbury in the Wicomico River. The results of Pearson's experiment show that there is little movement of striped bass from the upper portion of Chesapeake Bay into the lower.

Vladykov and Wallace (1952, pp. 163-170) tagged bass in the middle Chesapeake Bay area. Fish tagged at Galesville, Flag Pond, and Tilghman were found to remain relatively static during the summer and slowly migrate southward in the late fall. The Choptank and the Susquehanna Rivers were believed to be the main spawning grounds for these bass. They concluded that the bass of the upper Chesapeake Bay region comprised one population and they supported this finding with fin-ray counts. Vladykov and Wallace (1952, pp. 170-175) tagged striped bass in the Potomac and James Rivers and the returns indicated that both rivers may have local populations. The rather stationary James population led them to believe that little intermixing occurs between the fish of this system with those of Albemarle Sound.

Raney believes that there are at least three subpopulations in Chesapeake Bay and its tributaries. These subpopulations are found in the James River, in the York and Rappahannock Rivers, and in the Upper Bay. His conclusions resulted from a study of first-dorsal-spine counts and soft-dorsal and anal-ray counts. Lewis (1957), working with gill rakers, supported the findings of Raney. The use of morphometric data to distinguish the populations of striped bass within Chesapeake Bay showed that samples taken from the Potomac, York, Rappahannock, and James Rivers may all have been drawn from different populations. The only finding contrary to the results of other workers is that the York and Rappahannock Rivers do not appear to have one homogeneous population of striped bass. The samples from these two rivers were found to differ from one another in all characters other than prepelvic distance. With the exception of the James River samples, the regression of prepelvic distance on standard length was found to remain constant in specimens taken from the tributaries of Chesapeake Bay. Morphometric characters appear to be more acute indicators of differences in populations. It seems reasonable to believe that the environment would only have an influence on meristic characters during embryonic development, whereas body form (Martin 1949) is indirectly affected by the environment over a longer period of time. It therefore seems likely that the environments in the York and Rappahannock Rivers may not be diverse enough to cause differences in meristic characters but would cause differences in morphometric characters. On the basis of this study, the York and Rappahannock Rivers do not appear to have one homogeneous population of striped bass.

The James River population was found similar to the Rappahannock population in body depth and to the Potomac samples in prepelvic distance; all other characters differed significantly. It is concluded that the James River population is separable from all other samples studied within the Chesapeake Bay. This is in agreement with the finding of Raney (1957).

Vladykov and Wallace (1952) believed that the striped bass in the Potomac River were a distinct population. This study supports that view. In all characters other than prepelvic distance, the Potomac River samples were found to differ significantly from samples collected in the Rappahannock River, the nearest geographic area studied.

Chesapeake Bay on the basis of morphometric characters seems to be composed of at least four populations of striped bass; the James River, York River, Rappahannock River and Potomac River.

When James River samples were compared with samples from Albemarle Sound, the nearest area outside the Bay, the samples differed significantly in body depth and caudal-peduncle depth but were similar in predorsal distance, prepelvic distance, and head length. Vladykov and Wallace (1952, p.172) tagged striped bass in the James River and found very little intermixing with the fish from Albemarle Sound. Merriman (1941, p. 45-46) ran a tagging experiment in Albemarle Sound and found that the population tends to remain in the Sound all year round. Raney (1957) found that the number of first-dorsal spines in the James River samples were much higher and statistically different from collections in Albemarle Sound. The two characters, body and caudal-peduncle depths, show that the James and Albemarle Sound samples do not belong to the same population. The similarity in the other morphometric characters could indicate that the Albemarle population is more closely related to that of the James than the latter is to the York, the population which is closest geographically to the James.

Scruggs and Fuller (1955) indicate that perhaps two populations of striped bass exist in the Santee-Cooper System in South Carolina; one is located in the Cooper River below Pinopolis Dam and the other is a freshwater population living in the impounded waters. They base their postulation on the following evidence: below the dam, suitable spawning grounds are available and utilized, and therefore the downstream population need not migrate through the navigation locks to spawn; trammel-net catches taken to determine fish movement through the navigation locks yielded little positive evidence of migration; preliminary returns from a tagging study showed a limited intermingling of the two populations. Raney and Woolcott (1955) also presented evidence that two populations of striped bass may be present in the Santee-Cooper System. Their conclusions resulted from a study based on anal, dorsal, and pectoral soft-ray counts and also lateral-line scales. Samples collected from these areas were subjected to statistical tests in an attempt to separate these populations on the basis of morphometric characters.

In this study, a factor that may have biased the results is that the range of fish sizes (standard length) from the two areas have very little overlap (table 57). The samples taken from below Pinopolis Dam ranged from 107 to 350 mm. while those collected above were in the range of 41 to 171 mm., with only 18 specimens longer than 100 mm. It is believed that the comparisons are valid, since in both populations the relation of each dependent variable to standard length was linear. This is not positive evidence that the same relation exists in sizes not sampled. When the comparisons were made, the characters that proved to be homogeneous in slope were also found similar in intercept; therefore, this further supports the assumption that the comparisons were valid.

The samples collected below Pinopolis Dam were found to be significantly different in body depth and caudal peduncle depth from the samples collected above the dam. Both these samples were found similar in prepelvic distance, predorsal distance and in head length. The characters, body depth and caudal peduncle depth, are believed to be good criteria for separating these two populations.

The downstream Santee-Cooper samples were found to differ from the Albemarle Sound collections in body depth, caudal peduncle depth and in predorsal distance. They were found similar in prepelvic distance and head length. This seems to indicate that these two populations are not homogeneous.

SUMMARY AND CONCLUSIONS

1. The striped bass found along the Atlantic Coast exhibited north-south clines with respect to body and caudal-peduncle depths. The clines suggest that the differences found are the result of selection and thus genetically fixed.

2. Predorsal distances, head lengths, and prepelvic distances were found to be randomly distributed. However, the samples from the Santee-Cooper System in South Carolina did consistently have the larger body parts. These latter findings indicate that all characters are genetically fixed, but the effect of the immediate environmental fluctuations is not known. Most likely the differences found were caused by a combination of genetic and environmental factors.

3. Body proportions show that the Hudson River population is distinctly different from all others studied.

4. Within Chesapeake Bay, the James, York, Rappahannock, and Potomac Rivers, on the basis of morphometric characters, have separate populations of striped bass. Other populations may be present, but lack of adequate study material prevents any conclusions at this time.

5. The James and Albemarle Sound populations were found to differ in body and caudal-peduncle depths but were similar in predorsal distances, head lengths, and prepelvic distances.

6. The Santee-Cooper upstream and downstream samples differed in body depths and caudal-peduncle depths but not in predorsal distances, prepelvic distances, or head lengths. The two differences are believed to be good criteria for separating the populations.

7. Morphometric characters are believed to be good indicators for separating populations of striped bass found along the Atlantic Coast.

LITERATURE CITED

Hubbs, C. L., and K. F. Lagler
1947. Fishes of the Great Lakes Region. Bull. Cranbrook Inst. Sci. 26, xi + 186 pp.

Huxley, J.
1943. Evolution the modern synthesis. Harper and Brothers, New York and London. 645 pp.

Lewis, R.M.
1957. Comparative study of populations of the striped bass <u>Roccus saxatilis</u> based on gill raker counts. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 211.(In press).

Marr, J. C.
1955. The use of morphometric data in systematic, racial and relative growth studies in fishes. COPEIA, (1):25-31.

Martin, W. R.
1949. The mechanics of environmental control of body form in fishes. Univ. Toronto studies, Biol. No. 58. Pub. Ont. Fish. Res. Lab., No. 70.

Mayr, E., E.G. Linsley, and R.L. Usinger
1953. Methods and principles of systematic zoology. McGraw-Hill Book Co., Inc., New York. 328 pp.

Merriman, D.
1937. Notes on the life history of the striped bass (Roccus lineatus). COPEIA (1): 15-36.

1941. Studies on the striped bass (Roccus saxatilis) of the Atlantic Coast. U.S. Fish and Wildlife Service, Fish. Bull., No. 35, vol. 50, pp. 1-77.

Mottley, C. McC.
1941. The covariance method of comparing the headlengths of trout from different environments. COPEIA, (3):154-159.

Pearson, J. C.
1938. The life history of the striped bass, or rockfish, Roccus saxatilis (Walbaum). U. S. Bur. Fish. Bull., No. 28, vol. 48, pp. 825-851.

Raney, E. C.
1952. The life history of the striped bass, Roccus saxatilis (Walbaum). Bull. Bingham Oceanogr. Coll. 14(1):5-97.

Raney, E.C., and D.P. de Sylva
1953. Racial investigations of the striped bass, Roccus saxatilis (Walbaum). Jour. of Wildl.Mgt. 17(4):495-509.

Raney, E. C., W.S. Woolcott and A.G. Mehring
1954. Migratory pattern and racial structure of Atlantic Coast striped bass. Trans. Nineteenth N. Amer. Wildl. Conf.: 376-396.

Raney, E. C., and W. S. Woolcott
1955. Races of the striped bass, Roccus saxatilis (Walbaum), in southeastern United States. Jour. Wildl. Mgt. 19(4): 444-450.

Raney, E. C.
1957. Subpopulations of the striped bass, Roccus saxatilis (Walbaum), in the tributaries of the Chesapeake Bay. U. S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 208 (in press).

Scruggs, G. D., Jr., and J.C. Fuller, Jr.
1955. Indications of a freshwater population of striped bass, "Roccus saxatilis" (Walbaum), in Santee-Cooper Reservoirs. Proc. Southeastern Assoc. Game and Fish Comm.: 64-69.

Snedecor, G. W.
1946. Statistical methods, 4th ed. Ames, Iowa, Collegiate Press, 485 pp.

Vladykov, V. D., and D. H. Wallace
1952. Studies of the striped bass, Roccus saxatilis (Walbaum), with special reference to the Chesapeake Bay region during 1936-38. Bull. Bingham. Oceanogr. Coll. 14(1): 132-177.

APPENDIX

Table 1.—Analyses of covariance for samples of striped bass taken in all regions studied. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Squares	Variance Ratios
Body Depth				
Deviations from total regression within regions	2270	4.5348		$\frac{0.0426}{0.0018} = 23.67^{**}$
Deviations from individual regressions	2262	4.1940	0.0018	
Difference for homogeneity of regression	8	0.3408	0.0426	
Caudal Peduncle Depth				
Deviations from total regression within regions	2270	2.7297		$\frac{0.0428}{0.0010} = 42.80^{**}$
Deviations from individual regressions	2262	2.3872	0.0010	
Difference for homogeneity of regression	8	0.3425	0.0428	
Prepelvic Distance				
Deviations from total regression within regions	2270	2.2641		$\frac{0.0063}{0.0010} = 6.30^{**}$
Deviations from individual regressions	2262	2.2136	0.0010	
Difference for homogeneity of regression	8	0.0505	0.0063	
Predorsal Distance				
Deviations from total regression within regions	2270	1.7341		$\frac{0.0071}{0.0007} = 10.14^{**}$
Deviations from individual regressions	2262	1.6774	0.0007	
Difference for homogeneity of regression	8	0.0567	0.0071	
Head Length				
Deviations from total regression within regions	2270	1.8441		$\frac{0.0112}{0.0008} = 14.00^{**}$
Deviations from individual regressions	2262	1.7542	0.0008	
Difference for homogeneity of regression	8	0.0899	0.0112	

Table 2.—Analyses of covariance for samples of striped bass taken in the Hudson and Delaware Rivers. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Squares	Variance Ratios
Body Depth				
Deviations from total regression among regions	924	2.3150		$\frac{0.0037}{0.0023}$ = 1.61 N.S.
Deviations from total regression within regions	923	2.1209	0.0023	
Deviations from individual regressions	922	2.1172	0.0023	
Difference for homogeneity of regression	1	0.0037		$\frac{0.1941}{0.0023}$ = 84.39**
Difference for testing adjusted means	1	0.1941		
Caudal Peduncle Depth				
Deviations from total regression among regions	924	1.0071		$\frac{0.0000}{0.0011}$ = 0 N.S.
Deviations from total regression within regions	923	1.0069	0.0011	
Deviations from individual regressions	922	1.0069	0.0011	
Difference for homogeneity of regression	1	0.0000		$\frac{0.0002}{0.0011}$ = 0.18 N.S.
Difference for testing adjusted means	1	0.0002		
Prepelvic Distance				
Deviations from total regression within regions	923	1.1276		
Deviations from individual regressions	922	1.1073	0.0012	$\frac{0.0203}{0.0012}$ = 16.92**
Difference for homogeneity of regression	1	0.0203		
Predorsal Distance				
Deviations from total regression among regions	924	1.0805		$\frac{0.0003}{0.0011}$ = 0.27 N.S.
Deviations from total regression within regions	923	1.0661	0.0012	
Deviations from individual regressions	922	1.0658	0.0011	
Difference for homogeneity of regression	1	0.0003		$\frac{0.0144}{0.0012}$ = 12.00**
Difference for testing adjusted means	1	0.0144		
Head Length				$\frac{0.0065}{0.0006}$ = 10.83**
Deviations from total regressions within regions	923	0.5778	0.0006	
Deviations from individual regressions	922	0.5713		
Difference for homogeneity of regression	1	0.0065		

Table 3.—Analyses of covariance for samples of striped bass taken in the Hudson and James Rivers. Standard length was used as the independent variable in all comparisons.

Sources of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Squares	Variance Ratios
Body Depth				
Deviations from total regression within regions	1057	2.6570		$\frac{0.0172}{0.0025} = 6.88^{**}$
Deviations from individual regressions	1056	2.6398	0.0025	
Difference for homogeneity of regression	1	0.0172		
Caudal Peduncle Depth				
Deviations from total regression among regions	1058	1.5559		$\frac{0.0062}{0.0011} = 5.64^{*}$
Deviations from total regression within regions	1057	1.1366	0.0011	
Deviations from individual regressions	1056	1.1304	0.0011	
Difference for homogeneity of regression	1	0.0062		$\frac{0.4193}{0.0011} = 381.18^{**}$
Difference for testing adjusted means	1	0.4193		
Prepelvic Distance				
Deviations from total regression within regions	1057	1.0479		$\frac{0.0081}{0.0010} = 8.10^{**}$
Deviations from individual regressions	1056	1.0398	0.0010	
Difference for homogeneity of regression	1	0.0081		
Predorsal Distance				
Deviations from total regression among regions	1058	1.1327		$\frac{0.0050}{0.0011} = 4.54^{*}$
Deviations from total regression within regions	1057	1.1204	0.0010	
Deviations from individual regressions	1056	1.1154	0.0011	
Difference for homogeneity of regression	1	0.0050		$\frac{0.0123}{0.0010} = 12.30^{**}$
Difference for testing adjusted means	1	0.0123		
Head Length				
Deviations from total regression within regions	1057	0.5864		$\frac{0.0056}{0.0005} = 11.20^{**}$
Deviations from individual regressions	1056	0.5808	0.0005	
Difference for homogeneity of regression	1	0.0056		

Table 4.—Analyses of covariance for samples of striped bass taken in the James and Rappahannock Rivers. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Square	Variance Ratios
Body Depth				
Deviations from total regression among regions	482	0.8272		$\frac{0.0015}{0.0017}$ = 0.88 N.S.
Deviations from total regression within regions	481	0.8194	0.0017	
Deviations from individual regressions	480	0.8179	0.0017	$\frac{0.0078}{0.0017}$ = 4.59*
Difference for homogeneity of regression	1	0.0015		
Difference for testing adjusted means	1	0.0078		
Caudal Peduncle Depth				
Deviations from total regression within regions	481	0.6576		$\frac{0.0196}{0.0013}$ = 15.08**
Deviations from individual regressions	480	0.6380	0.0013	
Difference for homogeneity of regression	1	0.0196		
Prepelvic Distance				
Deviations from total regression within regions	481	0.2855		$\frac{0.0058}{0.0006}$ = 9.67**
Deviations from individual regressions	480	0.2797	0.0006	
Difference for homogeneity of regression	1	0.0058		
Predorsal Distance				
Deviations from total regression within regions	481	0.2146		$\frac{0.0082}{0.0004}$ = 20.50**
Deviations from individual regressions	480	0.2064	0.0004	
Difference for homogeneity of regression	1	0.0082		
Head Length				
Deviations from total regression within regions	481	0.1890		$\frac{0.0039}{0.0004}$ = 9.75**
Deviations from individual regressions	480	0.1851	0.0004	
Difference for homogeneity of regression	1	0.0039		

Table 5.—Analyses of covariance for samples of striped bass taken in the James and York Rivers. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Square	Variance Ratios
Body Depth				
Deviations from total regression within regions	544	1.0263		$\frac{0.0687}{0.0018}$ = 38.17**
Deviations from individual regressions	543	0.9576	0.0018	
Difference for homogeneity of regression	1	0.0687		
Caudal Peduncle Depth				
Deviations from total regression within regions	544	0.7379		$\frac{0.1179}{0.0011}$ = 107.18**
Deviations from individual regressions	543	0.6200	0.0011	
Difference for homogeneity of regression	1	0.1179		
Prepelvic Distance				
Deviations from total regression within regions	544	0.3383		$\frac{0.0122}{0.0006}$ = 20.33**
Deviations from individual regressions	543	0.3261	0.0006	
Difference for homogeneity of regression	1	0.0122		
Predorsal Distance				
Deviations from total regression among regions	545	0.3012		$\frac{0.0018}{0.0005}$ = 3.60 N.S.
Deviations from total regression within regions	544	0.2973	0.0005	
Deviations from individual regressions	543	0.2955	0.0005	
Difference for homogeneity of regression	1	0.0018		$\frac{0.0039}{0.0005}$ = 7.80**
Difference for testing adjusted means	1	0.0039		
Head Length				
Deviations from total regression within regions	544	0.4244		$\frac{0.0481}{0.0007}$ = 68.71**
Deviations from individual regression	543	0.3763	0.0007	
Difference for homogeneity of regression	1	0.0481		

Table 6.—Analyses of covariance for samples of striped bass taken in the James and Potomac Rivers. Standard length was used as the independent variable in all comparisons.

Sources of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Square	Variance Ratios
Body Depth				
Deviations from total regression within regions	490	1.0009		$\frac{0.1376}{0.0018}$ = 76.44**
Deviations from individual regressions	489	0.8633	0.0018	
Difference for homogeneity of regression	1	0.1376		
Caudal Peduncle Depth				
Deviations from total regression within regions	490	0.7352		$\frac{0.1668}{0.0012}$ = 139.00**
Deviations from individual regressions	489	0.5684	0.0012	
Difference for homogeneity of regression	1	0.1668		
Prepelvic Distance				
Deviations from total regression among regions	491	0.3344		$\frac{0.0004}{0.0007}$ = 0.57 N.S.
Deviations from total regression within regions	490	0.3321	0.0007	
Deviations from individual regressions	489	0.3316	0.0007	
Difference for homogeneity of regression	1	0.0004		$\frac{0.0023}{0.0007}$ = 3.29 N.S.
Difference for testing adjusted means	1	0.0023		
Predorsal Distance				
Deviations from total regression among regions	491	0.1927		$\frac{0.0008}{0.0003}$ = 2.67 N.S.
Deviations from total regression within regions	490	0.1679	0.0003	
Deviations from individual regressions	489	0.1671	0.0003	
Difference for homogeneity of regression	1	0.0008		$\frac{0.0248}{0.0003}$ = 72.94**
Difference for testing adjusted means	1	0.0248		
Head Length				
Deviations from total regression among regions	491	0.3088		$\frac{0.0006}{0.0006}$ = 1.00 N.S.
Deviations from total regression within regions	490	0.2779	0.0006	
Deviations from individual regressions	489	0.2773	0.0006	
Difference for homogeneity of regression	1	0.0006		$\frac{0.0309}{0.0006}$ = 51.50**
Difference for testing adjusted means	1	0.0309		

Table 7.—Analyses of covariance for samples of striped bass taken in the James River and Albemarle Sound. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Square	Variance Ratios
Body Depth				
Deviations from total regression within regions	454	0.8510		$\frac{0.0341}{0.0018}$ = 18.94**
Deviations from individual regressions	453	0.8169	0.0018	
Difference for homogeneity of regression	1	0.0341		
Caudal Peduncle Depth				
Deviations from total regression within regions	454	0.6352		$\frac{0.0785}{0.0012}$ = 65.42**
Deviations from individual regressions	453	0.5567	0.0012	
Difference for homogeneity of regression	1	0.0785		
Prepelvic Distance				
Deviations from total regression among regions	455	0.2575		$\frac{0.0008}{0.0006}$ = 1.33 N.S.
Deviations from total regression within regions	454	0.2538	0.0006	
Deviations from individual regressions	453	0.2530	0.0006	
Difference for homogeneity of regression	1	0.0008		$\frac{0.0037}{0.0006}$ = 6.17*
Difference for testing adjusted means	1	0.0037		
Predorsal Distance				
Deviations from total regression among regions	455	0.2001		$\frac{0.0011}{0.0004}$ = 2.75 N.S.
Deviations from total regression within regions	454	0.1998	0.0004	
Deviations from individual regressions	453	0.1987	0.0004	
Difference for homogeneity of regression	1	0.0011		$\frac{0.0003}{0.0004}$ = 0.75 N.S.
Difference for testing adjusted means	1	0.0003		
Head Length				
Deviations from total regression among regions	455	0.2850		$\frac{0.0003}{0.0006}$ = 0.50 N.S.
Deviations from total regression within regions	454	0.2840	0.0006	
Deviations from individual regressions	453	0.2837	0.0006	
Difference for homogeneity of regression	1	0.0003		$\frac{0.0010}{0.0062}$ = 1.61 N.S.
Difference for testing adjusted means	1	0.0010		

Table 8.—Analyses of covariance for samples of striped bass taken in the Potomac and Rappahannock Rivers. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Square	Variance Ratios
Body Depth				
Deviations from total regression within regions	362	0.6008		$\frac{0.1161}{0.0013}$ = 89.31**
Deviations from individual regressions	361	0.4847	0.0013	
Difference for homogeneity of regression	1	0.1161		
Caudal Peduncle Depth				
Deviations from total regression within regions	362	0.4927		$\frac{0.1086}{0.0011}$ = 98.73**
Deviations from individual regressions	361	0.3841	0.0011	
Difference for homogeneity of regression	1	0.1086		
Prepelvic Distance				
Deviations from total regression among regions	363	0.3073		$\frac{0.0031}{0.0008}$ = 3.87 N.S.
Deviations from total regression within regions	362	0.3020	0.0008	
Deviations from individual regressions	361	0.2989	0.0008	$\frac{0.0053}{0.0008}$ = 6.62*
Difference for homogeneity of regression	1	0.0031		
Difference for testing adjusted means	1	0.0053		
Predorsal Distance				
Deviations from total regression within regions	362	0.1294		$\frac{0.0049}{0.0003}$ = 16.33**
Deviations from individual regressions	361	0.1245	0.0003	
Difference for homogeneity of regression	1	0.0049		
Head Length				
Deviations from total regression among regions	363	0.2905		$\frac{0.0003}{0.0007}$ = 0.43 N.S.
Deviations from total regression within regions	362	0.2591	0.0007	
Deviations from individual regressions	361	0.2588	0.0007	$\frac{0.0314}{0.0007}$ = 44.86**
Difference for homogeneity of regression	1	0.0003		
Difference for testing adjusted means	1	0.0314		

Table 9.—Analyses of covariance for samples of striped bass taken in the Rappahannock and York Rivers. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Square	Variance Ratios
Body Depth				
Deviations from total regression within regions	416	0.6131		$\frac{0.0340}{0.0014} = 24.28^{**}$
Deviations from individual regressions	415	0.5791	0.0014	
Difference for homogeneity of regression	1	0.0340		
Caudal Peduncle Depth				
Deviations from total regression within regions	416	0.4597		$\frac{0.0239}{0.0011} = 21.73^{**}$
Deviations from individual regressions	415	0.4358	0.0011	
Difference for homogeneity of regression	1	0.0239		
Prepelvic Distance				
Deviations from total regression among regions	417	0.2978		$\frac{0.0004}{0.0007} = 0.57$ N.S.
Deviations from total regression within regions	416	0.2938	0.0007	
Deviations from individual regressions	415	0.2934	0.0007	
Difference for homogeneity of regression	1	0.0004		$\frac{0.0040}{0.0007} = 5.71^{*}$
Difference for testing adjusted means	1	0.0040		
Predorsal Distance				
Deviations from total regression within regions	416	0.2688		$\frac{0.0159}{0.0006} = 26.50^{**}$
Deviations from individual regressions	415	0.2529	0.0006	
Difference for homogeneity of regression	1	0.0159		
Head Length				
Deviations from total regression within regions	416	0.3736		$\frac{0.0158}{0.0009} = 17.56^{**}$
Deviations from individual regressions	415	0.3578	0.0009	
Difference for homogeneity of regression	1	0.0158		

Table 10.—Analyses of covariance for samples of striped bass taken above and below Pinopolis Dam in the Santee-Cooper River System. Standard length was used as the independent variable in all comparisons.

	Degrees of Freedom	Reduced Sum of Squares	Mean Squares	Variance Ratios
Body Depth				
Deviations from total regression within regions	288	0.4348		$\frac{0.0191}{0.0014} = 13.64^{**}$
Deviations from individual regressions	287	0.4157	0.0014	
Difference for homogeneity of regression	1	0.0191		
Caudal Peduncle Depth				
Deviations from total regression within regions	288	0.2507		$\frac{0.0202}{0.0008} = 25.25^{**}$
Deviations from individual regressions	287	0.2305	0.0008	
Difference for homogeneity of regression	1	0.0202		
Prepelvic Distance				
Deviations from total regression among regions	289	0.3873		$\frac{0.0014}{0.0013} = 1.08$ N.S.
Deviations from total regression within regions	288	0.3859	0.0013	
Deviations from individual regressions	287	0.3845	0.0013	
Difference for homogeneity of regression	1	0.0014		$\frac{0.0014}{0.0013} = 1.08$ N.S.
Difference for testing adjusted means	1	0.0014		
Predorsal Distance				
Deviations from total regression among regions	289	0.1195		$\frac{0.0010}{0.0004} = 2.50$ N.S.
Deviations from total regression within regions	288	0.1184	0.0004	
Deviations from individual regressions	287	0.1174	0.0004	
Difference for homogeneity of regression	1	0.0010		$\frac{0.0011}{0.0004} = 2.75$ N.S.
Difference for testing adjusted means	1	0.0011		
Head Length				
Deviations from total regression among regions	289	0.3682		$\frac{0.0001}{0.0013} = 0.08$ N.S.
Deviations from total regression within regions	288	0.3660	0.0013	
Deviations from individual regressions	287	0.3659	0.0013	
Difference for homogeneity of regression	1	0.0001		$\frac{0.0022}{0.0013} = 1.69$ N.S.
Difference for testing adjusted means	1	0.0022		

Table 11.—Analyses of covariance for samples of striped bass taken in Santee-Cooper (below dam) and Albemarle Sound. Standard length was used as the independent variable in all comparisons.

Source of Variation	Degrees of Freedom	Reduced Sum of Squares	Mean Squares	Variance Ratios
Body Depth				
Deviations from total regression within regions	246	0.4523		$\frac{0.0867}{0.0015} = 58.40^{**}$
Deviations from individual regressions	245	0.3656	0.0015	
Difference for homogeneity of regression	1	0.0867		
Caudal Peduncle Depth				
Deviations from total regression within regions	246	0.2690		$\frac{0.0403}{0.0009} = 44.78^{**}$
Deviations from individual regressions	245	0.2287	0.0009	
Difference for homogeneity of regression	1	0.0403		
Prepelvic Distance				
Deviations from total regression among regions	247	0.1674		$\frac{0.0001}{0.0007} = 0.14$ N.S.
Deviations from total regression within regions	246	0.1671	0.0007	
Deviations from individual regressions	245	0.1670	0.0007	
Difference for homogeneity of regression	1	0.0001		$\frac{0.0003}{0.0007} = 0.43$ N.S.
Difference for testing adjusted means	1	0.0003		
Predorsal Distance				
Deviations from total regression within regions	246	0.1155		$\frac{0.0072}{0.0004} = 18.00^{**}$
Deviations from individual regressions	245	0.1083	0.0004	
Difference for homogeneity of regression	1	0.0072		
Head Length				
Deviations from total regression among regions	247	0.2448		$\frac{0.0031}{0.0010} = 3.10$ N.S
Deviations from total regression within regions	246	0.2442	0.0010	
Deviations from individual regressions	245	0.2411	0.0010	
Difference for homogeneity of regression	1	0.0031		$\frac{0.0006}{0.0010} = 0.60$ N.S.
Difference for testing adjusted means	1	0.0006		

Table 12.—Summary of Y values for samples of striped bass listed from north to south. Y values determined from an equation of the type $Y = \bar{y} + b\ (X - \bar{x})$ for $X = 10$. Numbers in parenthesis represent the magnitude of the values when ranked from lowest to highest.

Location	Body Depth	Caudal Peduncle	Prepelvic	Predorsal	Head Length
Hudson	8.5833(1)	7.6201(1)	8.9460(3)	8.9917(5)	8.7654(2)
Delaware	8.6672(2)	7.6242(2)	8.8610(1)	9.0136(6)	8.8538(7)
Potomac	8.7056(5)	8.0231(9)	8.9821(5)	8.9572(1)	8.8023(4)
Rappahannock	8.6892(4)	7.6826(4)	8.9507(4)	9.0193(7)	8.7781(3)
York	8.7862(7)	7.7553(7)	8.9459(2)	8.9600(2)	8.7265(1)
James	8.6799(3)	7.6343(3)	8.9868(8)	8.9725(3)	8.8117(5)
Albemarle	8.7210(6)	7.7298(5)	8.9823(6)	8.9856(4)	8.8168(6)
Santee-Cooper (above dam)	8.8656(8)	7.7516(6)	9.1293(9)	9.1036(9)	8.8583(8)
Santee-Cooper (below dam)	8.9917(9)	7.9177(8)	8.9859(7)	9.0538(8)	8.8583(9)

Table 13.—Size range in mm. of striped bass taken from each locality.

Location	Range
Hudson	32-420
Delaware	55-227
Potomac	47-146
Rappahannock	39-294
York	31-286
James	45-267; one specimen 371
Albemarle	44-320
Santee-Cooper (above dam)	41-171; one specimen 275
Santee-Cooper (below dam)	107-350

Table 14—Summary of all comparisons between samples of striped bass collected along the Atlantic Coast. S represents significant at the one per cent level; S 5% represents significant at the five per cent level; NS represents not significant at the five per cent level.

Measurement *		Locality			
	Locality	Hudson	Rappahannock	James	Santee-Cooper (below dam)
B.D.	Delaware	S			
C.P.		NS			
Pp.D.		S			
Pd.D.		S			
H.L.		S			
B.D.	Potomac		S	S	
C.P.			S	S	
Pp.D.			S 5%	NS	
Pd.D.			S	S	
H.L.			S	S	
B.D.	Rappahannock			S 5%	
C.P.				S	
Pp.D.				S	
Pd.D.				S	
H.L.				S	
B.D.	York		S	S	
C.P.			S	S	
Pp.D.			S 5%	S	
Pd.D.			S	S	
H.L.			S	S	
B.D.	James	S			
C.P.		S			
Pp.D.		S			
Pd.D.		S			
H.L.		S			
B.D.	Albemarle			S	S
C.P.				S	S
Pp.D.				S 5%	NS
Pd.D.				NS	S
H.L.				NS	NS
B.D.	Santee-Cooper (above dam)				S
C.P.					S
Pp.D.					NS
Pd.D.					NS
H.L.					NS

* B.D. equals body depth; C.P. equals caudal peduncle depth; Pp.D. equals prepelvic distance; Pd.D. equals predorsal distance; H.L. equals head length.

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