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FISH EGGS AND LARVAE OF THE UPPER CHESAPEAKE BAY

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FOREWORD

The biological wealth of a highly productive estuary like Chesapeake Bay is readily apparent to those who enjoy its bounty of oysters, crabs, clams, and fish. About 500,000,000 pounds of these various seafoods are landed at bay ports each year. Thousands of people are directly or indirectly involved in the annual harvest—for many it is their livelihood, for many more it is wonderful outdoor fun.

Part of the wealth and greatness of the bay is, however, invisible to most of us. We never see or are usually unaware of the vast numbers of the immature stages of the species we know only as adults. This tremendous volume of life constitutes the source of larger forms. Each species plays an important role in the drama of life and each requires very special environmental circumstances for success.

William Dovel presents here a new and useful summary and analysis of the use which fish make of one of the world's richest estuarine nursery areas—the upper Chesapeake Bay and portions of its tributaries. He shows that nearly fifty species occur in this zone as eggs or larvae; that there are strong seasonal rhythms in growth and movement but that some young stages are present at almost all times; that users of the zone may originate in fresh water, the estuary, or the sea; and that suitable sampling and study of these valuable eggs and larvae are possible despite the large inherent variation in their abundance and the notable complexity of the estuarine environment.

Mr. Dovel emphasizes the importance of a characteristic of estuaries. The low-salinity portion, very frequently near densely populated areas, is a critical region in the life cycles of many species; but it is here also where many cities dump their wastes. Water quality and other environmental conditions in the nursery areas must be favorable — not merely tolerable — for the many small fish and associated organisms that develop there. If such quality is not protected, rich resources may be lost through effects most of us cannot even see.

Here, then, is valuable information garnered during an eleven year period—a catalogue of species, a summary of patterns, and identification of some of the essential areas necessary for the propagation and growth of extraordinarily important fish eggs and larvae in one of the world's greatest estuaries. Further research is required for optimal management, but Mr. Dovel has made a significant and valuable contribution.

L. EUGENE CRONIN
Director

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William L. Dovel

Contribution No. 460, Natural Resources Institute, University of Maryland

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INTRODUCTION

During the past eleven years, the author has been engaged in numerous investigations of the fish eggs and larvae prevalent in different areas of Chesapeake Bay. This report presents a synoptic characterization of the data collected during that period.

In the spring of 1960, the author, under the direction of the late Dr. Romeo J. Mansueti, began an intensive effort to gain a better knowledge of the biological characteristics of pelagic fish eggs and larvae that occur in channel areas of the lower Patuxent River (Fig. 1). No effort was made to investigate the eggs and larvae of shoreline areas. The area under investigation was later expanded to include additional areas of Chesapeake Bay (Table 1, Fig. 1). From 1960 to 1962, effort was devoted to designing appropriate field sampling techniques suitable for this estuarine system. In 1961, a one-year pilot survey was initiated over a 3-mile section at the mouth of the Patuxent River to determine the suitability of various types of gear and to gain familiarization with the ichthyoplankton found there. A weekly sampling program was initiated in January 1963 to determine seasonal biological characteristics of species present throughout the entire estuarine portion of the Patuxent River. This project continued for three years but with reduced effort during 1964 and 1965. From March 19, 1965 to May 24, 1966, a similar investigation was conducted in the Magothy River, Maryland.

Sampling was extended to the upper Chesapeake Bay on November 9, 1965 as part of an investigation to determine the effects of dredging and spoil disposal on the geology and biological communities of that area. This project was supported by the Philadelphia District, U. S. Army Corps of Engineers and the Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, under Contract #14-16-005-2096, and the Natural Resources Institute, University of Maryland.

An analysis of the fish egg and larvae information obtained from all areas listed above indicated the feasibility of formulating a general characterization to describe organism abundance, distribution and movement in physically different but ecologically related areas of Chesapeake Bay.

The purpose of this report is to present the general characterization, the data from which it was derived, and to discuss in detail those species for which the nature of the data warrants elaboration.

Areas of Investigation

Chesapeake Bay is a large Atlantic coast estuarine system containing many tributaries which, together, drain an area of 67,505 square miles (Wells, Bailey, and Henderson, 1929) of New York, Pensylvania, Maryland, Delaware, West Virginia, and Virginia. Each tributary is, in a sense, an individual estuary, differing in some respects from the dominant branch, the bay proper. A description of the study areas for this investigation must therefore describe the bay region in general and salinity gradients of the Patuxent, Magothy, and Susquehanna, in particular.

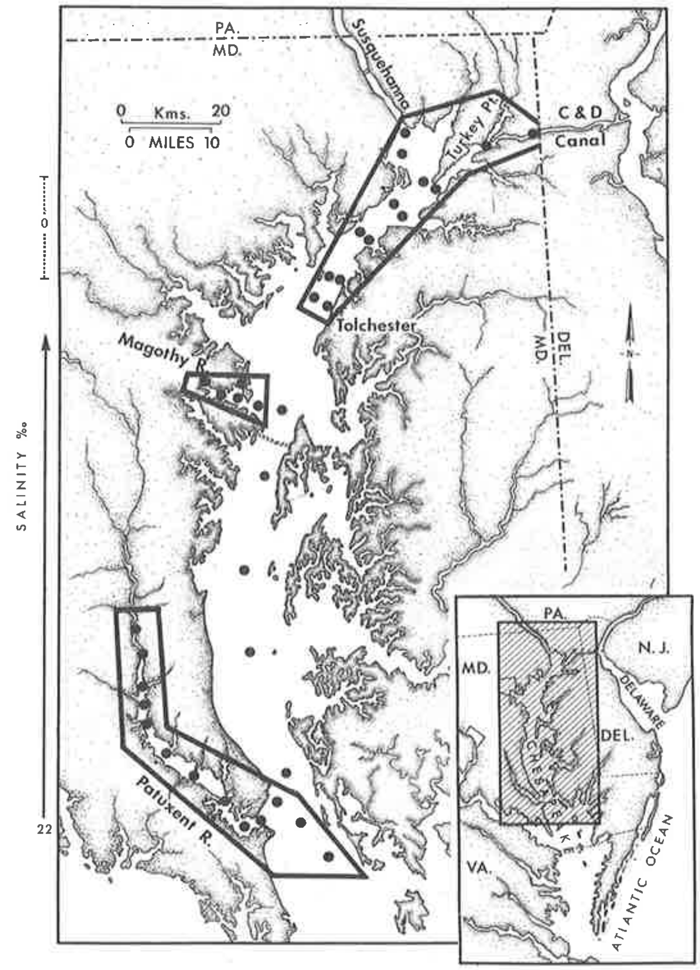

Figure 1. Fish egg and larvae sampling stations (●) in upper Chesapeake Bay 1960-1968. (Patuxent River to the Susquehanna and Delaware Rivers).

The Patuxent River (Fig. 1) is situated entirely in Maryland and drains 963 square miles (Corps of Engineers, 1930). The river is approximately 80 miles long (Mansueti, 1961) and empties into Chesapeake Bay about 25 miles north of the mouth of the Potomac. Tidewater extends about 56 miles upstream. From Lower Marlboro south, the river increases in width from 0.1 to 2.0 miles. Mean tidal amplitude varies from 1.2 feet at Solomons to 2.5 feet at Nottingham, about 40 miles upstream. Channel depth generally increases downstream from Lower Marlboro to Benedict Bridge, ranging from 9 to 40 feet. From Benedict Bridge south, depths range from 33 to 120 feet. The lower section of the river possesses much sandy shoal area. The soil on the watershed consists of sand and clay with some limestone (Nash, 1947). Water velocity increases from about 0.9 feet per second at the mouth to about 1.6 feet per second near its upper limits. The lower Patuxent River is a typical two-layered estuary with net upstream movement of subsurface, high saline waters and a net downstream movement of fresher, surface waters (Pritchard, 1951, 1955). The upper river is bordered by many fresh-water marshes. Further descriptions of this river appear in Nash (1947), Mansueti (1961), Heidel and Frenier (1965), Stross and Stottlemyer (1965), and Herman et al. (1968).

The Magothy River (Fig. 1) is 7.0 miles long and drains an area of only 31.1 square miles. Most of the river is less than 20 feet deep; however, a constricted entrance to Chesapeake Bay aids tidal currents in maintaining a short 40-ft deep channel where the river and the bay meet. Fresh-water inflow into the Magothy originates from Lake Waterford and direct watershed runoff. This flow is very small as compared with the flow into other tributaries of Chesapeake Bay. Salinity of the Magothy is greatly affected by the flow from the Susquehanna River, which drains into Chesapeake Bay approximately 40 miles north of the mouth of the Magothy. At times during spring runoff, lighter, less saline surface waters from the head of the bay flow into the Magothy River, creating a condition contrary to the normal estuarine chemical and circulation patterns. Salinity at the mouth of the river may be less than salinities found up-river (Pritchard and Bunce, 1959). Due to the limited input of fresh water and the shortness of the river, the salinity range for the entire river is small. Normally salinities between upriver and downriver stations do not vary more than several parts per thousand (o/oo). During the 15 months of investigation in this river, salinities at the uppermost sampling station ranged from 5 o/oo in late spring to 14 o/oo in late fall. A description of the Magothy River also appears in a report of the fish eggs and larvae of that river (Dovel, 1967).

Sampling in the upper Chesapeake Bay was performed along a 29-mile section from off Tolchester, Maryland, to Chesapeake City in the Chesapeake and Delaware Canal, plus the 8-mile channel section from Turkey Point to Havre de Grace in the Susquehanna River (Fig. 1). The 29-mile section is part of the main navigational channel of the upper Chesapeake and ranges in depth from about 55 feet off Tolchester to 35 feet in the C & D Canal. Water depth from Turkey Point to Havre de Grace fluctuates from 35 feet in the channel off Turkey Point to 20 feet for most of the 8-mile distance, then drops to 60 feet in the immediate vicinity of Havre de Grace.

Salinities in the upper bay fluctuate seasonally according to rainfall, but generally range from about 12.0 o/oo off Tolchester to 0.0 o/oo off Turkey Point (Stroup and Lynn, 1963). Water between Turkey Point and Havre de Grace is fresh and originates mostly in the Susquehanna River. This river accounts for slightly more than 50% of the fresh water contribution to Chesapeake Bay. The upper Chesapeake, leading into the Susquehanna River at Havre de Grace, also exhibits the two-layered circulation system described for the Patuxent River and will be referred to as the Susquehanna gradient.

The 27-mile Chesapeake and Delaware Canal, however, presents a unique pattern of water circulation between two large bodies of water. Differing tidal cycles and amplitudes in Chesapeake Bay and Delaware Bay, plus water storage capacities of several reservoir-like areas located along the canal, serve to complicate water movement. Water salinity within the canal remained consistently between 0.0 and 4.0 o/oo during April, May and June of 1966 and 1967. These waters appear to be fairly well-mixed vertically. Haight, Finnegan, and Anderson (1930) provide the best account of water velocities and movements in the canal for the period immediately following the completion of the canal in 1927. At present, water current velocities through the canal reach a calculated maximum of 2.5 knots (U. S. Coast and Geodetic Survey, 1967), with an average velocity of about 1.9 knots. Gray (1967) and Burgess (1965) document many physical changes that have taken place in the canal area since 1764, when the first surveys were made. The texture of the canal bottom resembles, by visual inspection, that found further south in Chesapeake Bay in areas of comparable depths. Biggs (1967) states that in geological records, deepwater Chesapeake Bay sediments would probably be characterized as homogeneous gray-green organic shales containing pyrite and scattered shell and sand layers.

The Susquehanna River drains an area of 27,501 square miles (Carlson, 1968) of New York, Pennsylvania, and Maryland. The large fresh water contribution from the river has profound influence on the biota of a large area of the upper Chesapeake. This influence is a primary concern when investigating fish eggs and larvae of the upper bay. The industrial use of Susquehanna River water, plus the construction of many dams, has altered the physical, chemical, and biological characteristics of that river and the waters flowing into the upper Chesapeake. Many of the physical changes that have taken place in the river are discussed by Whitney (1961). Some biological implications resulting from these changes are discussed by Mansueti and Kolb (1953). Specific changes in the patterns of reproductive activities and commercial harvest of striped bass, *Morone saxatilis,* also attributable to physical changes in the lower Susquehanna, are discussed by Dovel and Edmunds (1971).

METHODS

The tools and techniques developed for a comprehensive investigation of fish eggs and larvae of the large Chesapeake estuarine system are documented (Dovel, 1964). The basic approach and recent modifications are discussed only briefly here. Sampling at 13 main channel locations along the Patuxent River from Lower Marlboro to Hoopers Island Light in Chesapeake Bay was begun in January, 1963. Meter net collections were made at surface, mid-depth, and bottom on a weekly frequency, using netting fabric with 0.4 x 0.6 millimeter (mm) apertures. A complete sampling run of 43 miles required about 15 hours of working time and was usually completed in a single day.

The processing of samples emphasized discarding or excluding extraneous material in the field (see filtering device; Dovel, 1964). The system made it possible to reduce most samples to less than 30 ounces in volume without the loss of desired organisms. Plankton net contents were concentrated on a filter of netting fabric, then placed in a 30-oz wide-mouthed jar containing about 10 oz of 4% formalin. Permanent, white plastic-tape labels on the exterior of the jar provided a reusable surface on which field data were recorded in pencil.

Sampling of the Patuxent River during 1964 and 1965 was reduced to a biweekly frequency at one-half the number of original stations (Fig. 1) after a review of 1963 data indicated that reduced frequency would be adequate to produce basic information. Techniques used to sample the Magothy River and upper Chesapeake during 1965-68 were comparable to those used in the Patuxent during 1963-65 with one slight exception. Upper bay sampling stations were divided about equally between shallow (10ft.) areas and deeper (20-60 ft) channel areas. Sampling stations for all areas were located at approximately equal intervals along the gradient with some alterations necessary for locating areas free of obstacles which might damage the plankton sled. All channel tows were made in a downstream direction at speeds ranging from 1-3 knots. Data from all tows were standarized to a 10-minute duration. Temperature and salinity readings were made with an induction conductivity salinometer.

Variations in sample size necessitated some aliquoting. Aliquots from samples containing small fish ranged from 1/4 to 1/10 of the original sample. Aliquots from samples containing mostly fish eggs were usually 1 to 10 milliliters (ml) in size.

RESULTS

Results are presented in two forms. First, data for individual species, although collected from several locations in the Chesapeake, are combined to provide basic abundance, distribution, and movement patterns for each species in the upper Chesapeake estuarine system. Second, data for some species are discussed in detail where subtle differences in biological patterns seem to exist but could be obscured by a broad summarization, or where additional comments seem warranted.

An evaluation of the ecological significance of the patterns of Chesapeake ichthyoplankton can only be made by correlating biological data with the estuarine environment. Since an estuary is characterized by a salt concentration gradient to which fish are known to respond, the salinity gradient appears to be the logical link between the biological data and the environment. The variation in the salinity gradient from year to year, as a result of varying freshwater input, precludes the assignment of a fixed salinity value for a given geographical location. The validity of the major conclusions drawn in this report is subject to the acceptance of the salinity gradient as an adequate yardstick for the estuary.

The eggs and/or larvae (5,148,596) representing 48 species of fishes were collected and processed during the period January, 1960 to November 22, 1968 from all areas sampled (Tables 1, 2, 3, 4, 5, and 6.). Less than 0.1% of the total number of fishes collected could not be identified. This group, for the most part, is made up of common fishes which were found in a deteriorated condition when identification was attempted and will not be discussed in this report.

Although this investigation was directed primarily toward fish egg and larval stages, data for all fish collected which were not fully mature are included in this report. This criterion is necessary since larvae, juveniles, and adults are collected with differing degrees of efficiency as hydrographical conditions, mostly water temperature, and physiological responses change. Some juvenile and adult fish (many white perch), which usually would not be taken in warmer months, may appear in samples taken when fish activity is reduced during colder periods. The inclusion of data from these larger, almost mature fish which are still found in the nursery area is necessary in order to make a more complete determination of early life history movements of these species. The use of two calendar years in Table 6 assures the inclusion of all recorded captures of the young of a species during a complete year following the first occurrence of that species in the estuarine sampling area.

Table 7 presents numbers of bay anchovy larvae collected at different salinities. The combined distribution for all years (Grand Total) is used as generally indicative of organism distribution by salinity in the Chesapeake area.

Tables 8 and 9 are constructed after the pattern used in Table 7 and show the distribution and density of fish eggs and larvae in the upper Chesapeake Bay area as related to the salinity gradient. The patterns of abundance and distribution shown in these tables reflect contributions of a few dominant estuarine species. For example, 51.4% of all eggs came from waters with a 4 o/oo (12-15) salinity spread, with the bay anchovy and hogchoker accounting for 99% of the eggs in that range.

Tables 10 and 11 show the distribution of eggs and larvae as related to a water temperature gradient. Again, these tables reflect the predominance of eggs and larvae of a few dominant estuarine species. Eighty-three percent of fish larvae and juveniles were present during an 8-degree (22-29 C) temperature spread. This temperature range represents the period approaching maximum summer conditions. Table 12, Column A, presents the major species collected from the Patuxent River ranked by order of abundance for the period 1963-65. Column B provides numbers of the same fishes collected from the upper bay during 1966-67.

DISCUSSION

Species for which data were abundant were considered for discussion in detail in this section. Species for which biological patterns appear to be sufficiently interpretable through tabular presentation (Tables 1-12) are not discussed.

The abundance of fish eggs and larvae of some species that spawn in fresh water is directly correlated to individual species characteristics of egg deposition and attachment. The location of egg deposition in a tributary, plus the transporting effect of water currents, may suggest patterns of abundance not in keeping with actual biological production. For example, herring eggs which normally adhere to the substrate upstream in fresh water may become dislodged and move downstream. Collections made downstream may therefore represent only those eggs which have been transported away from their natural habitat and may not actually indicate species productivity in the area of occurrence. Movement in the opposite direction, where larvae from eggs deposited in the marine environment appear in brackish water samples, will also be discussed under appropriate species.

The eggs of many species which spawn in brackish water adhere to the smooth surfaces of oyster shells and other hard, submerged objects in shallow water areas. The resulting larvae apparently remain close to the spawning area and may not appear in samples collected only a short distance away in deeper water. This pattern of distribution is advantageous in estuarine areas where dissolved oxygen levels are reduced in summer in depths below about 50 feet and food organisms are fewer in number.

Species discussed in this section will be grouped according to the salt content of the environment where spawning takes place. This will provide a framework through which the reader should be able to grasp the concept of broad patterns of activity which are correlated with specific freshwater, estuarine, and marine environments.

Freshwater spawners

Family Clupeidae - herring

Clupeid eggs and larvae were present in all collecting areas but not necessarily at the same times or in comparable numbers (Tables 3-12). The eggs collected resulted from deposition upstream, dislodgment, and transport downstream by freshwater runoff. Four species are listed (Table 3); however, the great percentage of these eggs belong to two species: blueback herring *(Alosa aestivalis)* and alewife *(A. pseudoharengus)*. Egg condition (state of decomposition), the accumulation of detritus on the egg membrane, and general morphological similarities between these two species prohibit positive identifications. The eggs of *A. mediocris* and *A. sapidissima* are somewhat larger and should not be confused with *A. aestivalis* and *A. pseudoharengus* which are smaller and both about 1.0 mm in diameter (Mansueti and Hardy, 1967).

Clupeid larvae, possibly belonging to four species of *Alosa*, and one each of *Brevoortia (tyrannus)* and *Dorosoma*[1] *(cepedianum)*, were present in all areas. Although some differences exist in size at hatching and during comparable stages of larval development, size range overlap and similar morphological indexes prohibited positive identification of the majority of the newly-hatched specimens of the genus *Alosa*. Peritoneum color normally serves to distinguish juvenile blueback herring from the alewife. Hybridization and possibly the physiological state of the organism at time of preservation, as it affects the contractibility of melanophores, makes a color differentiation between dark and dusky sometimes very difficult. The 17,377 clupeid fish (Table 4) all possessed slightly pigmented peritoneums. It seems probable that both *A. pseudoharengus* and *A. aestivalis* are present in this group. Table 13 provides length frequency data for blueback herring, *Alosa aestivalis*, collected from two areas of the Chesapeake and possessing pronounced blueback characteristics. Data suggest the presence in the upper estuary of two distinct age groups, young-of-the-year and fish about 1 year old. Fish almost 1 year of age are present there in early spring, but were not found in later collections. Young-of-the-year and older fish were both found in the same area of low salinity water. Close inspection of organism size, as compared with water salinity at collection locations, suggests movement of maturing organisms toward higher salinity areas. While developing fish should show the tendency to spread throughout the estuary, it is also true that the salinity gradient varies with the season. Salt water penetrates further upstream during late summer and fall. The location of capture could conceivably remain the same while water salinities at a given location vary appreciably according to season.

Numbers of blueback herring *(A. aestivalis)* larvae and juveniles are insufficient for determining a definitive growth rate; however an approximation of this rate could be derived from the data in Table 13. This data would suggest that fish one year of age are about 80.0 mm total length (TL) or slightly larger and about 65.0 mm when six months old, using April 15 as the hatching date.

The scarcity of larvae less than 30 mm TL in Table 13 resulted from the inability to distinguish between the early developmental stages of different species of the genus *Alosa*, as mentioned above. The lack of specimens in collections taken in low salinity areas during periods of extreme cold raises the question as to whether these fish (0-year-class) left the upper estuary or became inaccessible for the period Novmber through February. The latter seems logical as these fish were present in the same low salinity area the following spring before apparently moving toward areas of higher salinities.

[1]Not otherwise listed in this report.

In summary, it would appear that, following spring hatching upstream in fresh water, young blueback herring and other members of the genus *Alosa* move slightly downstream but remain in the upper estuary until about 1 year of age, at which time they become less susceptible to plankton gear and move toward the lower estuary and the ocean. Movements through the estuary appear to be rapid. Fish appear to congregate and move in schools; major movement taking place in June or early July.

All *Alosa* larvae and juveniles were found in fresh water or waters of 12 o/oo or less salinity.

White perch, *Morone americana*

The abundance and distributions of eggs and larvae of the white perch are subject to some of the same conditions described for the freshwater clupeids. Mansueti (1964) states that great variation occurs in the attachment rate of detritus to eggs (or substrata) during different developmental stages. This factor, plus variations in water currents in the upper estuary, precludes a determination of the proportion of eggs that are transported downstream. The relatively large number of eggs recorded in Table 3 represents only eggs that have been transported away from the area of deposition but suggests a higher reproduction potential for this species than for many others in the Chesapeake estuarine system.

Eggs were found in waters having a temperature as low as 5 C; however, most occurred when temperatures ranged between 8 and 16 C, with some occurrence when temperatures were as high as 24 C (Table 10). Egg occurrences, as determined for this study, varied slightly from that documented in a comprehensive description of the eggs, larvae, and young of this species in the Patuxent River (Mansueti, 1964).

Larvae, which hatched upstream in fresh water, were present downstream in the sampling areas of all tributaries sampled. Mansueti (1964) suggests that low catches of larvae in the upper Patuxent River in fresh water were due to the demersal behavior of these fish and their swift transport downstream. Most larvae were found in fresh waters or waters having a very low salt content. This pattern was observed for the Susquehanna River during 1966 and 1967 when large numbers of white perch larvae moved out of this river and into the upper bay.

Following hatching in late March, April, and May, young white perch moved, mostly as planktonic larvae, toward brackish waters. Larvae remained abundant in low salinity waters until winter, when their numbers began to decline. From the following spring, when these fish were 1 year old, until fall, when about 18 months old, this year-class was present in the same area but in ever decreasing numbers. Their absence from collections was probably due to decreased efficiency of collecting gear as these fish grew, plus dispersal away from the nursery area. It would appear that at least some juvenile white perch remain in the most critical nursery environment for about one year.

Although spawning takes place over a rather short period, the variations in hatching dates contribute to the presence of a large size-range of individuals of the same year-class at any given time during the first summer. Table 14 provides length frequency data for white perch collected by and subject to the selectivity of the plankton gear described. It would appear that these data provide a fair representation of the growth for the first year of life. It was noticed, during the first winter of this investigation, that young-of-the-year fish and representatives of earlier year-classes were present concurrently on the nursery ground. The possibility that developing white perch return to the nursery ground during winter for several years should be investigated. Dovel et al. (1969) describe this type of movement for the hogchoker from the same area. Mansueti (1961, 1964) discusses the life history and some movements of this species in detail.

Striped bass, *Morone saxatilis*

Eggs of this species were present in low saline areas of the Patuxent River and upper Chesapeake Bay (Tables 3 and 8), but were not found in the Magothy River (Dovel, 1967). Striped bass eggs are normally deposited in fresh waters not far above brackish areas in Chesapeake Bay. There is some evidence[2] suggesting that spawning of this species may occur in low salinity waters of some Chesapeake tributaries. Tidal actions, freshwater runoff and turbulence produced in the vicinity of the salt-fresh water interface, the transitional zone where fresh and salt water meet, maintain necessary egg suspension. Since sampling was performed in the vicinity of the interface, the numbers of eggs collected should be correlated with total abundance. Eggs were collected from waters with an 11 to 24 C range in temperatures. Temperatures above 12 and 13 C appear conducive to unlimited spawning when water temperatures follow a gradual increase (Table 10). Eggs were abundant during the months of April, May and June (Table 15). Close inspection of the data indicates that although the period of egg occurrence varies according to season, generally the peak production period extends from mid-April to the last week of May, a period of about 6 weeks. Very few eggs were found after the first of June of any year. No appreciable number of eggs were found in areas where salinities were greater than 3 o/oo. Large numbers were found in the Chesapeake and Delaware Canal (Table 16) where salinities were greater than 0.1 o/oo, but less than 4.0 o/oo. No eggs were found in the 8-mile section of fresh water from Turkey Point to Havre de Grace during the spring of 1966. Forty-four eggs were collected in the same area during 1967 (Table 16).

Determinations of vertical distributions of eggs were attempted without the benefit of an opening and closing net. The numbers from bottom samples listed in Table 16 are therefore subject to vertical contamination as the plankton

[2]Chesapeake and Delaware Canal study now in progress, and Joe Boone, pers. comm.

sled passes through surface waters where suspended eggs occur. Although the extent of vertical contamination has not been determined, live eggs do not appear to be stratified. They appear fairly well dispersed throughout the water column as a result of the mixing forces of the estuary.

Larvae of this species were generally most abundant during the month of May. This was to be expected as the incubation period under normal conditions is less than two days. Larvae were found in greatest density in low saline waters (< 2.0 o/oo, Table 9). Areas of egg and larvae occurrence appear to be, at most, only slightly separated. This pattern appears to be characteristic of most upper Chesapeake tributaries but differs from patterns found in North Carolina and California estuaries.

Length frequency data collected for striped bass are not sufficient to calculate a growth rate for young fish but do provide an indication of the length of time developing striped bass could be collected with plankton gear in the nursery area. Generally speaking, young-of-the-year striped bass were not collected in appreciable numbers in the low salinity nursery area after June or July in any area sampled. Twenty-nine fish ranging in size from 64.2 to 119.9 TL (average 84.6 TL) were collected from a low saline (0.0 to 11.0 o/oo) area of the upper Chesapeake Bay during January through March, 1967. This information suggests that at least some small young-of-the-year fish will be found in the nursery area when almost one year old. It is not certain whether these fish remain there constantly during this time or move about in the estuary. Two fish, 32.0 and 35.0 mm TL, were collected from waters of 16.0 o/oo as early as mid-June, 1963.

A special attempt was made to determine the ratio of young striped bass to white perch on the nursery ground in upper Chesapeake Bay during 1966. Only fish possessing distinguishing characteristics were used. Newly-hatched white perch and striped bass up to about 6.0 mm TL can be separated with ease (Mansueti, 1958; 1964). Fish from about 6.0 to 12.0 mm TL cannot be separated by the usual meristic and morphometric characters. Fish larger than about 12.0 mm TL normally possess a full complement of spines and fin rays which can be used to separate species. Fish with twelve or less total spines and rays in the anal fin were classified as white perch (Mansueti, 1958; 1964). Those with 14 or more were identified as striped bass. Fish with 13 anal rays and spines were not used, as these fish could belong to either species.

A total of 3,834 fish were used for anal fin counts. Of these, 1,116 were eliminated due to fin condition or fin counts of 13. Of the remaining 2,718 fish, 2,606 or 68.0% were identified as white perch. This produced a ratio of 1 striped bass for every 23 white perch of comparable stages of development in the upper Chesapeake. In all probability, the true identification of the 1,116 unused specimens would alter this ratio only slightly.

Dovel and Edmunds (1971) discuss changes that have taken place in striped bass activity in the upper Chesapeake Bay in recent years. The abstract of that paper is presented here.

"Recent changes in striped bass *(Morone saxatilis)* spawning sites and commercial fishing areas in upper Chesapeake Bay; possible influencing factors."

Abstract

Chesapeake Bay annually contributes a large percentage of all the striped bass produced in North America. For many years, the lower Susquehanna River was considered the major reproductive area for the entire bay. Recent evidence suggests that the areas of greatest egg abundance, as well as commercial fishing for the striped bass in the upper bay now occur along the main channel from Worten Point to Chesapeake City on the Chesapeake and Delaware Canal. The shift has apparently resulted from major environmental alterations which have occurred in the last 90 years. The construction of the C & D Canal, at the head of Chesapeake Bay, has increased the total area suitable for species propagation and commercial fishing activities.

Yellow perch, *Perca flavescens*

Larvae of the yellow perch were most abundant in very low salinity waters (Table 9). This species, like the freshwater herring group and the white perch, spawns far upstream in fresh water. Their larvae then move downstream toward brackish waters. Yolk-sac absorption was complete by the time larvae were found in the low salinity nursery area by early April. Their growth rate is suggested in Table 17. Water temperatures, at times when larvae were abundant, ranged from 8 to 17 C (Table 11).

Estuarine Spawners

Bay anchovy, *Anchoa mitchilli*

Anchovy eggs were abundant in upper Chesapeake Bay from April to September of every year during 1963-67. Eggs were present as early as April 22 (1963) and as late as September 27 (1965, Fig. 2). Peak production occurred during July (Table 18, Fig. 2). Some eggs were found over a wide range of salinities (1 to 22 o/oo) but the area of greatest abundance occurred in waters with salinities of 13 to 15 o/oo. This area contributed 47.6% of all eggs collected. Patterns of egg distributions along the Patuxent salinity gradient for 1964 and 1965 indicated large numbers of eggs at 4 and 6 o/oo (Figs. 3 and 4). These concentrations were exceptions rather than the rule. Most eggs were present with water temperatures in excess of 20 C (Table 10, Fig. 2). A table of egg sizes (Table 19) indicates that eggs collected from more saline areas were smaller than eggs which came from low saline waters.

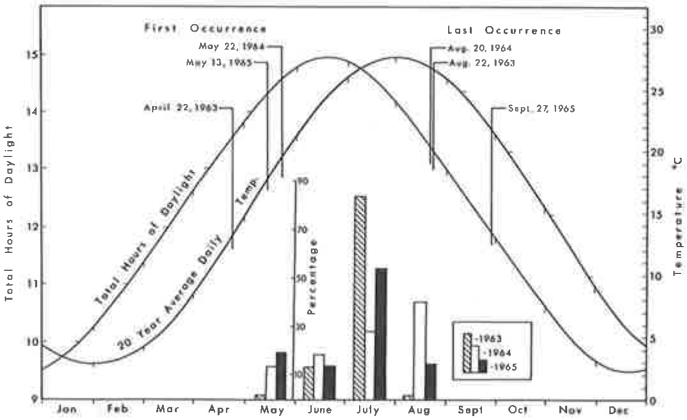

Figure 2. Seasonal occurrence of the eggs of the bay anchovy (**Anchoa mitchilli**) plotted against total hours of daylight and average surface water temperature at Solomons, Maryland, 1963-1965.

Larvae and juveniles were abundant throughout most of the year over much of the salinity gradients sampled (Tables 7, 9, and 20). Juveniles were most dense in low salinity areas upstream (Table 9). Seventy-two percent of all fish collected were found in waters of 3 to 7 o/oo. Vertically, the larvae appeared to be concentrated in surface waters (Table 20), at least during 1963. Some larvae or juveniles were collected in waters at all temperatures up to 31 C. Eighty-eight percent of the total was found when temperatures ranged between 23 and 27 C. Most of these fish were abundant in shallow water areas during summer (June to September). In colder months (October to March), fish were not as plentiful in samples and those present were found in deeper waters. Anchovies were abundant in low salinity waters at the head of Chesapeake Bay just south of Turkey Point and in the C & D Canal. Fish were present but not plentiful in fresh water in the Susquehanna River west of Turkey Point toward Havre de Grace.

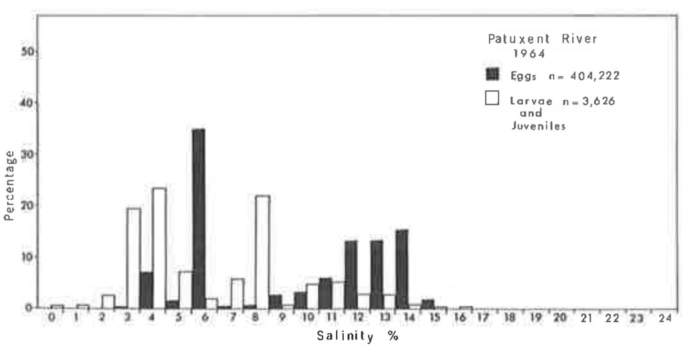

Figure 3. Distribution and abundance of the eggs and larvae of the bay anchovy (**Anchoa mitchilli**) in the Patuxent River in 1964 by salinity (o/oo) at location of capture.

Anchovies of the family Engraulidae are an important source of fresh fish, live bait, fish meal and a substitute for sardines along the coastal areas of most of the world's oceans. The north Atlantic coast of America is one of the few major coastal areas where anchovies are not utilized commercially (Hildebrand, 1943; Baxter, 1967). Anchovies of middle Atlantic Bight estuaries belong to two genera, *Anchoa* and *Anchoviella.* The bay anchovy, *Anchoa mitchilli,* is very abundant in the upper Chesapeake Bay but rarely exceeds 97 millimeters in length (Hildebrand and Schroeder, 1927). This species extends from Maine to Yucatan, Mexico (Mansueti and Hardy, 1967), and is abundant along most of the middle Atlantic coastal region of North America. Richards (1959) stated that numbers of anchovy eggs dominated the total abundance of fish eggs in the Long Island Sound area. Massmann (McHugh, 1967) found the anchovy to be "the most abundant species in Chesapeake Bay." Many investigators have recorded biological data relative to the bay anchovy, but very little information exists concerning movements of the early life history stages of this species in estuaries. Kuntz (1914), Hildebrand and Cable (1930), Hildebrand (1963b), Richards (1959), Wheatland (1956),

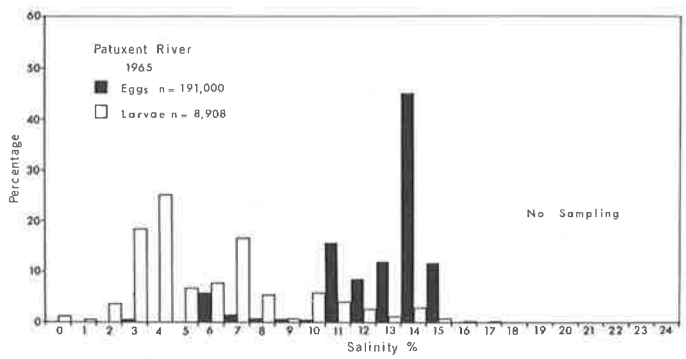

Figure 4. Distribution and abundance of the eggs and larvae of the bay anchovy (Anchovy (**Anchoa mitchilli**) in the Patuxent River in 1965 by salinity (o/oo) at location of capture.

and Herman (1958) provide information on the embryology of this species. Distribution information is available from many sources. Juveniles and adults are found primarily in estuaries and coastal waters in all types of environments; from muddy coves (Hildebrand and Schroeder, 1927), in grassy areas (Hildebrand, 1963b), in bayous (Springer and Woodburn, 1960), off sandy beaches (Reid, 1954; Kilby, 1955), and in deep offshore waters (Hildebrand, 1963b). Juveniles have ascended rivers at least 40 miles above brackish water (Massmann, 1954). Massmann (1962) records juvenile and adult anchovies in the York River System, Virginia, concentrated in two distinct locations, in fresh water and areas with 12 to 32 o/oo salinity. The data of Stevenson (1958) and Massmann (1953, 1954), the latter summarized in McHugh (1967), is perhaps the best available information on the abundance and distribution of this species in estuaries of the middle Atlantic region.

Egg and larval stages of the bay anchovy were very abundant in the upper Chesapeake area in low to intermediate salinities (0 to 21 o/oo). A single 10-minute plankton tow produced 141,440 eggs from 330 m^3 of water. This species shows some life history aspects similar to those of the hogchoker (Dovel et al., 1969). These two species provided the majority of the free-floating fish eggs collected in this investigation.

The anchovy, like the hogchoker, spawns throughout much of the lower estuary during midsummer conditions when water temperatures are at a maximum (Fig. 2). This information agrees with Stevenson (1958), who determined egg maturity for anchovies collected in Delaware Bay. The deposited eggs possess no oil globules and apparently occur throughout the water column. Vertical sampling contamination obviously accounts for an exaggerated egg distribution pattern, as well as an unreal range in water temperatures at which eggs are found. For example, eggs recorded as coming from a bottom sample where water temperature was 9.7 C (1963 data) may actually have occurred in an intermediate or surface sample where the temperature was as much as 4 degrees warmer.

Anchovy eggs collected in the lower salinity waters of the Patuxent River were appreciably larger than eggs of this species collected in ocean waters off Beaufort, North Carolina. Kuntz (1914) gives the length of the major axis of anchovy eggs collected at Beaufort at 0.65 to 0.75 millimeters with the minor axis 0.1 to 0.3 mm less. Eggs from the Chesapeake show a definite size-salinity correlation which could account for the differences between Chesapeake and Beaufort egg sizes. The incubation period is about 24 hours (Mansueti and Hardy, 1967) which would not permit the eggs to be carried by tidal currents many miles from the area of deposition. The distribution of anchovy eggs in the Chesapeake should, therefore, be generally indicative of the spawning area of this species.

Newly-hatched larvae were not abundant in samples taken from any area of the estuary. Slightly older larvae and juveniles, > 5.0 mm, were abundant and found upstream in low saline areas suggesting a migration to an upstream feeding or nursery area. The general trend of movement is shown in Figs. 3 (1964) and 4 (1965) but is somewhat complicated by the presence of what appear to be isolated groups of eggs located in salinities lower than those where eggs were most abundant. This movement was most obvious when viewing data collected with a weekly sampling frequency in the Patuxent River during 1963 (Fig. 5). An attempt to monitor movement of the larvae and juveniles as they moved upstream did not succeed. Small, recently-hatched larvae were found almost simultaneously in both upstream and downstream areas. Since most of the eggs are deposited in areas with salinities of 9 o/oo or greater, the occurrence of recently-hatched larvae upstream in low salinities suggests rapid movement of fish upstream toward the nursery ground.

Young anchovies were found predominantly in surface waters (Table 20) from about the first of May to the middle of October. These fish apparently moved out of surface waters when water temperatures dropped below about 11 C.

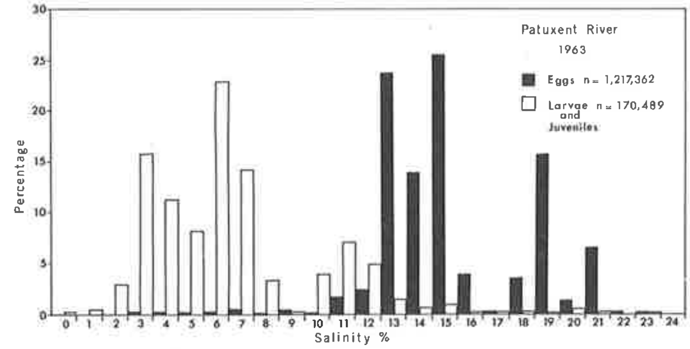

Figure 5. Distribution and abundance of the eggs and larvae of the bay anchovy (**Anchoa mitchilli**) in the Patuxent River in 1963 by salinity (o/oo) at location of capture.

During the colder period, December to May, young-of-the-year fish were collected in limited numbers in low salinity areas. During April until July, juvenile fish about one year of age and recently-hatched young-of-the-year were present concurrently on the nursery ground and could be separated according to size (Table 21). Fish collected during August through November included both young-of-the-year and older fish but could not be separated with certainty on the basis of length frequency (Table 21).

By late fall or winter, only young-of-the-year fish remain on the nursery ground. Fish of the previous year-class, now about 15 months old, appear to move from the area or become less vulnerable to plankton gear as water temperatures drop with the onset of colder weather. Young-of-the-year will be found in the nursery areas the following spring.

The upstream limits of the anchovy nursery area could not be determined from collections made in the Patuxent River. A plot of total number of fish collected during 1963 by location of capture (Fig. 6) showed the greatest abundance of fish (67.4%) at the sampling station (0) closest to freshwater. No determination could be made as to whether areas slightly further upstream in fresh water of

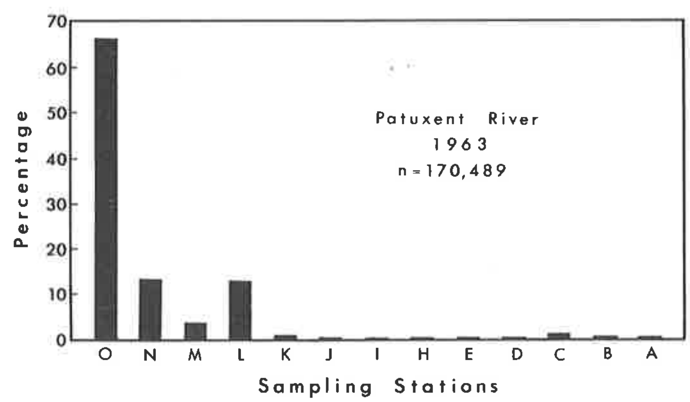

Figure 6. Distribution and abundance of bay anchovy (**Anchoa mitchilli**) by collection station in the Patuxent River during 1963.

the Patuxent would have contributed more or less organisms.

Sampling at the head of Chesapeake Bay provided data helpful in evaluating the importance of fresh water as a nursery environment. Sampling there was performed along two routes. One route extended along the navigational channel from off Tolchester to Havre de Grace in the Susquehanna River (Fig. 1). This route extended into fresh water by at least 8 miles at all times of the year. The other route extended along the main navigational channel from off Tolchester to Chesapeake City on the C & D Canal. Both ends of the canal route were located in low saline waters at all times of the year. Water in the short section from Old Courthouse Point to slightly south of Turkey Point was usually fresh. Developing anchovies were more abundant in the canal area than the lower. Susquehanna River area (Havre de Grace to Turkey Point, Fig. 7). A plot of collections by station (Fig. 7) and salinity for 1967 (Fig. 8) indicated an abundance of larval stages in low salinity areas. The lack of fish at freshwater stations IE and Old Courthouse coincides with reduced water salinities in those areas. Havre de Grace and Fishing Battery stations, located in fresh water (Fig. 7) produced less than 1.0% of the total fish collected during either year.

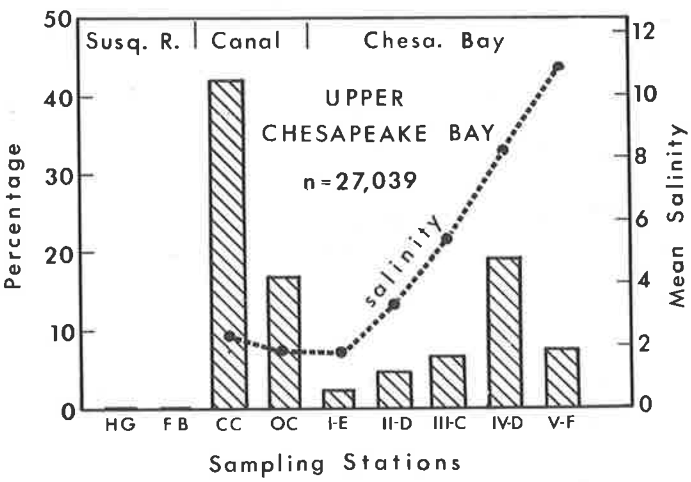

Figure 7. Distribution and abundance of bay anchovies (**Anchoa mitchilli**) by collection station and water salinity in upper Chesapeake Bay during 1966 and 1967.

HG = Havre de Grace
FB = Fishing Battery
CC = Chesapeake City
OC = Old Courthouse

I-E, II-D, III-C, IV-D, V-F } Channel stations between Turkey Point and Tolchester

A plot of the distribution of both eggs and larvae from the salinity gradient leading into the canal (to Chesapeake City) or Susquehanna River (to Havre de Grace) for 1967 (Fig. 8) suggests a pattern of upstream migration or movement of larvae and juveniles similar to such a movement in the Patuxent River (Figs. 3, 4, 5, and 6). Close inspection of the data shows that many of the fish recorded as occurring in fresh water actually occurred in water of 0.5 to 0.9 o/oo salinity. It is therefore apparent that in reference to a salinity gradient leading into the Susquehanna River, some few juvenile anchovies may be found upstream in fresh water, but the majority of these fish congregated in brackish

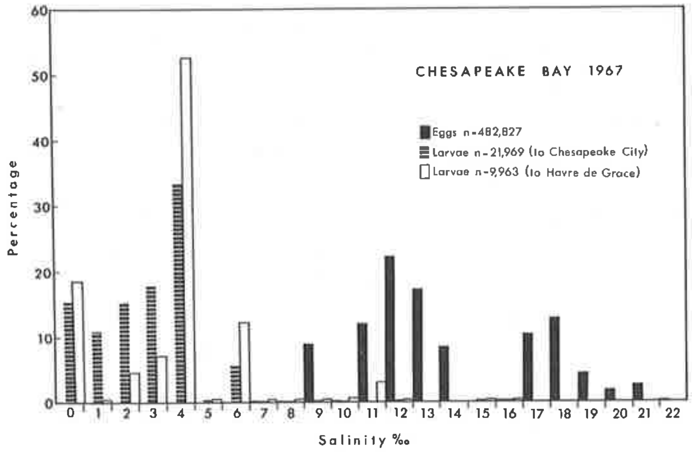

Figure 8. Distribution and abundance of the eggs and larvae of the bay anchovy (**Anchoa mitchilli**) by salinity in upper Chesapeake Bay during 1967. Larvae data are plotted along two sampling routes leading into the Susquehanna River and the Chesapeake and Delaware Canal.

waters very close to the salt-fresh water interface. A comparison of the concentrations of fish in the Patuxent and Susquehanna salinity gradients indicated a slightly different distribution pattern (Table 7). This difference appears to have been due to sampling effort as related to a shifting salinity gradient. An upstream shift of salt waters of the Patuxent during fall months precluded equal and constant sampling of very low salinity waters since sampling locations remained constant. Sampling effort for the Susquehanna adequately monitored the low salinity end of the gradient and adjacent areas of fresh water. This information would suggest that the distribution pattern determined for the Susquehanna gradient, i.e., concentration in brackish areas very close to the salt-fresh water interface, may be typical for other areas in the upper Chesapeake. There is, of course, some movement of a few fish well upstream, and spillover of many into fresh water bordering brackish areas.

The anchovies of the family Engraulidae reach sexual maturity at an early age. Hildebrand and Cable (1930) concluded that *A. mitchilli* may spawn when 2½ and 3 months old. Information presented in Table 21 tends to substantiate the claim of maturation in this short duration if maturity is attained by the time fishes reach 40 mm TL. Stevenson (1958) states that the bay anchovy reaches a maximum standard length (SL) of 75-80 mm in its second year. The largest fish recorded in Delaware Bay by Stevenson (1958) was 86 mm SL.

Table 21 indicates the presence of at least two year-classes of this species in the upper reaches of Chesapeake tributaries during early spring and summer. This information is based on collections made with plankton nets. Trawl catches of adult fish[3] from part of the same area (Patuxent River) and period do not indicate the presence of large numbers of older fish. All available information suggests that this

[3]A. J. McErlean, pers. comm.

species has a short life span in Chesapeake estuaries. We will assume that all bay anchovies are mature when one year of age. The rapid maturation and prolonged spawning season of this species in Chesapeake Bay contributes to a large total size range for young-of-the-year fish (Table 21). Perlmutter (1939) records 0-year-class fish from Long Island Sound as 20-55 mm. The potential for spawning late during the same year in which they were hatched may contribute to distinct early and late season spawners of this species, as mentioned by Stevenson (1958).

In summary, the bay anchovy produces large numbers of pelagic eggs and larvae in upper Chesapeake Bay tributaries and the bay proper. Spawning takes place along most of the salinity gradient with large concentrations of resulting larvae found in low salinity nursery areas. This species matures quickly, possibly before one year of age, and apparently has a short life span. The characteristics of spawning in one location followed by movement of larvae toward a low salinity nursery area is similar to the early life history movements of the hogchoker (Dovel et al., 1969).

At present, man utilizes the anchovy only indirectly in the Chesapeake Bay area. Here, as a forage fish, it constitutes a major portion of the diet of the striped bass, *Morone saxatilis* (Raney, 1952; Hollis, 1952; Dovel, 1968). We cannot overlook the possibility that this fish could also be an important food item for waterfowl and other animals. The abundance of anchovy larvae and juveniles in accessible estuaries makes this organism vulnerable to exploitation as a possible untapped natural resource. The prolific nature of this species, its rapid maturation and short life span favor exploitation. Its small size may be the primary reason why this anchovy is not used commercially, as are other larger members of the family Engraulidae. Any future plans for exploiting the bay anchovy must, however, take into consideration the true value of this species as a forage fish. In addition, the selective or unselective characteristics[4] of potential harvesting gear must be considered in relation to adverse effects such gear might have on other important species.

Northern pipefish, *Syngnathus fuscus*

Adults of the northern pipefish are common during warmer months in vegetated areas in the vicinity of Solomons. Recently-born larvae of 10-12.0 mm TL usually appear about the middle of May of each year. Individual or combined collections made during the summers of 1961-67 seem to indicate two spawning peaks about early May and late July (Tables 22 and 23). Growth appears more rapid following the second hatching about July, when water temperatures are approaching their maximum for the year. Young of this species appeared over most of the salinity range sampled for this investigation (Table 9).

[4] E. Dunnington, Pers. comm.

Naked goby, *Gobiosoma bosci*

Demersal and attached eggs of this goby are common in oyster shells in shallow areas in the vicinity of Solomons, Maryland. Larvae were apparently restricted close to egg deposition areas since few were collected in deeper channel areas in the lower Patuxent River with intensive sampling effort. Larvae of this goby were more abundant than similar stages of other gobies collected during this investigation (Tables 9, 11, and 12). In fact, naked goby larvae accounted for 55.2% of all fish larvae collected. Young gobies were most dense in low saline areas of 1 to 12 o/oo (Table 9). Some were collected as early as June 4 (1963) with large numbers present in most areas soon after mid-June of each year. Size data in Table 24 suggest that spawning takes place for a 2- to 3-month period. Larvae were generally abundant until about October or during the warmest period of the year. During 1963, 94.0% of the larvae collected occurred when temperatures were between 22 and 29 C with the first occurrence at 18.9 C.

Recently-hatched larvae < 12mm TL appear to be efficiently collected by the plankton gear used for this study (Table 24).

A total of 149 larvae were found west of Turkey Point (at Fishing Battery and Havre de Grace) in fresh water of upper Chesapeake Bay. Large numbers were collected from low salinity waters of the C & D Canal. No appreciable numbers of larvae were found in waters having salinities over 18 o/oo. Sampling effort was, however, reduced in these waters.

Silversides

Rough	Tidewater	Atlantic
Membras martinica	*Menidia beryllina*	*Menidia menidia*

The Maryland portion of the Chesapeake possesses the species listed above, all of which have demersal and attached eggs and morphometrically similar newly-hatched larvae. Positive identifications were made for fish which possessed a full complement of fin rays and scales. The anal fin count, relative positions of the dorsal and anal fins (Hildebrand and Schroeder, 1927) and scale counts (Bayliff, 1950) were used to differentiate species. All three species were common in low saline areas (Table 9) during the period April to December. Temperatures during this time ranged from about 12 C to maximum summer conditions approaching 30 C. Larvae were most common in surface waters. During 1966 and 1967, young silversides were present at upper bay stations located both in fresh water west of Turkey Point and in low saline waters in the C & D Canal.

Winter flounder, *Pseudopleuronectes americanus*

A single winter flounder egg was collected off Cove Point in 20 feet of water on March 14, 1966. Water temperature and salinity were 3.0 C and 20.7 o/oo respectively. The collection of this egg was unusual as eggs of this species adhere to the substrata and are not available to plankton gear. The egg was apparently scraped from the bottom of the bay by the apron attached to the front of the plankton sled (Dovel, 1964).

Larvae were present in areas where water salinities ranged up to 20 o/oo (Table 9), during the period February to May. Areas of peak abundance were found only where salinities ranged between 6 and 15 o/oo. Larvae were most abundant for a 1-month period of each year, usually during the last half of March and first half of April. Water temperatures during this time ranged from 3 to 18 C with most larvae present when temperatures ranged between 4 and 13 C (Table 11).

An inspection of data by vertical location of capture did not suggest definite vertical stratification. Samples from the Magothy River during 1966, however, indicated most larvae were found close to the bottom. This characteristic may be partly attributed to the descent of larvae that swim to the surface, then while resting, sink for a short period of time. Any descent in the shallow Magothy River (less than 20 feet) brings these fish close to the bottom. Samples from the Patuxent River (35 to 50 feet depth) did not suggest concentrations at either surface, mid, or bottom depths in 1963. The water depth, sinking rate of the larvae, lengths of their resting periods and response to illumination may thus affect the level at which these organisms are found.

All but 2 of the recently-hatched winter flounders collected were less than 11.0 mm TL (Table 25). It would appear that collecting methods employed in this study efficiently captured larvae up to about 8.0 mm TL. Fig. 9 provides an approximation of winter flounder growth during the period February to May for four different years. No migration of newly-hatched larvae from hatching area to a separate nursery area was noted.

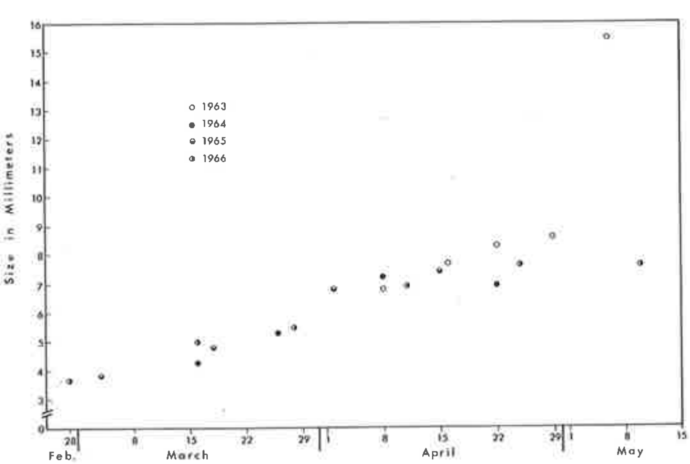

Figure 9. Length frequencies of winter flounders, **(*Pseudopleuronectes americanus*)**, in different locations of upper Chesapeake Bay (1963-1966), showing similarity of seasonal growth for different year classes.

Hogchoker, *Trinectes maculatus*

Dovel et al. (1959) provide an account of some aspects of the early life history of this species summarizing all information collected during the period 1963-68. The abstract of that paper is presented here.

"Some life history aspects of the hogchoker, *Trinectes maculatus*, in the Patuxent River estuary, Maryland."

Abstract

Information is presented on the abundance, distribution, and seasonality of hogchoker life history stages in the Patuxent River estuary. Egg collections indicate that the spawning area is located in the lower river in salinities greater than 9.0 o/oo. Following hatching during July and August, the larvae move upstream and congregate in a low salinity nursery area close to the salt-freshwater interface where they remain during winter. As spring approaches, the juveniles move toward the spawning area. These two distinct movements, upstream toward the nursery area in fall and downstream toward the spawning area in spring, apparently continue at least through the fourth year. As the fish mature, they progressively increase their range of travel away from the nursery ground toward higher salinities. Life history activities were determined by monitoring an abundant 1963 year-class using three sampling techniques: meter nets, shallow water trawls and deep water trawls. The importance of various segments of the estuary for completion of life history cycles is emphasized.

Skilletfish (clingfish), *Gobiesox strumosus*

Skilletfish, like gobies, are abundant in the lower Patuxent River. This species is associated with the oyster community where its eggs are deposited on hard substrate, mostly oyster shells. This species did not appear in very low salinity waters (Table 9). In 1963, larvae were present from May 13 to September 5, mostly in waters with salinities of 4 to 19 o/oo. Water temperatures ranged from 17 to 27 C. A description of the early development of this species in the Solomons area may be found in Runyan (1962) and Dovel (1963).

Marine Species

Atlantic menhaden, *Brevoortia tyrannus*

Menhaden eggs were found in the vicinity of Solomons for the first time in the spring (May and June) of 1963. They have since been collected there also in the fall (October and November) of 1967 and 1968. Water temperatures ranged from 13 to 20 C with salinities of 10 to 22 ppt.

The possibility exists that these eggs may have been transported a short distance upstream by a subsurface water current described by Pritchard (1951). A short incubation period (ca. 48 hrs at 22 C; Mansueti and Hardy, 1967) precludes movement over any appreciable distance. Although no adults in spawning condition have ever been reported from the upper portion of Chesapeake Bay, it is apparent that some eggs are occasionally, if not regularly, deposited in this area. These eggs have not been found north of the mouth of the Patuxent River in Chesapeake Bay. Young menhaden appeared in upper estuarine, low salinity areas (Table 9) in upper Chesapeake Bay tributaries during the period late March to late June. The majority of the 2,322 fish recorded in Table 4 ranged in size from 20 to 40 mm TL. Many of these fish were at least 25 mm TL, when they first appeared in collections in early spring (Table 26). We must conclude that these fish hatched and entered the upper estuary the previous fall or winter.

Only 25 specimens less than 20.0 mm TL were collected. Twenty-four of these (14.4 to 18.4 mm TL) were found in the C & D Canal on June 5, 1967. We can only wonder what significance there may have been in the collection of slightly smaller than normal fish in the canal which affords direct and fast access to the Atlantic Ocean through Delaware Bay. A specimen, 10.4 mm TL (Table 26, A) was found off Cove Point on November 7, 1967. This fish may have been on its way toward an upstream nursery area after hatching in the lower bay or in the Atlantic Ocean. Limited data (Table 26) suggest that these fish do not grow appreciably during winter or early spring but show accelerated growth during May and June before disappearing from plankton samples. Their disappearance is probably due to increased organism activity, gear avoidance and movement away from nursery areas where organisms are densely congregated. Accelerated growth during May is also characteristic of most other species recorded in this report.

Atlantic croaker, *Micropogon undulatus*

Dovel (1968) discusses aspects of the early life history of this species as related to a predator-prey relationship involving adult striped bass during winter months in mid and upper Chesapeake Bay areas. The information presented in that article was collected as part of this study. The abstract of that paper is presented here.

"Predation by striped bass as a possible influence on population size of the Atlantic croaker."

Abstract

Recent data collected from the upper Chesapeake Bay, Maryland and a review of commercial fishery statistics suggest that predation by striped bass on post larvae and juveniles of the Atlantic croaker, during periods of low water temperatures, may be a significant factor influencing the recent decline of the croaker on the northeastern coast of North America. The life history of the croaker, stomach analysis of adult striped bass, and commercial fishery statistics for both species during the period 1930-1965 are discussed in this connection.

Southern Kingfish, *Menticirrhus americanus*

Eggs probably of a sciaenid species and tentatively identified as *Menticirrhus americanus* (Table 8) were found in bottom samples collected along the channel of Chesapeake Bay from south of the Chesapeake Bay Bridge to Hoopers Island Light. The estuarine circulation pattern could affect the distribution of these eggs, as mentioned for menhaden eggs.

Eggs were found during May and June of 1965, 1966, and 1967. Salinities ranged from 15.9 to 19.5 o/oo with a water temperature range of 12.5 to 23.8 C. Eggs collected in May 1966 were maintained live and allowed to hatch. Resulting larvae survived for only 7 days, but were helpful in making the tentative identification. Larvae (Table 9) were collected in field samples in May 1966, September 1963 and September 1965.

Seaboard goby, *Gobiosoma ginsburgi*

One hundred sixty-six specimens were found in Chesapeake Bay channel locations between the Chesapeake Bay Bridge and Hoopers Island Light. Salinities ranged from about 17 to 22 o/oo (Table 9) during June to December when larvae were present. *Gobiosoma ginsburgi* was found concurrently with *G. bosci* but was apparently restricted to higher salinity areas, whereas *G. bosci* was very abundant throughout much of the upper bay in low salinity areas (0 to 17 o/oo). Young gobies, $<$ 10.0mm TL, of the genus *Gobiosoma* were present in waters with salinities greater than 20 o/oo but could not be identified to species due to similar morphometric characteristics (Hildebrand and Cable, 1938). Fish, $>$ 10.0mm TL, possessed distinguishing characteristics and were identified to species (Hildebrand and Cable, 1938; Massmann et al., 1963).

SUMMARY

The broad area of this investigation, upper Chesapeake Bay, is generally typical of the upper reaches of many Coastal Plain estuaries. The fauna is typically estuarine but should exhibit unique Chesapeake Bay characteristics. The following discussion attempts to present a synoptic view of the basic biological pattern of abundant early developmental stages of fishes found in upper Chesapeake Bay.

The biological information obtained during this investigation has been correlated with the estuarine salinity gradient, the temperature gradient, water depths, and seasons of occurrence in an attempt to ascertain life history patterns. An analysis of this information with special emphasis on the patterns of organism movement has made possible an evaluation of the nursery potential of the Chesapeake estuarine environment for fishes.

Salinity Correlations

Major emphasis has been directed toward correlations with the salinity gradient which serves as a yardstick to the estuary. Progressive changes in the location of an organism in relation to the salt content of the estuarine environment are assumed to indicate important migrations or movements, primarily between spawning and feeding areas with different salinities. The fishes represented here can be conveniently grouped in three main categories according to the salinity of the environment in which spawning takes place. These categories are freshwater, estuarine and marine.

Freshwater Spawners

The species listed here spawn close to the fresh-saltwater interface (striped bass), or many miles upstream (white and yellow perches and some of the herring groups). All possess yolk-sac food supplies and apparently do not depend on the nutritional capacities of their home tributaries for a short period following hatching. During this time larvae are planktonic and are carried downstream by freshwater runoff. Active feeding apparently starts for most of these fish as they approach low salinity waters. Larvae of freshwater fishes were abundant in spring in low salinity waters (< 13 o/oo) of the Patuxent and Magothy Rivers and upper Chesapeake Bay. This salinity range covers about 10 miles in the upper Patuxent River. Herman et al. (1968) state that the richest area of zooplankton in that river in spring is located near Trueman Point or about the middle of this 10-mile section. Numbers of adult zooplanktors reach a maximum there in March and April or about the time larvae of freshwater fishes are hatching in the upper estuary. During May, zooplankton abundance declines due partly to feeding by large numbers of recently-hatched fishes and young-of-the-year fishes still on the nursery ground. Early developmental stages of several species collected during this investigation show no appreciable growth prior to the first of May but show accelerated growth from May to late summer. As summer approaches, numbers of zooplanktors decrease and maturing fishes are less abundant in plankton samples collected in the low salinity area. By fall, many of the maturing fishes have moved toward the lower estuary.

In summary, developing fishes of the freshwater group hatch upstream and move downstream where they feed on phyto- and zooplankton produced in brackish water areas. Some fishes move farther downstream at the same time upper estuarine zooplankton abundance decreases and their food requirements change (e.g., striped bass and white perch). Some fishes either remain in or return to the low salinity nursery area for several years.

Estuarine Spawners

Estuarine fishes spawn and mature in brackish areas. Some hatch and remain in the same area while others, like the bay anchovy and hogchoker, spawn over much of the estuarine salinity gradient but move, as larvae, to low salinity nursery grounds upstream in summer and fall. The hogchoker, *Trinectes maculatus* (Dovel et al., 1969), and the bay anchovy, *Anchoa mitchilli,* are ideal species for showing upstream migration of larvae, since larvae were abundant in areas where eggs were scarce or nonexistent. The spawning grounds for many of these estuarine species apparently extend into the marine environment.

Fishes of the oyster community, gobies, blennies, toadfish, and skilletfish, plus silversides, killifish, pipefish, sticklebacks, and winter flounder spawn over much of the middle estuary but show no apparent movement toward a different nursery area.

In general, the larvae of the estuarine group of fishes either remain in the area where they were hatched or move upstream to the vicinity of the salt-freshwater interface as critical early growth begins. Immature stages of some fishes of this group exhibit cyclic movement within the estuary during early development stages (e.g., hogchoker).

Marine Spawners

The marine category consists of fishes whose larvae hatch in the marine environment and show varying degrees of dependency upon the estuary as a nursery area. This group includes the menhaden, American eel, spot, weakfish, and Atlantic croaker which show strong upstream migrations. Most larvae of these species generally hatch over a several-month period and appear in Chesapeake estuaries during late summer to early winter. Migrations carry most of these fishes upstream to the vicinity of the salt-freshwater interface and some into fresh water. The larvae and juvenile stages of these fishes were not found in abundance in the lower Patuxent and adjacent Chesapeake Bay. It would appear that species which accumulate in the estuary over a period of several months are most abundant where these fishes congregate to feed. Larvae and juveniles of all species mentioned so far in this category were found congregated upstream in low salinity areas. In addition, four young Atlantic herring and four darter gobies were also found in the same area. This pattern would suggest that the sampling methods employed were more efficient in determining the presence of ichthyoplankton once congregated on the low salinity nursery grounds than while in transport to these areas.

Post larvae and juveniles of the seaboard goby, kingfish, feather blenny, blackcheek tonguefish, harvestfish, and northern puffer were found in waters of intermediate salinities (11 to 22 o/oo). The absence of eggs of these marine spawners, with the possible exception of those of the kingfish, suggests upstream movement of larvae. The absence of larvae and juveniles from waters with salinities less than 11 o/oo would suggest that either the inshore movements of these forms were not pronounced, or that the presence of these forms was not sufficiently monitored by sampling gear.

A Common Estuarine Nursery

Early developmental stages of fishes from all three groups listed above utilize common low salinity feeding or nursery areas in the upper Chesapeake Bay. Each gradient or major tributary, which possesses a transition zone between fresh and salt waters, provides this nursery potential. These areas, as determined in this study, may be roughly described as water area with a 0 to 11 o/oo salinity range. Ninety-five percent of all fish larvae collected during this investigation were found in this salinity range (Table 27).

but before their full significance can be realized a critical comparison of maturation under both fresh and brackish water conditions must be made. The nursery area emphasized here is synonymous with the "critical zone" of estuaries described by Massman (1963) and referred to as having salinities of 1 to 15 or 5 to 15 o/oo (Massmann, 1964). There is probably no appreciable difference between the values of areas here designated as having salinities of 0 to 11, 1 to 15, and 5 to 15 o/oo. It seems probable that environmental differences, random movements of the organisms, and varying gear efficiency contribute to different salinity designations.

The "critical zones" are relatively small in Chesapeake tributaries; they must possess high turnover rates of food organisms to support large numbers of maturing fishes, especially during spring and summer months. Herman et al. (1968) describe the high production of copepods in the low salinity area of the Patuxent during spring. Heinle (1970) shows an inverse correlation between water temperature and the turnover time for the dominant copepods in

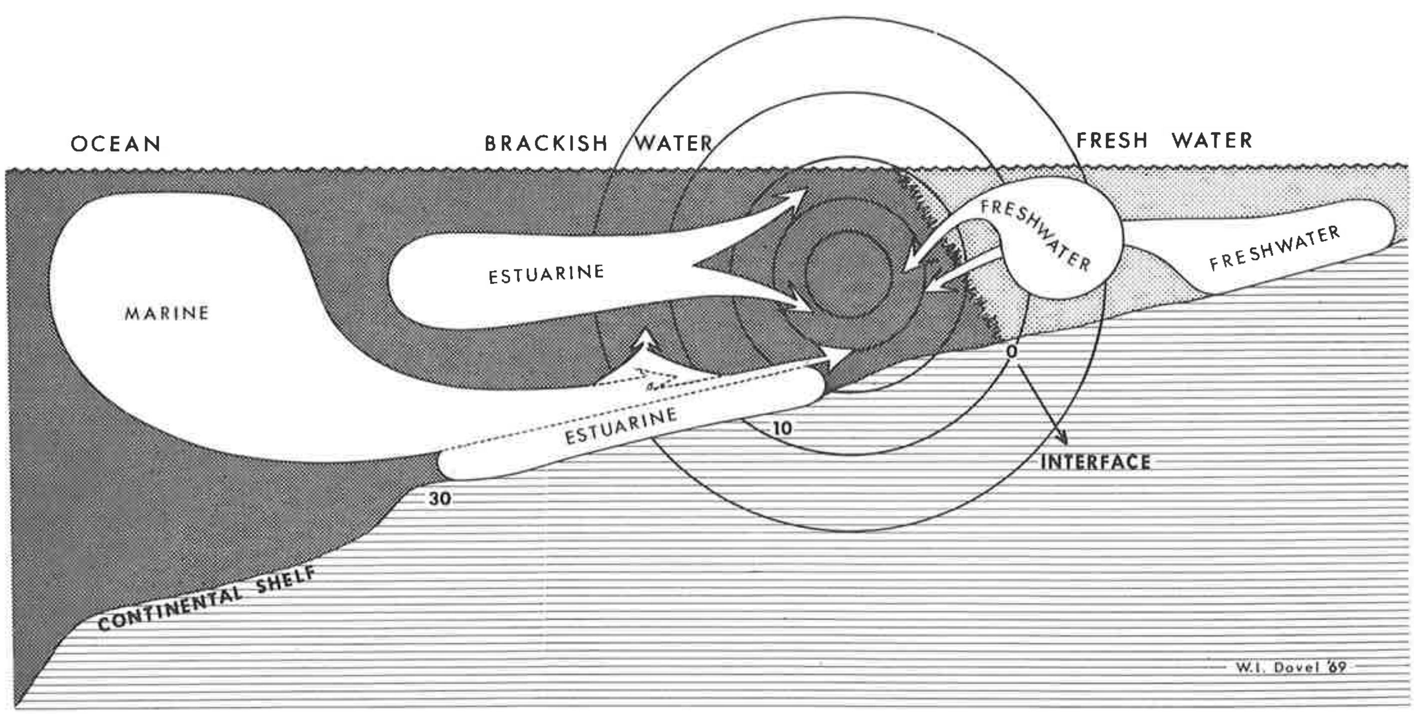

Figure 10. Schematic diagram of movements of estuarine-dependent fish larvae and juveniles toward a common low salinity nursery area. Numbers represent approximate salinity in parts per thousand (o/oo).

Movement

Critical Zone. Figure 10 depicts movement of developing fishes from different environments toward these common nursery grounds in the upper Chesapeake estuarine system. This figure suggests the importance of the low salinity estuarine environment as a nursery for fishes listed in this report. These brackish water nursery areas are obviously important,

that area as summer approaches. A turnover time of about one month during December and January decreases to about one day during midsummer.

Figure 11 emphasizes the specific and intricate movements of one important estuarine species, the hogchoker, in relation to the broad concept of larval and juvenile fish movements in the estuary.

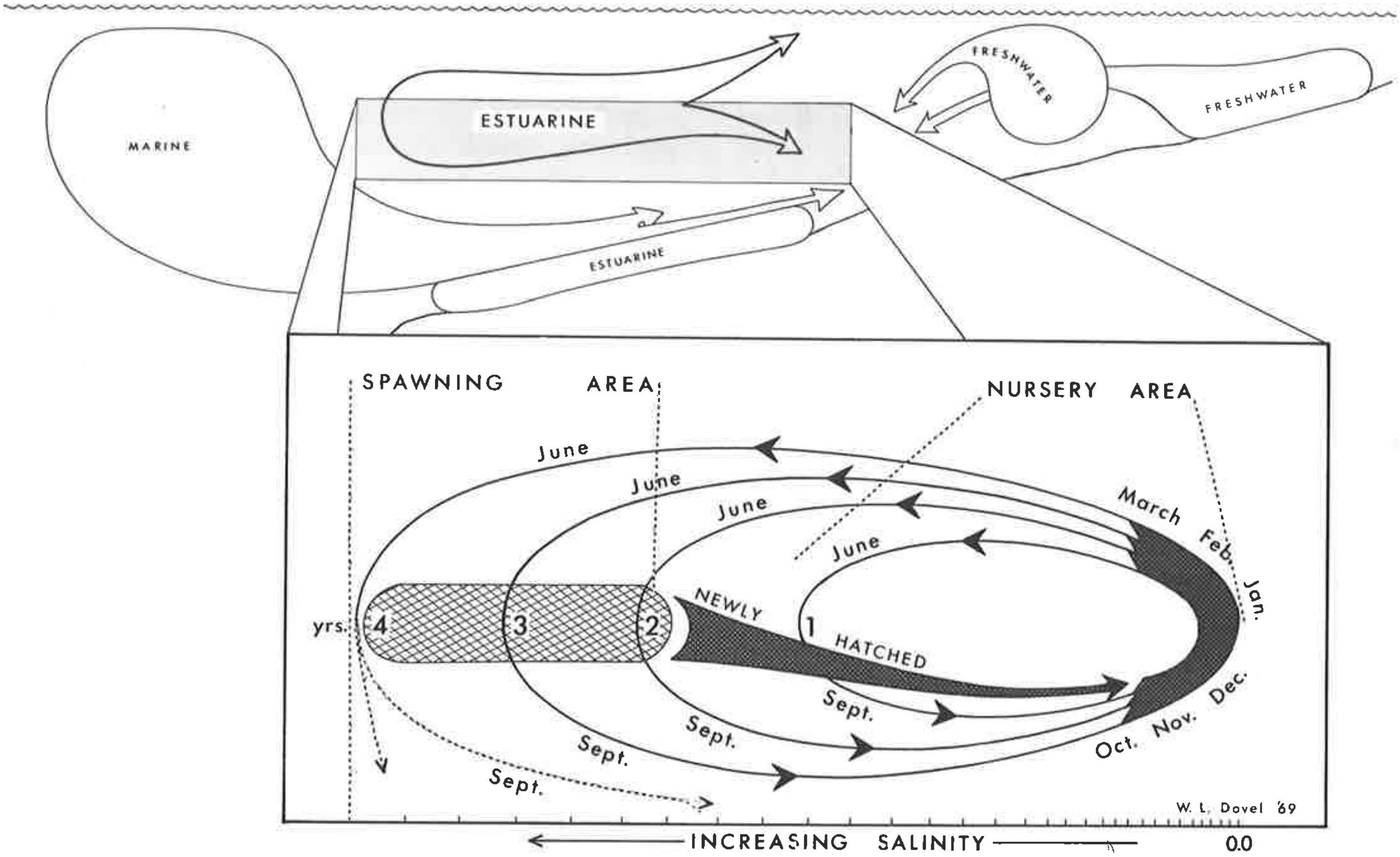

Figure 11. Schematic diagram of movements of major groups of developing estuarine-dependent fishes with a breakdown of the inter-estuarine activities of a single dominant species, the hogchoker (*Trinectes maculatus*).

The young stages of most species collected during this study go through some variation of the cyclic movement pattern depicted for the hogchoker. An understanding of these complex movement patterns for estuarine-dependent fishes is essential before we can gain a working knowledge of appropriate ecological relationships.

Stratification. Correlations with depth show some stratification, either deliberate or accidental, but conducive to the movement of larvae and juveniles toward nursery areas, as described above. Much of the movement described here is passive rather than deliberate but is beneficial to the organism's development. Marine and estuarine fishes utilize a subsurface, net upstream water current to move upstream, while freshwater species utilize fresh water runoff to move downstream. The increasing ability to swim against water currents makes it impossible at this time to determine the extent to which fish determine their own route of travel.

Survival. There is evidence to suggest that downstream movement of some newly-hatched larvae from freshwater spawners is not only beneficial but necessary. Conte et al., (1966), showed that as juvenile *Oncorhynchus kisutch* develop, they exhibit an increasing ability to tolerate high salinity waters. In the case of the Coho salmon this increased tolerance precedes the downstream migration by about 6 months. Baggerman (1960) found that the fry of *Oncorhynchus keta* could not live for long periods in fresh water. Larvae hatched in fresh water in March would begin to die by June if restricted to that environment. Further restriction would result in the death of all fish by November. Larvae, when presented with a salinity choice situation, generally preferred fresh water at the end of the yolk-sac period but within about 4 weeks, there was a change to a salt water preference. It may be assumed that downstream movement of young fishes in the Chesapeake estuarine system is not entirely accidental but is correlated with changing salinity tolerances or preferences and has been beneficial to the evolution of those species.

Rapid and rhythmical. The movements of some estuarine-dependent fish larvae, whether passive or active, appear to be rapid and predictably rhythmical. Rapid movement suggests the need for frequent sampling in the estuary in order to accurately monitor the presence of nektonic animals. Some movement is apparently so rapid that even a weekly frequency is insufficient to follow movement along the gradient (Dovel et al., 1969). A weekly sampling frequency does, however, provide an indication of the general areas of organism concentration. A less frequent sampling schedule may allow organisms to move in and out of an area undetected.

Temperature Correlations

Correlations of egg and larvae presence with environmental water temperatures did not suggest the existence of distinct categories associated with different temperature ranges, although each species has an optimal temperature range for reproduction. Generally, some fish eggs and larvae were present in the estuary when water temperatures were between 3 and 31 C (Table 11). Ninety percent of all eggs collected were found with temperatures > 19 C. Temperatures > 27 C accounted for only 1.0%. An eight degree spread, 20-27 C, accounted for almost 90% of the total eggs collected. This reflects production of the two dominant estuarine fishes, the anchovy and hogchoker.

Eighty-three percent of all larvae and juveniles occurred with temperatures of 22 to 29 C. Most of these forms were larvae representing a few dominant estuarine species and were present during or just prior to the period of maximum summer water temperatures. Many juveniles were also present in low salinity nursery areas during periods of minimal water temperatures when a slight movement downstream would place these fish in warmer waters. Subjection of larvae and juveniles to the coldest possible water temperatures in the upper estuary during the first years of life is characteristic for many estuarine-dependent species. This temperature-growth relationship should be thoroughly investigated.

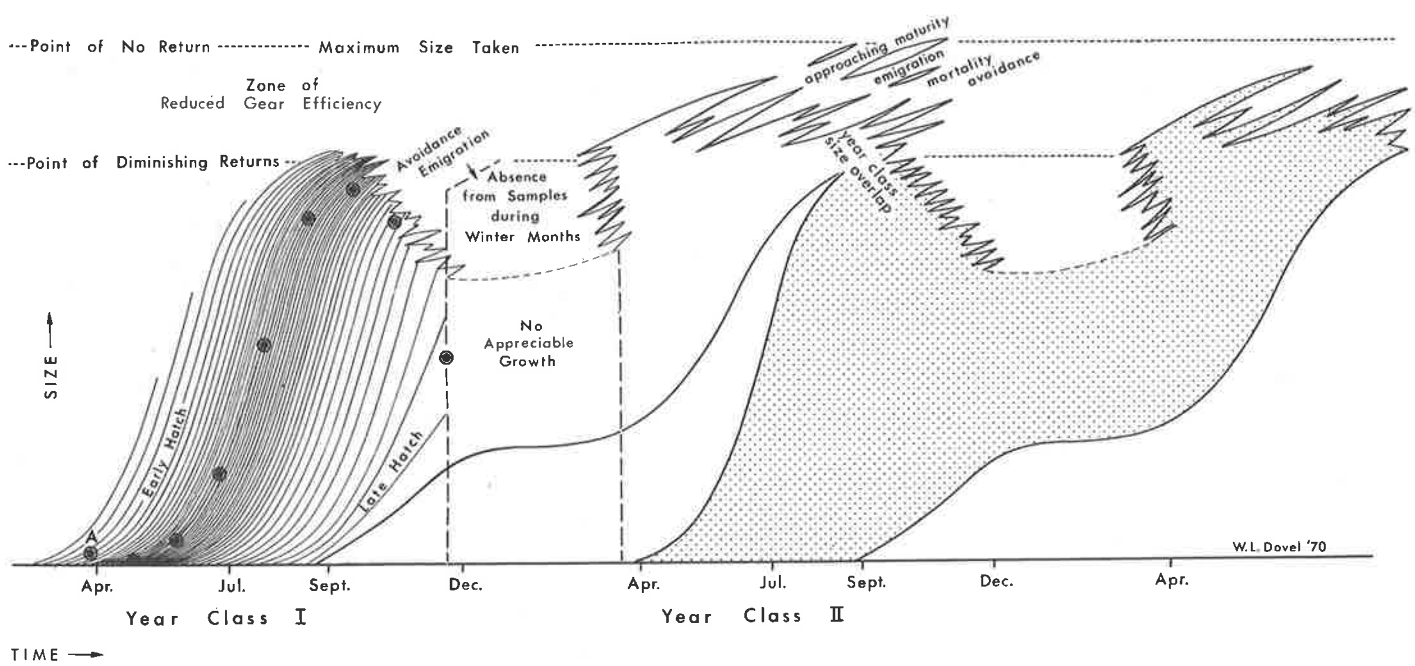

Figure 12. Schematic diagram of the generalized early growth pattern of estuarine-dependent fishes, derived from data collected with one-meter plankton nets.

Growth

This report documents the utilization of a common estuarine feeding area by fishes that originate in fresh water, the sea, and the estuary. Utilization of the estuary is undoubtedly correlated with a high growth potential in that environment. Although each species will follow a specific pattern of growth, it may be assumed that all estuarine-dependent forms gain nutritional benefits from the rich and productive coastal environment. Calculated patterns of growth will vary according to the abundance of different developmental stages, which in turn are affected by the characteristics and efficiency of collecting gear and sampling methods employed.

In consideration of inter-specific variations, the author planned to present individual growth curves for some species. A comprehensive examination of all raw data available suggested many problems in attempting to fit either a line or curve to the data in such a manner as to accurately portray the characteristics of early growth. It should be noted here that preliminary calculations produced line fits with high statistical correlation coefficients ($r = 0.8$). It is the author's opinion that while a high coefficient denotes good fit, this approach does not sufficiently convey the complex nature of the early growth of estuarine-dependent fishes.

In lieu of a single line fit, the author has developed a schematic diagram (Fig. 12) which will facilitate an understanding of larval and juvenile fish growth under estuarine conditions. It should be kept in mind that interpretations conveyed through this diagram have been derived from data collected with a one-meter net sampling approach (Dovel, 1964). The schematic was developed primarily from bay anchovy data but accurately conveys the general trend of growth for most species listed in this report.

The determination of an accurate pattern of growth for estuarine fishes requires the availability of at least some data on several developmental stages from hatching until the organism approaches maturity.

The pattern of growth calculated from these stages could probably be depicted by a simple sigmoid curve were it not for changes in the environment, sampling efficiency, and the biological characteristics of the species which interrupt smooth growth.

Due to a short life span in the estuary, this critical period of growth prior to maturity, during which changes occur, will usually extend through the organism's first year to a year-and-one-half of growth. Data for this period are available for species such as the bay anchovy, white perch, yellow perch, northern pipefish, hogchoker, and several others. Fragmentary information is available for gobies, blennies, winter flounder, menhaden, and others listed in tables 2, 3, and 4. In some cases, large numbers of larvae were collected but represented only a small size-range or period of growth in the total life history (Tables 24, 25, and 26). In cases of the naked goby or winter flounder, for example, only larvae less than 10 mm were efficiently captured. In the case of menhaden, fish 25 to 60 mm were available. Regardless of the number of larvae available, an insufficient coverage of the total size-range of the immature stages in cases such as these precluded a determination of a growth pattern for these species.

The following discussion outlines, in a general way, the growth of the early developmental stages of fishes that are dependent upon factors associated with low salt content of estuarine waters.

The production of fish eggs and consequently larvae of dominant species in the estuary approximates a normal distribution (Figs. 2 and 12; Dovel, 1969, Fig. 2). This distribution is suggested in Fig. 12 by using a normally distributed frequency of a generalized sigmoid growth curve. Each line theoretically represents one individual of the population. Mortalities could be built into this diagram by terminating the lines or the growth of individuals at appropriate stages of development, if such points could be determined. Growth of early-hatched fishes accelerates rapidly so that by early fall, gear that efficiently collects eggs and small larvae no longer effectively monitors the population. This point of diminishing returns may be attributed in part to the organism's ability to evade collecting gear, mortality, and reduced availability due to emigration away from the critical nursery area. By mid-winter, when water temperatures have dropped almost to freezing, small, late-hatched organisms are present but not abundant in the nursery area. Larger individuals, with the exception of white perch (in this study) are absent and remain so until about April when the water temperature rises above 10 C. No appreciable growth occurs during cold months. This period is represented by the jagged break in the diagram (Fig. 12).

As water temperatures rise in the spring, the slower-growing fish which have remained close to the nursery are joined by larger individuals which were absent during the cold months. The year-class now has a wide range of individual sizes. By August or late summer, faster-growing organisms of a new year-class attain a size comparable to the slow growers of the previous year-class. This period of size-overlap complicates the separation of year-classes on the basis of size and is attributed, in part, to prolonged spawning periods which result in varying rates of growth, as water temperatures fluctuate in the estuary. It may be assumed that if the organisms of the previous year-class were abundant during the period of size-overlap, and that both year-classes were sampled efficiently, the two age groups would show a definite bi-modal size distribution. Because of sampling limitations and the biological characteristics of estuarine fishes, members of a newly-hatched year-class are monitored far more accurately than older fish.

The developmental stages of many of the species listed in this report appear to be catchable in estuarine low-salinity areas during the first year to year-and-one-half of life. Their absence from samples after this time may be attributed to a combination of factors, including mortality, emigration, avoidance, and reduced gear efficiency. There is a point of no return in size for each species past which plankton sampling gear is not effective in sampling the population. This point may vary from 10 mm for the goby to something over 100 mm for several other species. For estuarine-dependent species that originate outside the estuary, growth patterns differ somewhat but suggest the same benefits from estuarine environmental factors conducive to maximum growth of early developmental stages of fishes.

It is obvious that the shape of a curve depicting periodic mean size of the population (Fig. 12, heavy black dots) will be substantially influenced by the distribution or pattern of occurrence of individuals. When a few larvae first appear in samples, their mean size (Fig. 12,A) may be slightly larger than the average size for newly-hatched forms. This pattern may result from the random chance of collecting representatives of the first larvae hatched, some of which may have hatched days before but did not appear in samples as a result of the sampling frequency used. As the bulk of new year-class begins to appear, the mean size may decrease slightly due to the influence of the concentration of newly-hatched (smallest possible) individuals. The calculation of a pattern of mean growth for estuarine fishes thus results from monitoring the peak activity of populations. With the onset of winter, the peak activity of a population may give way to the activity of the late hatch, or runts, which will reduce size estimates deflecting the upper end of the growth curve downward.

Fish eggs, recently-hatched larvae, or juveniles were present somewhere in the estuary at almost all times of the year. Species composition, relative abundance or density, distribution and movement patterns are constantly changing. Fig. 13 is symbolic of the complex activity that occurs as early developmental stages of estuarine-dependent fishes move through the estuary for brief intervals. It is here that some live out their lives entirely and many others, having come from opposite directions, receive an important start in life.

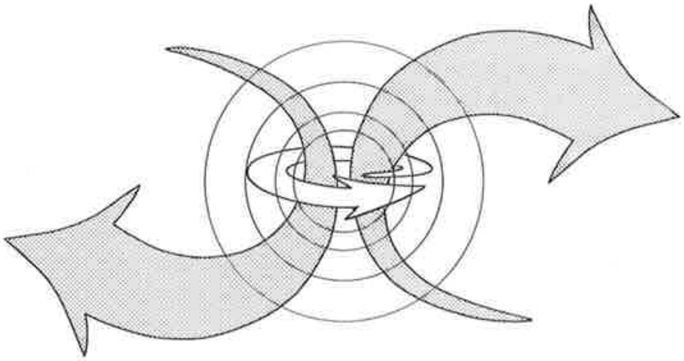

Figure 13. Stylized illustration of the movements of marine, freshwater and estuarine fishes through the critical nursery zone in an estuary.

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LIST OF TABLES

Table 1. Fish egg and larvae sampling effort in the upper Chesapeake Bay (1960-1968).

Area Sampled	Date	Purpose
Mouth, Patuxent R.	1960-1962	Designing Field Techniques
" " "	1961-1962	Pilot Study, Familiarization
Patuxent River (Estuarine Portion)	1963	Weekly Sampling
" "	1964	Biweekly Sampling
" "	1965	" "
Magothy River	1965-1966	" "
Upper Chesapeake Bay	1965-1968	" "

Table 2. List of Common and Scientific Names of Fishes Appearing in this Report.

Common name	Scientific name
Blueback herring	Alosa aestivalis
Hickory shad	Alosa mediocris
Alewife	Alosa pseudoharengus
American shad	Alosa sapidissima
Atlantic menhaden	Brevoortia tyrannus
Atlantic herring	Clupea harengus
Bay anchovy	Anchoa mitchilli
Golden shiner	Notemigonus crysoleucas
Spottail shiner	Notropis hudsonius
White catfish	Ictalurus catus
Channel catfish	Ictalurus punctatus
American eel	Anguilla rostrata
Atlantic needlefish	Strongylura marina
Halfbeak	Hyporhamphus unifasciatus
Killifish	Family Cyprinodontidae
Rainwater killifish	Lucania parva
Fourspine stickleback	Apeltes quadracus
Threespine stickleback	Gasterosteus aculeatus
Spotted seahorse	Hippocampus erectus
Northern pipefish	Syngnathus fuscus
White perch	Morone americana
Striped bass	Morone saxatilis
Pumpkinseed	Lepomis gibbosus
Johnny darter	Etheostoma nigrum
Yellow perch	Perca flavescens
Silver perch	Bairdiella chrysura
Weakfish	Cynoscion regalis
Spot	Leiostomus xanthurus
Southern kingfish	Menticirrhus americanus
Atlantic croaker	Micropogon undulatus
Red drum	Sciaenops ocellata
Darter goby	Gobionellus boleosoma
Naked goby	Gobiosoma bosci
Seaboard goby	Gobiosoma ginsburgi
Green goby	Microgobius thalassinus
Striped blenny	Chasmodes bosquianus
Feather blenny	Hypsoblennius hentzi
Southern harvestfish	Peprilus alepidotus
Rough silverside	Membras martinica
Tidewater silverside	Menidia beryllina
Atlantic silverside	Menidia menidia
Winter flounder	Pseudopleuronectes americanus
Hogchoker	Trinectes maculatus
Blackcheek tonguefish	Symphurus plagiusa
Skilletfish (clingfish)	Gobiesox strumosus
Northern puffer	Sphaeroides maculatus
Striped burrfish	Chilomycterus schoepfi
Oyster toadfish	Opsanus tau

Table 3. Numbers of fish eggs collected at various locations in the upper Chesapeake Bay during 1963-67.

Species	Patuxent River 1963	Patuxent River 1964	Patuxent River 1965	Magothy River 1965	Upper Bay 1966	Upper Bay 1967	Total
Fresh							
Blueback herring *Alosa aestivalis*				x	x	x	4,394
Hickory shad *Alosa mediocris*				x			1
Alewife *Alosa pseudoharengus*	x				x	x	1,933
American shad *Alosa sapidissima*					x	x	308
Clupeidae sp.	x				x	x	39,915
White perch *Roccus americanus*	x	x	x	x	x	x	59,736
Striped bass *Roccus saxatilis*	x	x	x		x	x	38,643
Brackish							
Bay anchovy *Anchoa mitchilli*	x	x	x	x	x	x	3,310,258
Winter flounder *Pseudopleuronectes americanus*						x	1
Hogchoker *Trinectes maculatus*	x	x	x	x	x	x	411,954
Marine							
Atlantic menhaden *Brevoortia tyrannus*	x	x	x		x	x	9,942
Southern kingfish *Menticirrhus americanus*					x	x	2,393
					Total		3,879,477

Table 4. Numbers of fish larvae collected at various locations in the upper Chesapeake Bay during 1963-67.

Species	Patuxent River 1963	Patuxent River 1964	Patuxent River 1965	Magothy River 1965	Bay 1965	Upper Bay 1966	Upper Bay 1967	Total
Fresh								
Blueback herring *Alosa aestivalis*	x			x			x)	) 17,337
Alewife *Alosa pseudoharengus*	x	x		x			x)	)
American shad *Alosa sapidissima*						x		236
Clupeidae sp.	x	x	x	x		x	x	78,919
Golden shiner *Notemigonus crysaleucas*	x							2
Spottail shiner *Notropis hudsonius*	x	x						32
White catfish *Ictalurus catus*							x	12
Channel catfish *Ictalurus punctatus*						x	x	139
Atlantic needlesifh *Strongylura marina*	x			x		x	x	19
Halfbeak *Hyporhampus unifasciatus*		x	x			x		25
White perch *Roccus americanus*	x	x	x	x		x	x	51,275
Striped bass *Roccus saxatilis*	x	x	x			x	x	10,022
Pumpkinseed *Lepomis gibbosus*				x			x	5
Johnny darter *Etheostoma nigrum*						x	x	80
Yellow perch *Perca flavescens*	x	x	x			x	x	23,634
Brackish								
Bay anchovy *Anchoa mitchilli*	x	x	x	x		x	x	239,116
Fourspine stickleback *Apeltes quadracus*	x	x						30
Threespine stickleback *Gasterosteus aculeatus*							x	1
Northern pipefish *Syngnathus fuscus*	x	x	x	x		x	x	529
Naked goby *Gobiosoma bosci*	x	x	x	x		x	x	700,222
Green goby *Microgobius thalassinus*			x	x		x	x	135
Striped blenny *Chasmodes bosquianus*	x	x	x	x				1,008

Table 4. (Continued)

Species	Patuxent River 1963	Patuxent River 1964	Patuxent River 1965	Magothy River 1965	Bay 1965	Upper Bay 1966	Upper Bay 1967	Total
Rough silverside *Membras martinica*	x	x	x			x	x	884
Tidewater silverside *Menidia beryllina*	x	x					x	1,019
Atlantic silverside *Menidia menidia*	x	x	x				x	2,345
Menidia sp.	x	x	x	x		x	x	138,325
Winter flounder *Pseudopleuronectes americanus*	x	x	x	x		x	x	14,303
Hogchoker *Trinectes maculatus*	x	x	x	x		x	x	2,374
Skilletfish (clingfish) *Gobiesox strumosus*	x	x	x	x				683
Oyster toadfish *Opsanus tau*	x	x	x			x		9
Marine								
Atlantic menhaden *Brevoortia tyrannus*	x	x		x		x		2,322
Atlantic herring *Clupea harengus harengus*	x							4
American eel *Anquilla rostrata*	x					x	x	160
Spotted seahorse *Hippocampus erectus*	x							3
Silver perch *Bairdiella chrysura*							x	8
Weakfish *Cynoscion regalis*	x					x	x	368
Spot *Leiostomus xanthurus*	x				x	x		41
Southern kingfish *Menticirrhus americanus*	x				x	x		3
Atlantic croaker *Micropogon undulatus*	x	x	x		x	x	x	468
Red drum *Sciaenops ocellata*	x							1
Darter goby *Gobionellus boleosoma*		x						4
Seaboard goby *Gobiosoma ginsburgi*	x				x	x	x	166
Feather blenny *Hypsoblennius hentzi*					x			42
Southern harvestfish *Peprilus alepidotus*	x	x						101
Blackcheek tonguefish *Symphurus plagiusa*					x			10
Northern puffer *Sphaeroides maculatus*	x							34
								1,286,455

Table 5. Seasonal occurrence of fish eggs collected by meter nets in upper Chesapeake Bay (1963-67).

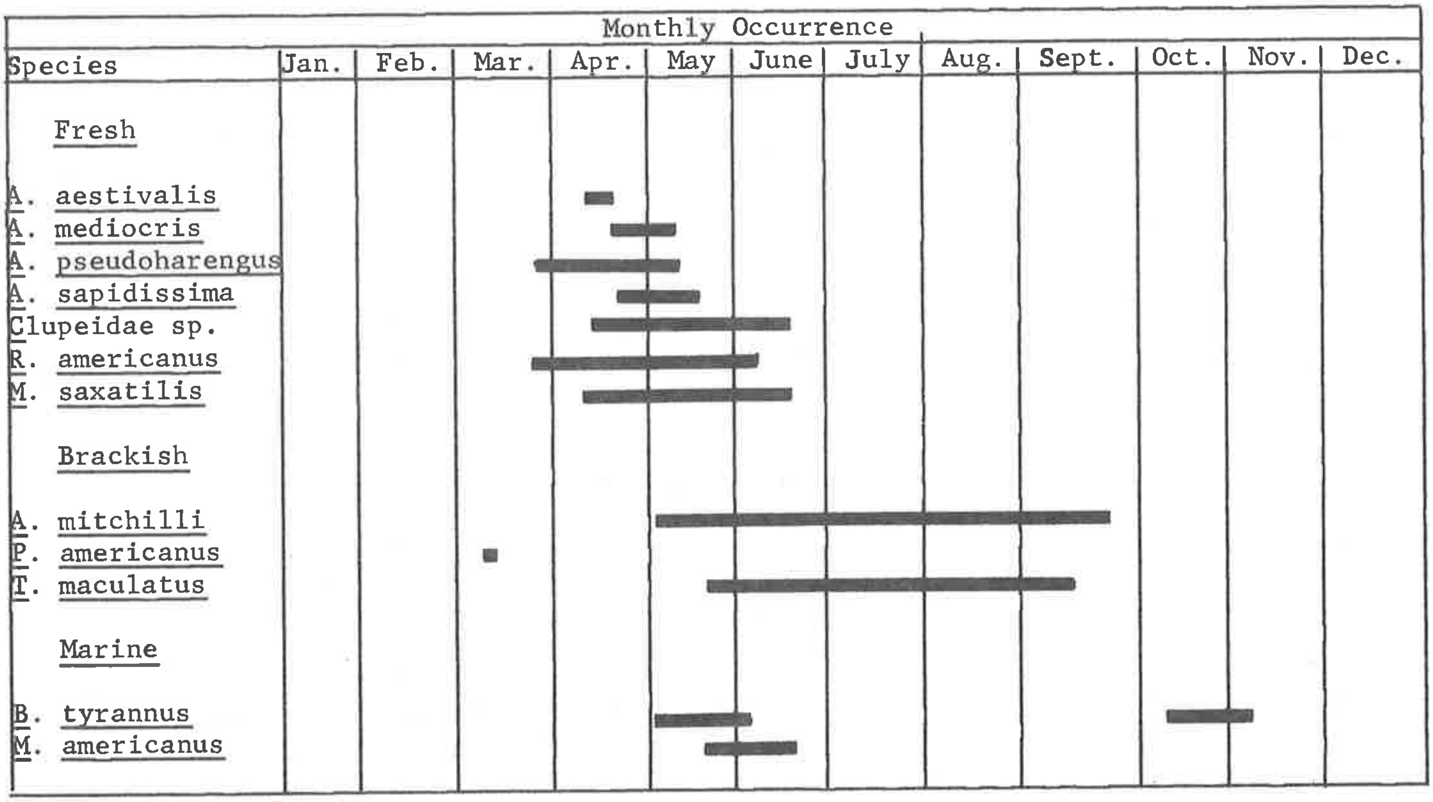

Table 6. Seasonal occurrence of fish larvae and juveniles collected by meter nets in upper Chesapeake Bay (1963-67). Bars represent recorded occurrence during organism's first year of growth.

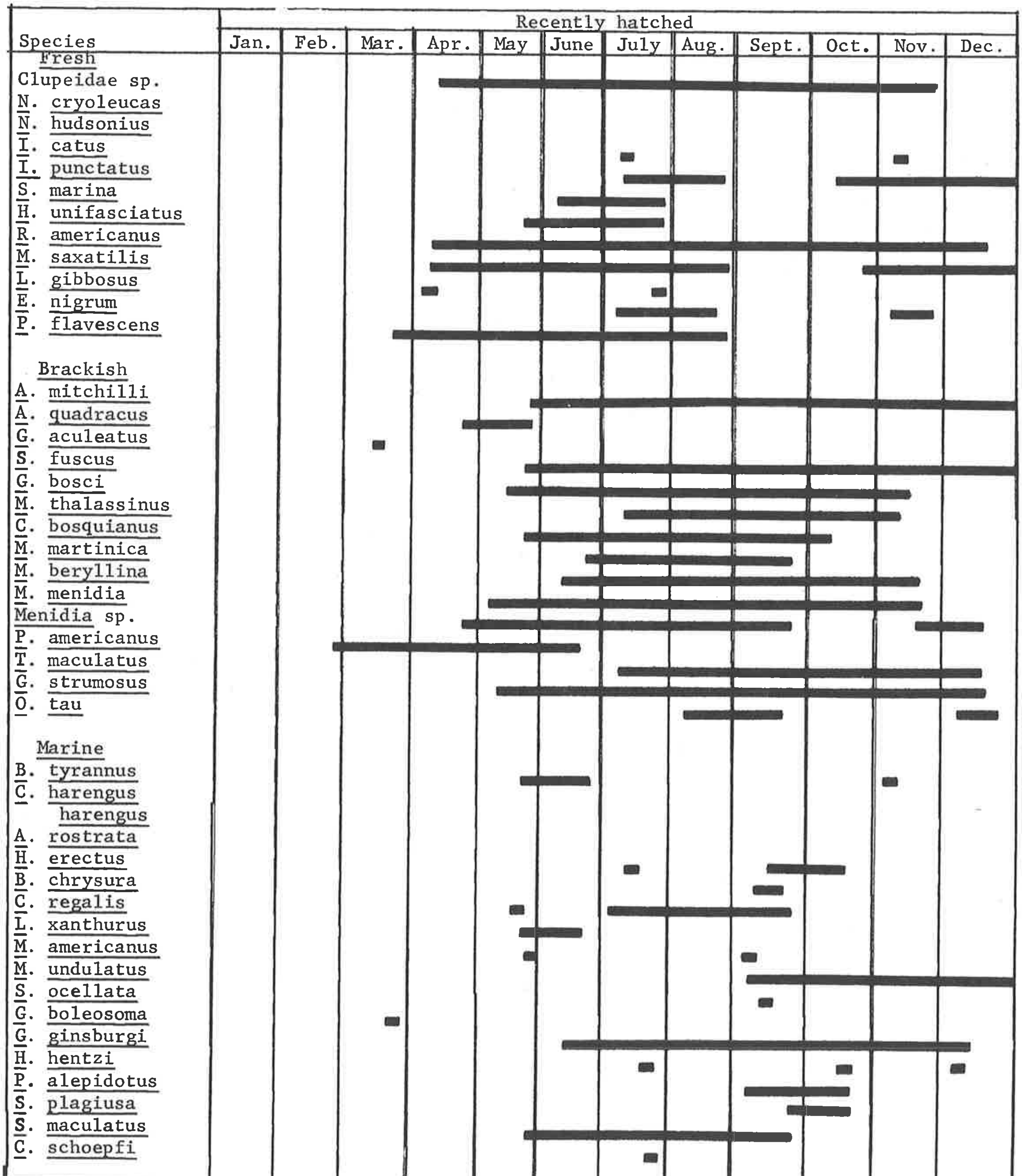

Table 6. (Cont.) Seasonal occurrence of fish larvae and juveniles collected by meter nets in upper Chesapeake Bay (1963-67). Bars represent recorded occurrence during organism's first year of growth.

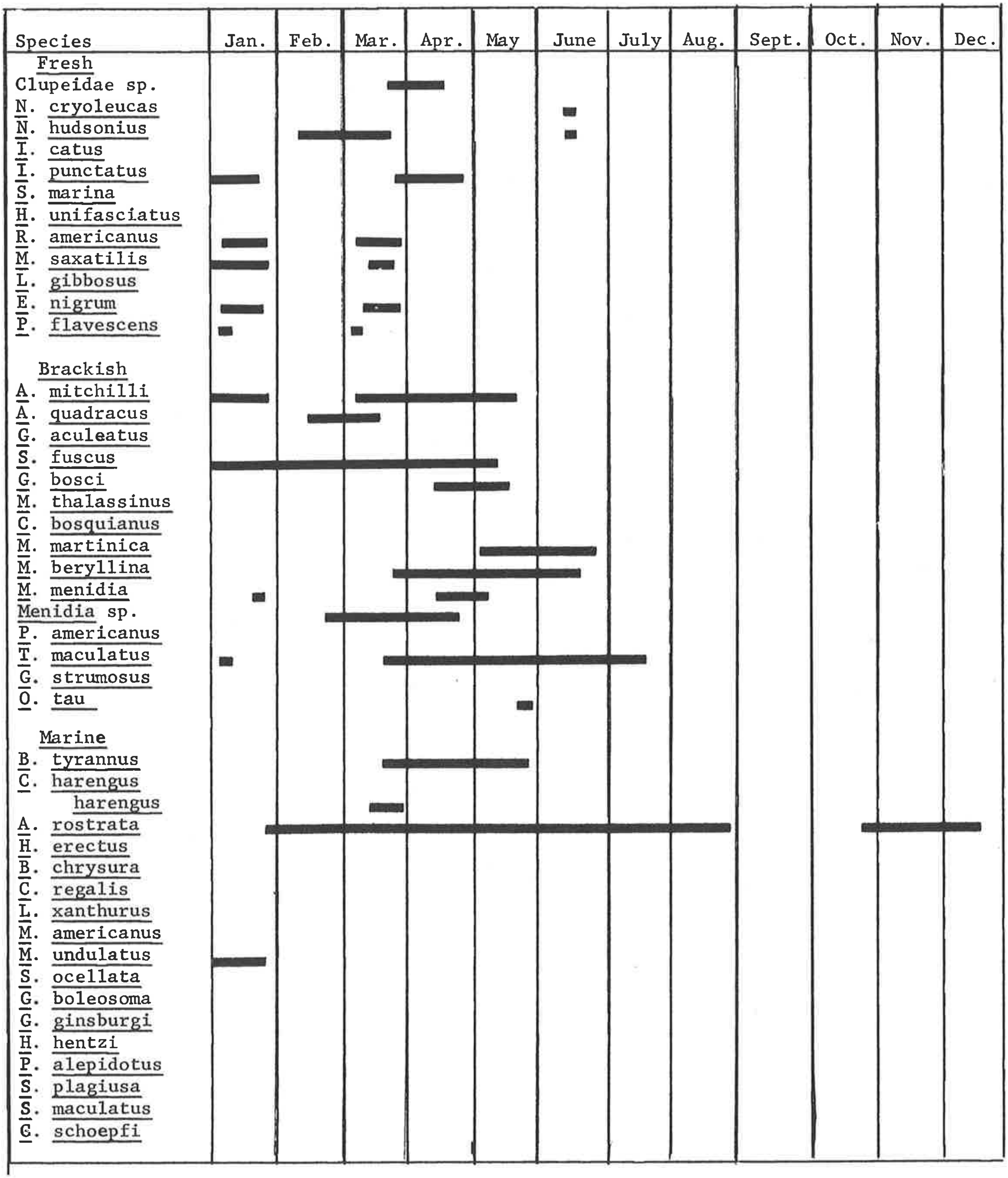

Table 7. Distribution of . larvae of the bay anchovy, *Anchoa mitchilli*, by water salinity. ..lections made in the Patuxent and Susquehanna River gradients - 1963-67.

Sal. o/oo	Patuxent River 1963	1964	1965	Totals	%	Upper Chesapeake Bay 1966	1967	Totals	%	Grand Total	%
23	26			26	+					26	+
22											
21	156			156	+					156	+
20	971		2	973	0.5					973	0.5
19	48	2		50	+					50	+
18	66			66	+					66	+
17	18	1	1	20	+					20	+
16	210	3	3	216	0.1	27	4	31	0.2	247	0.1
15	1,744	2	49	1,795	1.0	8	2	10	+	1,805	0.9
14	1,201	24	231	1,456	0.8	46		46	0.4	1,502	0.8
13	2,787	94	76	2,957	1.6	25		25	0.2	2,982	1.5
12	8,531	97	214	8,842	4.8	117	4	121	1.0	8,963	4.6
11	11,997	186	298	12,481	6.8	23	298	321	2.7	12,802	6.6
10	6,613	176	498	7,287	4.0	15	46	61	0.5	7,348	3.8
9	479	18	46	543	0.3	13	24	37	0.3	480	0.3
8	5,706	805	472	6,983	3.8	24	20	44	0.4	7,027	3.6
7	24,134	214	1,472	25,820	14.1	74	13	87	0.7	25,907	13.3
6	38,950	64	684	39,698	21.7	78	1,209	1,287	10.8	40,985	21.0
5	14,082	260	586	14,928	8.2	14	51	65	0.5	14,993	7.7
4	19,776	856	2,234	22,866	12.5	421	5,232	5,653	47.6	28,519	14.6
3	26,536	716	1,628	28,880	15.8	375	714	1,089	9.2	29,969	15.4
2	5,080	92	314	5,486	3.0	389	467	856	7.2	6,432	3.3
1	1,224	12	14	1,250	0.7	229	22	251	2.1	1,501	0.8
0	152	4	86	242	0.1	32	1,857	1,889	15.9	2,131	1.1
Total	170,487	3,626	8,908	183,021	99.8	1,910	9,963	11,873	99.8	194,896	99.9

Table 8. Distribution of fish eggs by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of eggs collected from various locations during several years.

Salinity o/oo	Species: *A. aestivalis*	*A. mediocris*	*A. pseudoharengus*	*A. sapidissima*
23				
22				
21				
20				
19				
18				
17				
16				
15				
14				
13				
12				
11				
10				
9				
8				
7		1		
6				
5				
4				
3			2	
2	16		6	
1				152
0	3,089		1,010	156
Total	3,105	1	1,018	308

Table 8 (cont.). Distribution of fish eggs by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of eggs collected from various locations during several years.

	Species				
Salinity o/oo	*B. tyrannus*	Clupeidae	*A. mitchilli*	*R. americanus*	*R. saxatilis*
23					
22	3,968		1,773		
21			92,783		
20	1,792		22,720		
19	13		211,096		
18	322		103,955		
17	9		52,288		
16	27		48,055		
15	70		340,794		
14	139		356,654		
13	81		449,826	1	
12	56		216,909		6
11			132,788	30	
10	24		15,724		18
9			114,979	8	
8			23,894		12
7			35,811	28	22
6			151,836	31	10
5		3	6,288	10	289
4			28,320		105
3		2	133	16	2,635
2		6,617	1,459	83	4,521
1		2,651	56	401	8,358
0		29,884		20,110	20,612
Total	6,501	39,157	2,408,141	20,718	36,588

Table 8. (Cont.) Distribution of fish eggs by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of eggs collected from various locations during several years.

	Species			
Salinity o/oo	*M. americanus*	*P. americanus*	*T. maculatus*	Total
23			388	2,158
22			155	5,896
21			53,050	145,833
20		1	7,986	32,499
19	358		15,959	227,426
18	269		90,378	194,924
17			43,315	95,612
16	117		47,261	95,460
15	247		47,912	389,023
14			46,686	403,479
13			22,979	472,887
12			17,797	234,768
11			1,793	134,611
10			10	15,776
9			24	115,011
8			40	23,946
7			9	35,871
6				151,877
5				6,590
4				28,425
3			4	2,792
2				12,702
1				11,618
0				74,861
Total	991	1	395,746	2,914,045

Table 9. Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity o/oo	*Alosa aestivalis*	*A. pseudo-harengus*	*A. sapi-dissima*	*Brevoortia tyrannus*	*Clupea harengus*	*Anchoa mitchilli*	*Notemigonus crysoleucas*
23						26	
22	1						
21						156	
20						971	
19						50	
18						66	
17						20	
16						247	
15						1,805	
14						1,502	
13						2,982	
12						8,963	
11	98			4	2	12,802	
10					2	7,348	
9				10		580	
8		2		68		7,027	
7	2			44		25,907	
6	14			42		40,985	
5		2		336		14,993	
4	2	4		70		28,519	
3	42	60		334		29,969	2
2	16	25		124		6,342	
1	2	48		1,090		1,501	
0	3,089	662	88	173		2,131	
Total	3,266	803	88	2,295	4	194,892	2

Table 9. (Cont.) Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity	Etheostoma nigrum	Perca flavescens	Bairdiella chrysura	Cynoscion regalis	Leiostomus xanthurus	Menticirrhus americanus	M. undulatus
23							
22				5			
21				9			5
20							
19						3	3
18							5
17				1			
16				1			38
15				1			17
14					2		4
13		24		15	1		50
12					1		23
11		43					14
10		44					6
9		59					18
8		9			14		44
7	24	79		2	4		45
6		38		6			19
5	29	200	1	1			16
4	20	29	1				23
3		355		2			2
2		942	6		2		1
1		1,041			13		11
0	2	9,571			4		1
Total	75	12,434	8	43	41	3	345

Table 9. (Cont.) Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity o/oo	*Notropis hudsonius*	*Ictalurus catus*	*Ictalurus punctatus*	*Anguilla rostrata*	*Strongylura marina*	*H. unifasciatus*	*Apeltes quadracus*
23				1			
22				5			1
21							
20				5			
19				4			
18							3
17							5
16							1
15				1			5
14				3	1		2
13							
12				4	3	1	3
11						1	
10							1
9							
8				4			1
7				14			4
6				6		18	
5							
4	2			4			
3				14			
2							
1	12			4			
0	18	8	46			2	
Total	32	8	46	69	4	22	26

Table 9. (Cont.) Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity o/oo	Gasterosteus aculeatus	Hippocampus erectus	Syngnathus fuscus	Roccus americanus	Morone saxatilis	Lepomis gibbosus
23						
22			1			
21		1	12			
20			5			
19		1	48			
18			8			
17			22			
16			42		1	
15			50			
14			45			
13		1	42	1		
12			71	9		
11			30	143	2	
10			6	63		
9			12	16	18	
8			10	150	4	
7			6	161	9	
6				226	2	
5			4	516	55	
4			2	55	5	
3			1	815	104	
2			2	730	87	
1	1			8,422	4,657	
0				80,985	2,475	2
Total	1	3	419	92,292	7,419	2

Table 9. (Cont.) Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity o/oo	Sciaenops ocellata	Gobionellus boleosoma	Gobiosoma bosci	G. ginsburgi	Microgobius thallasinus	C. bosquianus	Hypsob. hentzi
23			2				
22							
21			14				2
20			2				
19	1		5	166			
18			588				
17			11		1		
16			91		35	44	
15			318		9	29	
14			1,309		35	186	
13			3,987		8	124	
12			13,327		14	330	
11		4	51,446		2	178	40
10			20,244			63	
9			12,516		8	17	
8			13,770			4	
7			23,642				
6			20,287				
5			51,641			16	
4			34,797				
3			116,434				
2			135,658				
1			48,580				
0			1,201				
Total	1	4	549,870	166	112	991	42

Table 9. (Cont.) Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity o/oo	Peprilus alepidotus	Membras martinica	Menidia beryllina	Menidia menidia	Pseudopleuronectes americanus	Trinectes maculatus
23						32
22	2					1
21	1					36
20					1	47
19	1					37
18						3
17	13				33	17
16	13				104	33
15	15	1	1		385	86
14	3	11		4	1,035	101
13	42	1		14	440	28
12	16	2		78	1,000	58
11		16	1	28	1,949	30
10		52	4	33	418	26
9				66	660	54
8		16	22	147	3,590	122
7		16	6	448	39	22
6		128	75	38	2,043	28
5		2	17	44	112	74
4		122	102	56		90
3			20	40	2	57
2		41	69	10	19	11
1			27	138	1	840
0		21	33		3	214
Total	106	429	377	1,144	11,834	2,047

Table 9. (Cont.) Distribution of fish larvae and juveniles by water salinity in upper Chesapeake Bay (1963-67). Numbers represent total number of fish collected at various locations during several years.

Salinity o/oo	*Symphurus plagiusa*	*Gobiesox strumosus*	*Sphaeroides maculatus*	*Chilomycterus schoepfi*	*Opsanus tau*	Totals
23						61
22						16
21	10		2			250
20			1			1,032
19		1	2			322
18			1			674
17		1	1		2	127
16		2	4			656
15		1	3		5	2,732
14		156	17		1	4,417
13		9	2			7,771
12		255	1	2		24,161
11		66				66,899
10		25				28,335
9		6				14,040
8						25,004
7						50,474
6		12				63,967
5		5				68,064
4		2				63,905
3						148,253
2						144,085
1						66,729
0						100,729
Total	10	541	34	2	8	882,703

Table 10. Distribution of fish eggs by water temperature (^{o}C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of eggs collected at various locations during several years.

	Species				
Temp. ^{o}C.	*A. aestivalis*	*A. mediocris*	*A. pseudoharengus*	*A. sapidissima*	*B. tyrannus*
31					
30					
29					
28					
27					
26					
25					
24					
23					
22					3,425
21				38	
20					
19		1			28
18					66
17				48	70
16					67
15		1			184
14	2,788		184	44	5,963
13			308	176	65
12			218	2	58
11			1		
10			98		
9	219		9		
8	16				
7	82		212		
6					
5					
4					
3					
2					
1					
0					
Totals	3,105	2	1,030	308	9,926

Table 10. (Cont.) Distribution of fish eggs by water temperature (^oC) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of eggs collected at various locations during several years.

	Species				
Temp. ^oC	Clupeidae sp.	A. mitchilli	R. americanus	R. saxatilis	M. americanus
31		25			
30		2,049			
29		5,775			
28		6,578			
27		175,464			
26	8	474,390			
25		438,427		10	
24		292,535	6	8	
23		493,390			
22		209,463	72	20	
21	561	148,634	88	1,989	
20	1,763	128,467		2,104	
19	77	52,924	48	437	
18	64	31,981		1,332	
17		6,345	1	400	
16	13,273	13,245	12	444	
15	24	4,471	990	3,032	
14	6,188	13,158	1,808	7,111	627
13	11,376	11,435	2,773	16,279	
12	2,342		9,601	2,401	364
11	765	13	548	1,020	
10	2,193		4,650		
9	523	2	1,722		
8			862	1	
7			50		
6					
5			1		
4					
3					
2					
1					
0					
Totals	39,157	2,508,771	23,232	36,588	991

Table 10. (Cont.) Distribution of fish eggs by water temperature (°C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of eggs collected at various locations during several years.

	Species		
Temp. °C	*P. americanus*	*T. maculatus*	Totals
31			25
30		50	2,099
29		264	6,039
28		2,260	8,838
27		1,355	176,819
26		55,496	529,894
25		19,212	457,649
24		49,053	341,602
23		46,405	539,795
22		106,403	319,383
21		33,315	184,625
20		28,766	161,100
19		46,184	99,699
18		609	34,052
17		233	7,097
16		16	27,057
15			8,702
14			37,871
13			42,412
12			14,986
11			2,347
10			6,941
9			2,475
8			879
7			344
6			
5			1
4			
3	1		1
2			
1			
0			
Totals	1	389,621	3,012,732

Table 11. Distribution of fish larvae and juveniles by water temperature (°C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

	Species					
Temp. °C	*Notemigonus crysoleucas*	*Notropis hudsonius*	*Ictalurus catus*	*Ictalurus punctatus*	*Anguilla rostrata*	*Strongylura marina*
31						
30						
29						4
28				1	4	
27				1	3	3
26				4		3
25			8		9	
24	2	2		30	16	3
23					13	
22						2
21						
20					6	1
19						
18						
17						
16						
15					10	
14					20	
13					4	
12					6	
11					3	
10				1	13	
9		6			3	
8		8		2	6	
7		2	4	7	4	
6					2	
5		6		2	13	
4				2	6	
3		4			4	
2				2	4	
1		2		2	2	
0					2	
Totals	2	30	12	54	153	16

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (^{o}C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

Temp. ^{o}C	Species *Alosa aestivalis*	*Alosa pseudoharengus*	*Alosa sapidissima*	*Brevoortia tyrannus*	*Clupea harengus*	*Anchoa mitchilli*
31						940
30						922
29						3,402
28	6					5,728
27	540	56		29		60,550
26	36	22				40,780
25		16,148	12	10		39,556
24	12	173		218		16,708
23	108	50		738		15,092
22		1		257		646
21		2	200	178		1,184
20				286		1,674
19				66		216
18						784
17	2			48		5,992
16				62		155
15						7
14	2	2		70		414
13	12	1		13		19
12				5		609
11	6					42
10			3			24
9				8		90
8				2		8
7					2	137
6						1
5	6					40
4		1		1	2	25
3	2					1
2						14
1						1
0						6
Totals	732	16,	215	1,991	4	197,629

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (^{o}C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

	Species					
Temp. ^{o}C	Hyporhamphus unifasciatus	Apeltes quadracus	Gasterosteus aculeatus	Hippocampus erectus	Syngnathus fuscus	Roccus americanus
31						
30						
29					2	
28					2	166
27					9	320
26	2				34	175
25				1	47	8,259
24	1			1	70	793
23				1	23	333
22	18				36	229
21					37	877
20	1	4			14	30
19					61	6,621
18		1			107	8,549
17					20	5,478
16		1			4	106
15					2	1,758
14		1			3	19,611
13		3			4	31,672
12						15,214
11					5	1,879
10						254
9					2	120
8					2	1,888
7					1	15
6						
5					1	9
4			1			32
3		1				30
2						31
1						9
0		14			3	2
Totals	22	25	1	3	489	104,460

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (°C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

Temp. °C	*Morone saxatilis*	*Lepomis gibbosus*	*Etheostoma nigrum*	*Perca flavescens*	*Bairdiella chrysura*	*Cynoscion regalis*
31						
30						
29						90
28		2				52
27	1					138
26	2			15		29
25	4		8	4		12
24	94			1		16
23	2					
22	2					
21	283			28	3	2
20	176			4		
19	20			1	5	26
18	1,000					4
17	3,532			956		
16	2			7		
15	28			16		
14	332			2,099		
13	1,272			4,488		
12	447			6,634		
11		3		1,260		
10				268		
9				148		
8				2,009		
7	1		24	26		
6				66		
5			24	1		
4	4		21	3		
3	5					
2	3					
1	1					
0						
Totals	7,211	5	77	18,034	8	369

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (°C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

	Species					
Temp. °C	Leiostomus xanthurus	Menticirrhus americanus	Micropogon undulatus	Sciaenops ocellata	Gobionellus boleosoma	Gobiosoma bosci
31						24
30						2,572
29						19,905
28	3					122,715
27						101,998
26						54,828
25					4	117,094
24	2		2			48,176
23		2	3	1		72,039
22						18,567
21	5					1,860
20						70
19	14		4			842
18	1		1			130
17						152
16						20
15	15		3			30
14		1	2			1
13			2			20
12	1		30			
11			36			6
10			5			
9			28			
8						
7			34			
6			2			
5			19			
4			39			
3			18			
2			36			
1			5			
0			1			
Totals	41	3	270	1	4	561,049

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (^{o}C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

	Species					
Temp. ^{o}C	Gobiosoma ginsburgi	Microbobius thalassinus	Chasmodes bosquianus	Hypsoblennius hentzi	Peprilus alepidotus	Membras martinica
31			3			
30		2	5			
29		2	13			
28			6			58
27		19	72		1	72
26	1	8	298		7	71
25		31	167	40	21	105
24	1	49	248		36	405
23			60		26	150
22	28		152			18
21	3		64			
20	8		118			
19	1		1		4	
18	2		2			32
17	3					13
16					1	
15						
14		1				10
13	1					
12						
11	2			2		
10						
9	2					
8						
7						
6						
5						
4						
3						
2						
1						
0						
Totals	52	112	1,209	42	96	934

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (°C) in upper Chesapeake Bay (1963-67). Numbers represent total numbers of fish collected at various locations during several years.

	Species					
Temp. °C	*Menidia beryllina*	*Menidia menidia*	*Pseudopleuronectes americanus*	*Trinectes maculatus*	*Symphurus plagiusa*	*Gobiesox strumosus*
31		12				
30		30				
29	6	23		14		
28	32	35		35		
27	70	33		62		2
26	8	48		148		31
25	83	58		176		27
24	133	908		193		2
23	44	21		103		10
22	1	13		8		71
21	13	114		6		2
20		482		26		37
19		26		23		8
18		77		2		336
17			2	22		1
16		20	11	8		
15		1	25	1		
14	1		66	81		
13	2		317	66		
12	1	2	314	17		
11			2,066	34	1	
10		2	2,389	6		
9	2		653			
8	2		1,990	10		
7	24	2	741	36		
6			89	846		
5			3,169	73		
4	1		535	8		
3		4	41			
2						
1						
0						
Totals	423	1,911	12,408	2,004	1	527

Table 11. (Cont.) Distribution of fish larvae and juveniles by water temperature (^{o}C) in upper Chesapeake Bay (1963-67). Numbers represent numbers of fish collected at various locations during several years.

	Species			
Temp. ^{o}C	Sphaeroides maculatus	Chilomycterus schoepfi	Opsanus tau	Total
31				979
30				3,531
29				23,461
28				128,845
27			2	163,981
26	3	2	2	96,557
25	2		1	181,887
24	17		1	68,313
23	5			88,824
22	1			20,050
21				4,861
20	1			2,938
19	1			7,940
18	2			11,366
17				16,221
16	2			399
15			1	1,897
14				22,717
13				37,896
12				23,280
11			2	5,347
10				2,965
9				1,062
8				5,927
7				1,060
6				1,006
5				3,363
4				681
3				110
2				90
1			1	23
0				28
Totals	34	2	10	927,267

Table 12. Species represented by larval stages in collections from upper Chesapeake Bay (1963-67). Species arranged by order of abundance in the Patuxent River (A) and the upper Bay (C).

Species	Location of Collection: A Patuxent R. in order of abundance	B Upper Bay	C Upper Bay in order of abundance	Totals
Gobiosoma bosci	505,606	32,264	2	537,870
Anchoa mitchilli	179,674	15,218	3	194,892
Roccus americanus	32,243	59,319	1	91,562
Perca flavescens	9,195	3,239	4	12,434
Pseudo. americanus	8,750	3,084	6	11,834
Clupeidae sp.	5,968	-	-	5,968
Menidia sp.	5,889	-	-	5,889
Roccus saxatilis	6,272	1,147	7	7,419
Brevoortia tyrannus	2,282	13	21	2,295
Trinectes maculatus	1,661	386	10	2,047
Menidia menidia	936	208	14	1,144
Gobiesox strumosus	500	41	16	541
Chasmodes bosquianus	464	527	9	991
A. pseudoharengus	262	541	8	803
Syngnathus fuscus	218	201	15	419
Micropogon undulatus	122	223	13	345
Alosa aestivalis	160	3,106	5	3,266
Membras martinica	155	314	11	469
Menidia beryllina	86	291	12	377
Peprilus alepidotus	76	30	17	106
Anguilla rostrata	46	23	18	69
Notropis hudsonius	32	-	-	32
Cynoscion regalis	25	18	20	43
Cyprinodontidae sp.	10	-	-	10
Apeltes quadracus	7	19	19	26
Cyprinidae sp.	4	-	-	4

Table 13. Length frequencies of blueback herring, *Alosa aestivalis*, larvae collected in upper Chesapeake Bay. 1963 and 1967 data combined to produce a general pattern.

Size in millimeters	March	April	May	July	August	September	October	November
120								
115								
110								
105								
100								
95								
90		1						
85								
80		3						
75	1	2	1				2	1
70		1					2	
65						1	3	1
60						1	1	1
55							1	
50					3	4		
45				4	17	5		
40				4	9			
35			1	7				
30				1				
25								
20								
15					1	1		
10								
5								
0								

Table 14. Length frequencies of the white perch, Roccus americanus, larvae collected in upper Chesapeake Bay. Data for several years (1963-67) combined.

Size in millimeters	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
100	3				1			1	1		3	
95			1									
90	1									1	1	
85	2		1			2				2	6	1
80	5		7	1					2		8	2
75	10		3		2			1		1	13	1
70	8	1	7	2			1	2		1	7	3
65	13		5	8			3	1			9	3
60	8		8	3		1	7	1			5	1
55	8		2	1			2	1			1	
50	2		2				8	4				
45	1				1		1	6				
40						1	3					
35						3						
30						10	5					
25						16	13					
20					2	24	10					
15					7	42	18					
10						42	10					
5				28	40	26	13					
0			6	685	514	49	1					

Table 15. Monthly abundance of striped bass eggs from upper Chesapeake Bay, 1963-67. Data from the Patuxent River and Bay combined.

	Months of Collections					
	April		May		June	
Year	Total	%	Total	%	Total	%
1963	664	32.9	1,344	66.6	12	0.6
1964	48	87.5	1,150	12.5	-	-
1965	3,826	99.5	18	0.5	-	-
1966	3,818	32.1	8,085	68.0	-	-
1967	5,792	32.3	10,955	61.1	1,169	6.5
Grand Totals	14,148		21,552		1,181	

Table 16. Vertical distribution of the eggs of the striped bass (*Morone saxatilis*) by date and location of collection in upper Chesapeake Bay during 1966 and 1967.

		Sampling Dates					
		1966		1967			
Sampling Stations		April	May	April	May	June	Total
Havre de Grace	S[1]	-	-	2	-	-	2
	B[2]	-	-	4	-	32	36
Fishing Battery	S	-	-	-	-	-	-
	B	-	-	-	6	-	6
Chesa. City	S	1,352	372	2,134	856	240	4,954
	B	908	1,216	190	1,352	368	4,034
Old Courthouse	S	296	1,580	756	690	4	3,326
	B	1,002	3,098	1,210	470	96	5,876
I B	S	-	3	-	2	8	13
	B	-	136	-	-	-	136
I E	S	71	197	292	19	-	579
	B	50	449	173	2,440	36	3,148
II B	S	71	2	450	-	-	523
	B	1,124	20	336	-	8	1,488
II D	S	134	163	35	62	32	426
	B	5	12	42	18	148	225
III C	S	-	348	39	610	20	1,017
	B	-	190	6	184	7	387
III E	S	37	344	2	121	-	504
	B	-	-	3	303	132	438
IV B	S	17	6	8	154	-	185
	B	-	-	2	688	-	690
IV D	S	-	440	94	2,864	2	3,400
	B	-	12	-	44	16	72
V B	S	-	2	-	26	-	28
	B	-	-	-	46	-	46
V F	S	-	3	14	-	-	17
	B	-	-	-	-	-	-
Vert.	S	1,978	3,460	3,824	5,404	306	14,974
Dist.	B	3,089	5,133	1,962	5,551	843	16,602
Total		5,067	8,593	5,786	10,955	1,149	31,576

1 - S = Surface
2 - B = Bottom

Table 17. Length frequencies of yellow perch, *Perca flavescens*, larvae collected from upper Chesapeake Bay during 1966 and 1967. Data for both years combined.

Size in millimeters	January	March	April	May	June	July
101	1					
99	1					
98	1					
93						1
83		1				
45						1
36						2
35						1
34						1
27						1
22						
21						1
15				1		
14				3		
13				2		
12				4		
11				11		
10			12	32		
9			24	25	1	
8			81	8		
7		1	168	1	1	
6		1	248	3		
5			30	2		
4				2		

Table 18. Monthly abundance of the eggs of the bay anchovy (*Anchoa mitchilli*) from the Chesapeake Bay area for the period 1963-67 Includes samples from Patuxent and Magothy rivers and Chesapeake Bay.

	1963		1964		1965		1966		1967		
Months	No.	%	No.	%	No.	%	No.	%	No.	%	Total
April	2	+	-	-	-	-		-	-	-	2
May	35,127	1.9	56,014	13.9	36,273	10.6	1,220	0.9	-	-	128,634
June	212,202	11.5	74,224	18.4	58,922	17.2	75,184	65.2	170,924	28.5	591,456
July	1,478,203	85.4	110,653	27.4	204,862	59.7	38,747	33.6	423,090	70.6	2,255,555
August	23,243	1.3	163,331	40.4	42,933	12.5	23	+	5,011	0.8	234,541
September	-	-	-	-	60	-	-	-	-	-	60
Totals	1,748,777		404,222		343,050		115,174		599,025		3,310,258

Table 19. Relative sizes of bay anchovy eggs collected at different salinities. Each range and mean was calculated from 30 individual measurements.

Salinity	Major Axis		Minor Axis	
	Range	Mean	Range	Mean
5 o/oo	1.33 - .92	1.119	1.26 - .86	1.035
10 o/oo	1.36 - .86	1.045	1.15 - .83	.978
15 o/oo	1.12 - .84	.968	1.09 - .65	.896
20 o/oo	1.11 - .86	.949	.95 - .84	.887

Table 20. Frequency distribution of the larvae of the bay anchovy, *Anchoa mitchilli*, by month of collection, water salinity, and vertical distribution in the Patuxent River during 1963.

Salinity o/oo		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Station Total	%
	Surf	-	-	-	-	-	-	-	-	-		
23	Bot	-	-	-	-	26	-	-	-	-	26	+
	Surf	-	-	-	-	-	-	-	-	-		
22	Bot	-	-	-	-	-	-	-	-	-		-
	Surf	-	-	-	-	-	-	-	-	-		
21	Bot	-	-	-	151	5	-	-	-	-	156	0.1
	Surf	-	-	-	-	-	-	-	-	-		
20	Bot	-	-	2	969	-	-	-	-	-	971	0.6
	Surf	-	-	-	-	-	-	-	-	-		
19	Bot	-	-	12	34	-	1	1	-	-	48	+
	Surf	-	-	-	-	-	-	-	-	-		
18	Bot	-	-	-	49	-	-	14	-	3	66	+
	Surf	-	-	-	-	-	-	-	-	-		
17	Bot	-	-	-	-	9	9	-	-	-	18	+
	Surf	-	-	-	-	-	1	-	-	-		
16	Bot	-	1	1	198	1	1	-	-	6	209	0.1
	Surf	-	-	-	1,386	42	-	-	-	-		
15	Bot	-	4	-	91	210	5	-	-	6	1,744	1.0
	Surf	-	-	-	757	34	54	-	-	-		
14	Bot	1	-	1	110	43	190	6	-	6	1,202	0.7
	Surf	-	85	2	83	122	172	-	-	-		
13	Bot	-	-	-	52	1,671	596	4	-	-	2,787	1.6
	Surf	-	-	2	1,935	2,948	2,680	-	-	-		
12	Bot	13	-	16	658	382	206	2	-	-	8,842	5.0
	Surf	1	-	9	179	10,754	-	-	-	-		
11	Bot	8	-	-	658	382	-	-	2	4	11,997	7.0
	Surf	-	-	159	648	3,798	1,738	-	-	-		
10	Bot	-	-	42	-	72	152	2	2	-	6,613	3.9
	Surf	6	68	79	80	188	-	-	-	-		
9	Bot	8	-	22	24	-	-	-	4	-	479	0.3
	Surf	6	-	826	-	284	4,024	-	-	-		
8	Bot	-	566	-	-	-	-	-	-	-	5,706	3.3
	Surf	-	540	8	1,428	16,012	6,000	-	-	-		
7	Bot	62	2	28	24	-	30	-	-	-	24,134	14.2
	Surf	-	434	230	314	37,304	-	-	-	-		
6	Bot	-	-	8	10	566	-	-	-	84	38,950	22.8
	Surf	-	1,544	684	994	6,750	1,340	-	-	-		
5	Bot	-	42	424	-	2,304	-	-	-	-	14,082	8.3
	Surf	-	82	186	19,208	-	-	-	-	-		
4	Bot	-	-	-	160	-	140	-	-	-	19,776	11.6
	Surf	84	-	116	200	22,172	3,604	-	-	-		
3	Bot	-	110	10	-	240	-	-	-	-	26,536	15.6
	Surf	-	538	-	4,508	-	-	-	-	-		
2	Bot	-	-	4	30	-	-	-	-	-	5,080	3.0
	Surf	12	676	526	-	-	-	-	-	-		
1	Bot	-	12	-	-	-	-	-	-	-	1,226	0.2
	Surf	24	-	128	-	-	-	-	-	-		
0	Bot	-	-	-	-	-	-	-	-	-	152	0.1
	Surf	133	3,967	2,955	31,720	100,408	19,613	-	-	-	158,794	
	Bot	92	737	570	3,218	5,911	1,330	29	8	109	12,006	
Total		225	4,704	3,525	34,938	106,319	20,943	29	8	109	170,800	100.1
%		0.1	2.8	2.1	20.3	62.4	12.3	+	+	0.1	0.1	99.9

Table 21. Length frequency of bay anchovy larvae and juveniles collected in upper Chesapeake Bay. Data for several years combined (1963-67).

Size in millimeters	** 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
120																													
115																													
110																													
105																													
100																													1
95																													
90																													
85																													
80																									1	1		1	1
75																			4	1	3				2		2	6	3
70																			4	1	6			1	2	2	2	4	4
65																			1	3	13	1		3	4	4	8	15	13
60																			7	2	13		6	9	8	15	11	12	1
55																		1	7	11	10	1	12	19	9	12	5	1	
50	2	1																	10	5	29	1	11	9	14	1		1	
45												1							1		8		6	5	4	1	1		
40	4			3	1															2	1	1	2	1	1				
35	9	1		11	1											4				2			1						
30	8	3		10							1					1			3	1									1
25	2	3		3																									2
20																													9
15																										2	1	7	26
10																										2	44	12	48
5																			5	1						32	58	62	71
*0																											2	11	18
			Jan.					Feb.					Mar.					Apr.					May					June	

* Categories of 5 mm: 0-4.9, 5-9.9, 10-14.9

** Each month divided into 5 six-day periods; 31st day added to last period

Table 21. (Continued).

	1					1				1			1									1		1					
		1	1			3				1		1					1												
		3		3		2		2	1	1	1		1		3		1			1		1		1					
	3			6		7	1	4		2	1	2	2		3		1		4	1				2					
1	1	5	3	4		2	2	4	4	1	6	1	7		4		3		3					1					
2	3	4	1	7			2	2	10		4	2	5		5		3				1	1		1					
3	1	4		4		2	2		1	2	2		2		2		1		4			3							
1						2	3	2		2	1	1	4	2	20		22		11	2		4							
		1		3		6		3	2		1	2	8	4	59		28		12	3		5		2		1			
			1	3	2	9	4	3	5	4	11	4	5	7	89		35		13	3		5				4			
		6	7	4	4	21	15	13	14	1	10	3	5	1	53		21		23	3		11		4	1	5			
	1	15	5	5	4	35	21	16	15	1	5	4	2	4	62		33		32			13		5	1	1		1	3
	3	11	9	14	10	40	18	17	20		10	3	15	5	60		29		16	7	6	10		10	5	8	3	7	5
	4	31	11	23	7	48	9	29	35	5	16	4	13	7	28		25		8	4	4	13		2	3	6	1	5	2
10	23	35	32	60	13	44	5	21	34	9	30	13	32	13	57		13		4		1	4			1			5	
6	52	62	42	58	32	46	6	49	33	3	43	16	16	13	26		5					3			2			1	
	73	90	75	141	44	70	9	50	56		33	3	23		5		5		2			2							
5	35	148	93	148	61	79		45	12		7		6				3					1							
	25	95	44	61	33	22		18					1																
30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
		July						Aug.				Sept.							Oct.					Nov.				Dec.	

Table 22. Length frequencies of northern pipefish, *Syngnathus fuscus*, collected at Solomons, Maryland from 17 July 1961 to 25 July 1962.

	July 1961	Aug. 1961	Sept. 1961	Oct. 1961	Nov. 1961	Dec. 1961	Jan. 1962	Mar. 1962	Apr. 1962	May 1962	June 1962	July 1962
110	2									3	5	
105										1		1
100	1											
95												1
90			1							1		
85	1										1	1
80								1	1		1	1
75	2										1	1
70	1										2	
65	2										3	
60	2										2	1
55	7		1				1				2	
50				1	1						5	
45	6	1		3							29	
40	9	2		6						3	64	
35	4	1	2	3		1				11	55	
30	1		4	5	1					26	27	1
25	1		2	4						32	11	
20			2	8						30	11	1
15	1	1	2	13						48	18	
10		5	7	4						21	22	2
5		1									3	
0												

Table 23. Length frequencies of northern pipefish, *Syngnathus fuscus*, collected in upper Chesapeake Bay. Data from the period 1963-67 combined.

Size in millimeters																													
120																													
115																													
110																													
105																			1										
100																1				1									
95																													
90																													
85	1					1																							
80																		1											
75								1												1									
70											1																		
65																													1
60																													1
55																											1		2
50																											1		
45	1																										6		5
40																											10		7
35																									1	4	5		1
30																									4	1	4		3
25																									2	1	4		
20																									3	1	4		1
15																								1	14		13		2
10																							1	6	7		6		5
5																													
*0																													
**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
			Jan.					Feb.					Mar.					Apr.					May				June		

* Categories of 5 mm: 0-4.9, 5-9.9, 10-14.9.
** Each month divided into 5 six-day periods. 31st day added to last period.

Table 23. (Continued).

Size in millimeters	30	31	32	33	34	34	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
120						1																						
115																													
110																													
105						1																						
100				1																					2		1	
95																	1											
90				1																								
85				1																								
80				4																								
75																													
70				2																			1				
65				1					1																		
60			1	1																								
55			1													5								2		1	
50	3	1	4		1								1			2				1			3		1	
45	1	1	3	1	2	1					1			2		1		5				1							
40	2	1	9		3	1			3				2	4		2		1												
35	2	1	1										2				5												
30			2						2				2		2		7		3			1							
25				2		3						1	1	1		2		15												
20					2					1		2	1			2		17												
15					1				2			1	4	1		12		16		2										
10	1	1	4	1	3		1		5			19	2	2		13		17												
5						1		2			3				2														
0																													
		July						Aug.				Sept.					Oct.					Nov.				Dec.		

Table 24. Length frequencies of naked goby, *Gobiosoma bosci*, larvae collected from the Patuxent River during 1963.

Size in Millimeters	May	June	July	August	September	October
15					1	
14		1	1			
13		2	4			
12		11	20	4		2
11		19	40	14	5	7
10		14	54	37	31	5
9		8	42	25	21	3
8		14	39	22	14	1
7		23	29	26	16	2
6		30	36	36	18	
5		52	45	45	12	
4		66	46	17	1	
3		27	56	16		
2		1	15	4		
1						
0						

Table 25. Length frequencies of winter flounder, *Pseudopleuronectes americanus*, larvae collected in upper Chesapeake Bay. Data from several years (1963-1967) and idfferent locations combined.

Size in millimeters	February	March	April	May
23				
22				
21				
20				
19				
18				
17				
16				1
15				1
14				
13				
12				
11				
10			1	
9		2	32	
8		8	173	
7		23	161	2
6		60	155	
5		108	72	
4	1	166	19	
3	9	95	3	
2		7		
1				
0				

Table 26. Length frequencies of menhaden, Brevoortia tyrannus, collected in upper Chesapeake Bay, 1963-67. Data compiled from several areas.

Size in millimeters	**13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	51	52	53	54	55
120																							
115																							
110																							
105																							
100																							
95																							
90																							
85																							
80																							
75																							
70																							
65																							
60																1	2						
55															2	1	8						
50												3			1	11	2						
45												9	2	1	7	4	2						
40										2	3	10	4	6	8	7							
35	3				3	3		4	13	30	5	31	7	5	2	2							
30	1		4		7	6	9	6	27	37	6	15	4	3	1								
25			4		4	2		1	2	3				2									
20																							
15														4 1/									
10																				1			
5																							
0																							
	Mar.					Apr.					May					June					Nov.		

* Categories of 5 mm: 0-4-9, 4-9.9; 10-14.9. 1/(4 of 24 measured).
** Each month divided into 5 six-day periods. 31st day added to last period.

Table 27. Cumulative percentages of fish larvae collected from different salinity ranges in Chesapeake Bay. Data compiled from the Patuxent, Magothy, and Susquehanna River gradients during the period 1963-1967.

Salinity (ppt)	Percent			
0	11.4			
0-1	18.9			
0-2	35.2			
0-3	52.0			
0-4	59.2			
0-5	66.9			
0-6	74.1			
0-7	79.8			
0-8	82.6			
0-9	84.2	Total number		
0-10	87.4	of organisms	=	5,148,596
0-11	95.0			
		Eggs	=	3,879,478
0-12	97.7	Larvae	=	1,269,118
0-13	98.6			
0-14	99.0			
0-15	99.4			
0-16	99.5			
0-17	99.5+			
0-18	99.6			
0-19	99.6+			
0-20	99.7			
0-21	99.7+			
0-22	99.7+			
0-23	99.7+			

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