PREDICTING ABUNDANCE OF STRIPED BASS, *MORONE SAXATILIS*, IN NEW YORK WATERS FROM MODAL LENGTHS[1]

HERBERT M. AUSTIN[2] AND CLARENCE R. HICKEY, JR.[3]

ABSTRACT

The abundance of cohorts for any given year class of striped bass, *Morone saxatilis,* prior to their leaving Chesapeake Bay is inversely related to the modal length of fish in that year class 2 yr later in New York waters. The modal length of bass in their third year migrating into the New York area is a reliable index of the abundance of that year class. When back extrapolated modal lengths at the end of the second year of life are considered for the dominant year classes in the New York fishery (ages III-VI), a high degree of inverse correlation is found between age II and modal length and reported landings suggesting that this is an effective method of predicting the abundance of the stock for the fishery.

In discussing natural fluctuations in fish populations, Royce (1972) posed the question, "... can we forecast their occurrence to take maximum advantage of periods of high abundance and protect populations during periods of scarcity?" This question is pertinent to the striped bass, *Morone saxatilis*, stocks of the Atlantic coast of the United States. The Atlantic coast commercial catch of this species, while following a pattern of fluctuations, has been in an upward trend in recent years, apparently as a result of an increasing abundance of fish (Koo 1970; McHugh 1972). This increasing abundance has been reflected by an increased commercial harvest in the State of New York. Concurrently, although not as well documented, is an increase in the number of recreational fishermen utilizing the resource. Both phenomena necessitate the gathering of management information while the resource is still in good condition.

Most (>80%) of the New York commercial harvest of striped bass occurs in the waters of eastern Suffolk County (Figure 1) where the major fisheries are primarily with haul seine and pound net. Fish taken in this region are predominantly of Chesapeake Bay origin (Neville et al. 1939; Alperin 1966; Schaefer 1968, 1972; Koo 1970; Austin and Custer 1977; Austin and Hickey;[4] Texas Instruments, Inc.[5]).

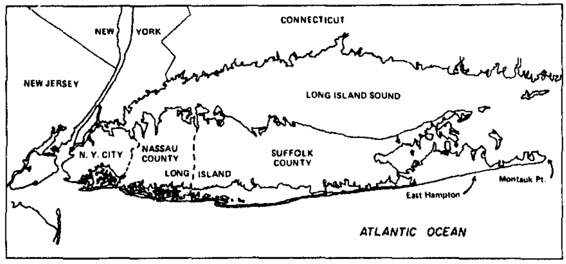

FIGURE 1.—Location of Long Island, N.Y., and the southeastern tip near Montauk Point where striped bass were collected during 1972 and 1974.

This study was designed as one phase of a program to tag and monitor "short" or prerecruit striped bass (less than the legal, 406-mm New York State limit). As stated by Talbot (1966), little is known of these fish outside of their nursery areas. Monitoring of these fish, then, permits study of the next year's catch, a segment of the striped bass population often overlooked in fishery investigations.

Prerecruit striped bass in New York waters of eastern Long Island are predominantly 2- and

[1]New York Ocean Science Laboratory, Contribution No. 82. Funded by a grant to the New York Ocean Science Laboratory from the State of New York, Project No. BR74-17F.

[2]Division of Fisheries Sciences and Services, Virginia Institute of Marine Science, Gloucester Point, VA 23062.

[3]Environmental Specialists Branch, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

[4]Austin, H. M., and C. R. Hickey, Jr. 1974. Migration and mortality of striped bass tagged in eastern Long Island, p. 11-16. Proc. Am. Littoral Soc./N.Y. Ocean Sci. Lab. Fish Tag Seminar, Dec. 1974, Montauk, N.Y.

[5]Texas Instruments, Inc. 1976. Report on relative contribution of Hudson River striped bass to the Atlantic coastal fishery. Unpubl. rep., 110 p. Texas Instruments, Inc., Dallas, Tex.

Manuscript accepted September 1977.
FISHERY BULLETIN: VOL. 76, NO. 2, 1978.

3-yr-old fish which are making their first annual migration from their Chesapeake Bay nursery areas to the northern summer feeding ground (Austin and Hickey see footnote 4). The concentrated study of one age-group of fish permits monitoring of the cohorts for successive years starting with first departure from their home grounds and, thereby, permits a description of differences or variations in migration and abundance on an annual basis, as well as an accurate evaluation of year class mortality in successive years.

METHODS AND MATERIALS

Prerecruit striped bass were randomly removed from the catches of commercial haul seine and pound net fishermen in the waters of East Hampton on the southeastern end of Long Island, N.Y. (Figure 1). Samples were collected during May and June 1972 and April-June 1974, thus the age II fish were of the 1970 and 1972 year classes, respectively. Fork lengths were measured in the field to the nearest millimeter and scale samples were removed for age determination. The fish were then tagged (Floy[6] FD-69B anchor tags) and released. The initial purpose of the study was tagging of prerecruit fish to monitor the seasonal migration and mortality of cohorts as they reached legal size in the different states. The feasibility study was focused on the 1970 and 1972 year classes. Large differences in the modal size of the fish in their third year (II+) existed between the two year classes (Figure 2). The smaller sized 1970 year class of fish were from the most abundant Chesapeake Bay year class on record (Schaefer 1972). Examination of the literature shows that the length of cohorts may be inversely proportional to the abundance or density of the fish (Stevens 1977; Texas Instruments[7]), suggesting to us that the length of the striped bass, when they first appear in New York waters, could be an indicator of year class strength and subsequently a means of predicting stock abundance in local waters. Consequently the focus of the study was redirected towards examination of these differences.

Schafer (1968, 1972) stated that most commercially harvested striped bass in New York are of four age-classes, III-VI. Based on this, Schaefer

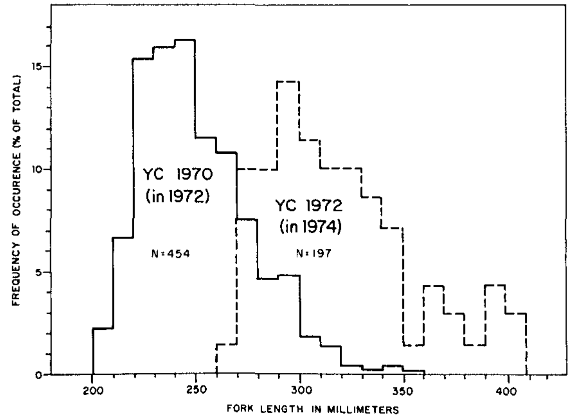

FIGURE 2.—Length-frequency distribution of age II striped bass captured by commercial fishing gear near eastern Long Island, N.Y., during 1972 and 1974.

(1972) related the New York harvest to a 4-yr mean brood production (year class strength; expressed as annual mean number of juveniles per standard seine haul in Chesapeake Bay, Md.) 3 to 6 yr prior to the harvest. He concluded that approximately 70% of the variability in annual New York landings could be explained by annual fluctuations in year class strength in Maryland waters of Chesapeake Bay.

We hypothesized that the growth rate of striped bass, and, therefore, the body length at the end of the 2-yr residence time in the Chesapeake Bay nursery grounds, is a density dependent function with the length inversely proportional to the year class abundance (number of fish). This hypothesis was tested via a correlation analysis using modal lengths at age II+ (our data combined with published data of Alperin 1966 and Schaefer 1968) and year class abundance indices supplied by the Maryland Department of Natural Resources. The analyses were performed using a Hewlett-Packard Model 9100B programmable calculator with an X-Y plotter, which provided both a regression line and a correlation analysis and coefficient.

The relationship resulting from the above analysis suggested that the density dependent hypothesis is true. Since Schaefer (1972) described a relationship between the annual New York harvest (reported commercial landings) of striped bass and the Chesapeake Bay year class abundance, and since we have described a probable relationship between year class abundance and modal length at age II+ in New York waters, it seemed reasonable to test the correlation between

[6]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[7]Texas Instruments, Inc. 1975. First annual report for the multiplant impact study of the Hudson River estuary. Unpubl. rep., vol. 1, p. VIII-8-VIII-12. Texas Instruments, Inc., Dallas, Tex.

the New York harvest and the modal length at age II+ via Model II correlation analysis.

These analyses were performed in an effort to describe a method for predicting the commercial harvest (and therefore the apparent abundance) of striped bass in New York waters. As each of the several steps in the analyses were dependent on the results of those previously calculated, they are discussed in more detail along with the results below.

The reliability of the suggested technique for predicting the abundance of striped bass in New York waters is dependent on several assumptions:

1) The Chesapeake Bay stock of fish is the major contributor of striped bass to the New York commercial fishery, as suggested by the several authors noted above;
2) The annual relative contribution of the several Atlantic coastal breeding stocks to the coastal stock of fish and, therefore, to the New York fishery remains constant or that it fluctuates or cycles in a consistent manner;
3) The commercial fishery for striped bass in New York effectively collects representative "samples" of the Chesapeake Bay stock of fish; this assumption appears to be valid based upon the relationships described by Schaefer (1972), Texas Instruments, Inc. (see footnote 5) and those described herein, and based upon our observations and those of Schaefer (1972) that many size classes of fish are present in the commercial catch—small age II prerecruits to large mature fish >16 kg total weight;
4) The forecast of commercial striped bass landings is based upon past historical landings in relation to past life history events of the species (year class abundance and length at age II+) and does not reflect changes in commercial fishing effort or any changes in the contributions to the reported landings by recreational fishermen; we have assumed a constant fishing effort, as did Schaefer (1972), and thus compared our results with his; while we recognize the weakness in this assumption, there is no alternative as there is no estimate of effort.

RESULTS AND DISCUSSION

Year Class Strength and Modal Size

The lengths of striped bass at age II+ near Long Island are probably related to ecological circumstances encountered by the fish during their first 2 yr of residence in the rivers of Chesapeake Bay (density, competition, amount of available food). Similarly, Cushing (1968) found a close relationship between the mean length of age III Atlantic herring, *Clupea harengus*, and the density of their food source in the sea, and Clark (1967) described reduced growth rates for sunfish, *Lepomis*, due to overcrowding, excessive competition, and reduced food supply. It has also been demonstrated by Anthony (1971) that the growth of young (age I and II) Atlantic herring is inversely related to their abundance, and Wagner (1969) has stated that in most fishes the growth rate per individual is inversely related to their density.

If an inverse relationship exists between the abundance of a year class of striped bass and the cohort length at age II+, a similar relationship should exist between the commercial harvest (as an index of abundance) and the length at age II+, assuming that fishing effort remains approximately constant. To test this hypothesis, age II+ modal length data for year classes 1970 and 1972 (Figure 2) were combined with other published modal length data for year classes at age II+ in New York waters from Alperin (1966) and Schaefer (1968) (Table 1), providing a total of eight annual data points. A correlation analysis was performed between these eight annual modal lengths of age II+ fish and their respective Chesapeake Bay year class strengths 2 yr earlier (Figure 3). The year class strength data (supplied by the Maryland Department of Natural Resources) are expressed as the annual mean

TABLE 1.—Comparison of observed and computed modal fork lengths for age II striped bass in New York waters.

Year class	Year class strength[1]	Observed modal length at age II (mm)	Computed modal length at age II[2] (mm)
1954	5.2	[3]313	318
1958	18.1	[4]285	278
1959	1.3	[3]335	330
1960	6.4	[3]310	314
1961	14.4	[3]290	289
1962	12.2	[3]300	296
1970	26.8	[5]245	251
1972	8.5	[5]295	307
Mean		297.9±53.0	297.9±50.4
Standard deviation		26.5	25.2
t_r = 6.99			
n = 8			
P<0.001			

[1]Courtesy Joseph Boone, Maryland Department of Natural Resources, Annapolis, Md., data expressed as annual mean number of age 0+ juveniles per standard seine haul.
[2]Based on the relationship $Y = 333 - 3X$, where Y is the modal length of age II+ fish and X is the strength of the year class (Figure 3).
[3]Extrapolated from Schaefer (1968).
[4]Extrapolated from Alperin (1966).
[5]Data from the present investigation.

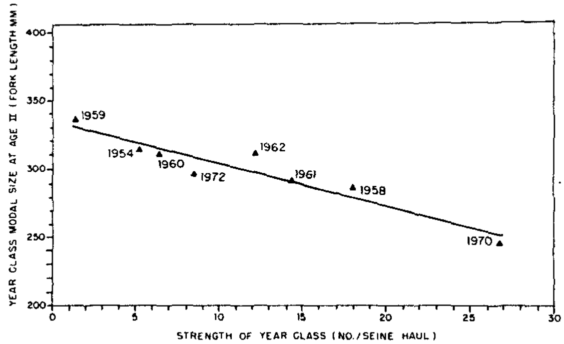

FIGURE 3.—Modal size (mm fork length) of age II striped bass from Long Island waters as a function of Chesapeake Bay year class strength. Year classes are indicated.

number of age 0+ juveniles per standard seine haul near the Maryland shores of Chesapeake Bay. These are the same data used by Schaefer (1972). The relationship ($Y = 333 - 3X$) yielded a correlation coefficient of -0.95 ($r^2 = 0.90$), suggesting that 90% of the annual variation in modal length at age II+ for striped bass in New York waters can be explained by annual fluctuations in year class abundance in the waters of Chesapeake Bay.

Modal Size and the New York Commercial Harvest

The equation described above ($Y = 333 - 3X$) was used to calculate (and thus to estimate) modal lengths of age II+ fish for those 8 yr for which actual modal lengths exist. A *t*-test comparison between the observed age II modal sizes and those computed using the correlation formula above showed no significant difference at the 0.001 probability level (Table 1). Since no significant difference existed between the observed and calculated modal lengths, the assumption was made that reliable modal lengths could be calculated for years in which no actual measurements exist. The equation described above was, therefore, used to estimate modal lengths of age II+ striped bass for all years between 1954 and 1972, using the corresponding year class abundance data. A correlation analysis was then performed (similar to that done by Schaefer 1972) between the New York landings of striped bass (Y) and a 4-yr mean of the computed modal lengths of age II+ fish 1 to 4 yr prior to harvest (X). The relationship ($Y = 15{,}205{,}309 - 46{,}859X$) (Figure 4A) yielded a correlation coefficient of -0.86 ($r^2 = 0.74$) significant at the 0.001 probability level ($t_r = 6.06$, $n = 13$). This expression permits the hindcasting of New York landings as well as a forecast 1 yr in advance, with 95% confidence limits. The hindcasts and 1-yr forecasts (for 1975) are superimposed on the actual New York landings in Figure 5A.

As stated by Schaefer (1968, 1972), the New York harvest is predominantly fish of ages III-VI. Close examination of his catch data for 1962, however, revealed that age VII fish, although <2% of the catch in number, could constitute a significant proportion of the catch by weight. Schaefer's (1968) age-frequency distribution shows that in 1962 the age III fish outnumbered the age VII by about 10:1. Using the mean age-weight relationships of Mansueti (1961) as 1.8 lb at age III and 12.5 lb at age VII, the age III fish in Schaefer's (1968) 1962 catch thus outweighed the age VII fish by less than 1.5:1. Similarly, the age VI fish (mean

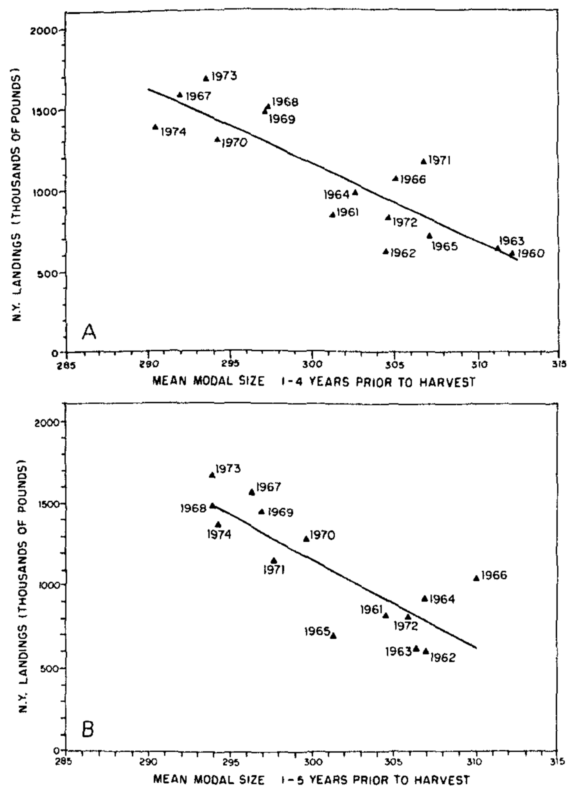

FIGURE 4.—Relationship of New York commercial landings of striped bass to the mean modal size at age II: A) 1 to 4 yr prior to harvest; B) 1 to 5 yr prior to harvest.

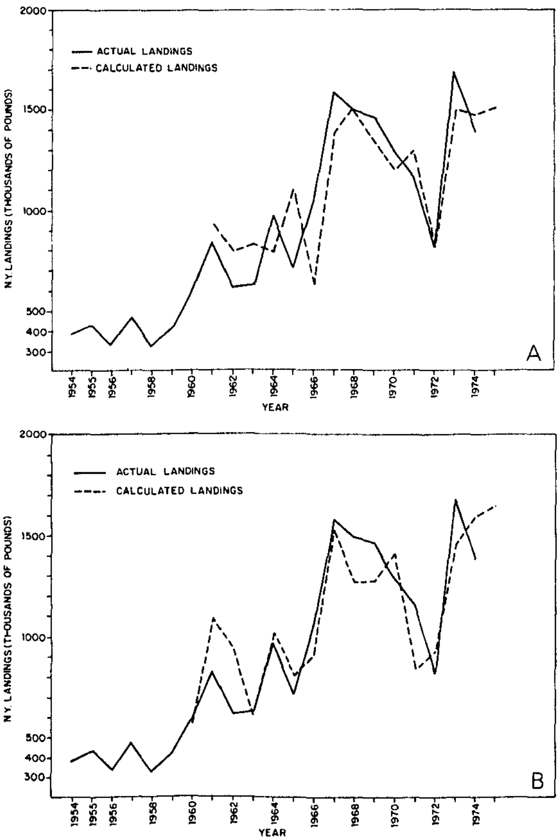

FIGURE 5.—Actual New York commercial landings of striped bass from 1954 through 1974 with calculated landings through 1975 superimposed using: A) 4-yr mean modal sizes of age II fish; B) 5-yr mean modal sizes of age II fish.

weight 8.1 lb) outnumbered the age VII fish by 2:1, but outweighed them by only 1.3:1.

It was apparent that during some years the New York harvest of striped bass may be dominated by five age-groups rather than four, as suggested by Schaefer (1972). Another correlation analysis was, therefore, performed between the New York landings (Y) and a 5-yr mean of the computed modal sizes of age II+ fish 1 to 5 yr prior to harvest (X). This 5-yr function was expressed as a linear relationship (Y = 17,315,491 − 53,810X) (Figure 4B) with a correlation coefficient of −0.83 (r^2 = 0.69), significant at the 0.001 probability level (t_r = 5.05, n = 12). Although this coefficient was reduced slightly from that of the 4-yr function above (r = −0.86), the fit of estimated-to-actual landings (with 95% confidence limits) was better for many years (Figure 5B) and was closer to the actual landings than the calculated predictions of Schaefer (1972) (Table 2).

Size, Age, and Migration

As stated, age II+ modal sizes may be computed. Another method of size determination at age II+ is by back calculation of scale radii from larger, older fish. Although no age II modal sizes determined by this method were used in the predictive models, our attempts to do so produced some interesting information. Mansueti (1961) described the body length-scale length relationship of striped bass as an allometric linear function, permitting the back calculation of size at each year of age using the scale radii method. Scales from 142 age III striped bass captured in eastern Long Island waters during 1973 (year class 1970) were made available to the authors by the New York State Department of Environmental Conservation. The ages were rechecked and the fork lengths at age II determined by back calculation from body length:scale radii ratios. The length-frequency distribution of back-calculated data was bimodal, with equal peaks at 205 mm and 235 mm. The second peak was 4.1% lower than the observed unimodal size of 245 mm. Although the back calculated values were slightly lower than the observed, the fit suggests that back calculations may be used for obtaining age II sizes of striped bass during years when these data are lacking.

Unpublished length-frequency data for age II striped bass of the year classes 1968, 1969, and 1971 taken in the Virginia rivers of the Chesapeake Bay System were made available to the authors by John V. Merriner of the Virginia Institute of Marine Science. These data showed bimodal distributions similar to that of the back-calculated age II lengths above (Merriner pers. commun.). Merriner suggested that multimodal frequencies occurred because the fish were from different river systems. Merriner's data were from Virginia rivers while our data (Austin and Hickey

TABLE 2.—Comparison of actual and calculated commercial landings of striped bass in the State of New York 1972-75.

Year	Actual landings[1]	Calculated landings 4-yr function[2]	Calculated landings 5-yr function[2]	Calculated landings by Schaefer (1972)
1972	818,150	926,903	852,860	908,000
1973	1,673,984	1,447,975	1,496,965	1,455,000
1974	1,378,529	1,592,301	1,477,594	1,607,000
1975	1,137,074	1,639,160	1,500,732	—

[1]Courtesy Fred Blossom, National Marine Fisheries Service, NOAA, Patchogue, N.Y.
[2]Forecasts using the linear regression formulae discussed in the text.

see footnote 4) suggest that the bass we examined for back calculation of length were from both Maryland and Virginia rivers, which could explain the differences in the results of the back calculations and the observed lengths. These data suggest that the size-frequency distribution of age II striped bass on Long Island could be bimodal rather than unimodal. The fact that they were not may be due to striped bass migrating by size rather than by age. Two observations of prerecruit striped bass near Long Island lend support to this theory: 1) 100% of the small 454 sublegal fish tagged in 1972 were age-group II, and 2) only 28% of the 696 sublegal fish tagged in 1974 were age-group II (year class 1972), the remaining 72% were age-groups III (65%) and IV (7%). Those fish probably were the larger 1972 and the smaller 1971 and 1970 fish. This large overlap in length ranges permitted an intermingling of the age-classes during the migration of 1974.

Management Implications

The size increments between different year classes at the same age, and the size differences of individuals within the same year class have several implications:

1) Faster growing large individuals of any given year class or a less abundant year class of larger individuals are subject to earlier exploitation in Chesapeake Bay and along the entire Atlantic seaboard;
2) Slower growing individuals or small individuals of a large year class may be recruited several months later than normal in Chesapeake Bay, but perhaps not until a full year later among the northern Atlantic States; a late recruitment in the Chesapeake area might result in more available fish to the fisheries in the other coastal states when the fish migrate out of the bay;
3) Projecting sizes of fish on the basis of age or vice versa may be invalid, e.g., age II fish in 1972 compared with age II fish of Merriman (1941) or Mansueti (1961).

The use of a mean 4- or 5-yr modal function for prediction of landings treats all year classes equally. A weighted mean providing greater representation to more abundant year classes might result in more accurate predictions of landings. Such a method could be used by any State simply by monitoring the spring catches of age II+ prerecruit fish taken by commercial fishermen. This would require, in New York for example, annual monitoring of the spring run with measurements of sublegal fish. The use of observed modes rather than computed modes for prediction of landings will probably result in more accurate estimates, as suggested in Table 3.

TABLE 3.—Comparison of actual New York commercial landings of striped bass with those calculated using computed and observed age II modal values, for years in which sufficient empirical data exist.[1]

Item	1964	1965
Actual N.Y. landings	925,500	702,935
4-yr function:		
Landings calculated using:		
Computed modes	1,021,090	807,881
Empirical modes	913,314	618,102
5-yr function:		
Landings calculated using:		
Computed modes	799,588	1,098,771
Empirical modes	—	849,631

[1]Computed and observed age II modal values are those on Table 1.

The eastern New York commercial harvest of striped bass is primarily dependent upon the year class abundance of the Chesapeake Bay stock. The harvest is influenced not only by the larger and older individuals, but also by the annual recruitment of age III fish, especially when dominant year classes are present.

Knowledge of Chesapeake Bay year class strength or age II+ modal sizes in New York waters offers a means of forecasting the New York commercial harvest, and thus the apparent abundance of striped bass in New York waters.

If, as suggested, the level of the New York harvest is primarily related to the Chesapeake Bay stock of fish, than the former can be used as a qualitative measure of the latter.

Such predictive tools as those discussed should be flexible to allow for the occurrence of more than four age-groups of fish in the catch. This may be especially important when dominant year classes are present for several years. Necessary, then, is the annual monitoring of the prerecruit fish in the commercial catch by age or year class, length, and weight. Age-weight data are especially important as commercial landings are recorded by weight of catch and not by numbers of fish. Differences noted between calculated and observed landings may be due to environmental variability, changes in fishing effort, the dominance of a particular year class in the fishery, and the fluctuation in the relative contributions of fish from the several Atlantic coastal breeding grounds. Future research and managment efforts should take these into consideration.

ACKNOWLEDGMENTS

We acknowledge the help of the following: Joseph Boone, Maryland Department of Natural Resources, Annapolis, Md., for unpublished Maryland year class data; John V. Merriner, Virginia Institute of Marine Science, Gloucester Point, Va., for his unpublished Virginia data; Bryon H. Young, New York State Department of Environmental Conservation, Stony Brook, N.Y., for the use of unpublished data; and Fred Blossom, National Marine Fisheries Service, Patchogue, N.Y., for data on New York landings. J. L. McHugh, State University of New York, and Jack P. Wise and Richard H. Schaefer, National Marine Fisheries Service, reviewed the manuscript. Their comments are appreciated.

LITERATURE CITED

ALPERIN, I. M.
1966. Dispersal, migration and origins of striped bass from Great South Bay, Long Island. N.Y. Fish Game J. 13:79-112.

AUSTIN, H. M., AND O. CUSTER.
1977. Seasonal migration of striped bass in Long Island Sound. N.Y. Fish Game J. 24:53-68.

ANTHONY, V. C.
1971. The density dependence of growth of the Atlantic herring in Maine. Rapp. P.-V. Réun Cons. Int. Explor. Mer 160:197-205.

CLARK, G. L.
1967. Elements of ecology. John Wiley and Sons, N.Y., 560 p.

CUSHING, D. H.
1968. Fisheries biology. Univ. Wis. Press, Madison, 200 p.

KOO, T. S. Y.
1970. The striped bass fishery in the Atlantic States. Chesapeake Sci. 11:73-93.

MANSUETI, R. J.
1961. Age, growth and movements of the striped bass, *Roccus saxatilis*, taken in size selective fishing gear in Maryland. Chesapeake Sci. 2:9-36.

MCHUGH, J. L.
1972. Marine fisheries of New York State. Fish. Bull., U.S. 70:585-610.

MERRIMAN, D.
1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. U.S. Fish Wildl. Serv., Fish. Bull. 50:1-77.

NEVILLE, W. C., C. L. DICKINSON, AND J. R. WESTMAN.
1939. Striped bass (*Roccus saxatilis*). *In* A biological survey of the salt waters of Long Island, 1938. Part I, p. 107-113. N.Y. State Conserv. Dep., Suppl. 28th Annu. Rep., 1938, No. 14.

ROYCE, W. F.
1972. Introduction to the fishery sciences. Academic Press, N.Y., 351 p.

SCHAEFER, R. H.
1968. Size, age composition and migration of striped bass from the surf waters of Long Island. N.Y. Fish Game J. 15:1-51.
1972. A short-range forecast function for predicting the relative abundance of striped bass in Long Island waters. N.Y. Fish Game J. 19:178-181.

STEVENS, D. E.
1977. Striped bass (*Morone saxatilis*) year class strength in relation to river flow in the Sacramento-San Joaquin estuary, California. Trans. Am. Fish. Soc. 106:34-42.

TALBOT, G. B.
1966. Estuarine environmental requirements and limiting factors for striped bass. *In* A symposium on estuarine fisheries, p. 37-49. Am. Fish. Soc. Spec. Publ. 3.

WAGNER, F. H.
1969. Ecosystem concepts in fish and game management. *In* G. M. Van Dyne (editor), The ecosystem concept in natural resource management, p. 259-307. Academic Press, N.Y.