FISHES IN THE SHORE ZONE AND OTHER AREAS OF THE DELAWARE RIVER ESTUARY

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DELAWARE BOARD OF GAME AND FISH COMMISSIONERS

and the UNIVERSITY OF DELAWARE

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ABSTRACT

Information was collected during the period August 1958-February 1960, concerning the distribution of fishes in the shore zone in relation to the various environments found at sixteen sites within the Delaware River estuary and adjacent areas of the Atlantic coast. Over 54,000 fishes comprising 66 species were collected in the shore zone. Data were occasionally collected concerning the presence of these 66 species in the deeper waters of the estuary as well as the occurrence of 72 species not caught in the beach zone area. Measurements of salinity, temperature, oxygen saturation, and turbidity of the water were taken at the time of fish collection. Observations of tide condition, plant associations, bottom type and associated animals were also made at the collection sites.

A critical analysis of the relationship of these fishes to their environment has not been made, but the investigation provided an opportunity to delineate the parameters of the conditions under which these species are found. Many forms such as Pomatomus saltatrix, Leiostomus xanthurus and Cynoscion regalis were found over a wide range of salinity, temperature, and oxygen saturation values extending far up the estuary. Other fishes, such as

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4 The junior author was assigned the responsibility of preparing this report for the University of Delaware and submitting it to the Delaware Board of Game and Fish Commissioners. His role as author was secondarily acquired when the senior authors left the employ of the University before submitting a completed report to the Game and Fish Commission.

Trachinotus carolinus and T. falcatus, seemed to be restricted in their distribution with respect to these factors, and these species were found only in the lower part of Delaware Bay. The least amount of correlation was found between fish distributions and turbidity.

Heavy spawning activity seemed to be associated with several nearshore areas of the estuary. Our shore zone sampling areas, ranked in order of decreasing affiliation with spawning, were: Augustine Beach, Salem, Woodland Beach, Cape May, Lewes, Slaughter Beach, Fortesque, Moore's Beach, Cohansey River mouth, Reed's Beach, Bower's Beach, Great Egg Harbor, Townsend's Inlet, and Penn's Grove. The reproductive condition of specimens collected in these and other areas indicated a sequential spawning of both resident and non-resident species. Spawning periods for many of the species that were tolerant of low salinity waters seemed to be correlated with the time at which the adults of these species were found in the shore zones of the upper Bay.

Stomach analyses showed that at least 41 of the species studied were feeding heavily on small fishes (Anchoa mitchilli, Menidia spp.) and/or on benthic invertebrates. Areas supporting luxuriant growths of intertidal plants yielded great numbers of the small forage fishes and invertebrates. These areas were also found to be the areas richest in juvenile fish, indicating the value of such zones as nursery grounds.

INTRODUCTION

The biological productivity of estuaries ranks among the highest levels of production in any natural area (Odum 1959; 1961). This is supported locally by an evaluation of the productivity of the Delaware River estuary and immediate offshore area (Shuster, 1959), estimated at an annual multi-million dollar sport and commercial fishery harvest. Productivity and other scientific studies of estuaries are a relatively new endeavor, but there is sufficient amount of reliable data about the significance of estuaries in the natural production of protein foods to justify considerable concern over an apparent increased trend in the destruction of this productivity.

In recent years the water quality of the Delaware River estuary and adjacent areas has undergone a continuing and rapid change, as a result of increasing urbanization and industrialization of the Delaware Valley (see State of Delaware Intrastate Water Resources Survey 1959). These modifications of the water, though subtle, are nevertheless significant, and their cumulative effect is toward probable irrevocable change of the aquatic environment. For example, deforestation and poor land management in the upper Delaware River has resulted in higher temperatures of runoff water, with a lessened capacity for dissolved oxygen, and a higher load of silt and dissolved

nutrients (Buljan, 1959; Colman, 1950). Industrial and domestic pollution throughout the Delaware Valley, and spraying of insecticides during seasons of reproduction of aquatic species are compounding these changes. The inevitable threat of radioactive waste disposal or leakage in the marine environment (National Academy of Science - National Research Council, 1957), perhaps poses the greatest threat to the estuarine community, notwithstanding possible detrimental effects to the human consumers of the estuary's commercial products.

In all instances, alarm over what is happening to our estuaries (for examples, see Shuster, 1959; Goodwin et al, 1961; Thompson, 1961) is reinforced by the knowledge that we lack truly comprehensive data on biological, physical, chemical, and geological characteristics of the waters as they were 100, 50, or even 10 years earlier. The lack of a suitable yardstick by which to measure these changes will be more apparent as the trend of unnatural ecological changes continues in estuaries. Unless comprehensive surveys of these waters and the adjacent coast are begun at once, the next generation will similarly decry our lack of foresight for not making inventory of our present resources, moribund as they may be. The need for biological surveys was seen many years ago and initiated, for example by Dr. Reginald Truitt of the Chesapeake Bay Laboratory, Maryland, and Dr. Emmaline Moore of the New York Conservation Department. A similar inventory of the resources and hydrography in the region of the Delaware River estuary was initiated by Dr. Eugene Cronin in 1951 as a part of the program at the newly established University of Delaware Marine Laboratories. It seemed logical to the authors, therefore, to expand upon one of these inventory-hydrography studies, a shore zone fishes survey by one of our colleagues, Dr. Franklin C. Daiber (1952, 1954; reported also in Shuster, 1959). Accordingly, we proposed in 1958 an ecologically-oriented inventory of shore zone fishes as a part of the Dingell-Johnson fisheries research program in Delaware.

It was our purpose, in continuing the survey started by Dr. Daiber, to study the distribution and biology, and description of some of the physical and chemical parameters of the environment in which fishes are found at selected shore zone sites throughout the Delaware River estuary and adjoining areas. We have tried also to evaluate this estuarine, shore zone area as a nursery ground for juvenile fishes by comparing our haul seine data with that obtained in a study of the distribution and ecology of fish larvae in the estuary during 1960-1961. This latter study was carried out with a grant from the National Science Foundation (NSF Grant G-8774). We propose to present evidence that this estuary also provides vital support for one or more stages in the life cycles of many sport and commercial fishes.

HISTORICAL BACKGROUND

There are numerous publications dealing with estuarine species and with certain aspects of the estuarine environment. These publications are useful sources of information, particularly on techniques of study and some details of estuarine ecology. Collation of these many sources of information, important as it may be as background for our study, reached, however, a point of diminishing return. This is because there was a lack of specific applicability to the present study, especially in regards to chronological and geographical factors. Further, extensive ecological studies are rare, if not impractical or impossible, since a truly comprehensive ecological study would include a more detailed accounting of all the kinds of factors that have ever been studied and probably many more that even now have not been considered. In most instances ecological studies are limited by one or more of several factors: number and quality of researchers, extent and quality of facilities and instrumentation, duration of study, level of accuracy attempted in the study, geographical area being studied, systematic comparison with studies in other areas, etc. Despite these drawbacks and restrictions, several of which also limited our study, a considerable number of excellent studies pertinent to the ecology of estuarine species can be cited. We have selected a few of these to present a more complete background for estuarine studies in Delaware.

Studies in Other Geographical Areas

Some of the faunal studies on the populations of fishes on the shore habitat that should be consulted for background information on the diversity of inshore fish communities include investigations by: Bean (1889) in Great Egg Harbor, New Jersey; Sherwood and Edwards (1901) in New England; Gunter (1938, *et seq.*) and Arnold *et al.* (1960) in the Gulf of Mexico; Nichols and Breder (1927), Lobell (1939), Greeley (1939) and Perlmutter (1939) in Long Island; Pearse, *et al.* (1942) in North Carolina Warfel and Merriman (1944) and Merriman and Warfel (1945) in Connecticut; Mansueti (1950) and Hildebrand and Schroeder (1928) in Chesapeake Bay; Massmann *et al.* (1952) in Virginia; Smith (1907) in North Carolina; and Reid (1954), Kilby (1955) and Springer and Woodburne (1960) in western Florida. Studies of the estuary and shore zone as a habitat include those of Metcalf (1920), Milne (1940), Day (1951), Capstick (1957), Rangarajam (1958) and Trites (1960). The relationship of fishes to temperature is discussed by Doudoroff (1942), Gunter (1957a) and Mantelman (1958). Salinity relationships are covered by Sumner (1906, 1907), Chidester (1922), Massmann (1954), Gunter (1957b), Pearse and Gunter (1957), Canagaratnam (1959) and Renfro (1959). Huntsman (1918) and Merriman (1947) noted the effect of tide upon fishes. Studies on the food and feeding regime of estuarine fishes have been done by Townes (1937) in New York, Merriman *et al.* (1953) in New England, Cadenat (1954) and Longhurst (1957)

in West Africa, and Thompson (1957a,b) in Australia. Smith (1950) and Pearcy (1960) conducted biological studies in Long Island Sound, Filice (1958) in San Francisco Bay, and Light et al. (1954) on the intertidal invertebrates of central California.

Studies in the Region of the Delaware River Estuary

Until the advent of the University of Delaware Marine Laboratories in 1951, the history of studies on the fishes of the Delaware River estuary is brief; the list of prior publications is even briefer. Abbott (1878) commented upon freshwater and anadromous fishes in the Delaware River from the vicinity of Bordentown. Fowler (1906, 1920) catalogued the fishes of New Jersey, including the Delaware River estuary, and published (1911) a report on the fishes of Delaware. Subsequently, Fowler (1952) revised his 1906 list to include offshore species. June and Reintjes (1957) and Reintjes and Roithmayr (1960) reported on the commercial and sport fishes off Delaware Bay.

At the outset of studies at the University of Delaware, Mr. William H. Amos started a reference list to provide a bibliography on the hydrography and biology of the Delaware River estuary (Amos, 1956), in conjunction with other studies on invertebrates (Amos, 1952, 1954, 1960) and on the aquatic animals of Delaware (Amos, 1955). Daiber (1954:58-59) listed the fishes taken in lower Delaware Bay during the years 1951-1954 and has reported extensively upon the Weakfish (Daiber 1954, 1955, 1956, 1957, 1958). A review of these and other studies at the University has been included in the evaluation of the biological productivity of the estuary by Shuster (1959). Several brief studies on the hydrography and chemistry of Delaware waters have also been reported by us and our colleagues (Cronin, 1952, 1954; Shuster, 1956, 1959, de Sylva and Kalber, 1960b).

In addition to these publications many others have been issued by our Marine Laboratories: twenty-one technical Contributions; four semi-technical reports in an Information Series, four Biennial Reports (1952, 1954, 1956, 1958); and six volumes of general articles in the University's Estuarine Bulletin. Over fifty research reports, including this report, are still in manuscript form. One of the latest of these, on the Striped Bass, is by de Sylva (1961).

Although the study reported here was limited to that dealing with fishes found in the shore zone and deeper waters in the Delaware River estuary area, it is apparent that such a study could never be complete without a concomitant knowledge of the invertebrate associates, and the physical and chemical environment of these fishes. Concomitant studies on invertebrates and the environment are important to fisheries studies. We hope to point out in the ensuing discussion that environmental changes are among the predominant factors determining the

abundance of the fishes in the Delaware River estuary.

The immediate precedent for our study was that of Daiber (1952, 1954). He initiated a beach zone study (see Daiber, 1954:62)

> "in order to learn what species of fish inhabited the beach area, the effects of salinity and temperature changes on fish distribution in such an area, the importance of this zone as a nursery and the distinctness of the region as an ecological habitat."

Daiber's results should be consulted for comparison with our findings. Since they are reported in a recent biological evaluation report by Shuster (1959), we have not included much of this material in our report. He found during a one-year period (October 1952 through November 1953) at five stations (Lewes Beach, Slaughter Beach, Kitts Hummock, Woodland Beach, and Augustine Beach) on the western shore of Delaware Bay that the most abundant shore zone fishes were euryhaline species. Daiber's survey also indicated that the shore zone is a highly productive area for small, forage fishes and for the young of certain commercially important species. The Atlantic Silverside, Menidia menidia ranked first in year-round abundance and probable importance as a forage fish of the Delaware Bay shore zone.

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In the field we (DPdeS and FAKJr) were assisted by Mr. William P. Davis, a Research Aid at the University's Bayside Laboratory during the summer of 1959. Numerous other persons assisted us from time to time or donated specimens. Mr. Phillip H. Melson, master of the former research vessel Acartia, materially aided us in making trawl collections during 1958. Assistance in the titration of oxygen and salinity samples was rendered by Miss Patricia Pfordt and Mr. L. Rhodes Vessels, Research Aids at the University's Bayside Laboratory.

Mr. Robert E. Smith was the principle field investigator at the Bayside Laboratory in a National Science Foundation-sponsored ichthyoplankton program (NSF Grant G-8774) directed by one of us (DPdeS). Information that was obtained from these fish plankton

collections is acknowledged in the appropriate places in this report by the notation: de Sylva and Smith (NSF-Ichthyoplankton Project). As a part of this NSF-Ichthyoplankton Project, we identified the larval, juvenile, and adult fishes obtained by Mr. Thomas L. Hopkins in plankton tows at Indian River Inlet, Delaware, from July 1956 through July 1958. This zooplankton study was sponsored by a University of Delaware Research Foundation, Inc. grant to Dr. Carl N. Shuster, Jr.

Our shore-zone collection of fishes has provided material for another study. During the summer of 1960, Charlotte H. Purnell undertook a study supervised by one of us (DPdeS) on "Studies of the genus Menidia in the Delaware River estuary." Mrs. Purnell was recipient of an award in the National Science Foundation Research Participation for Secondary School Teachers program.

Acquisition of juveniles and adults was facilitated by the loan of collecting equipment through the courtesy of the Sport Fishing Institute, Mr. Richard H. Stroud, Executive Vice-President. The bibliography of unpublished graduate degrees in fishery biology, Jenkins (1959) also of the Institute, brought to our attention several of the references cited in this report.

We wish to thank the commander of the U. S. Coast Guard Station at Cape May, New Jersey, for allowing us to seine in the vicinity of the station. Numerous waterfront home-owners permitted us to collect from their properties.

The treatment of topics in this report is patterned after the monograph by Gunter (1945) on the marine fishes of Texas. Mr. Theodore P. Ritchie and Mr. Woodrow L. Whaley assisted in the final draft of the tables and figures.

MATERIALS AND METHODS

In 1958, shore zone collections were made at twenty sites along the shores of the Delaware River estuary and adjoining areas, from Indian River Inlet, Delaware to Great Egg Harbor, New Jersey. Subsequently, sixteen of these sites (see Fig. 1) were sampled approximately every two months. In comparison, Daiber's (1952, 1954) biweekly seining schedule enabled him to make an intensive study of five sites; we sampled less frequently, but obtained a wider geographical coverage. Our collecting sites, hereafter designated as sampling stations or stations, were selected because they were readily accessible and seining was relatively easy. Generally, a station was established in an area near to vegetation, bulkheads, or other structures which might provide shelter for young fish.

The sampling was done by two men with haul seine of 1/4-inch mesh, measuring 4 by 60 feet, with a 6-foot bag of 1/8-inch mesh sewn in the middle. Usually three hauls of about 50 yards

in length were made. The hauls were made parallel to the beach, although occasionally a perpendicular haul was made. Wherever feasible the seine was towed with the tide, since Paloumpis (1958), working in fresh-water streams, noted with few exceptions, that more specimens were taken towing with the current than against it.

At each station, upon completing the seine hauls, the water temperature was taken about one foot beneath the surface. Water samples were taken at the same depth for salinity and oxygen determinations in the laboratory; the methods of Knudsen (1901) and Oxner (1920), and Winkler (1888), respectively, were used.

Other observations were made on relative water clarity, condition of surf and sea, wind force and direction, sky cover and cloud type, vegetation, bottom type, and depth of water.

We collected 54,000 fishes comprising 66 species in the shore zone (Table 11). Of these, 30,450 specimens and 50 species, including 7 additional species, were taken at Lewes Beach (Table 12). The preponderance of numbers of specimens and of species at the Lewes site, in comparison to other sites, is largely a reflection of our greater, more frequent collecting effort at Lewes. All fishes, except only representative samples from large collections of silversides and anchovies, were preserved in 10 percent formalin; collections are stored in the Bayside Laboratory of the University of Delaware, Lewes, Delaware. Several references were used in the identification of species: Jordan and Evermann (1896-1900), Norman (1934), Breder (1948), and Bigelow and Schroeder (1948, 1953a, b).

The study on stomach contents by one of us (FAKJr) was tabulated, giving both the frequency of occurrence of food items and the size of the fishes (total length in centimeters), wherever sufficient fishes were available for examination. Occasional observations on food organisms is given within the textual description of a few fishes. A summary of the major food items in the stomachs of 2,055 specimens of 17 fish species is given in Table 49. Identifications of invertebrates were made with the aid of Pratt (1935), Miner (1950), Pennak (1953), and Eddy and Hodson (1955). Pearse (1949) was consulted for taxonomic nomenclature.

DESCRIPTION OF SAMPLING STATIONS

The shore zone of the Delaware River estuary area is characterized by shallow, gradually sloping sandy or muddy beaches which are often subjected to wave erosion. The following is a brief description of each sampling area:

Lewes Beach: Three areas were generally sampled: Roosevelt Inlet, along a jetty northeast of the Bayside Laboratory, and next to a partly submerged barge on the beach. The inlet is characterized by a fairly rapidly sloping beach,

composed of coarse sand which shifts readily with slight wave action. Below the low tide mark is a heavy mud substrate. The marsh plants Spartina alterniflora and Salicornia occur in the area. The jetty is a typical sandy beach situation with dune communities above the high water mark. The bottom is predominantly sand and gravel. The barge is the remnants of a derelict hull on the beach and is described by Amos (1959).

Slaughter Beach: This area is typical of others along lower Delaware Bay -- a sandy beach habitat, similar to Lewes Beach, but broken by a series of short, wooden groins perpendicular to the beach. The coarse sand characterizing the intertidal zone produces an unstable benthic habitat. Some detritus or bryozoa occurred periodically.

Bowers Beach: The region south of Bowers to north of Kitts Hummock is almost impossible to seine due to a nearly permanent heavy concentration of organic detritus which sometimes reaches more than a foot in depth. The detritus is composed of finely broken pieces of marsh plant rootstocks, and is often loosely cemented by marl and sand particles. This detritus was always very rich in mysids, and harbored the American Eel and White Perch, which were seemingly unaffected by the high silt content. Beneath the silt, the bottom is typically sandy; leading to a gradual, sloping beach. A few intertidal plants occurred in this area.

Woodland Beach: In profile this beach was relatively steep, becoming flat just below the low water mark. Coarse sand typified the intertidal zone, but the subtidal area was sand and gravel with a heavy coat of sticky mud. In the north part, remains of a jetty offered some protection from wave action.

Augustine Beach: This is a region of diverse habitats. The northernmost section is heavily covered with rushes (Scirpus); toward the center of the collecting area there were piles of gravel, rubble, and boulders on the sandy bottom. The southernmost sector was characterized by clay outcroppings, with some silt, sand, rubble and gravel interspersed. Rushes were patchy at the intertidal zone.

Penns Grove, New Jersey: This station was the furtherest upriver site, as well as the northernmost collecting area of the survey. It is centered between two industrial plants on the east bank of the Delaware River. The bottom is mainly gravel and sand, but the presence of much debris made collecting difficult. The beach is sandy; a wooded area is nearby.

Salem: The beach at Salem is somewhat similar to that at Augustine Beach, except that the bottom is mostly fine sand. Rushes were encountered along the shoreline in abundance during the warm months.

Cohansey River: The first few collections were made at the delta of the Cohansey River, in a typical tidemarsh region. The gently sloping shore was covered with marsh grasses, while the subtidal zone was a heavy, sticky clay, up to a foot deep. The intertidal zone was usually sandy. Later, a more accessible location was discovered at nearby Sea Breeze, and collecting was changed to this area. The habitat was roughly similar except for the relatively smaller amounts of clay in the subtidal zone, and in the reduced amount of dune and marsh grass.

Fortesque: This area is very similar to that of Sea Breeze, except for the higher content of detritus over the bottom. This was one of the most difficult areas to seine.

Moores Beach: Due to the heavy deposits of hard clay or mud which were exposed at low water, this area was also difficult to seine. Abundant stands of intertidal plants occurred along this beach. The interspersion of clay clumps and plants in the sandy stretches offered good protection for fishes.

Reeds Beach: The substrate at this area was similar to that found at Fortesque, but abundant sand outcroppings were more characteristic of this area, in spite of occasional heavy detritus.

Cape May Canal: This area was located at the western end of the Canal, next to the U. S. Coast Guard Station. The area is north of the northern granite jetty, and is a typical sandy beach habitat, exposed to the pounding of the surf, although a bar about 100 yards offshore reduces the surf somewhat. The bottom was primarily sand, but the circulation is poor because of the jetty, often resulting in an accumulation of detritus, debris and silt. The beach slopes gradually into the tidal zone.

Cold Spring Inlet: The inlet was collected only on three occasions. It was consistently poor in its fauna, and was characterized by fine sand bottom and broken shell. The water was generally clean and clear, in contrast to that of the Delaware Bay.

Hereford Inlet: This is very similar to Cold Spring Inlet, except that the surf is greater.

Townsends Inlet: This exposed area on the open Atlantic was subjected to severe surf pounding. Several bars offshore took the full impact of the breaking waves. The gradually sloping beaches were characterized by fine sand and broken shell.

Great Egg Harbor: The collections were made at Beesley's Point, a region well inside the bay away from the open Atlantic. The collection site was between two wooden bulkheads, where

the bottom was sandy, with extensive interspersed gravel beds. Tide marsh plants were well established along the shoreline and the water was generally clear.

ICHTHYOPLANKTON AT INDIAN RIVER INLET

A summary of our (de Sylva and Smith, NSF-Ichthyoplankton Project) analysis of the fishes collected in the plankton at Indian River Inlet by Hopkins (1958), during 1956-1958 (University of Delaware Research Foundation, Inc.-Zooplankton Project), is given in Table 50. This table provides data on the seasonal distribution of young fishes in the flood tide waters of Indian River Inlet, Delaware; both number of specimens and range of specimen size in millimeters is indicated. We identified 41 genera which included: one doubtful species identification, six unidentified species, and two genera in each of which we lumped two species. Six of the species listed under the 41 genera are in addition to the 131 species reported in the section on an "Annotated list of fishes collected in the region of the Delaware River estuary." When the results of the NSF-Ichthyoplankton Project are summarized, a few more species will undoubtedly be added to the list of 144 species in this report.

ECOLOGICAL CONDITIONS IN THE SHORE ZONE

Bottom Conditions

Sand, mud (comprised of silt and clay whose relative proportions were not determined), and detritus represent the three bottom sediments most commonly encountered (Table 1). Sand is predominant in the lower and upper stretches of the estuary, whereas mud and detritus typify the middle sectors. Detritus often formed a dense, water-logged mat overlying the sand or mud and, in some instances, was partially mixed into the heavier sediments. This detritus may have been responsible in part for the scarcity of fishes in the shore zone during the colder months. Tnere appeared to be a relation between bottom composition and season; for example, wind action during the winter months and the abundance of dead vegetation resulted in much detritus.

The texture of the sediments on beaches at or near several of our sampling stations was described by McMaster (1954): Townsends Inlet, Herefords Inlet, Cape May Canal, and Reeds Beach. In general, the sands of the Atlantic Coast are fine-textured; inside Delaware Bay the sands are medium to coarse.

Tidal Stage

Although we intended to make most of the collections during flooding tides or at high water, this was not always possible. A frequency distribution of all collections shows that the mean tidal stage (in hours) was +0.16; the range was from -7 to +7, when high tide time is designated as zero hours (Table 2).

Temperature

Temperature (Table 3) varies greatly in shallow water. The overall picture of temperature variation in the estuary shows that while the mean temperature was about the same for all areas, the range was greater in certain areas, and hence the fish fauna was subject to a greater range of conditions in those areas. In general, the seasonal pattern of temperature change at a site is indicative of its up bay or down bay location; this is largely due to the difference between increase or loss of heat in river water and in seawater. Also, those of our collecting sites near extensive tidal flats generally had a wider range of temperature than sites without associated flats.

Daiber's data (in Shuster, 1959: Table 2) are comparable to ours. The minimum-maximum temperatures at his five collecting stations were: Lewes Beach (4.5 to 28° C), Slaughter Beach (3 to 32° C), Kitts Hummock (3 to 36° C), Woodland Beach (2.5 to 29° C), and Augustine Beach (2 to 28° C).

A temperature-related factor, ice and slush (see Table 1), also creates an environmental condition which is more prevalent along the beaches than in deeper waters. This ice fringe undoubtedly causes, especially during formation and melting, a marked change in local salinity conditions of the shallow water. The erosion effect of ice is well known. This too undoubtedly alters local ecological conditions and must be considered in any detailed ecological study of the shore zone.

Salinity

The salinity regime of Delaware Bay and River (Table 4) is characteristic of estuarine conditions. Our data is comparable for those stations reported by Daiber (1954). Due to the river flow, salinity is lower in the headwaters of the estuary, but the range of salinity is less there than that encountered further downstream. In the western portion of the bay, where the river flow is more pronounced, the salinity gradient increases regularly toward the sea. Such a gradient is not as clearly defined along the eastern shore, where the circulation presumably is due more to Coriolis effect and other geostrophic forces on tidal currents than to river flow. Usually, the salinity values are an index to seasonal runoff conditions; seasonal changes in the salinity gradient are more pronounced on the western side of the estuary.

Oxygen

The biological significance of the values obtained for dissolved oxygen and oxygen saturation is difficult to evaluate because of the high amount of organic matter interfering with the chemical determination. Generally, oxygen values are lower in areas of high detritus. The Augustine Beach-Salem area is probably one of high autotrophic activity, as indicated in part by inorganic phosphate values (Kalber, 1960).

The high values of dissolved oxygen (Table 5) encountered in the shallow, upstream waters, might be due to oxygenation by wind and low salinity values. A similar picture is seen in the distribution of oxygen saturation (Table 6).

Dissolved oxygen follows closely the water temperature and river flow cycles, with flow rate the more important factor: the colder the water the greater the amount of dissolved oxygen (DO); oxygen-content of the water decreases when river flow increases (from U. S. Department of Health, Education, and Welfare; Public Health Service data). Dr. A. Joel Kaplovsky, Director of the Delaware Water Pollution Commission, has outlined to one of us (CNSJr) the probable role of surges in stream flow in decreasing the DO. Oxygenophilic substances, adsorbed to the surface of the sediments, are transported by the surges. These substances deplete the oxygen content of the water. Such a mechanism has obvious biological significance, and, Dr. Kaplovsky believes, may be an important factor in fish kills in the river portion of the estuary. Actually, the relationship between oxygen content of the water and the many physical, chemical, and biological factors which may alter it are even now not well understood (see Hull, 1960).

Tabular Summary of Shore Zone Ecological Conditions

Ecological data associated with the fishes collected in the shore zone are given in Tables 7 through 12. The data are given according to the frequency of collections in which the fishes occurred at: various temperatures (Table 7); various salinities (Table 8); various dissolved and saturation values of oxygen (Table 9); different tidal stages, water clarity, and bottom conditions (Table 10), and various localities and seasons (Tables 11 and 12). Our temperature and salinity data and the occurrence of fishes is similar to that of Daiber (see Tables 5 and 6 in Shuster, 1959).

ANNOTATED LIST OF

FISHES COLLECTED IN REGION OF THE DELAWARE RIVER ESTUARY

The following annotated list of 131 species of fishes includes those collected by seining along the shore, 66 species, as well as species collected or reported from offshore areas. Six additional species (Table 50) are reported from the ichthyoplankton of Indian River Inlet. Unless otherwise stated, measurements given in the discussion under each species are for the sexes combined and refer to total length in centimeters. The nomenclature and taxonomic sequence suggested by the American Fisheries Society (1960) has been followed almost entirely.

Carchariidae - Sand Sharks

Sand Shark, Carcharias taurus Rafinesque

One 40 cm. specimen was collected in the beach seine at Lewes on 18 August 1959. This species is rather commonly taken in trawls in Delaware Bay, where specimens over 9 feet in length have been taken. A 7-foot, 225 pound specimen was taken on hook and line in the estuary at New Castle, Delaware on 28 August 1960; our records show that the salinity at this point would be about 2 to 4 °/oo.

Lamnidae - Mackeral Sharks

Thresher Shark, Alopias vulpinus (Bonnaterre)

None were taken in the shore zone, but several specimens about 5 feet long were caught in trawl nets in lower Delaware Bay during the summer of 1960. This is a relatively common species in the menhaden purse seine catch, where it is evidently captured as it pursues the menhaden.

Carcharhinidae - Requiem Sharks

Sandbar Shark, Carcharhinus milberti (Müller and Henle)

One specimen, (61 cm. total length) was caught at Lewes on 18 August 1959, in the beach seine. Several were taken from gill nets at the Bayside Laboratory, Lewes, in 1960. They are taken often by trawlers in Delaware Bay, and apparently do not reach a large size in Delaware waters. Sandbar Sharks were one of the five most abundant elasmobranchs taken by otter trawl during the summer of 1958 (Bearden, 1959).

Smooth Dogfish, Mustelus canis (Mitchill)

This species is rather common during the summer along the beaches at Lewes and occurred in the beach-seine collections and gill nets. It was often taken on hook and line from the beach and was common in the trawl catches in lower Delaware Bay in 1959. One specimen was taken at Cape May in October. We captured young of 25 cm. in length, at a water temperature of 22.0° C. on June 20; these young bore fresh placental scars, indicating that they had been born recently. Salinity records for the captures at Lewes ranged from 27.5 to 28.6 °/oo. In the Bay, this species is replaced in the trawl catches from November to late spring by Squalus acanthias. During the fall and spring, the two species are sometimes taken together. These dogfish were one of the most abundant of elasmobranchs collected by otter trawl in Delaware Bay from June to September, 1958 (Bearden, 1959).

Blue Shark, Prionace glauca (Linnaeus)

On the night of 4 August 1958, while anchored in about 35 feet of water off Indian River Inlet, we attracted several dozen Blue Sharks, about 35-45 cm. total length, to our submerged night light. Numerous young butterfish (7-10 cm.) were in the area, and the sharks appeared to be making passes at the aggregations. Subsequent stomach examination of two sharks revealed one small butterfish in each, plus some well-digested fish flesh.

Atlantic Sharpnose Shark, Scoliodon terraenovae (Richardson)

None were taken in the beach collections, but one 70-cm. female was collected from a gill net set in 7 feet of water off the Lewes station on 6 May 1960. The water temperature was 15.0° C.

Sphyrnidae - Hammerhead Sharks

Bonnethead, Sphyrna tiburo (Linnaeus)

One 35 cm. female specimen was captured in a gill net at Lewes on 26 June 1960.

Squalidae - Dogfish Sharks

Spiny Dogfish, Squalus acanthias Linnaeus

The Spiny Dogfish occurred commonly in the gill nets at the Lewes station, but was not taken in the beach seine. It is

a common form in the winter trawl fishery, and apparently moves offshore or northward during the summer, when it is replaced in Delaware Bay by Mustelus canis. During our 1958 trawl studies it first occurred in lower Delaware Bay in November, when the bottom temperature had reached 11° C. Squalus was captured in the gill nets at Lewes as late as 21 June 1960, when the water temperature was about 22° C.

Squatinidae - Angel Sharks

Atlantic Angel Shark, Squatina dumerili LeSueur

None occurred in the shore zone, but this species is not rare in the trawl catches. It occurs at least as far into the Bay as the Bowers Beach area, where the mean salinity for the shore zone is about 19 °/oo.

Rajidae - Skates

Clearnose Skate, Raja eglanteria Bosc

Only one specimen, 30 cm. long, was taken in the beach seine. This species was first taken on 2 May 1960, in a gill net off the Lewes station. This species and the Little Skate have been studied intensively by Fitz (1956). Kalber (1962) has studied the digestion of natural food protein by this skate.

Little Skate, Raja erinacea Mitchill

This species was not taken during the beach-seining operations, but occurred in the gill nets off the Lewes station from the time the nets were first pulled on 2 May 1960 and again on May 4 and 6. Thereafter it was replaced by the Clearnose Skate, which is the predominant form in the Bay during the summer. Fitz (1956) found that this species enters and leaves Delaware Bay, during mid-October through November and mid-April through mid-June respectively, when the water temperature approaches 15° C.

Barndoor Skate, Raja laevis Mitchill

One 70-cm. specimen was collected from the gill nets set in 6 feet of water on 2 May 1960. This large species is not uncommon in the commercial trawl catches in Delaware Bay.

Dasyatidae - Stingrays

Roughtail Stingray, Dasyatis centroura (Mitchill)

A 40-cm. (disk width) specimen was taken on 2 August 1958, in a haul seine at the Lewes station. This form seldom occurs in very shallow water (see Bigelow and Schroeder, 1953: 358), but is common in trawl catches in the Delaware Bay. This species, relatively abundant in trawl catches in the Delaware Bay, and D. sayi have been studied by Hess (1959a, 1959b, 1961).

Bluntnose Stingray, Dasyatis sayi (LeSueur)

This form is said to be not uncommon in the shore zone at Lewes, but we took only four specimens in nighttime hauls at the Lewes station. These specimens averaged about 12 inches total length. Another specimen, about 1 foot long, was taken at Cape May in October 1959, at a temperature of 18.0° C. and a salinity of 28.6 °/oo.

Myliobatidae - Eagle Rays

Bullnose Ray, Myliobatis freminvillei LeSueur

During the summer of 1958, one hundred ninety one specimens of immature and mature Bullnose Rays were collected in Delaware Bay and studied by Bearden (1959). They occurred in water from 8 to 45 feet in depth, 18 to 26.2° C in temperature, and 24.77 to 30.22 °/oo in salinity. Stomach contents yielded large numbers of moon snail shells, Polynices duplicata. The hermit crab, Pagurus pollicaris, and the edible mussel, Mytilus edulis were the only other food organisms of any great significance.

Acipenseridae - Sturgeons

Atlantic Sturgeon, Acipenser oxyrhynchus Mitchill

This species did not occur in the shore zone, but one specimen 20 inches long was taken in a trawl haul in lower Delaware Bay in 23 feet of water on 14 November 1958. The bottom water temperature was 10.9° C. A few sturgeon are caught each year by commercial fishermen in the Delaware River estuary (see back cover of the Summer 1959, Delaware Conservationist, 3 (3)).

Elopidae - Tarpons

Tarpon, Megalops atlantica Valenciennes

None occurred in the shore zone, but a dead specimen, approximately 4 feet long, washed in at Lewes Beach in August 1960. Another specimen of approximately the same size was reported to have been washed ashore at Indian River Inlet in July 1959.

Clupeidae - Herrings

Blueback Herring, Alosa aestivalis (Mitchill)

Adults were very abundant in the gill nets at the Lewes station in May and June, and during 1961 ripe females were reported from Bowers during the second week in April. The distribution of juveniles in the shore zone (Table 11; Fig. 1) shows that by March these have already penetrated far into the estuary and that the adults enter fresh water (0.93 °/oo chlorinity), probably as part of the spawning run. No Blueback Herring were taken in May in the beach collections. It appears that following their early growth in brackish waters, the juveniles move seaward with warm weather in July, further seaward by August, and leave the estuary by late fall.

Alewife, Alosa pseudoharengus (Wilson)

This species was not abundant in any seine hauls, although adults were commonly taken in trawls in lower Delaware Bay in the fall of 1958. Juveniles first appeared at Lewes in June and were taken again in August at Lewes, and as far upbay as Augustine Beach and Salem in August and October, respectively (Table 11; Fig. 2). The spawning period is not known in Delaware waters, but Hildebrand and Schroeder (1928: 90-91) note that this species ascends the rivers tributary to Chesapeake Bay. Its relative scarcity in our collections suggests that it swims in the deeper strata until it enters fresh waters, where it apparently spawns in the Delaware River estuary. Larvae ascribed to this species were collected at Augustine Beach by de Sylva and Smith (NSF - Ichthyoplankton Project).

American Shad, Alosa sapidissima (Wilson)

Adults were common in the gill nets in May 1960, but had been reported in lower Delaware Bay by the second week in April 1960. A few shad were reported taken during the first week of March 1961, off Bowers Beach. No juveniles were taken in the seines, but de Sylva and Smith (NSF - Ichthyoplankton Project) collected larvae at Augustine Beach.

Atlantic Menhaden, Brevoortia tyrannus (Latrobe)

This menhaden is common in the offshore waters of the lower Bay and in the waters outside the Delaware. June and Reintjes (1957) show the distribution of the fishery for adults in the middle Atlantic.

The upper parts of the Delaware River estuary are important as a nursery area for juvenile menhaden, where they frequent the rushes of the intertidal zone. June and Chamberlain (1959) have succinctly summarized the life history of the menhaden in the estuary and stress the importance of nutrients in the estuary in the production of plankton as menhaden food.

Length frequencies of young menhaden (Table 13) indicate that growth is fairly rapid during their stay in the nursery grounds. The seasonal distribution of juvenile menhaden is shown in Fig. 3. Menhaden probably spawn offshore from fall to spring and the young drift into the Delaware tributaries. de Sylva and Smith (NSF - Ichthyoplankton Project) collected postlarvae throughout the winter months. The larvae utilize the shore zone, and were particularly abundant near plants, where they could generally be found in abundance. In May the distribution in the estuary is widespread. Juveniles remain in the upper estuary in July. Adults were taken during July in the shore zone of lower Delaware Bay, as well as being taken in trawls from mid-summer to mid-November in the bay. Young menhaden often were found closely associated with juvenile jacks (Caranx hippos).

Menhaden of various sizes occur over a wide temperature and salinity range. As is the general rule (see Gunter, 1945), most of the specimens taken in low salinity waters were advanced postlarvae or juveniles, while adults did not penetrate below 20 °/oo.

Atlantic Herring, Clupea harengus harengus Linnaeus

One juvenile (39 mm. Total Length) was collected at Townsends Inlet on 15 July 1959 in association with Sphyraena and Pomatomus. The water was 21° C, and the salinity 26.0 °/oo. An adult (20 cm. T.L.) was taken in the gill net at Lewes on 6 May 1959, at a water temperature of 15.0° C. Postlarvae have been collected in plankton tows as far south as Indian River Inlet by de Sylva and Smith (NSF - Ichthyoplankton Project).

Atlantic Round Herring, Etrumeus sadina (Mitchill)

None occurred within the Delaware Bay, but this species was common in the stomachs of White Marlin, Makaira albida (Poey), caught by anglers between Five-Fathom Bank and Fenwick Shoals off the mouth of Delaware Bay, in less than 20 fathoms.

Atlantic Thread Herring, Opisthonema oglinum (LeSueur)

Two adults, 19 and 20 cm. T.L., were taken at Lewes on 2 August 1958 in a haul seine. A third, 20 cm. long, was taken in a dip net under a night light at Indian River Inlet on 3 August 1958.

Engraulidae - Anchovies

Striped Anchovy, Anchoa hepsetus (Linnaeus)

Stevenson (1958) has discussed the biology of this species in the Delaware River estuary. The Striped Anchovy was not a common species in our samples. Only 137 specimens were taken during our studies, the period of abundance being in August. They were present in the collections from March to October (Fig. 4), in areas of relatively high salinity (>22.5 °/oo); this is in marked contrast to the following species, which penetrates fresh water (Stevenson, op. cit.). Although the two species occasionally occurred together, A. hepsetus was always far outnumbered by A. mitchilli, which totaled several thousand in our collections. The centers of abundance seemed to be at Lewes and Cape May. The Striped Anchovy and four other small fishes (Sheepshead Minnow, Mummichog, Striped Killifish, and the Atlantic Silverside) found in tidewater areas were illustrated by Nancy H. Booth in the Summer 1957, Delaware Conservationist, 1(3):8-9.

Bay Anchovy, Anchoa mitchilli (Valenciennes)

This anchovy was one of the most widespread forms in the Delaware area, being absent only from December through March, and occurring at every station within the Delaware River estuary (Fig. 5). It occurred only once in Atlantic coastal water, at Townsends Inlet in October. This species, discussed extensively by Stevenson (1958), was found in waters from 14-32° C and from fresh water to high salinity (0-31 °/oo). Its abundance suggests that this ubiquitous species is an important factor in the economy of the estuary as an ecological system. Food studies conducted by us show that this is one of the more important forage fishes of the region for juvenile predatory fishes. Studies by other workers on food habits have shown that the anchovies rank high in importance as food for adult predator fishes.

Esocidae - Pikes

Chain Pickerel, Esox niger LeSueur

One specimen, 53 cm. total length, was collected at Roosevelt Inlet, on 14 June 1958, by C. M. Bearden in a beach seine. The salinity was approximately 22 °/oo and the tide was ebbing at the time of collection.

Synodontidae - Lizardfishes

Inshore Lizardfish, *Synodus foetens* (Linnaeus)

Two adults were found following a fish kill presumed to have been caused by algal decomposition at White House Cove, Indian River Bay, Delaware, on 18 August 1960.

Cyprinidae - Minnows and Carps

Goldfish, *Carassius auratus* (Linnaeus)

Several juvenile Goldfish were collected in the upper estuary, one of which was taken in a salinity of 5.4 °/oo. They occurred in February (Woodland Beach and Augustine Beach) and March (Augustine Beach), and ranged in length from 5-11 cm. Three unusually large adults, measuring approximately 40 cm. in length were collected from Penns Grove in February.

Carp, *Cyprinus carpio* Linnaeus

Juvenile Carp occurred in the collections of most months at Salem, Augustine Beach, or Penns Grove, in from fresh water to relatively low salt water (to 4.4 °/oo).

Silvery Minnow, *Hybognathus nuchalis* Agassiz

This was a not uncommon form in the upper regions of the collection areas, and while it was generally restricted to fresh water areas, two adults were taken at Woodland Beach in a salinity of 8.3 °/oo (Fig. 6). Unlike other cyprinids taken in our survey, it was not captured below 5° C. Probably this species and other freshwater forms follow the general pattern of moving downstream in the Delaware River during colder months, and when the water is less saline. Generally, they were taken over clean bottom, and in turbid to slightly turbid waters, characteristic of most of the freshwater areas sampled. A collection of 70 individuals, ranging from 5 to 17 cm. was made using rotenone on 24 August 1960, at Fort Mott, New Jersey.

Golden Shiner, *Notemigonus crysoleucas* (Mitchell)

A 10 cm. specimen was collected on 21 March 1959 from Augustine Beach, and a 15 cm. specimen was taken on 16 July 1959 from Salem. The latter occurred in a salinity of 4.4 °/oo. Both specimens were taken from among shore zone vegetation.

Bridle Shiner, Notropis bifrenatus (Cope)

This shiner was restricted to lower salinities than the following species (Fig. 7). Fifty specimens were collected, all in the upper part of the estuary at Salem and Augustine Beach. It was one of the few species taken during the very cold winter of 1958, at Salem, when two specimens were taken at a temperature of 0.1° C amidst extensive slush ice.

Spottail Shiner, Notropis hudsonius (Clinton)

This species is reported to be common in brackish waters of Chesapeake Bay, but we took only 12 adults on four occasions at Salem and Augustine Beach. These few occurred at from 5 to 29° C and from 0 to 4 °/oo, over sand bottom and at high water.

Ictaluridae - Freshwater Catfishes

White Catfish, Ictalurus catus (Linnaeus)

One juvenile, 12 cm. long, was taken at Penns Grove on 13 July 1959 at a salinity of 1.8 °/oo. Another specimen, 15 cm., was seined in the same location on 14 October 1959. This bore lamprey scars on the lower side and between the pelvic fins.

Brown Bullhead, Ictalurus nebulosus (LeSueur)

Bullheads were taken only in March at 2 stations, and in salinities less than 1 °/oo. One 12-cm. specimen was taken at Salem, and 25 specimens, from 10 to 12 cm., and one adult measuring 22 cm., were taken from Augustine Beach.

Anguillidae - Freshwater Eels

American Eel, Anguilla rostrata (LeSueur)

Although the exact number collected is difficult to state, since many quickly escaped from the beached seine, we recorded over 829 eels. It occurred sporadically in our collections, but was most abundant at Slaughter Beach, Bowers, Moores Beach and Fortesque (Fig. 8). The collecting sites of both areas were generally covered with finely ground plant stem material, probably originating in the tidemarshes. This detritus apparently served both as a substrate in which the eels lived and also for food organisms (Table 14). Their greatest occurrence was from May to October, when juveniles and adults were predominant, but elvers were collected by us in February and March. These were common over detritus-covered bottoms and in turbid waters. The elvers were found in large concentrations in tributaries and

small feeder streams in lower Delaware during February and March (Table 15).

Eels were taken in almost every ecological situation. They were equally distributed at all tidal stages, but seemed to be taken more often in turbid than clear water (Table 10).

Belonidae - Needlefishes

Flat Needlefish, Ablennes hians (Valenciennes)

One adult was collected in a haul seine off Lewes, in August 1958.

Atlantic Needlefish, Strongylura marina (Walbaum)

Juveniles (6-11 cm.) were taken throughout the estuary (Fig. 9), but usually only adults occurred in the southern part of the Bay (i.e., at Lewes). This species occurred in the warmer months, at a temperature of from 22 to 30° C, and a salinity of 2 to 30 °/oo.

Houndfish, Strongylura raphidoma (Ranzani)

One specimen, about 60-70 cm. long, was caught by hook and line by an unidentified angler off Roosevelt Inlet, at Lewes in the summer of 1958 and brought to the Bayside Laboratory. This tropical species is occasionally taken by anglers off Atlantic City, New Jersey and Ocean City, Maryland.

Hemiramphidae - Halfbeaks

Halfbeak, Hyporhamphus unifasciatus (Ranzani)

Three specimens, 16-17 cm., were collected by Charles M. Bearden using a dip net and night light, 21-23 June 1958. Two specimens, 10 and 13 cm., were taken at Lewes in a seine on 18 August 1959.

Cyprinodontidae - Killifishes

Sheepshead Minnow, Cyprinodon variegatus Lacépède

Although not commonly taken by us in the Delaware River estuary, several collections in tidepools in the marshes along Indian River, Rehoboth, and Assawoman Bays produced large samples of this species. A few occurred nearly year round in

the Delaware River estuary (Fig. 10), with the largest number being taken at Reeds Beach in October 1958 (110). Males in spawning coloration were taken in Assawoman Bay and Indian River Bay in July, but no similar individual was taken in the Delaware River estuary proper. Specimens occurred from 4 to 35 °/oo salinity and from 4 to 24° C.

Banded Killifish, Fundulus diaphanus (LeSueur)

The Banded Killifish occurred in brackish to fresh waters of the upper estuary, but it was never taken in the same collection as F. heteroclitus, which seems to replace it ecologically in the lower estuary. F. diaphanus occurred when the salinity was low (<1 °/oo) and at low temperatures (1 to 10° C). Like a number of freshwater species, it occurred in our collecting areas during the colder months.

Mummichog, Fundulus heteroclitus (Linnaeus)

The Mummichog was one of the commonest forms in the estuary and was taken during every month, and at all stations but Cold Spring, which was sampled incompletely (Fig. 11). The exact number collected is not known, but it probably exceeded 860. It appeared to be less abundant on the estuary's western shore than on the eastern. Salinity conditions (0-35 °/oo), tidal stage, water clarity, or bottom type seemed to be irrelevant in the occurrence of this species in our hauls.

Size range is given in Table 16. Food studies (Table 17) show that this species is predominantly a plant and detritus feeder. Movements of this species have been discussed by Chidester (1920).

Striped Killifish, Fundulus majalis (Walbaum)

While less abundant than the former species, this was nevertheless one of the more common species in the estuary (Fig. 12). This species was taken in somewhat higher salinities and temperatures than F. heteroclitus, and was taken in a range of 7-30 °/oo and a temperature range of 7-30° C. Even though it also occurred year round, it was uncommon along the Delaware side of the estuary north of Lewes. The salinity factor seems to be more important than for the Mummichog, and there seemed to be a very slight tendency for the species to be taken more at periods of high water than F. heteroclitus.

Adequate collections for comparing length frequencies of the sexes were not obtained, but one sample taken from Indian River Inlet in August shows that at least the larger males and females have distinct growth differences (Table 18). Whether this is due to differential growth rate or mortality remains to be demonstrated.

Food habits of this species (Table 19) are distinct from those of the preceding species. F. majalis fed more on animal food, and Limulus eggs were the predominant item. Since the Horseshoe "Crab" spawns in May or June, the occurrence of its eggs in the diet of the Striped Killifish is obviously seasonal. Shuster (1958) reported observing large schools of Fundulus sp. along the shores of Raritan and Delaware Bays during high water, feeding upon the eggs and larvae of Limulus washed out of the beach by the waves.

Spotfin Killifish, Fundulus luciae (Baird)

One 16-mm. specimen was collected by Mr. Oliver Crichton in a tidepool of Canary Creek, tributary to the Lewes-Rehoboth Canal, on 27 July 1959. The salinity was 41 °/oo.

Rainwater Killifish, Lucania parva (Baird and Girard)

One 38-mm. specimen of this killifish was taken in May 1959 at Slaughter Beach, and single specimens occurred at Cohansey and Lewes in July. Twenty were taken at Fortesque in July, and 35 were collected in Assawoman Bay in August of 1958.

Poeciliidae - Livebearers

Mosquitofish, Gambusia affinis (Baird and Girard)

Eight individuals, 25 to 35 mm. T.L., were collected in Assawoman Bay on 13 June 1958. The water was very clear, the temperature was 26° C, and they were taken with Cyprinodon variegatus, Fundulus majalis, and F. heteroclitus over sand bottom with clumps of red and green algae.

Gadidae - Codfishes and Hakes

Fourbeard Rockling, Enchelyopus cimbrius (Linnaeus)

None were collected in the shore zone, but adults of this species are occasionally captured in trawls or by anglers from the mouth of Delaware Bay and outside of the capes.

Atlantic Cod, Gadus morhua Linnaeus

One specimen, 70 mm., was collected at Indian River Inlet on 30 April 1957, by Mr. Thomas L. Hopkins.

Pollock, Pollachius virens (Linnaeus)

One specimen, 68 mm., was collected in the Delaware Bay shore zone at Cape May, on 17 March 1959. The salinity was 27.5 °/oo, and the temperature was 6.5° C. Another about this same size, was collected on 16 April 1957 by T. L. Hopkins at Indian River Inlet. A 14-cm. specimen was caught by us on hook and line on 8 July 1958 from among a rock pile at the "ice breakers" in the mouth of Delaware Bay. The depth was 15 feet, and the water temperature was about 22° C at the surface.

Silver Hake, Merluccius bilinearis (Mitchill)

No specimens were collected in the shore zone, but trawl collections made on 13-14 November 1958, produced subadults, ranging from 11 to 13 cm. These collections were made at five stations in lower Delaware Bay in from 18 to 27 feet of water. The bottom temperatures were from 10.7 to 11.8° C and the salinities ranged from 23.4 to 29.5 °/oo. One adult, 20 cm. long, was collected in a trawl in the mouth of Delaware Bay in September 1958.

Spotted Hake, Urophycis regius (Walbaum)

Eleven specimens from 11 to 14 cm. were taken, two were taken in March and four in May from Slaughter Beach, and five were taken at Reeds Beach in May. Adults are very common in the trawl catches in the Bay, and many were taken in trawl hauls from September to November 1958.

Squirrel Hake, Urophycis chuss (Walbaum)

A few adults of this species were taken by us in lower Delaware Bay on 14 November 1958. No juveniles were taken in the shore zone.

Gasterosteidae - Sticklebacks

Fourspine Stickleback, Apeltes quadracus (Mitchill)

This species was most abundant in February and March (Fig. 13). Twenty six specimens were collected, all about 3 to 4 cm. long. They occurred from 3 to 27° C and from 0 to 35 °/oo.

Threespine Stickleback, Gasterosteus aculeatus Linnaeus

Although this species was taken in the same collections as Apeltes, (Fig. 14) its distribution was somewhat more

restricted to lower temperatures (0-27° C) and salinities (5-13 °/oo). The greatest numbers occurred in Great Egg Harbor in company with Apeltes.

Fistulariidae - Cornetfishes

Cornetfish, Fistularia tabacaria Linnaeus

Two specimens were found entangled in patches of Ulva in White House Cove, Indian River Bay, following a fish kill presumed due to decomposing algae on 18 August 1960.

Centriscidae - Snipefishes

Longspine snipefish, Macrorhamphosus scolopax (Linnaeus)

A 7.2-cm. specimen was reported by Mr. Donald Kunkle, Oyster Research Laboratory, Bivalve, Rutgers-The State University of New Jersey (in Litt.), to have been caught or snagged by hook and line by Mr. Edward Bateman of Bivalve, about mid-July 1959. It was taken in Delaware Bay about four miles southwest of the can buoy at the upper end of Deadman Shoal. This is east of Bowers, at approximately 39°04' N, 75°07' W, in about 20 feet of water.

Syngnathidae - Pipefishes and Seahorses

Northern Pipefish, Syngnathus fuscus Storer

This is represented by 120 specimens, from 5 to 22 cm. long (Table 20; Fig. 15). It occurred from March to October, and was relatively widely distributed at different collecting stations. It penetrates well up into the estuary as the water warms up, and is taken at a wide range of salinities (3 to 30 °/oo) and temperatures (3 to 35° C). It occurred at all tide levels and water clarities, yet seemed to be less common over mud bottom than other types. The larvae were commonly found by de Sylva and Smith (NSF - Ichthyoplankton Project). Length frequencies (Table 20) indicate that growth is fairly rapid during their stay in the estuary. The appearance of small pipefish through October indicates a protracted season in the estuary or several spawning groups.

Spotted Seahorse, Hippocampus erectus Perry

One specimen was taken in a trawl in Delaware Bay in August, 1958, and a juvenile was captured at the surface in a plankton net on 23 August 1960, off Cape Henlopen.

Mr. Donald Kunkle reported (Ibid.) that they collected many from April to September during 1959 while dredging oysters in eastern Delaware Bay.

Centropomidae - Snooks

Snook, Centropomus undecimalis (Bloch)

A snook, probably the above species, was reported by Mr. Theodore P. Ritchie of the Bayside Laboratory, to have been taken by a spearfisherman about mid-July 1959 at the Fenwick wreck off Fenwick Island, Delaware.

Serranidae - Sea Basses

Black Sea Bass, Centropristes striatus (Linnaeus)

One juvenile was collected within the confines of the estuary; this was a specimen 35 mm. long, collected at Slaughter Beach on 24 March 1959. A 25 mm. specimen was collected by trawl in Delaware Bay on 28 July 1954. Several hundred dead specimens were picked up following a fish kill at Indian River Bay (see under Synodontidae, page 21). Juveniles are taken on hook and line, in fish traps, and in oyster trays in the Lewes-Broadkill Canal during the summers, and adults are commonly caught at the rock piles or "ice breakers" west of Cape Henlopen and also off Indian River Inlet. The largest fish are apparently caught farthest offshore.

Snowy Grouper, Epinephelus niveatus (Valenciennes)

Two specimens were captured on hook and line in Sinepuxent Bay, Maryland on 15 August 1960, and one of the specimens (11 cm. long) was donated by Mr. G. S. Patton. Although this Sinepuxent Bay is out of our regular collecting area, the occurrence of this species is noted here because of its scarcity in northern waters.

White Perch, Roccus americanus (Gmelin)

White Perch were taken in most localities and in nearly every collecting period (Fig. 16). They were most abundant in the middle stretches of the estuary, being relatively uncommon in high or very low salinity water. They occurred over a wide range of salinities (0 to 30 °/oo) and temperatures (0 to 30° C). At times they were abundant in turbid waters and over detritus-covered bottoms. Adults were commonly taken in trawl collections during the fall of 1958, and ripe males and females were captured in mid-November. In July and August 3 to 4 cm. individuals

were taken at Penns Grove and Lewes, and evidently the young do not necessarily seek out a brackish-water habitat. The general biology of the White Perch is reviewed by Conover (1958). Several size groups are seen in the length frequencies (Table 21).

Food of White Perch (Table 22) consists primarily of amphipods, mysids and copepods.

Striped Bass, Roccus saxatilis (Walbaum)

Juvenile Striped Bass were common during the late summer and fall in the upper estuary (Fig. 17, Table 23). Adults weighing from 1 to 6 pounds are taken through the late winter and in the early spring in the tidal waters of southern Delaware. Many specimens were taken in brackish water, and, generally, R. saxatilis is found in fresher water than R. americanus (Table 8).

Small specimens (2 cm.) were taken at Lewes in June (Table 23). These specimens may have come from nearby Canary Creek, and the discovery of larval Striped Bass from Lewes in a salinity of 32 °/oo suggests that spawning occurs nearby. Spawning occurs in freshwater areas in May, and young were common in the nursery grounds at Salem and Augustine Beach. A sample of young taken from Penns Grove in August revealed over 80 percent with deformed fins. The proximity of a chemical plant suggests that industrial effluent might have affected these young during their development (see Krishna, 1953).

Striped Bass were generally abundant where shore zone plants occurred in the freshwater and brackish waters of the estuary. During the winter most bass apparently move to the deeper waters, where they are taken by trawlers.

The biology of the Striped Bass in estuarine waters is reviewed by Raney (1952). Food of Striped Bass in Chesapeake Bay is reported by Hollis (1952). Studies on young fishes from Delaware waters are given here (food items in Table 24), and elsewhere, in a more intensive study (de Sylva, 1961).

Lutjanidae - Snappers

Gray Snapper, Lutjanus griseus (Linnaeus)

One specimen, 20 mm. long, which appears to be this species, was collected at the Lewes station on 3 September 1959 by F. A. Kalber and W. P. Davis. The salinity was 25.5 °/oo, and the temperature was 25.2° C.

Priacanthidae - Bigeyes

Short Bigeye, Pristigenys alta (Gill)

Two specimens, 22 and 24 mm., were collected along shore of the Intercoastal Waterway at the 34th Street Bridge, Atlantic City, on 25 July 1960.

Centrarchidae - Sunfishes

Pumpkinseed, Lepomis gibbosus (Linnaeus)

Nine juvenile Pumpkinseeds were collected during the survey. Two came from Salem in July and seven were taken in February, March and August at Augustine Beach. They occurred in water with less than 0.5 to 7.2 °/oo salinity, and a temperature of from 5 to 29° C.

Bluegill, Lepomis macrochirus Rafinesque

Eight juveniles were taken, most of them in December, when they occurred at Woodland Beach, Penns Grove, Augustine Beach, and Fortesque (Fig. 19). One juvenile was taken in May at Augustine Beach, and one specimen, 22 mm. long, provisionally assigned to this species, was taken at Penns Grove in July. They occurred over a salinity range of from 0 to 12 °/oo and a temperature range of from 5 to 20° C.

Largemouth Bass, Micropterus salmoides (Lacépède)

One specimen, 17.5 cm. total length, was taken at Sea Breeze, near Cohansey River on 17 December 1959. The salinity was 7.3 °/oo, and the temperature was 6.0° C.

White Crappie, Pomoxis annularis Rafinesque

Five juveniles were taken, two at Augustine Beach in March and May, two at Penns Grove in August, and one at Salem in February (Fig. 19). They occurred in water with a salinity less than 2 °/oo, and temperatures from 1.2 to 19.5° C.

Percidae - Perches

Yellow Perch, Perca flavescens (Mitchill)

Three juveniles and one adult were collected in the upper estuary. Three came from Augustine Beach in February, October

and May, and one was taken at Woodland Beach. The salinity range was 0 to 6.3 °/oo, and the temperature was 4.8 to 19.5° C.

Pomatomidae - Bluefishes

Bluefish, Pomatomus saltatrix (Linnaeus)

Juvenile Bluefish were abundant in the shore zone of the lower estuary, and were collected in abundance at Lewes in July and August (Fig. 20). Juveniles occurred in clear to turbid water of the surf zone over sand bottom. They were often found in company with postlarval anchovies and clupeids. The juveniles seemed particularly abundant during the summer at Townsends Inlet, Lewes, and Indian River Inlet. While they are primarily taken in high salinity water, individuals occurred at Augustine Beach and Salem at a salinity as low as 3 °/oo. The young appear about the middle of June. Occasionally there is a run of large fish offshore, and a second one inshore, just preceding the inshore occurrence of the young. Borcea (1929) has described the inshore movement of juvenile Bluefish in the Black Sea. In Delaware waters, a few 1 to 2 pound individuals were taken by anglers off Slaughter Beach in early May 1959. Rapid growth occurs during the estuarine portion of their life (Table 25) where they feed predominantly upon fishes and mysids (Table 26). Growth of adult Bluefish has been studied by Hamer (1959). Aspects of the life history are summarized by Lund (1960) whose racial studies showed that the Bluefish drifting into Delaware waters were racially distinct from groups from adjacent waters. During August 1958, ripe females with freely running eggs were obtained off Indian River Inlet, but attempts at fertilization of the eggs were unsuccessful. Larval Bluefish of 4 mm. were collected from off Ocean City, Maryland, and larger larvae were taken from Delaware waters by de Sylva and Smith (NSF - Ichthyoplankton Project).

Carangidae - Jacks, Scads and Pompanos

Blue Runner, Caranx crysos (Mitchill)

An 18-cm. specimen was captured in July 1959, by an angler in Rehoboth Bay and given to the Bayside Laboratory.

Crevalle Jack, Caranx hippos (Linnaeus)

Young jacks were captured from July to August throughout the estuary (Fig. 21). Small specimens (from 2 to 4 cm.) occurred predominantly at Lewes from June to August, although these sizes also were taken further up the estuary during the late summer and early fall. A bimodal distribution in sizes and the appearance of a 3 cm. specimen in October (Table 27)

suggests that recruitment into the estuary is an extended process. By late October most jacks have left the collecting areas.

The juveniles occurred in salinities from 2 to 3 °/oo; no adults were captured.

Like most carangoids, juvenile jacks are apparently sight feeders and usually occur in relatively clear water over clean bottom. Stomach analyses (Table 28) show that benthic crustacea are important food items.

Round Scad, Decapterus punctatus (Agassiz)

This species was not taken from the shore zone at the regular stations, but two specimens, 10 cm. long, were taken from the intracoastal waterway at Atlantic City, New Jersey, at the 34th Street Bridge, on 25 July 1960. One adult was collected by a trawler in 35 feet of water in lower Delaware Bay on 17 September 1958, and adults are occasionally taken from stomachs of White Marlin caught off Delaware Bay. Young specimens, 30 to 50 mm., apparently this species, were found in the stomachs of Euthynnus, Sarda, and Pomatomus brought into Indian River Yacht Basin and Ocean City, Maryland. Most of those caught off Indian River Inlet were taken from 10 to 12 miles offshore.

Lookdown, Selene vomer (Linnaeus)

Three specimens, 42 to 46 mm., were collected in the surf at Lewes, on 23 July 1958, and a young specimen occurred at Lewes on 18 August 1959. The water temperature at the latter station was 23.5° C. A fifth specimen, 40 mm. long, was captured from rather heavy surf at Indian River Inlet on 18 July; the temperature was 20.5° C.

Banded Rudderfish, Seriola zonata (Mitchill)

Two specimens, about 20 cm. long were caught off Indian River Inlet in August 1959. One was taken in the Lewes-Rehoboth Canal by Mrs. J. Volk at Lewes on 10 June 1959. Several juveniles, about 8 to 10 cm., were observed swimming about the pilings of the laboratory dock during July 1959. This species has been found in the stomachs of White Marlin caught off the New Jersey and Delaware coast.

Pompano, Trachinotus carolinus (Linnaeus)

Forty specimens were collected, all but one of them under 5 cm. One 14 cm. specimen was collected at Moores Beach in August 1959. All were taken during July and August (Fig. 22)

in rather high salinity water (18 to 30 °/oo) and Fortesque was the fartherest point up the estuary this species was captured. It was common in the surf at Lewes in July.

Permit, Trachinotus falcatus (Linnaeus)

Twelve specimens were captured from July to October; eight at Lewes, two specimens at Fortesque, one at Reeds Beach in October, and one at Moores Beach in August (Fig. 23). They occurred generally in high salinity water (19 to 30 °/oo).

Coryphaenidae - Dolphins

Dolphin, Coryphaena hippurus

No juveniles occurred in the shore zone but adults are taken during the late summer by trawling vessels off Indian River Inlet, and a few are caught near Five Fathom Bank.

Pomadasyidae - Grunts

Pigfish, Orthopristis chrysopterus (Linnaeus)

This species was taken once, September 1959, in the shore zone at Lewes; temperature 27° C and salinity 27 °/oo.

Sciaenidae - Drums

Silver Perch, Bairdiella chrysura (Lacépède)

Silver Perch were taken from June to November and occurred throughout the estuary (Fig. 24). Post larvae and juveniles often were taken in extremely turbid water and in heavy detritus. Although juveniles occurred upstream, post larvae and small juveniles (2 to 3 cm.) were taken only at Slaughter Beach and Lewes, suggesting that spawning occurs in waters of higher salinity. Growth in the estuary (Table 29) is rapid. Presumably, this species moves into deeper water of the Bay in the late fall, for in mid-November the adults and young-of-the-year were not uncommon in trawl collections made in the fall of 1958. Food studies are presented in Table 30.

Weakfish, Cynoscion regalis (Bloch and Schneider)

The comprehensive studies by Dr. Daiber and his students from 1952 through 1960 on the biology and ecology of the weakfish have contributed much information on this species in the

Delaware Bay area. Data reveal that waves of adult Weakfish entered Delaware Bay during the years 1952-1956 (Daiber, 1957). Each year the largest fish arrived first, from late May through early June, followed by waves of progressively smaller, younger fish. Roe condition during the spawning season was reported by Seguin (1959). Harmic (1958) found that spawning occurred near the Delaware shore in two peaks, in early June and early July, and that hatching occurs over a wide range of salinities (12 to 32.5 °/oo). Fitz (1955) briefly described the development of the Weakfish egg from the time of fertilization up through hatching. Juvenile Weakfish were taken by us from July to November (Fig. 25 and Table 31). By July, the juveniles are widely distributed in the estuary in salinities as low as 3.9 °/oo. A few were taken upstream in late October, 1959. We took them by trawl in November 1958, from deeper water. Daiber (1954, 1955) collected juveniles from late July through the early fall in commercial and experimental trawls. The habits of the young and their distribution closely coincides with that of Bairdiella, although the latter apparently is more widespread in the estuary in the fall. Studies on the food habits (Table 32) show a wide variety of items taken, with crustaceans of considerable importance.

Results of a study on the escapement of one and two-year old Weakfish from trawl nets has been reported by Daiber (1958b). Escapement through a two-inch mesh is less than 10 percent; a three-inch mesh allowed escapement of 83% to 53% for the one and two-year old fish respectively.

Weakfish have supplied data for three statistical studies (Werner, 1957; Hager, 1958; Seguin, 1960). In the latter study, a number of meristic and morphometric analyses were made of young-of-the-year collections from Long Island Sound to North Carolina. From these analyses, Sequin (1960) determined that there probably were three populations of Weakfish along the middle Atlantic coast.

Spot, Leiostomus xanthurus (Lacépède)

Young (2 cm.) first appeared in April at Lewes, and by May they were distributed as far as Augustine Beach, where fourteen specimens of this size were taken in low salinity (2.0 °/oo) water. A sample of 191 specimens, 22 to 24 mm. long, was taken on 2 May 1959, by Dr. Daiber and students, using rotenone in Canary Creek, near Lewes. Young Spot remained in the shore zone of the estuary through August (Fig. 26) when specimens of 10 to 14 cm. were taken. Adults occurred in trawls in June, September, and October. Post larvae from the mouth of Delaware Bay were obtained by de Sylva and Smith (NSF - Ichthyoplankton Project). The biology of the species has been studied by Dawson (1958).

Northern Kingfish, Menticirrhus saxatilis (Bloch and Schneider)

Most of the juveniles of this rather common species appeared relatively late in the summer to late October (Fig. 27, Table 33). The smallest specimens occurred in the lower bay. Unlike most of the Sciaenidae taken during the survey, Menticirrhus was never taken in the upper estuary, and did not occur in water less than 8 °/oo, and it was common only in waters above 16 °/oo. The tendency for it to occur on the New Jersey side of the estuary suggests that it avoids areas of low salinity, and follows the general circulatory pattern of higher salinity water which moves into the estuary on the New Jersey side. Spawning may occur outside of the bay, and the young are carried into the nursery grounds. Growth of young kingfish (Table 33) is rapid; the appearance of small fish during October suggests that spawning is protracted, or that the progeny of several spawning populations enter our area. At least two year classes are found here during the summer, and larger adults are taken by anglers in the surf during the summer, and by trawlers in the deeper waters in the bay through October. Results of food studies are presented in Table 34.

Atlantic Croaker, Micropogon undulatus (Linnaeus)

Once abundant, adults of this species have virtually disappeared from Delaware waters, according to anglers and commercial fishermen. One adult was taken in the shore zone at Lewes on 23 July 1958 and a second was reported to have been picked up in a fyke net during June 1960. Another was found dead in the shore zone at Indian River Bay on 19 August 1960. Adults were reported by anglers from Salem in October 1959 where the salinity is about 3 to 4 °/oo and a few large adults are caught in the spring off Bowers (Fig. 28). A ripe male was taken in a trawl in lower Delaware Bay on 15 September 1958. Twelve young were taken in the shore zone at Reeds Beach in October 1958 and in 1959 at Slaughter Beach, Bowers and Cape May. Young did not penetrate the estuary very far, and none were taken in the salinity below 18 °/oo. They were not taken at temperatures below 14° C. Daiber (1954) had seined post larvae at Woodland Beach in October 1952, and at down bay stations in late fall, winter, and early spring, 1952-1953.

Black Drum, Pogonias cromis (Linnaeus)

Ninety-four drum were collected during this survey. During 1958, only eight were taken, and the remainder were taken during the summer of 1959 (Fig. 29, Table 35). According to veteran watermen, juveniles and adults are abundant during years when beds of Blue Mussels (Mytilus edulis) are extensive. During the summer of 1958, mussels were reported to be limited, while in the winter of 1958-1959 large sets occurred in lower Delaware Bay between Bowers and Slaughter Beach in an area where Blue Crabs are dredged (Hillman, 1959). Young Black Drum, 8 to

10 cm., were taken at Augustine Beach and Salem in August at salinities of 7.2 and 7.4 °/oo, respectively. Two specimens, 15 cm. long were taken in August 1960 at Salem in a salinity of 2.2 °/oo. Thus, unlike Menticirrhus, this species was not restricted to areas of high salinity.

An 18 mm. specimen was collected at Lewes near the shore, at the Bayside Laboratory dock by W. P. Davis on 6 July 1959. The tide was flooding, and the specimen was swimming with schools of Menidia. This species is the only one studied by us in which mollusks were important as food (Table 36).

Sparidae - Porgies

Scup, Stenotomus chrysops (Linnaeus)

Juveniles and subadults were common in trawls in the lower part of the estuary, but neither were taken in the shore zone. Adults are common at the rock piles and during 1960, very large adults (locally called "shad porgy") were taken just outside of the Delaware Capes.

Fifteen specimens 19 to 49 mm. were trawled by us from Delaware Bay on 28 July 1958. Four subadults were picked up along the beach in Indian River Bay on 19 August 1960.

Pinfish, Lagodon rhomboides (Linnaeus)

A 35 mm. specimen was collected by Mr. K. Price at Lewes Beach on 21 June 1960. Larvae were found at the mouth of Delaware Bay by de Sylva and Smith (NSF - Ichthyoplankton Project).

Ephippidae - Spadefishes

Atlantic Spadefish, Chaetodipterus faber (Broussonet)

None were caught by us, but an adult spadefish was reported caught at Lewes Beach during the summer of 1958.

Chaetodontidae - Butterflyfishes

Spotfin Butterflyfish, Chaetodon ocellatus (Bloch)

Three dead juveniles from 2 to 5 cm. were collected following a fish mortality in Indian River Bay (see under Inshore Lizardfish, page 21).

Labridae - Wrasses

Tautog, Tautoga onitis (Linnaeus)

One 4 cm. specimen was obtained from a mass of Ulva in a seine haul at Townsends Inlet on 25 August 1959. Numerous young, about this size, were observed by skin divers around the "ice breakers" off Cape Henlopen. Adults are common about these rock piles, as well as at the breakwaters off Lewes. A 5 cm. specimen was found along the beach at Indian River Bay on 19 August 1960, following a fish mortality.

Cunner, Tautogolabrus adspersus (Walbaum)

Two specimens 15 and 16 cm. were caught on hook and line at the "ice breakers" on 8 July 1958.

Scombridae - Mackerels and Tunas

Atlantic Mackerel, Scomber scombrus (Linnaeus)

One adult, 32 cm. long, was taken in a gill net on 6 May 1960 in Lewes. Mackerel have been reported to be formerly a common fish in the winter fishery operated by charter boats off Indian River Inlet.

Atlantic Bonito, Sarda sarda (Bloch)

None occurred in the shore zone but this species is occasionally taken by trawlers in the lower estuary. It is common in the sport fishery, and apparently comes closer to shore than most scombrids.

Istiophoridae - Billfishes

White Marlin, Makaira albida (Poey)

This species is caught by anglers in some numbers during the summer between Five Fathom Bank and Fenwick Shoals, Delaware, over depth of 20 fathoms. The occurrence and ecology of the White Marlin in the middle Atlantic bight has been reported by de Sylva (1959a, 1959c, and 1959d).

Blue Marlin, Makaira nigricans Lacépède

Blue Marlin are occasionally seen or hooked further offshore during the summer.

Xiphiidae - Swordfishes

Swordfish, Xiphias gladius (Linnaeus)

A juvenile, about 30 cm. from the tip of the bill to the hypural base, was taken from the stomach of a White Marlin caught by an angler on 4 August 1960, near Five Fathom Bank. The body of the fish was well digested but probably had not been in the stomach very long. Another specimen, also decomposed and about the same length, was taken from the stomach of a 25-pound Dolphin, Coryphaena hippurus, caught northeast of Ocean City, Maryland, on 13 July 1960.

Gobiidae - Gobies

Naked Goby, Gobiosoma bosci (Lacépède)

G. bosci was collected from July to October (Fig. 30). Unlike G. ginsburgi, it penetrated the estuary well into brackish water (8 °/oo). It was never abundant, and its secretive habits undoubtedly prevented capture of more of these by seine. It occurred between 15 and 29° C and was taken mostly at ebb or low tide. Two adults were trawled from 15 to 21 feet of water off Liston Point and off the Cohansey River on 27 October 1958. The larvae of this and the following species were abundant in the lower Delaware Bay plankton tows made by de Sylva and Smith (NSF - Ichthyoplankton Project).

Several 12 mm. specimens were collected in a tidepool on 23 July 1959, at Lewes. Larvae taken in plankton nets approached this size, so that those from the tidepool probably had settled recently.

Seaboard Goby, Gobiosoma ginsburgi (Hildebrand and Schroeder)

Thirteen specimens were collected on five occasions from Lewes between June and September. All were adults, the maximum size being 53 mm. They occurred in higher salinity water (22 to 30 °/oo) and temperatures were 22 to 25° C, and they were never taken at any place other than Lewes.

Triglidae - Searobins

Northern Searobin, Prionotus carolinus (Linnaeus)

One 2 cm. juvenile was collected from Lewes on 6 August 1959. Four 15 cm. specimens were found dead on the beach at Indian River Inlet on 19 August 1959. Adults are common in Delaware Bay during the summer and fall, and many are caught by anglers in the mouth of the Bay and in the ocean outside of the Capes.

Striped Searobin, Prionotus evolans (Linnaeus)

Although this species is common in trawl catches in the lower estuary, none were taken in the shore zone of the estuary. Twenty-two individuals, 7 to 11 cm., were taken at Indian River Inlet on 19 August 1959. Like P. carolinus, this species is a common constituent of the trawl catches. Specimens of evolans which we examined were generally considerably smaller than those of P. carolinus.

Dactylopteridae - Flying Gurnards

Flying Gurnard, Dactylopterus volitans (Linnaeus)

A 49 mm. specimen was taken from the stomach of a White Marlin caught near Five Fathom Bank, at the mouth of Delaware Bay on 30 July 1959.

Ammodytidae - Sand Lances

American Sand Lance, Ammodytes americanus De Kay

Two 7 cm. specimens were taken, both from a beach seine at Townsends Inlet on 15 July 1959. This species was observed to be a common item in the stomachs of Bluefish caught off of Indian River Inlet. Bluefish which were caught near the bottom seemed especially to have been feeding on sand lances. Larvae were fairly common in the plankton (de Sylva and Smith, NSF - Ichthyoplankton Project).

Uranoscopidae - Stargazers

Northern Stargazer, Astroscopus guttatus (Abbott)

One adult about 60 cm. was taken at Lewes in August 1958. Juveniles were taken from the shore zone in July at Lewes and at Woodland Beach and in October at Slaughter Beach.

Blenniidae - Combtooth Blennies

Striped Blenny, Chasmodes bosquianus (Lacépède)

Five adults were taken in June 1960, from trays used by one of us (CNSJr) in oyster mortality experiments in Rehoboth Bay, Delaware. Mr. R. A. Livellara informed us that blennies were common residents of these oyster trays in Rehoboth and Indian River Bays.

Ophidiidae - Cusk-eels

Striped Cusk-eel, Rissola marginata (De Kay)

Although adults are common in the trawl catches in the lower estuary, only three were taken in the shore zone by seines. Two sub-adults came from Cape May in July, and one was taken at Lewes in August. Juveniles have been taken by T. L. Hopkins in plankton tows at Indian River Inlet and three adults were picked up along the beach at Indian River Bay on 19 August 1960. Larvae were found in Delaware waters by de Sylva and Smith (NSF - Ichthyoplankton Project).

Stromateidae - Butterfishes

Butterfish, Poronotus triacanthus (Peck)

None were taken from the shore collections but sub-adults and adults occurred commonly in trawl catches in the lower estuary. Specimens ranging from 7 to 10 cm. were collected with a night light and dip net off Indian River Inlet on the night of 4 August 1958, where the depth of water was greater than 35 feet.

Sphyraenidae - Barracudas

Northern Sennet, Sphyraena borealis (De Kay)

This species occurred only in areas of relatively high salinity, 11 to 30 °/oo, the lower value occurring in Great Egg Harbor. Sennet were taken generally in clear water and over sand bottom. They occurred in Townsends Inlet, Great Egg Harbor and Lewes in July and at Hereford Inlet in August. At Lewes they first appeared in early June and were not taken after late July (Table 12). Only juveniles were captured, all of which were about the same size (Table 37). Their food (Table 38) consists primarily of fishes although mysids were also important.

Mugilidae - Mullets

Striped Mullet, Mugil cephalus (Linnaeus)

This species occurred in the same hauls as M. curema, and a few occurred throughout the year at Lewes (Table 12). During the summer it penetrates estuarine waters as low as 4 °/oo, somewhat lower than M. curema (Figure 31). Sub-adults and 2 to 3 cm. specimens occurred during the summer, but only small specimens were taken during the winter months. Spawning occurs well

to the south in late fall and the small specimens are those picked up as they first come in to shore (Table 39).

White Mullet, Mugil curema Valenciennes

Many specimens were taken during the summer and fall (Table 40, Fig. 32), but forty-one specimens, 2 to 3 cm. long, were collected in December of 1959 at Moores Beach (Table 11). Both species tolerate relatively low temperatures (2 to 6° C) but M. curema did not occur below 13 °/oo salinity. In contrast to M. cephalus, no sub-adults were taken until late August, when four occurred at Lewes.

Atherinidae - Silversides

Rough Silverside, Membras martinica (Valenciennes)

Although never common in the estuary, on three occasions it was the only atherinid in the seine hauls. A collection of four specimens was obtained in the Delaware River at Marcus Hook, near Chester on 3 September 1957, by the Academy of Natural Sciences of Philadelphia. The Rough Silverside was taken only in August, at Bowers, Cape May, Fortesque and Salem (Fig. 33). Generally, their number was rather large, and ranged from thirty at Bowers to four hundred seventy-five at Cape May. Plankton collections at Indian River Inlet in 1956 and 1957 by Hopkins (1958) contained a number of this species, and four adults were picked up along the beach at Indian River Bay on 18 August 1960.

Tidewater Silverside, Menidia beryllina (Cope)

This species was relatively rare in the areas studied. Specimens from the upper river were common in collections at the Academy of Natural Sciences in Philadelphia, but we took only twenty-eight in the entire estuary during our studies. Although it was collected on two occasions during the summer (Penns Grove and Cohansey), the Tidewater Silverside was taken more often during the winter (Fig. 34). From late fall to spring, like many freshwater forms, it tended to penetrate further into the Bay, and the appearance of it at several widely scattered down-Bay localities in December suggests that these may have dropped downstream from small tributaries of the Bay. It is not known, however, if populations of M. beryllina occur in the upper regions of these tributaries. M. beryllina was taken in waters with salinities of 0 to 27 °/oo; M. menidia, 2 to 35 °/oo.

Atlantic Silverside, Menidia menidia (Linnaeus)

M. menidia was the most widespread species taken during the study and next to Anchoa mitchilli it was the most numerous. No accurate estimate of the numbers collected is possible because of the huge schools encountered, but we estimate that the figure exceeded 25,000. In some cases it was necessary to spill part of the sample back in the water to bring the net in. This species occurred in every month, and was abundant at every station except Penns Grove, where only one specimen was captured, in October (Fig. 35, Table 41). It occurred in all habitats and in all salinities and temperatures encountered. Warfel and Merriman (1944) thought that turbidity might be a factor in limiting the availability of the species but our data did not suggest that M. menidia was any less available in turbid water. The life history of this species in Chesapeake Bay has been studied by Bayliffe (1950). Merriman (1941) reported on the growth of this species. Food studies by Kendall (1902) on specimens from Woods Hole, Massachusetts, showed that copepods are a predominant food. Our studies (Table 42) concur with Kendall's findings for a different habitat.

Bothidae - Lefteye Flounders

Smallmouth Flounder, Etropus microstomus (Gill)

A few specimens from 5 to 9 cm. were taken in the shore zone from June to October. Juveniles occurred only at Lewes, but a few adults up to 13 cm. were taken from trawl hauls in lower Delaware Bay. The three collections in the shore zone occurred at low water. The stomachs of two specimens contained Neomysis, a hermit crab, and soft molluscan remains; stomachs of four others were empty.

Summer Flounder, Paralichthys dentatus (Linnaeus)

Juveniles were taken from early June through late October (Table 43, Fig. 36). The smallest specimen, 4 cm., was taken in early June. The larvae, during late winter and early spring, drift into Delaware waters (de Sylva and Smith, NSF - Ichthyoplankton Project), but the occurrence of a 5 cm. specimen in October suggests late-spawned individuals drift in over a long period. The juveniles are well distributed throughout the estuary in May, but by August they have moved into the mouth of the estuary. They were not taken in water below 6 °/oo and most were taken in much higher salinities. They occurred in temperatures between 15 and 28° C and were taken at a variety of tides, water clarities and bottom types. Both juveniles and adults occurred in the shore zone, and in the late fall adults and large O-class individuals were taken in trawl nets. Food of this species (Table 44) consists primarily of mysids.

Fourspot Flounder, Paralichthys oblongus (Mitchill)

None occurred in the shore zone, but 8 to 16 cm. specimens were taken in trawl hauls in the lower estuary in October and November 1958. Of eight specimens examined, five had eaten Crangon, two contained Neomysis, and one was empty.

Windowpane, Scophthalmus aquosus (Mitchill)

This flounder was taken in the lower regions of the estuary, usually along sandy beaches (Fig. 37), from the end of April to October, although the period of relative abundance was greatest only through July (Table 45). Large trawl collections were made over sandy bottom in the lowermost portion of the Bay. Its distribution is very similar to that of Paralichthys dentatus. The two were often taken together, although the distribution of the juveniles is not restricted to sand bottom as seems to be the case in the adults. Food of the species is composed largely of mysids (Table 46). The biology of the species in New England has been studied by Moore (1947).

Pleuronectidae - Righteye Flounders

Yellowtail Flounder, Limanda ferruginea (Storer)

None occurred in the shore zone, but one 15 cm. adult was collected in a trawl on September 15, 1958, in lower Delaware Bay.

Winter Flounder, Pseudopleuronectes americanus (Walbaum)

This flatfish is represented by forty-eight specimens in the collection. Indian River Bay seemed to be important nursery grounds for the young which first appeared as 4 to 7 cm. individuals in early June (Table 47). They occurred in salinities from 8 to 30 °/oo and in temperatures from 6 to 28° C. This species and Paralichthys dentatus were taken together but, as seen in Tables 43 and 47, P. dentatus tends to be larger. Specimens collected by de Sylva and Smith (NSF - Ichthyoplankton Project) show that in the Delaware area larvae of P. dentatus drifted in earlier, in the early winter, whereas those of Pseudopleuronectes occur somewhat later in the winter (Fig. 38). During the fall, the two species apparently migrate into deeper water. While P. dentatus moves far offshore, apparently to spawn, Pseudopleuronectes remains in the coastal waters during the winter, departing in the late winter, presumably prior to spawning. McCracken (1954) discussed the age and size stratification of this species with depth. Food of the species (Table 48) is composed principally of annelids.

Soleidae - Soles

Hogchoker, Trinectes maculatus (Bloch and Schneider)

This is probably the most numerous flatfish in our area, but only a few specimens occurred in the shore zone and these were less than 10 cm. long. In contrast to their relative absence in the shore zone, great concentrations of adults occurred in trawl hauls made over mud bottom. Seldom was an accurate count possible in trawl hauls made in the Bay. In one instance four hundred eighty-five Hogchokers were taken by a 15-minute tow using a 30-foot, 2-inch mesh, otter trawl. This trawl was made off Fortesque, in 8 feet of water over mud bottom. In the shore zone at Lewes, the species only occurred in August and September but it occurred well up into the estuary in low salinity water (Fig. 39). A late post larvae, about 3 cm., was collected at Salem in August, 1959, in a salinity of 4.7 °/oo and in temperature of 35.1° C. Of fifteen stomachs examined (Table 49), twelve contained food and seven of these contained polychaetes. One contained crustacean remains and three contained unidentified soft remains. Castagna (1955) has discussed the biology of the species in Florida waters.

Echeneidae - Remoras

Sharksucker, Echeneis naucrates (Linnaeus)

None were collected by us but a specimen about 2 feet long was reported to have been caught on hook and line in Roosevelt Inlet during August 1958. Since large Sand Sharks (Carcharias) are not rare in this region, the occurrence of Echeneis is not surprising.

Marlinsucker, Remora osteochir (Cuvier)

This species does not occur within the Delaware River estuary, but occurs on White Marlin captured off the mouth of Delaware Bay. Specimens (18 to 20 cm.) are often taken from the branchial chambers of the marlin, and, more often than not, there are two individuals on each host.

Balistidae - Filefishes and Triggerfishes

Orange Filefish, Alutera schoepfi (Walbaum)

Four filefish were taken in a trawl off Lewes near The Shears shoal in Delaware Bay during August 1960. These were approximately 20 inches long. Skin divers report that they are common about the "ice breakers" near Cape Henlopen.

Gray Triggerfish, Balistes capriscus (Gmelin)

One 17 cm. specimen was collected in a trawl in early August 1959, in lower Delaware Bay. A second, larger specimen, believed to be this species was collected about two weeks later in a trawl, but data are not available on this specimen.

Tetraodontidae - Puffers

Smooth Puffer, Lagocephalus laevigatus (Linnaeus)

Two specimens, 20 cm. long, were collected in a fyke net at Lewes in October 1960. This species is, at times, abundant in Rehoboth Bay and, according to anglers, appears in great numbers in some years, only to disappear again for a period of several summers.

Northern Puffer, Sphaeroides maculatus (Bloch and Schneider)

This species was uncommon in our regular beach seine collections, but probably is just beyond the depth which we fished, since fyke hauls at Lewes produced quantities of adults, from 18 to 24 cm., during May and June 1960. The adults entered the area in late April or early May and work up the beaches of the lower bay (Fig. 40). Specimens taken in mid-May 1960 were ripe, and by July the young, 2 to 3 cm., began to appear in our beach seines. Juveniles occurred far up the estuary in salinity as low as 13 $^{o}/_{oo}$ in July. Specimens occurred in the estuary through late October.

Diodontidae - Porcupinefishes

Striped Burrfish, Chilomycterus schoepfi (Walbaum)

Two specimens were collected from a fyke net at Lewes in July 1960. The specimens were approximately 20 cm. long. Mr. Donald Kunkle, Oyster Research Laboratory, Rutgers - The State University of New Jersey, reported (in Litt.) that they collected two specimens at Bivalve, New Jersey, one of which was taken in September 1959.

Batrachoididae - Toadfishes

Oyster Toadfish, Opsanus tau (Linnaeus)

The toadfish is a common resident of the oyster grounds in the Delaware River estuary, but it was not common in our collections. Juveniles occurred from July to October (Fig. 41). They

occurred in waters 13 to 29 °/oo and were frequently taken among debris, at low tide, and over mud or silt bottom. The smallest individuals occurred in October 1959 and a ripe female was taken in July 1960. A specimen was taken at Woodland Beach, but this apparently was not unusual since fishermen report that the species is not uncommon, well up into the Bay.

Lophiidae - Goosefishes

Goosefish, Lophius americanus (Valenciennes)

This species never occurred in our beach samples. During the winter, however, several specimens in a moribund condition were observed in the shore zone at Lewes. During winter they are commonly taken by trawlers well up into Delaware Bay.

DISCUSSION

Resume of Accomplishment

In the preceding sections we have reported, to varying extents, the distribution, biology, and ecology of over 54,000 fishes representing 138 species occurring in the region of the Delaware River estuary; 66 of these species (see Tables 11 and 12) were obtained by use of a haul seine in the beach shore zone. A critical analysis of the relationships of these fishes to their environment was not made, but we have attempted to delineate the parameters of the conditions under which they are found.

We have both confirmed and extended the earlier shore zone fishes survey by Daiber (1952, 1954, and in Shuster, 1959). The latter report on his survey should be examined in conjunction with our report.

On the basis of experiences gained in this and other research, we outline in succeeding sections our interpretations upon: 1) the Delaware River estuary as a nursery area for fishes; 2) how man-made alterations of the estuarine environment affect fishes; and 3) fisheries-important ecological relationships within the estuary.

The Delaware River Estuary as a Nursery Area for Fishes

The fish eggs, larvae, and juveniles collected by de Sylva and Smith (NSF - Ichthyoplankton Project) indicate that the Delaware River estuary is the site of spawning for over 60 species of fishes whose larvae grow within these waters. After its larval stage, the probability of survival of a young fish is closely related to the period of time -- between its passive drift as a larva and its assumption of postlarval development in the shallow "nursery" grounds -- that it is exposed to really adverse conditions. The length of this exposure, we feel, may be the most "critical" period in the life cycle of coastal species. Once it has entered the estuarine nursery ground, it is still subjected to natural environmental catastrophes and may be destroyed completely as a result of an unfavorable change in temperature, salinity, or the occurrence of a severe storm or other weather change. The aforementioned dangers, however, probably are more than offset by the vast available food supply and shelter from predators. Also, in many species, the juvenile fishes apparently grow up in an environment where the water and the organisms living in it maintain a "buffer" system of natural phenomenon delicately balanced among themselves.

Once the post larvae can actively swim, the chances for survival are probably greatly increased. For example, Shelbourne (1960) has shown that the survival of the egg to the juvenile stage could be as high as 10% in stocking young plaice into the sea merely by holding the young until they were relatively motile.

The importance of environmental conditions to the early life history of fishes is well documented, as by Hjort (1926), Tait (1952), Marr (1956), Harmic (1958), Tabb (1958), and Vladimirov and Semenov (1959).

Harmic (1958) found eggs and larvae of the Weakfish within the Delaware River estuary in waters with temperatures ranging from 17.0° to 26.5° C and salinities from 12.05 to 31.13 parts per thousand. In laboratory propagation experiments, Harmic found that some hatching occurred in waters ranging from 12.0° to 31.5° C (optimum hatching occurred between 18° and 25° C), and 12.00 to 32.50 parts per thousand. Experiments employing sudden temperature and salinity changes of the magnitude encountered in the Delaware Bay estuary drastically reduced the percentage of eggs hatching. Harmic (1958) concluded that the ranges of temperature and salinity determined in the laboratory helped explain the survival, on a geographical-hydrographical basis, of Weakfish eggs and larvae in the estuary.

We rank, in descending order of relative importance as nursery grounds, the shore zones at our sampling stations in the Delaware River estuary area as follows: Augustine Beach, Salem, Woodland Beach, Cape May, Lewes, Slaughter Beach, Fortesque, Moores Beach, Cohansey River, Reeds Beach, Bowers Beach, Great Egg Harbor, Townsends Inlet, and Penns Grove. This

ranking is based upon observations made during our collecting trips and upon the data amassed on the relative number of species and specimens, and environmental conditions at each station. These and comparable areas should be protected from alteration insofar as possible.

Man-made Alterations of the Estuarine Environment Affect Fishes

In the light of our studies, we believe that there are a number of man-caused conditions that are imminently threatening the "health" of the estuary. We, therefore, address our remarks towards pondering the question: What might be the effect on the fishes utilizing the shore zone of the Delaware River estuary if permanent or temporary modifications were made of their environment?

Actual or potential long term changes in the aquatic environment are discussed by the International Passamoquoddy Fisheries Board (1960), Beeton (1961), and Thompson (1961). It is apparent, from these reports that all of the indirect changes -- caused by industrialization, farming, or urbanization -- may be far more significant than those caused by man's efforts to harvest fish from the sea. In view of the long history of pollution in the estuary, it is possible that over-fishing by man (see Foerster, 1948 and Huntsman, 1948) in the Delaware River estuary is not a major factor in the decline of its fisheries. Perlmutter (1959) has alerted fisheries biologists to the possibility that detrimental changes are occurring in the Middle Atlantic Bight fisheries. For evidence he points out that the spectacular growth and development of the otter-trawl fishery has been matched by a general downward trend in harvest of food species. The intensification of fishing effort and decreased harvest, particularly of the larger-sized fishes, was taken as an indication or warning of the poor state of the fisheries. The cause or causes of the fisheries decline were not mentioned, but, according to our thesis, the decline is in part linked to the fate of the early life stages of these fishes in estuaries.

In commenting upon the following list of alterations, which we feel can have far reaching effects upon the biological productivity of the estuary, we invoke the old adage that "an ounce of prevention is worth a pound of cure." Detrimental effects are often long-lasting and difficult, if not impossible, to correct. Therefore, we advise that close attention be given to the following engineering and management possibilities: (1) Prevent increased siltation in the sites where development of eggs and larvae occur; (2) Prevent conditions causing the water to remain continually turbid and silt laden, and thus to reduce phytoplankton productivity; (3) Prevent removal of the plants from the shore zone areas where they now serve as shelter in the nursery grounds for the fish and their food organisms (see also, Limbaugh, 1955). These plants also assist in the

removal of silt from the water. (4) Eliminate installation of retaining walls which cause currents which keep silt particles in the water (see Inglis and Kestner, 1958); (5) Prevent the destruction of the tidal marshes. For example, prevention of natural flooding of the marshes would drastically reduce the flow into the adjacent waters of nutrients necessary for phytoplankton growth; (6) Prevent building of structures that will restrict the free flow of water carrying fresh supplies of plankton, nutrients or oxygen to the nursery grounds; (7) Prevent any substantial increase or decrease in the natural fluctuation of salinity of the nursery grounds; (8) Prevent the spraying of insecticides, dumping of pollutants, particularly radioactive wastes, on the nursery grounds; (9) Prevent sudden discharge of water several degrees colder or warmer than the water environment of the fish.

In all of the above points, there is room for more research and confirmation or rejection of each recommendation given. Our present knowledge strongly suggests, however, that these points highlight several critical areas wherein man is interferring with and upsetting natural processes, even to his ultimate detriment by lowered water quality, and decreased commercial and recreational harvests of seafood.

Siltation and Turbidity

There is much evidence that land use practices throughout a watershed, erosion, and pollution are associated with the success or failure of downstream inhabitants. For example, deforestation causes an increased silt load in the streams (Coleman, 1950; Buljan, 1959), which results in a higher turbidity. The effect of turbidity on fishes and the aquatic habitat is discussed by VanOosten (1948) and Buck (1956). These effects are complex: for, while increased turbidity may decrease visibility for fishes and sufficient light penetration to permit photosynthesis, increased nutrient content of the silt may increase productivity. Further, Perlmutter (1961) has advanced the hypothesis that increased turbidity may favor survival of larval organisms by decreasing solar radiation which generally is injurious to eggs and larvae. It is possible, of course, that this might favor some species yet decrease the chances of survival for other species. In addition to these considerations, increases in run-off may directly increase plankton production and, therefore, the production of fish (Nikolaev, 1958; Gun'ko, 1959). Lucas (1956) has shown that in the English Channel high phosphate values were associated with high plankton concentrations (see also Ingle and de Sylva, 1955).

Dredging in estuaries is generally considered detrimental to aquatic life, but a biased study by Ingle et al. (1955) has shown that while limited adult fish mortalities may occur, the long term effect is the recirculation of nutrients from the bottom which in turn contribute to vital plankton production.

Since their study was concerned with mobile, adult fishes, dredging in the spawning or nursery grounds still must be considered as highly detrimental to the early life stages of fishes and to benthic organisms.

Domestic and Industrial Pollution

Pollution in estuaries is covered in detail by Ericksen-Jones (1957), Laevastu (1959) and Hynes (1960). The detrimental effects of sewage upon aquatic life has been reviewed often, yet sewage can be a revocable form of pollution, for, following oxygen depletion, the secondary effects of regeneration of nutrients may contribute much to the nutrient cycle (Kalber, 1959a, b, 1960; Kalber in Shuster, 1959). Other pollution, including industrial wastes, sulfite liquors and detergents (see Henderson et al.1959 and Laevastu 1959) has been adequately reviewed, and the effect of these upon fish life studied. Unfortunately, nearly all studies have been made on adult fishes; few studies have been made on the effects of these toxicants on larval and juvenile fishes and upon their food chain. Krishna (1953) showed that slight modifications of the pH were sufficient to cause complete mortality of developing trout (Salmo) eggs. In the estuary, where circulation may be restricted and the flushing time relatively long, pH could be a critical factor, depending upon where the pollution occurred in relation to the spawning grounds.

Pesticides and Herbicides

Pesticide spraying has subtle as well as immediate effects (Harrington and Bidlingmayer, 1958); Darsie and Corriden, 1959). The nursery grounds where our collections were made were all less than 4-1/2 feet deep, some ranging as low as 6 to 12 inches. Yet these areas support sizeable populations of juvenile and, in many cases, post-larval fishes. Though these fishes may, in general, exhibit a high level of tolerance to toxic hydrocarbons, when the toxic hydrocarbons are sprayed at the high temperatures of the summer, they could easily have a far reaching effect if unwisely sprayed over a coastal area. We are also concerned because possible long term genetic effects of insecticides on fishes and their foods have not been investigated. There is another complicating factor in insect control. Unfortunately, the same shore zone vegetation that is thought to retain mosquito and other dipteran larvae is also a haven for the post-larval and juvenile fishes and their food.

Pollution by Radioactive Wastes

Experiments have shown that ionizing radiation produces abnormalities in developing eggs and larvae (National Research Council - National Academy of Sciences, 1957). Thus, eggs and

larvae might incur direct somatic effect of a fairly extensive spawning ground in Delaware waters, if radioactive waste disposal is uncontrolled. Genetic effects on older fishes, their food organisms, and their predators would be recognized more slowly, and would be more subtle and more insidious. The infauna and filter-feeding epifauna which have been shown to be dominant food items in the diets of the fishes of the shore zone (Table 12) would be affected. Yet the importance of these organisms in accumulating and concentrating radio isotopes, and their incorporation into fish flesh during the food cycle have not been fully investigated. Clearly, research on this aspect of radioactive wastes is urgently needed.

A Consideration of Ecological Relationships in the Estuary

Concerning Food Webs: Predators and Prey; Competitors

We should know more about the relationships among those species that fishermen consider to be "unimportant" or "important" to their sport or commercial interests. Broadly speaking, we know that the so-called "unimportant" species are the prey or competitors of "important" forms. The countless forage fishes such as the anchovies, silversides, herrings and gobies are eaten in the nursery areas by juveniles of other species, and by the adults in the offshore grounds. We have summarized our data on major food items in Table 49. Further study of the food habits and relationships of these offshore species is clearly needed.

The biomass of noncommercial species, particularly those in the trawl catches, often appears to be larger than that of the commercial species. This abundance of "unimportant" species is undoubtedly important when competition for food is considered. When the amount of food available to all species is encroached upon by such ubiquitous and "undesirable" forms as sharks, skates, rays, searobins, Windowpane, and Hogchoker, all of which are exceedingly abundant in trawl catches, then some species suffer in the competition. Kalber (1962) suggests that fishes living where the food supply is qualitatively marginal may have difficulty utilizing alternate food supplies when food stocks are low. In the Delaware River estuary where habitat conditions may already be marginal, due to man-made changes in the environment, biological competition from other fishes, better able to survive the changes, may crowd out the more desirable commercial and sport fishes. Generally speaking, it appears that the species most "desirable" to the angler and commercial fisherman is also the least tolerant of severe environmental conditions. Under circumstances of adverse environmental conditions, then the least tolerant or adaptable species will be the first to be affected.

Fishes, particularly the resident species, of the Delaware River estuary are, with few exceptions, bottom or bottom-feeding forms. Fishes, such as the Atlantic Menhaden, American Shad, and Bluefish, are midwater or surface forms but these comprise only a small percentage of the total species. A gradually increasing silt load and anaerobic benthic conditions of the Delaware River estuary would favor a fauna adapted to the silt or mud bottom. It is not known if this has occurred in the Delaware River estuary, but changes appear to have occurred in the species composition (see Daiber's list and distribution of shore zone fishes in Shuster, 1959). Although fairly complete faunal lists of the Delaware River estuary are lacking, trends based on scattered literature, are apparent; it certainly appears to us (DPdeS and FAK,Jr.) as if the trend is in the direction of an even more prevalent silt-mud infauna. This we also adduce from evidence provided by stomach contents during our present studies. Correspondingly, species favored by sand, gravel, and rocky substrate are becoming increasingly less common.

Natural and Artificial Reefs

Management of the estuary, such as envisioned in the establishment of artificial reefs or habitats, and the prevention of the establishment of retaining walls which prevent settling out of silt particles could restore the Delaware River estuary habitat for such species as Weakfish, Atlantic Croaker, Black Drum, Scup, and Black Sea Bass. A program is needed to increase the area of natural or artifically built feeding grounds, such as oyster and mussel beds, and to decrease siltation which may smother these mollusks. Such reefs of living animals would act directly not only as food for fishes but would attract forage fishes and various invertebrates toward the establishment of the complex enriched reef biotope. Finally, extensive reefs of filter-feeding animals could conceivably remove much material from suspension, resulting in higher light penetration and photosynthetic activity, and, therefore, plankton and fish production.

Survival of Estuarine Fishes

The fishes abundantly found in the shore zone of the Delaware River estuary apparently are well-suited and adapted for their existence there under natural conditions. The extent of this ability to adapt is evidenced further by their survival under most man-made changes in the environment. Many of these species are eurythermal, euryhaline, and occur over a wide range of oxygen values, bottom types and water clarities. Estuarine fishes have evidently become successfully adapted to the dynamic but delicate balance among physical, chemical and biological forces within the ecosystem. All evidence points to the estuary as an important place for the juveniles to find food and

shelter during the critical period of their existence. Except in a few cases of stenohaline forms, mostly tropical species, lowered salinity is tolerated by the younger stages as well as the adults of such species. Actually the distribution of larval stages seems to reflect a "need" for lowered salinity. Whether this "need" for lowered salinity is due to osmoregulatory requirements, or to the shelter for the fishes and their food offered by brackish water emergents of the estuary, remains to be proven. Ingle and de Sylva (1955) and June and Chamberlain (1959) suggested that this fresh water-salt water transition zone is actually needed for growth of phytoplankton which provides the basic source of food for animals. The dynamics of this transition zone for phytoplankton growth in the Delaware is discussed by Kalber (1960). Seshaiya (1959) found significant differences in the spawning cycle of estuarine fishes which he suggested were due to differences in the chemical environment.

The Attractiveness of the Estuarine Environment

We found no evidence during our study that, within broad limits, fishes in the estuary chose or avoided a particular area because of any one physical environmental factor. Rather, the attraction of the estuary may be synergistic, combining such factors as abundant food and relatively quiet water for the predatory species with shelter among vegetation for prey species such as anchovies and silversides. Plants also serve to anchor the substrate and thus aid in the establishment of a permanent or semi-permanent infauna and epifauna which, in turn, becomes available for the predatory fishes. These plants, in physically causing the settlement of suspended silt particles, probably assist in increasing the transparency and consequent sunlight penetration and, phytoplankton production. Most areas of the estuary are shallow and the bottom sediments are subject to violent and rapid shifting during the frequent storms that occur throughout the year. Any material which tends to anchor, protect or solidify the substrate will be advantageous to the establishment of food organisms.

Then, too -- it is so obvious that it has been known for a long time -- only a relatively few freshwater and marine species of fishes can exist within the wide range of constantly fluctuating estuarine conditions. The few species that are able to survive in the estuarine environment establish large populations, exploiting the relative lack of competitors for abundant food and shelter in the estuary.

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PREFACE TO TABLES

The data accumulated by de Sylva and Kalber during the beach-seine project and by Hopkins (1958) during a zooplankton project, as analyzed further by de Sylva and Smith (NSF - Ichthyoplankton Project), are summarized in the following 50 tables. The data have been arranged to provide the reader with as full-as-possible-knowledge of the range of information obtained. The data include: seasonal and geographic distribution and abundance of fishes collected in the shore zone; environmental conditions, including seasonal hydrographic and habitat conditions; morphometric data (standard length measurements) and the diets of species of fishes most abundant in the collections; and, analysis of ichthyoplankton collected at Indian River Inlet.

In a few cases it is not possible for the reader to obtain identical values for corresponding items when comparing one column or table with a comparable one (or, for that matter, with the raw data). This paradox is apparently due to a selection by the senior authors of specific data for presentation in one column or table against either a lumping or refinement of the same data, whichever was convenient, in other columns or tables. Except for this minor distraction, the reader will find that the data from one table to the next is essentially similar and does not prevent comparison of the data among columns or tables.

CNSJr

Table 1. Distribution of bottom types, ice, and fouling organisms, in the shore zone of the Delaware River estuary area at time of collection, in order of prevalence.

	1958 Aug.	Oct	Dec	1959 Mar	May	Jul	Aug	Oct	Dec	1960 Feb	Prevalent Types
Lewes Beach	S	S,R, G	I	S,G	S,G	Si,S G	Si,S G	S,MS M	S,M, Si,M	MS,S	S,G
Slaughter Beach	M	-	I	S,D	D,S G	Si, S	S,G	B,S	D,M, S	S,G, B	S,D
Bowers Beach	-	-	I	D,S	M,D	D,S	S,D	D, MS	D,G	D,S, G	D,S
Woodland Beach	-	-	I	S,G M	MS, M,D	M,D, S,B	Si,S	S	S,D, G	S	S,M
Augustine Beach	-	S,Si R	I	M,R	S,Cl, M	M,Si, G,S,R	S,Si Cl,R	M,S, Cl	SM, R,Cl	S,M, G,D	S,M
Penns Grove	-	-	I	M,R, G,D	S,R, G,D	G,R, S,D	G,R, M	S,R, G	G,S, R	S,R, G	G,S
Salem	S,M, Cl	S	M,D, I,R	S,R	S,Cl R,D	S	S,R	S,D, M	MS, D	S,D	S,M
Cohansey River	-	-	S,Si I	S,M, R,G	D	S,G, M,D	S, Cl	SM, Cl	Cl,S, M	S,M	S,M
Fortesque	M	S	I	S,D	D,S Cl	D,M, S	D,S M	S,Cl, R	D,S	D, R,S	D,S

Moore's Beach	M	Si,M S	S,M, I	M,R, S	-	M,S G	M,S	M,S	M,Cl, S,Si	M,S, D	M,S
Reed's Beach	M,Si, Cl	S,R	I	D,S	D,M, Si	M	S	D,S	D,S	D,S	D,S
Cape May	S	S,R	Si,S	S,D	M,D, Si,S	MS	D,S	MS, S	S,D	D,S	S,D
Cold Spring Inlet	S,R	-	I	-	M,S	M,S, R	-	-	-	-	M,R
Hereford Inlet	S,R, Si	-	S,M	M	-	S,SM, R	M,Cl, R	S,R Si	-	-	S,R
Townsend's Inlet	S,R	S,R	S,R	-	S,R	S,R	S,Cl	S,R	-	S,R	S,R
Great Egg Harbor	-	S,M R,D	-	S,G, M,D	S,R G	S,G M	S,R	-	S,G, D	S,R, D	S,G

S = sand M = mud MS = muddy sand SM = sandy mud

R = rubble or coarse shell Si = silt (inorganic, fine) Cl = clay

D = detritus (organic, coarse) G = gravel I = ice or slush

B = Bryozoa

Table 2. Tidal stage in the shore zone of the Delaware River estuary area at time of collection, referred to time of high water in hours (i.e., 0 = slack high).

	1958 Aug	Oct	Dec	1959 Mar	May	Jul	Aug	Oct	Dec	1960 Feb
Lewes Beach	0	-6		+6½	+1	+1	-5	+1½	+6	+4
Slaughter Beach	-7			+1	-4	-3	-1	-6	+2	0
Bowers Beach				-4	-2½	+ ½	+3	+3½	+3½	+1
Woodland Beach				-5	+6½	-4½	+6	+ ½	0	-3½
Augustine Beach		-2		+3	-2	-4	- ½	+2	-1½	-1
Penns Grove				+1	-1	-5	-6	+3½	+2	+2
Salem	+4½	-4	+5½	-2	+1	-5	-1	+4½	+5½	-2
Cohansey River			-5	-2	+3	+2	+ ½	+3	+2½	-5
Fortesque	-1	-1		- ½	- ½	+6	-2½	+6½	+6½	-6½
Moore's Beach	0	+7	- ½	+3		+3	+3½	+6½	+ ½	+4
Reed's Beach	+4	-1		+1	+2	+2	+1	-6½	+1	+2½
Cape May	-1	-1½		0	+2	-1	-3	+7	-1½	- ½
Cold Spring Inlet	- ½				-1½					
Hereford Inlet	-2		+3	- ½		-5	-5	+6		
Townsend's Inlet	-5	-2	+5	0	0	-4	-5	+5		+6
Great Egg Harbor		+1½		+2	-3	-1	-4½		+3	-4

Table 3. Distribution of water temperature (°C) in the shore zone of the Delaware River estuary area at time of collection.

	1958 Aug	Oct	Dec	1959 Mar	May	Jul	Aug	Oct	Dec	1960 Feb	Min.	Mean	Max.
Lewes Beach	23.5	17.5	3.0	9.8	14.2	24.8	25.2	22.4	7.5	5.5	3.0	15.3	25.2
Slaughter Beach	25.5	17.3	2.8	5.9	18.0	24.3	31.0	15.0	6.2	4.0	2.8	15.0	31.0
Bowers Beach	25.8	17.6	2.5	11.2	18.8	23.4	28.0	16.3	6.5	3.8	2.5	15.4	28.0
Woodland Beach	26.2	17.1	1.6	13.2	18.2	26.0	29.0	16.9	6.2	4.0	1.6	15.8	29.0
Augustine Beach	26.5	17.5	1.4	7.4	19.5	30.0	24.0	18.7	5.6	4.8	1.4	15.5	26.5
Penns Grove	-	-	-	12.3	21.0	29.5	27.0	18.8	5.2	2.6		16.6	
Salem	26.0	17.2	0.1	9.5	20.2	28.8	31.5	16.0	5.4	1.2	0.1	15.8	31.5
Cohansey River	-	-	-	6.5	21.0	28.8	27.4	17.2	6.0	3.5		15.8	
Fortesque	25.0	15.0	1.5	5.5	22.0	25.0	25.2	16.1	6.1	4.0	1.5	14.5	25.2
Moore's Beach	25.7	12.5	1.5	7.0	23.4	23.7	27.0	17.5	6.0	2.6	1.5	14.4	27.0
Reed's Beach	26.5	14.0	1.0	7.0	24.1	24.0	26.4	17.1	6.0	5.0	1.0	15.1	26.5
Cape May	23.5	15.8	3.0	6.5	18.8	23.1	24.3	18.0	7.5	3.9	3.0	14.4	24.3
Cold Spring Inlet	15.5	-	-	-	16.2	22.1	24.0	-	-	-		19.5	
Hereford Inlet	23.5	-	3.1	12.9	-	23.0	23.2	16.0	-	-		17.0	
Townsend's Inlet	21.0	14.0	4.0	6.2	18.2	21.0	22.1	17.2	7.4	6.6	4.0	13.8	22.1
Great Egg Harbor	-	15.0	-	6.2	20.2	22.0	19.8	-	6.0	5.0		13.4	
Mean	24.2	15.9	1.8	8.5	19.6	25.0	25.9	17.5	6.4	4.0	1.8	-	25.9

- no collection

Table 4. Distribution of salinity (°/oo) in the shore zone of the Delaware River estuary area at time of collection.

	1958 Aug	Oct	Dec	1959 Mar	May	Jul	Aug	Oct	Dec	1960 Feb	Min.	Mean	Max.
Lewes Beach	29.7	28.0	21.5	26.9	28.4	30.1	25.5	29.8	18.4	25.0	18.4	26.3	30.1
Slaughter Beach	18.5	22.2	19.8	22.5	26.0	19.8	30.7	25.4	19.3	23.2	18.5	22.7	30.7
Bowers Beach	14.6	12.6	18.0	19.0	18.3	14.3	27.2	23.5	20.3	19.0	12.6	18.7	27.2
Woodland Beach	11.0	10.2	4.9	8.3	6.3	13.0	12.1	11.2	4.4	5.4	4.4	8.7	13.0
Augustine Beach	6.4	4.5	1.2	0.05	2.0	7.3	7.2	3.1	0.05	0.05	0.05	3.2	7.3
Penns Grove	-	-	-	0.8	*	1.8	1.4	1.0	0.05	0.05		0.7	
Salem	3.9	2.2	0.3	0.9	3.0	4.4	4.7	3.3	0.05	0.05	0.05	2.3	4.7
Cohansey River	-	-	-	8.1	8.4	15.0	15.5	15.3	7.3	19.4		12.7	
Fortesque	18.5	18.7	6.5	12.4	16.0	17.8	19.2	17.5	11.7	12.9	6.5	15.1	19.2
Moore's Beach	19.9	18.8	18.2	14.5	18.2	14.6	18.9	19.5	13.4	13.1	13.1	16.9	19.9
Reed's Beach	26.1	19.0	19.4	20.2	23.6	22.2	22.7	21.0	17.2	17.5	17.2	20.9	23.6
Cape May	28.6	28.0	20.6	27.5	29.3	28.6	29.6	28.6	24.1	28.2	20.6	27.3	29.6
Cold Spring Inlet	30.1	-	-	-	31.6	-	31.7	-	-	-		31.1	
Hereford Inlet	19.2	-	31.4	34.6	-	29.0	31.6	30.4	-	-		29.3	
Townsend's Inlet	29.4	29.4	28.2	-	-	26.0	31.7	30.9	28.5	29.3		29.1	
Great Egg Harbor	-	26.3	-	10.6	18.9	10.9	-	-	25.3	19.4		18.5	
Mean	22.4	18.3	15.8	14.7	16.4	17.0	20.6	18.6	13.6	15.2	13.6	-	22.4

* no results

- no collection

Table 5. Distribution of dissolved oxygen (ml/L) in the shore zone of the Delaware River estuary area at time of collection.

	1959 Jul	Aug	Oct	Dec	1960 Feb	Mean
Lewes Beach	4.2	-	3.8	6.1	4.7	4.7
Slaughter Beach	4.3	6.6	6.5	1.8	5.6	5.0
Bowers Beach	4.7	6.4	5.2	-	4.7	4.2
Woodland Beach	5.1	5.8	6.4	6.8	7.0	6.2
Augustine Beach	7.2	6.4	7.0	9.5	8.5	7.7
Penns Grove	7.0	4.1	4.1	*	8.8	6.0
Salem	7.8	6.3	7.5	9.3	8.1	7.8
Cohansey River	4.8	6.5	5.9	6.0	7.3	6.1
Fortesque	5.6	3.8	6.2	3.2	6.7	5.1
Moore's Beach	4.3	1.3	5.6	3.8	4.1	3.8
Reed's Beach	4.9	5.3	4.3	4.0	5.0	4.7
Cape May	4.3	4.2	2.7	3.3	4.0	3.7
Cold Spring Inlet	3.9	-	-	-	-	3.9
Hereford Inlet	3.1	5.9	5.9	-	-	5.0
Townsend's Inlet	5.4	5.6	5.1	-	6.3	5.7
Great Egg Harbor	6.1	4.2	-	2.6	6.3	4.8
Mean	5.2	5.2	5.5	4.7	6.2	-

- no collection

* sample frozen

Table 6. Distribution of oxygen saturation (%) in the shore zone of the Delaware River estuary area at time of collection.

	1959 Jul	Aug	Oct	Dec	1960 Feb	Mean
Lewes Beach	83	-	71	78	62	74
Slaughter Beach	79	144	105	23	70	84
Bowers Beach	83	131	85	-	57	71
Woodland Beach	92	110	96	79	80	91
Augustine Beach	136	108	106	107	92	110
Penns Grove	126	71	61	*	86	86
Salem	141	119	112	104	82	112
Cohansey River	100	122	94	72	85	95
Fortesque	102	70	98	39	78	77
Moore's Beach	76	25	93	47	46	57
Reed's Beach	91	103	71	50	62	75
Cape May	82	82	47	44	52	61
Cold Spring Inlet	71	-	-	-	-	71
Hereford Inlet	60	116	100	-	-	92
Townsend's Inlet	94	106	91	-	77	92
Great Egg Harbor	103	76	-	34	79	73
Mean	95	99	89	56	72	--

- no collection

* sample frozen

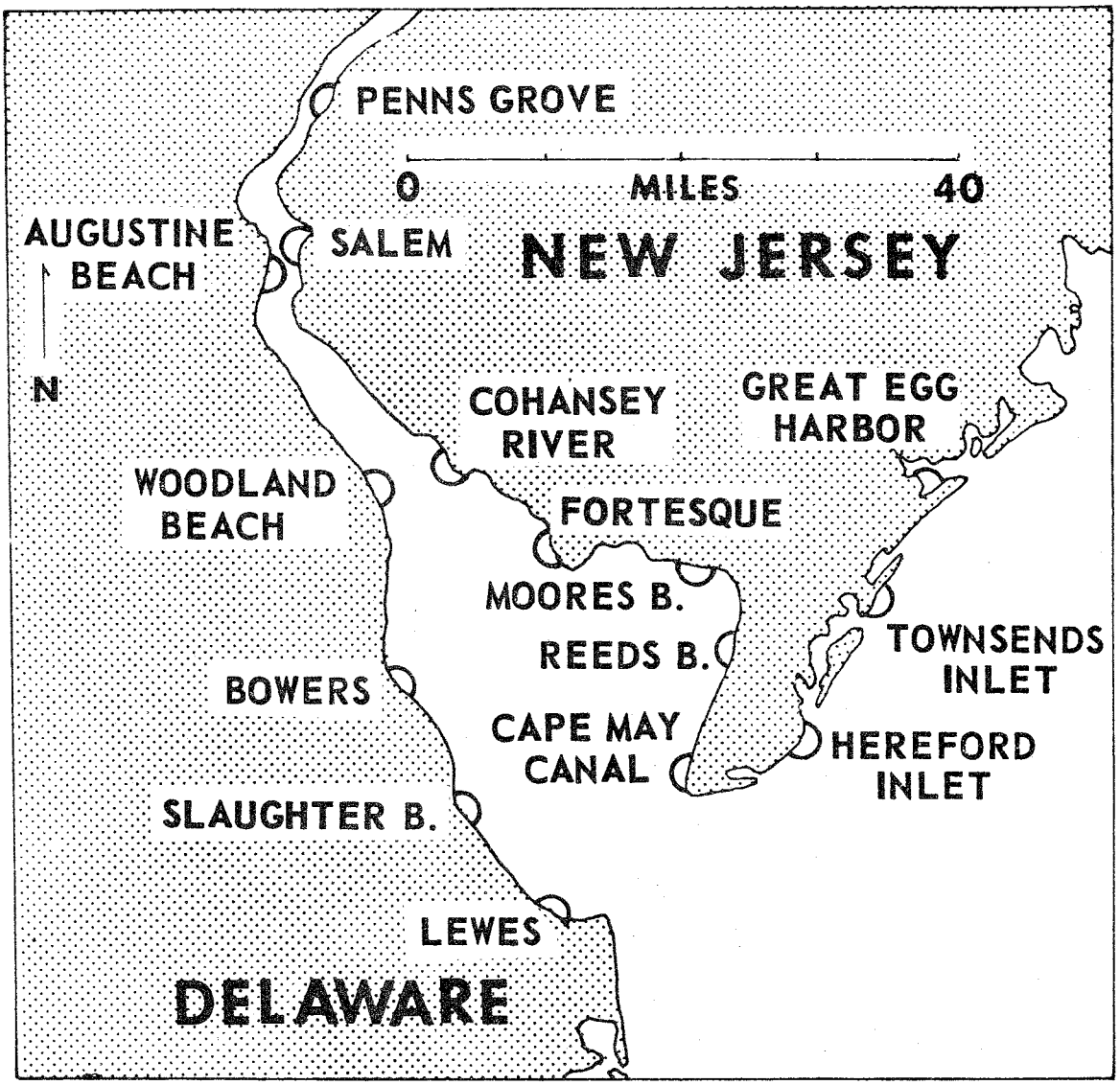

PENNS GROVE
0
MILES
40
AUGUSTINE BEACH
SALEM
NEW JERSEY
N
COHANSEY RIVER
GREAT EGG HARBOR
WOODLAND BEACH
FORTESQUE
MOORES B.
REEDS B.
TOWNSENDS INLET
BOWERS
CAPE MAY CANAL
HEREFORD INLET
SLAUGHTER B.
LEWES
DELAWARE

Table 7. Frequency of collections in which species occurred at various temperatures (°C) in the Delaware River estuary area, 1958-1960.

Species / Temperature	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Mustelus canis															
Dasyatis sayi												2			1
Alosa aestivalis															
A. pseudoharengus							1	1							
Brevoortia tyrannus								1							
Clupea harengus															
Anchoa hepsetus															
A. mitchilli															
Synodus foetens															
Carassius auratus						1	1		1						
Cyprinus carpio	1							1 2				1			1
Hybognathus nuchalis							2	2	1						
Notemigonus crysoleucas									1						
Notropis bifrenatus	1		1				1	1	1						
N. hudsonius							1								
Ictalurus catus															
I. nebulosus								1	1						
Anguilla rostrata					1	3		3	1				1	2	2
Strongylura marina															
Cyprinodon variegatus					1			1						1	1
Fundulus diaphanus			1				3		1			1			
F. heteroclitus		2	3	1	1	4	1		3	2	1	1	1		2
F. majalis									1	3		1	1	1	2
Lucania parva															
Gambusia affinis								1							
Pollachius virens								1							
Urophycis regius					1	1	6	2				1			2
Apeltes quadracus							1	3	1			1			1
Gasterosteus aculeatus															
Fistularia tabacaria															
Syngnathus fuscus			3			2	1	1		2			1	1	1
Centropristes atriatus								1							
Roccus americanus		2	3	1	3	4	2	1	3	2	1	2	1	2	
R. saxatilis		2	3	1	1	3	1		2	1					
Lepomis gibbosus							1		1						
L. macrochirus							1	3							
Micropterus salmoides								1							
Pomoxis annularis			1						1						
Perca flavescens							1								
Pomatomus saltatrix															
Caranx hippos															
Selene vomer															
Trachinotus carolinus															
T. falcatus						2	1		2	1				1	1
Bairdiella chrysura											1				
Cynoscion regalis										1					
Leiostomus xanthurus														2	
Menticirrhus saxatilis															
Micropogon undulatus														1	
Pogonias cromis															
Lagodon rhompoides															
Stepotomus chrysons															
Orthopristis chrysopterus															
Chaetodon ocellatus															
Tautoga onitis															
Gobiosoma bosci															
G. ginsburgi															
Prionotus carolinus															
P. evolans															
Ammodytes americanus															
Astroscopus guttatus															
Rissola marginata															
Sphyraena borealis								1							
Mugil curema								1							1
M. cephalus															
Membras martinica								5				1			
Menidia beryllina			1		2	5	2	13	5	2	1	1	1	1	2
M. Menidia															
Etropus microstomus															
Paralichthys dentatus															1
Scophthalmus aquosus								1							
Pseudopleuronectes americanus															
Trinectes maculatus															
Sphaeroides maculatus															
Opsanus tau															
Total collections	1	2	3	1	3	5	7	15	5	3	2	2	1	2	4

Table 7. continued

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
				1				2		2											
				1																	
			1							3	1				1						
								2	2	1		1		2							
1	1			3	3	2		1	3	2	1	2		1	1	2		1			
							1														
				1	1			2		1	1										
3	2	3	4	6	4	2		4	6	11	6	7	1	2	3	1	1	1			
													1								
....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
						1							2		1						
						1				1		1	1								
															1						
						1															
										1			1		1						
					1																
	2	3	3	3	3	2		1	2	3	3	5	3	1	2	1	1	1			
								2	2	1	2	1	1			1					
1	....	....	1	..	2	....	....	1	..	1	..	3	....	....	....	....	....	....	....	....	....
	2			1	5	1	1	1		2	2	2	1	3	5	5	1				1
	5	1	1	7	4	3	1	1		1	1	1	2	3	3	3					
				1					1	2	1		1		1						
														1							
				1						1											
					1			2					1								
....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....
1	2	1			2	1		2		1	1	1	1	3	4	4					1
													1								
1	4	1	1	2	3	2		1		2	1	1	1	1	2	2					
	2				1	1	1	1		1					3						
															1						
						1															
													1								
				1	1	1															
....	....	....	....	2	....	....	2	..	2	..	4	..	5	..	3	..	3	..	1	..	1	....	....
2		1	2	1	1		1		3		1		2		2		3			1			
																	1						
										2			1		3		1						
1								1					1		1								
1	2		1	2	2	2					1		1		1		4		5		5		1		
		1		2						4	4		3		4		1		3		1			
				2		1		2		2	2				2		1		2		1			
2	3	2	2	1	1		1	3		2	3		3		1		2						
1	1	1		1						1													
....	1	....	....	1	....	....	....	1	..	3	..	3	..	2	..	2	....	1	....	1	..	1	....	....
													1								
													1								
													1								
													1								
								1					1								
	1	2	1								2	1	1		1						
								1		1											
								4			1		1								
													1								
....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	1										1	1									
									1				1								
							1	3	2	3	2	2									
1								2	3	1	2										
	1			1				2	1	4	1	4	1								
										1		2									
	1											1				1					
3	3	7	5	7	4	4	3	10	6	13	6	7	2	1	3	1	1	1			
				1				1													
....	1	....	....	4	..	1	....	3	..	3	..	7	..	3	..	2	..	1	..	1	....	....	....
1				3				2		2		3		2		1					
1	2							4		1		3		3		1		1			
		1		18										1							
1				1						2		2		1							
	1							1				2		1							
4	4	7	6	10	4	4	4	11	11	15	6	8	3	4	5	5	1	1	1		1

Table 8. Frequency of collections in which species occurred at various salinities (°/oo) in the Delaware River estuary area, 1958-1960.

Species / Salinity	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mustelus canis																			
Dasyatis sayi																			
Alosa aestivalis	1		1						1							1			
A. pseudoharengus	1				1		1												
Brevoortia tyrannus			2	1	3	1	1	1	1					1			1		1
Clupea harengus																			
Anchoa hepsetus																			
A. mitchilli	1		2	3	2	1	1	2	2			1	1	1	1	3	1	1	5
Synodus foetens																			
Carassius auratus	3					1													
Cyprinus carpio	4	1	1		1														
Hybognathus nuchalis	3		2	1	2				1										
Notemigonus crysoleucas	1				1														
Notropis bifrenatus	5		1																
N. hudsonius	1		1		2														
Ictalurus catus	1		1																
I. nebulosus	1	1																	
Anguilla rostrata	2	1	1	1	1	2			3			1	1	2	1	1	1	1	3
Strongylura marina			1				1	1											1
Cyprinodon variegatus					1					1				1		1			
Fundulus diaphanus	6																		
F. heteroclitus	3		3	1	4	1		3	2	1		2		2		2			1
F. majalis								1	3			2	1	2	1	3	2	1	4
F. luciae										1									
Lucania parva																			
Pollachius virens																			
Urophycis regius																			
Apeltes quadracus	1					1			1			1						1	
Gasterosteus aculeatus	1											1							
Fistularia tabacaria																1			
Syngnathus fuscus				1	2	1	1		2			1	1	1	1	2	1		
Centropristes striatus																			
Roccus americanus	2	1	3	3	4	2	1	3	2	1		3	2		2	3	1	1	2
R. saxatilis	2	1	3	1	3	1		2	1							2			
Lepomis gibbosus	2				1			1											
L. macrochirus	2		1			1							1						
Micropterus salmoides								1											
Pomoxis annularis	2	1	1																
Perca flavescens	1		1	1			1												
Pomatomus saltatrix				1	1		1									1			
Selene vomer			1	1	2		1					2							1
Trachinotus carolinus																			
T. falcatus																			
Bairdiella chrysura					2	1		2	1				1	1	1	2		1	2
Cynoscion regalis				3	2			2	1				1	1	1	2			2
Leiostomus xanthurus			1		1		1					1				1			
Menticirrhus saxatilis									1							2		1	1
Micropogon undulatus																			1
Pogonias cromis						1		1		1			1			2			
Lagodon rhomboides																			
Stenotomus chrysops																			
Orthopristis chrysopterus																			
Chaetodon ocellatus																			
Tautoga onitis																			
Gobiosoma bosci									1				1			1			1
G. ginsburgi																			
Prionotus carolinus																			
P. evolans																			
Ammodytes americanus																			
Astroscopus guttatus															1				
Rissola marginata												1							
Sphyraena borealis														1		1			
Mugil curema																			
M. cephalus					4					1		1							2
Membras martinica					1														
Menidia beryllina	1		2					1						1					
M. menidia			2	3	4	2	2	3	3			3	2	3	2	3	2	1	6
Etropus microstomus																			1
Paralichthys dentatus							1				1			1		1	1		1
Scophthalmus aquosus							1		1										1
Pseudopleuronectes americanus									1			1							1
Trinectes maculatus						1	1		1					1					
Sphaeroides maculatus														1					1
Opsanus tau														1					1
Total collections	11	1	3	3	4	2	2	3	3	1	1	3	3	3	2	3	2	1	7

Table 8. continued

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	41
										3							
										1							
	1		1				1				2						
			2								2						
1					1	1	1		2	2	2						
							1										
1			1							2	2	1					
4	1	1		2	2	2	1	2	6	7	6	1					
								1									

6	3	1	2	1	2	2	2	2	3	7	2	1				1	
						1				2	3						
2			1						2		1					1	
5	1	1	1		2	2	2	2	3	8	2	1				1	
7	3	1	1		1	1	1	2	3	3	3						1
							1	1			1						
								1									
			1		1		1										
1			1			1		1		1						1	
2	1							1								1	
								1									
2	1		2		1	1	1	1	3	4	4					1	
			1														
3	2		1		2	1	1	1	1	2	2						
1	1	1	1		1					3							

	1						3		2	5	3						
1	1								3	3	2						
1										2	2						
1	1									1	1						
2	2				1		1	2	4	5	5		1				
1	2			1	1	1		1		3	3						
							1		1	2							
4		1				2	1	1	2	6	4		1				
				1		1			1								
2	2			1		1			1	2	2	1					
								1									
								1									
								1									
								1					1				
					1	2		1	1								
			1		1	1					2						
		1	1			1		1		2							
								1									
							1										
						1		1									
1			1				1		2	2	1						
									1	3	2						
	2		1	1			1		2	2	1					1	
								2		1							
1						2		1									
11	5	1	2	2	4	3	5	3	9	12	9	2	2		1	1	
			1						1								
	1				1	1	1	1	4	5	2						
					1				4	5							
1			1			1	1	1	2	2	1						
					1			1									
						1		1	1	2	1						
						1			1	2							
11	5	1	2	2	4	3	5	3	9	13	9	2	2		1	1	1

Table 9. Frequency of collections in which species occurred at various dissolved oxygen values (ml/L) and oxygen saturation values (% saturation) in the Delaware River estuary area, 1958-1960.

	Dissolved Oxygen, ml/L								
	1	2	3	4	5	6	7	8	9
Alosa aestivalis				4					
A. pseudoharengus				1	2				
Brevoortia tyrannus				2	2	2	3		
Clupea harengus					1				
Anchoa hepsetus			1	2	1				
A. mitchilli		1	2	10	9	8	4		
Carassius auratus				1			1	1	
Cyprinus carpio				1			1	1	1
Hybognathus nuchalis					2	1		1	2
Notemigonus crysoleucas							1		
Notropis bifrenatus								2	1
N. hudsonius					2		1	1	
Iotalurus catus				1		1			
Anguilla rostrata	1	1	1	9	7	6	4	1	
Strongylura marina					3		1		
Cyprinodon variegatus	1			1	1	1			
Fundulus diaphanus								2	
F. heteroclitus	1	2	3	6	3	5	4		2
F. majalis		1	6	7	4	6			
Lucania parva	1			2					
Apeltes quadracus		1	1	1	2		2	1	
Gasterosteus aculeatus						1			
Syngnathus fuscus		1		5	4	2	2		
Roccus americanus	1	1	2	5	7	10	6		
R. saxatilis		1		3	6	3	3		
Lepomis gibbosus						1	1	1	
L. macrochirus			1			1			1
Micropterus salmoides						1			
Pomoxis annularis				1				1	
Perca flavescens							1	1	
Pomatomus saltatrix				4	2				
Caranx hippos				2	1	4	1		
Trachinotus carolinus				2	1				
T. falcatus				1					
Bairdiella chrysura		1		4	7	5	2		
Cynoscion regalis		1		7	5	2	3		
Leiostomus xanthurus				2		2	1		
Menticirrhus saxatilis		1		4	4	3			
Micropogon undulatus		1			1	1			
Pogonias cromis	1	1		3	5	4			
Tautoga onitis					1				
Gobiosoma bosci					4	1			
Prionotus carolinus				1					
Ammodytes americanus					1				
Astroscopus guttatus				1	1	1			
Rissola marginata				1					
Sphyraena borealis				3	1	1			
Mugil curema			1	4					
M. cephalus	1	1		2	3	2			
Membras martinica						1			
Menidia beryllina		1	1		1	2	1		1
M. menidia		2	6	16	14	14	5	1	
Etropus microstomus				1					
Paralichthys dentatus		1		4	1				
Scophthalmus aquosus		1		1	1				
Pseudopleuronectes americanus				1	1				
Trinectes maculatus					2	1			
Sphaeroides maculatus					1				
Opsanus tau					2				
Total collections	1	2	8	16	16	14	6	3	2

Table 9. continued

Oxygen Saturation, °/o												
20	30	40	50	60	70	80	90	100	110	120	130	140
					2	2						
				1		1	1			2	1	1
							1					
					2	1	1					
			1	2	5	5	5	7	1	1	1	3
				1	1		1					
					1			1	1			1
					1		1	2				
												1
						1	1	1				
				1			1					1
1		2	1	2	5	3	5	4	1	2	1	2
								1			1	
1					2		1					
						1	1					
1	2	3	1	3	4	1	1	5	1		1	1
	2	3	1	2	6	2	4	3				
1						1		1				
	1		1	1	4							
					1							
		1			2	2	2	3	1	1		1
1	1	1		1	5	3	3	6	1	3	2	1
		1		1	2	1	1	2	1	2		
							1	1				1
	1				1			1				
					1							
					1	1						
							1	1				
					2	1	2		1			
					1		2	3		1		
						1	1	1				
							1					
		1			1	2	4	5		2	1	2
		1			2	4	2	5	1	1	1	1
						1	1	1		1		1
		1			1	2	4	3		1		
		1				1		1				
1		1			2	1		3		2		1
								1				
						1	1	3				
					1							
							1					
							2	1				
						1						
					1	1	2	1				
		1			1	3		3				
1		1			3							
											1	
	1	1			1			2		1		
	2	2	5	4	13	6	7	9	1	2	1	3
					1							
		1			2	2	1					
		1				1		1				
					1			1				
						1	1			1		
							1					
							1	1				
1	2	3	5	4	14	7	9	11	1	3	1	3

Table 10. Frequency of collections in which species occurred at different tidal stages, water clarity, and bottom conditions in the Delaware River estuary area, 1958-1960. Data are combined for all seasons and all sizes of fishes. Tidal stage is referable to mean high water, where 0 = Mean High Water; numbers indicate hours before or after mean high water.

Species	TIDAL STAGE													
	Low	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6
Mustelus canis														
Dasyatis sayi														
Alosa aestivalis			1	1	2	2		1			1			2
A. pseudoharengus					1			1					1	1
Brevoortia tyrannus		1	2	3		4	3	2	3	4	2	3	1	2
Clupea harengus				1										
Anchoa hepsetus			1		1	1			2	1			1	
A. mitchilli	2	3	2	5	3	6	8	10	7	5	11	3	1	7
Esox niger											1			
Carassius auratus					1		1				2			
Cyprinus carpio		1	1			2	1					1	1	
Hybognathus nuchalis			1				2	1	2				2	
Notemigonus crysoleucas			1								1			
Notropis bifrenatus						2	2				1		1	
N. hudsonius					1		1	1	1					
Ictalurus catus			1								1			
I. nebulosus						1					1			
Anguilla rostrata	3	4	3	4	3	4	7	10	5	4	7	5	2	5
Strongylura marina			1	1				3	1			1	1	2
Cyprinodon variegatus	1			1			1	5		1	1		1	1
Fundulus diaphanus						2	1			1	1			
F. heteroclitus	3		5	6	3	5	6	11	4	6	5	5	3	3
F. majalis	3	1	2	1	1	4	9	11	7	5	8	1	2	5
F. luciae														
Lucania parva				2	1			2		2				
Gambusia affinis													1	
Pollachius virens								1						
Urophycis regius				1					1	1				
Apeltes quadracus			1	1	1	1		2	3	1	2	1	1	3
Gasterosteus aculeatus				1		1		2	2	1				
Syngnathus fuscus	3	1	2	1	3	2	5	6	3	3	3	2	1	3
Centropristes striatus														
Roccus americanus	3	3	3	3	3	5	4	10	6	6	6	2	1	2
R. saxatilis	2	1	3	1	1	2	1	4	3	3	5	2	1	
Lepomis gibbosus			1				1		1		1			
L. macrochirus	1					1	1	1		1				
Micropterus salmoides										1				
Pomoxis annularis		1				2					1			
Perca flavescens						1	1	1		1				
Pomatomus saltatrix			1	4	1	1	2	3	2		3	3		3
Caranx hippos			1	2		3	3	4	3	1		2	2	1
Selene vomer						1		1						
Trachinotus carolinus			1			1	2		1	1	1	1		1
T. falcatus			1				1	1	1				1	
Bairdiella chrysura	3	1	2	4	1	1	6	7	3	2	4	2	1	4
Cynoscion regalis	2		1	2	2		4	4	2	1	5	2		3
Leiostomus xanthurus			1	1		3	3	1	2	1	2		1	1
Menticirrhus saxatilis	3	3	3		1	1	4	5	1		2		1	3
Micropogon undulatus	1	1						1			1			
Pogonias cromis	2		1	1		2		2	6	2	1	2	1	2
Tautoga onitis			1											
Gobiosoma bosci	1	1	1				1				2			2
G. ginsburgi			1					1						
Prionotus carolinus			1										2	
Ammodytes americanus				1										
Astroscopus guttatus		1		1					1					
Rissola marginata						1	1							
Sphyraena borealis				2	1	1	2	2	2	1	2	1	1	1
Mugil curema						3	1	2	2		2	1	1	1
M. cephalus	1	1		1	2		2	5		1	1	2	1	2
Membras martinica						1					1	1		
Menidia beryllina		1	1				1	1		3	1		1	1
M. menidia	4	3	8	8	6	9	13	21	12	10	16	5	3	11
Etropus microstomus		1	1										1	
Paralichthys dentatus	1	1	1	4	1	2	5	4	1	1	3		1	1
Scophthalmus aquosus	2						4	3	2	1	2			3
Pseudopleuronectes americanus	1	1	1	1	1	1	1	2	2		1		2	3
Trinectes maculatus	1		1				2			1				
Sphaeroides maculatus			1	1	1				1					1
Opsanus tau	1	1	1					1			1	1	1	1
Total collections	4	4	9	9	6	12	15	24	13	12	16	6	6	11

Table 10. continued

WATER CLARITY					BOTTOM CONDITIONS										
Clear	Slightly Turbid	Turbid	Very Turbid	Muddy	Rubble	Gravel	Sand	Sandy Mud	Muddy Sand	Silt	Mud	Clay	Detritus	Ice	Bryozoa
5	3	2	1		1		6			2	1		1		
1		3				1	4								
10	6	13		1	1	3	16		1	2	7		4		
1							1								
4	1	3	1				4			1	1		2		
20	11	35	5	3	1	2	40	1	3	8	11		9		1
			1												
.....	1	3	.....		1	.....	2	.....	.....	.....	1	.....	.....	.....	.....
1	1	4	1		1	1	3	1			1			1	
	4	4			1		4	1	1				1		
		2					1				1				
	1	5					3	1			2			1	
	2	2					4								
1		1				2									
		2					1				1				
15	10	25	6	7	1	3	27		2	5	12		14		1
4	2	2				1	3			2	1		1		
.. 2	 1	 6	 2	 1	.....	1	... 7	.....	.....	1	... 3	.....	1	.....	.....
	2	3			1	1	2				1				
25	12	19	6	3	2	2	35	1	2	5	13		7		
25	6	20	6	5			34		1	5	15		7		
											1				
4	1	3	1			1	5			1	2		1		
1							1								
1							1								
	1	2					1						2		
7	4	5	1	1			13				3		2		
.. 3	 2	 2	.....	.....	1	.....	3	.....	.....	.....	2	.....	1	.....	.....
9	7	16	3	2			20		2	6	3		6		
	1						1								
8	11	29	4	4	2	3	25		2	3	8		13		1
5	9	9	3	3	2	3	16		1	2	4		1		
	1	3					3				1				
	1	4				1	1	1					2		
		1									1				
1	1	2				1	2				1				
		4						2	1		1				
..11	 3	 6	 1	.....		2	.. 15	.....	.....	4	... 1	.....	1	.....	.....
8	5	8		1			17			3	3				
1		1					2								
7		2					6			1	1		1		
2		2		2			2			2	1				
11	6	15	3	4		2	22		1	6	5		4		
7	4	10	4	3			12		1	4	6		5		
8	2	5					12		2		1		1		
9		11	3	2			11		1	6	3		3		1
		2	2				2		1						1
.. 6	 4	 9	 1	 2	.....	1	.. 10	.....	1	... 6	... 4	.....	.....	.....	.....
2							2								
2		4	2				3	1		2	1				1
1	1								1	1					
1		2					1			2					
1							1								
1		2					1				1				1
3							1			1	1				
12		4					13			3	1				
11	1	3					9			4	2				
.. 6	 3	 6	 2	 2	.....	.....	11	.....	2	... 2	... 3	.....	1	.....	.....
2	1						2						1		
3	1	5		1	1	1	2	1			4				1
47	18	47	13	7	1	3	72	1	4	10	22	1	19	1	1
1		2					2			1					
9	1	12	1	1		1	9		2	6	4		4		
8	2	6	1	1			10		2	2	3		2		
8	2	6		1		1	11			4	2		1		
	1	2	1	1			1		1		2		1		
3	1	2					4			1	1				
4	1	4		1			2	1		3	2		1		
52	22	54	14	7	3	5	78	2	5	10	27	1	20	1	1

Table 11. 59 species of fish collected at various localities and seasons in the shore zone of the Delaware River estuary area, 1958-1960. Figures refer to the number of individuals taken; minimal estimates are preceded by the symbol for "greater than" (>).

Species	Lewes	Slaughter Beach	Bowers Beach	Woodland Beach	Augustine Beach	Penns Grove	Salem	Cohansey River	Fortesque	Moore's Beach	Reed's Beach	Cape May	Cold Spring Inlet	Hereford's Inlet
Mustelus canis	1											1		
Dasyatis sayi	4													
Alosa aestivalis	3	25		1			6			3		50		
A. pseudoharengus	2				4		7							
Brevoortia tyrannus	515	190	5	2	134	1	495	17	30		68	12		
Anchoa hepsetus	101	5							10			20		
A. mitchilli	>3400	450	200	200	1000	75	2000	120	500	24	250	550		
Carassius auratus				1	4	1								
Cyprinus carpio					4		4							
Hybognathus nuchalis				3	9	12	15							
Notemigonus crysoleucas					1		1							
Notropis bifrenatus					13		37							
N. hudsonius					10		2							
Ictalurus catus						2								
I. nebulosus					30		1							
Anguilla rostrata	61	171	125	31	9	3	22	4	111	113	105	70		2
Strongylura marina	10				2		2		4					
Cyprinodon variegatus	4			1				1	10	2	110			2
Fundulus diaphanus					22	4	4							
F. heteroclitus	25	4	9	19	94	24	32	3	30	19	38	22		500
F. majalis	424	15	1	2				65	168	650	70	45		100
Lucania parva	1	1						1	20					
Urophycis regius		6									5			
Apeltes quadracus	2	1		1	1				2		1	2		1
Gasterosteus aculeatus		1					1				1	7		2
Syngnathus fuscus	47	5	4	17	1		3	9	1	1	5	19		
Roccus americanus	37	4	29	54	65	88	162	18	55	16	3	8		
R. saxatilis	1	1	3	1	109	54	50	3		29	1	1		
Lepomis gibbosus					7		2							
L. macrochirus				3	4	1			1					
Pomoxis annularis					2	2	1							
Perca flavescens				1	3									
Pomatomus saltatrix	57	2			6	4				1		6		
Caranx hippos	11			1	23		22			1	1	1		
Trachinotus carolinus	33	2						11		11		1		
T. falcatus	8								211					
Bairdiella chrysura	3600	209	33	7	30		30	6	18	2	1	100		
Cynoscion regalis	90	96	19	162	8		11	1	12	61	2	230		
Leiostomus xanthurus	203	1		1	14		2	1				1		
Menticirrhus saxatilis	153	4						14	22	11	3	85		
Micropogon undulatus	1	1	6								1	4		
Pogonias cromis	38	11		3	3		1	3	1	29	4	1		
Gobiosoma bosci	33	3	1	1				2	1			1		
G. ginsburgi	6													
Astroscopus guttatus	1	1		1										
Rissola marginata	1											2		
Sphyraena borealis	76													9
Mugil cephalus	37	28					1		4	2	6	2		
M. curema	31									42		3		
Membras martinica			30				77					475		
Menidia beryllina	1	3			7	1		11		2				
M. menidia	>14,000	>1100	150	>480	>500	1	>500	>280	>1000	>350	>500	>1100	>800	>1500
Etropus microstomus	4													
Paralichthys dentatus	15	5	2	2				1	1	1	7	4		
Scophthalmus aquosus	60	1		15					4		20	4		
Pseudopleuronectes americanus	39	1							1		2			
Trinectes maculatus	7	2	1	5			1							
Sphaeroides maculatus	22			1					1			6		
Opsanus tau	22			1					3					

Table 11. continued

Townsend's Inlet	Great Egg Harbor	TOTAL	1958			1959						1960	
			August	October	December	March	May	July	August	October	December	February	TOTAL
		2						1		1			2
		4							4				4
		88		5		3		29	51				88
		13		7					6				13
		1469	334	34			408	588	100	4	2	1	1471
1		137				5	15		114	3			137
22		>8791	580	2000			550	1500	3000	1250	11		8891
		6				3				1		2	6
		8			2	3	1	1	3		1		11
		39				2	2		14		18	3	39
		2				1		1					2
		50			2	1	8				2		13
		12						1	4			7	12
		2						1		1			2
		31				31							31
	2	>829	158	57		14	88	289	141	34		48	829
		18	2					6	10				18
		130	3	113		2		2	1	1	1	1	124
		30				21					4	5	30
16	25	>860	42	64	34	300	38	250	42	21	30	32	853
1	61	>1602	100	650		5600	3	250	417	27	20	8	7075
		23					1	22					23
		11				2		5					7
1	13	25				8	1				8	9	26
	46	58				27					1		28
3	5	120	12	10		1	13	45	30	9			120
	11	550	70	77		38	45	129	124	63	13	1	560
		253	39	127		3	2	57	7	16	1		252
		9				1		2	1			5	9
		9					1				8		9
		5				1	1		2			1	5
		4					2			1		1	4
53		126	87					26	16	1			130
3	8	71	7	6				17	29	2			61
		58						34	4				38
		219	1	3				5	3				12
2	2	>3640	91	100				5200	152	108			3651
		>692	124	1				400	133	10			668
	2	225					214	6	4				224
90	1	383	28	113				50	140	52			383
		13		1				1		11			13
		94	2	6				31	54	1			94
		42	2	1				25	9	5			42
		6	1					2	3				6
		3						2		1			3
		3						2					3
57	7	149	9					140					149
	3	83	58	28	4			59	37	3	2	9	200
16		92		16				26	9		41		92
	1	582	552						30				582
		26				1		1	10	2	12		26
>800	>1800	>24,771	>2200	>5700	>500	>1600	>1600	>5800	>10,000	>650	>360	>130	>24,540
		4		1					3				4
		38	1	6			14	11	5	1			38
2		106	52	1			40	11	1	1			106
	5	48	7	9		1		12	19				48
		16	2				2	3	8	1			16
		30					7	3	15	5			30
		26		1				5	20				26

Table 12. 50 species of fish collected in the shore zone at Lewes, Delaware, 1958-1960. Figures refer to number of individuals taken; minimal estimates are preceded by the symbol for "greater than" (>).

Species	1958 June 12	June 27	June 30	July 1	July 3	July 23	August 1	August 2	August 22	October 5	October 23	1959 March 29	April 14	April 30
Mustelus canis						1								
Dasyatis sayi												1		
Alosa aestivalis														
A. pseudoharengus		1												
* Opisthonema oglinum								2						
Brevoortia tyrannus	5	1	1		1						7			
Anchoa hepsetus														
A. mitchilli	80	66	37		17	47	>200			>500	27			
Anguilla rostrata	1		2		2	8	1			3	1			
Strongylura marina	.....						1	...	1	.....				
* Hyporhamphus unifasciatus														
Cyprinodon variegatus			2			850	3			1				
Fundulus heteroclitus		33	1		14	>200	11							
F. majalis					4	45	49			4	7	2	2	
* F. luciae														
Lucania parva			1			28								
Apeltes quadracus												1		
Syngnathus fuscus	1	1			1	6	7	2			3			1
Roccus americanus		6				2	2				12			
R. saxatilis	.....	2	.....			1	.....							
* Lutjanus griseus														
Pomatomus saltatrix	1	2	10		42	8	26	3	2					
Caranx hippos		1				5								
Trachinotus carolinus														
T. falcatus														
* Selene vomer						3								
Bairdiella chrysura			2		100		71	1		2	1			
Cynoscion regalis						3								
Leiostomus xanthurus	12	18			5								8	198
Menticirrhus saxatilis	.....					2	..	11	..	2	.....	8	.....	
Micropogon undulatus						1								
Pogonias cromis											4			
* Lagodon rhomboides														
Gobiosoma bosci							1							
G. ginsburgi							1							
* Prionotus carolinus														
Astroscopus guttatus														
Rissola marginata														
Sphyraena borealis	1				1	1								
Mugil cephalus	.....					12	..	21	...	1	.....	4	.....	6 .
M. curema	13	22		7	26									
Menidia beryllina												1	2	
M. menidia	150	204	91	75	229	365	768	87		500	203	500	8	30
Etropus microstomus											1			
Paralichthys dentatus	3	3	1		4	1	1				5			
Scophthalmus aquosus	4	16	6		4	1	51							1
Pseudopleuronectes americanus	4	15			5	2			6		3			
Trinectes maculatus														
Sphaeroides maculatus														
Opsanus tau											1			

* Collections at Lewes were made at a greater frequency than at the other stations; thus, species caught at Lewes but not observed during the regular collecting trips are not reported on Table 11. These seven additional species are marked above by an asterisk.

Table 12. continued

May	June			July				August		September		Oct.	1960 Jan.	Feb.	June	Total
7	10	20	26	1	4	8	21	6	18	3	13	10	6	13	18	
		1														2
									4							4
		1					1		1							4
								2							1	4
																2
1	3				>500		2									521
								1	99			2				102
15	25	>1000	>500	12	15	13	>200	>500	>1800	>100	140	160	10			> 5,464
		1				1	30	12	9		1			4	2	78
.....		5	.....			1	.....	1	.. 6	.. 17	.....					32
									3							3
															1	857
	1	1		2		4			2					6		> 275
1	10						25	2	321		17	12	1		4	506
							1									1
							1									30
														1	7	9
						22		6	7	6	7				6	76
									23							45
.....	1	.....									2	.....				6
										1						1
			7	7		6	3	2	8	3						130
			1			6	3	1	1						4	22
				7	1	15	7		3							33
							5	2		1						8
									1							4
			>100	6	>1000	>1000	>1000	56	64		20					> 3,423
							9	40	41		1					94
7					1			2	1							252
1	.....						15	... 26	... 91	... 8	 4	.....				168
																1
					1		3	5	25	1	2					41
															1	1
							24		8	3						36
							2		4	5					1	13
								1							13	14
							1									1
									1							1
			23	5	24	32	15								9	111
.....			209	.....			2	.....					9	.....	68	 332
						11	11	4	5							99
																3
34	70	>1000	>1000	>1000	> 500	>1000	75	30	>9000	30	>100	70	120	24	>100	> 17,363
									3	4					2	10
			1	2		1	1	1	4	1	1					30
3	1	1		1		4			1							94
		1				11		6	13	6					30	102
									7	1						8
7								15		1						23
							1	1	19	10						32
																> 30,471

Table 13. Length frequencies of 390 Atlantic Menhaden, Brevoortia tyrannus, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length	June		July		August		September		October	
(cm.)	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
4			1							
5		2	1	3						
6		2	4	2		2				
7		1	37	17		22				
8			7	56		66				
9			2	28		60				
10						21			3	
11					3	6			11	
12					4	5			8	
13				2	2				5	1
14				1	1					1
15				1						1
24			1							
Number	0	5	53	110	10	182	0	0	27	3
Mean Length	-	6	7	8	12	9	-	-	12	14

Table 14. Length frequencies of 178 American Eel, Anguilla rostrata, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	Feb	Mar	May		June		July		Aug		Oct	
	15-28	15-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-31
4		1										
5	11	6			1							
6	1	2			6			3				
7					2			1				
8							1	1	1			
9			4		1							
10			8	1	1			1		1		
11			23	2								
12			9	5	1		1	2				
13			6	1				1				
14			3	4			1	1			1	
15			3	3			3	1	1	1		
16			2	1			1	2	2			
17				2			1	5	5			
18			3		1			4	2	1		
19			3					1	2	1		
20												
21									1	2		
22									1			
23									1			
24								1				
32								1				
41						1						
48						1						
49					1							
Number	12	9	64	19	14	2	8	26	17	6	1	
Mean Length	5	5	12	13	15	44	14	15	17	17	14	

Table 15. Frequency of occurrence of food items in the stomachs of 47 American Eel, *Anguilla rostrata*, total length from 5 to 49 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)																					Total
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	24	32	41	48	49	
Invertebrates																						
Annelida														1	1	1						4
Polychaeta		1																				1
Nereis											1											
Arthropoda																						1
Crustacea (remains)				1																		
Mysidacea																						3
Neomysis									1					1				1				1
Decapoda							1															1
Emerita																		1				
Isopoda																						1
Edotea							1															
Amphipoda													1	1			1	1				4
Xiphosura (*Limulus*) larvae													1	2			1	1				12
eggs				1		1		1	3		1											2
Invertebrate eggs			1					1														3
Insecta (remains)				1		2																
Vertebrates																						1
Fishes (unidentified)														1								
Antherinidae															1			1	1			3
Menidia																						1
fish eggs				1																		
Miscellaneous														1								2
unidentified remains			1																			1
detritus														1								
Empty	2			1	1	1		2	1	2	1	2	2	1		2				1	1	20
Number of stomachs examined.	3	1	1	3	1	3	1	4	4	2	3	2	5	6	1	3	1	1	1	1	1	47

Table 16. Length frequencies of 1446 Mummichog, Fundulus heteroclitus, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	March 16-31	May 1-15	June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	Oct 1-15	December 1-15	December 16-31
1			3								
2			35		8	35			4		7
3	74	1	80		27	128			13	6	53
4	285	3	51		16	51	1	1	6	1	32
5	61	2	90	2	13	23			2		14
6	28	1	42	6	20	28				2	1
7	20	3	15	5	14	28		5	3	2	3
8	3	2	6	2	2	12		3	9	2	
9	1	2	1			11		4	12	2	
10	4					1		1	11	1	
Number	476	14	323	15	100	317	1	14	60	16	110
Mean Length	4	6	4	6	5	4	4	8	6	6	4

Table 17. Frequency of occurrence of food items in the stomachs of 67 Mummichog, *Fundulus heteroclitus*, total length from 3 to 10 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.) 3	4	5	6	7	8	9	10	Total
Invertebrates									
Annelida									
Polychaeta (remains)	1			1					2
Polychaeta (tubes)						2			2
Nematoda (parasitic)					1	1	3	1	6
Nematoda (soil)								1	1
Crustacea (unidentified)									
Amphipoda (remains)				2	2	1			5
Amphipoda (tubes)						1	1		2
Gammaridae		4	1*	1*	1		1		6 (2*)
Decapoda (remains)				1					1
Insectivora				1					1
Mollusca									
Gastropoda (fr. water)				1					1
Vertebrates									
Fishes (unidentified)						1	2	1	4
Menidia					1				1
Miscellaneous									
Algae		5	2	2	3		1	1	14
Fecal pellets					1				1
Sand		1	1		1				3
Soft tissue (unidentified)			2	1				2	5
Plant detritus		9		3	4			2	18
Empty			2	5		3	1	1	12
Number of stomachs examined	4	9	8	18	9	7	6	6	67

* (indicates stomach full but individual food organisms were not counted)

Table 18. Length frequencies of 775 Striped Killifish, Fundulus majalis, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	June 1-15	July 1-15	July 16-31	August* 18 male	August* 18 female	August 18-31	October 1-15	October 16-31
2	2		5					
3	7	10	10			2		5
4	26	10	5			6	7	12
5	94	3	14			1	23	3
6	94		10	2		15	47	3
7	43			3		14	42	
8	28		3	2		26	28	
9	13		4	4	3	5	8	
10	6		1	5	6		2	
11				19	1		1	
12			5	22	2		2	
13				2	23		1	
14				1	21		2	
15					9			
16					2			
Number	313	23	57	60	67	69	163	23
Mean Length	6	4	6	11	13	7	7	4

* Collection of 127 specimens from Indian River Inlet, showing range in size of males and females.

Table 19. Frequency of occurrence of food items in the stomachs of 64 Striped Killifish, Fundulus majalis, total length from 3 to 14 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.) 3	4	5	6	7	8	9	10	12	13	14	Total
Invertebrates												
Annelida												
Polychaeta (remains)		1		2						1		4
Polychaeta (tubes)			1	1		1		1				4
Crustacea												
Amphipoda (remains)				1		1						2
Amphipoda (tubes						1						1
Decapoda (remains)						1	1					2
Isopoda (remains)							1					1
Edotea					1*							1*
Arachnoidea												
Xiphosura												
Limulus (eggs and larvae)	1		4	10	2	11	4			6		38 (16*)
			1*	6*	2*	5*	1*				1*	
Insectivora (remains)					1							1
Homoptera (larvae)						2						2
Diptera (larvae)		1										1
Vertebrates												
Fishes (unidentified)				1	1	1						3
Miscellaneous												
Sand			1			1						2
Soft tissue		1				1				1		3
Plant detritus	1	1	2									4
Empty			4	3		3			1		1	12
Number of stomachs examined	1	5	9	16	6	18	3	1	1	2	2	64

* (indicates stomach full but individual food organisms were not counted)

Table 20. Length frequencies of 83 Northern Pipefish, Syngnathus fuscus, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	June		July		August		October	
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-31
5		3	1			1	2	
6		1	1	1		1		
7		2	1		1			
8		1	2		2	2	1	2
9			1			7		2
10			1			3		
11			1			3		3
12			2	1	2	2	1	1
13				1	1	1	1	2
14					2		1	3
15	2			1	1			2
16								1
17			1			2		
18	1	1						
19		1						
20								
21	1				1			
22			1					
Number	4	9	12	4	10	22	6	16
Mean Length	17	18	10	12	12	10	10	12

Table 21. Length frequencies of 528 White Perch, Roccus americanus, collected in the shore zone of the Delaware River estuary are, 1958-1960.

Total length (cm.)	March	May	July		August		October		Dec
	1-15	1-15	1-15	16-31	1-15	16-31	1-15	16-31	15-31
3			23						
4			57	1		1			
5			76	4		4	1		
6	2	1	33	5		11	5		
7	7	1	1			9	17	1	
8	12	5	3			8	19		4
9	17	3	13			2	13		1
10	11	1	17	8		2	3		2
11	2		7	13		7	1		
12		1		10		6			
13				1		9	1		
14		1				11		1	
15		3				4	2	1	
16		1				9		1	
17		1				6		5	
18	1					1	2	2	
19		1					1	2	
20									
21					2		2	1	
22					1		1	1	
23							1	1	
Number	52	19	230	42	3	90	69	16	7
Mean Length	9	11	6	10	21	11	9	17	9

Table 22. Frequency of occurrence of food items in the stomachs of 116 White Perch, Roccus americanus, total length 3 to 23 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)																					Total
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Invertebrates																						
Annelida				1		1																2
Polychaeta				1					1				3	1			1					7
Bryozoa							1			1						1						3
Arthropoda																						
Crustacea (remains)				1			2		2						1							6
Mysidacea																						
Neomysis			1	1		4	1	2		1	1		1		2	2			1		1	18
Cladocera			1				1			1												3
Decapoda																						
Crangon							1								1		1					3
Paleomonetes									1													1
zoea		1		1																		2
Isopoda				1			1						1			1						4
Amphipoda				1						1			1			1			1			5
Gammaridae						2			1		1											4
Gammarus				1		2	2	2	2		1		5	1	1	1	1					18
tubes									1													1
Copepoda		2		4	1	6	4															17
eggs - crustacean																						0
Xiphosura (Limulus)																			1	2		3
Insecta							1															1
Invertebrate eggs				1				1														2
Vertebrates																						
Fish							2									1						3
Miscellaneous																						
Unidentified flesh			1	1	1	1	2	1				1				1						9
Plant detritus																						
Empty	1	1	2	1	6	1	1	1	1	2		2	1		2	1	1		1	1		26
Number of stomachs examined	1	4	4	13	8	15	15	5	8	6	3	3	6	3	6	6	2		4	3	1	

Table 23. Length frequencies of 328 Striped Bass, Roccus saxatilis, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	March 15-31	June 1-15	June 16-30	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15	Sept. 16-30	Oct. 1-15	Oct. 16-31	Dec. 16-31
2			2									
3												
4					3							
5							4				1	
6				1			5					
7				1			26			2		
8							48			5		
9				6			24			19		
10				15	1		9			36	1	
11	1			17	1		2			42		
12		1		7			1			21	1	
13				2	1					6		
14										2		
15					1		1			2		
16										1		1
17											1	
18										2		
19											1	
20												
21											2	
22										1		
31			1									
Number	1	1	3	49	7	0	120	0	0	139	7	1
Mean Length	11	12	-	10	9	-	8	-	-	11	15	16

Table 24. Frequency of occurrence of food items in the stomachs of 279 Striped Bass, Roccus saxatilis, total length 4 to 31 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)																					Total
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	29	31	
Invertebrates																						
Annelida																						
Polychaeta						1	1	3	1													6
Nematoda (parasitic)					2		1	1		1												5
Bryozoa							1															1
Coelenterata (Hydrozoa)									1													1
Crustacea	1					2	7	3	4		1	2		1	1					1		23
Mysidacea	3		1	5	6	14	20	32	15	2												98
Decapoda				3	1	1																5
Crangon	2			1	1	3	10	7	4	2	1	1	3									35
Paleomonetes				3	14	3	7	1	1													29
Callinectes								1								1		1	1			4
Portunidae					1			1														2
Hoplocardia						1																1
Amphipoda - Gammaridae	1			2	1	9	14	15	8	1												51
Isopoda				1		1		1														3
Copepoda		2	1	2				1														6
Xiphosura (Limulus; eggs and larvae)	1		1	9	10																	21
Insecta																						
Hymenoptera												1										1
Diptera			1																			1
Vertebrates (unidentified)							1															1
Fishes (unidentified)				1		1	3	2	2	1												10
Clupeidae									1		1											2
Engraulidae					1	2	2	1							1							7
Syngnathidae								1														1
Atherinidae								1					1									2
Miscellaneous																						
Sand, stone				2	2		1	1	1	2												9
unidentified					2	1		1														4
plant detritus						1	1			1												3
Empty		1	1	2	4	4	2	2	2	4											1	23
Number of stomachs examined	3	5	5	24	31	35	60	59	27	10	3	4	4	1	2	2	0	1	1	1	1	

Table 25. Length frequencies of 333 Bluefish, Pomatomus saltatrix, collected in the shore zone of the Delaware River estuary area, 1958-1960. [1]

Total length (cm.)	June		July		Aug.		Sept.		Oct.
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15
3					7				
4	1		1	1	40				
5		1			5				
6		21	2	1					
7		14	17	6	1	1			1
8		6	24	18	2	1			
9			9	1		2			
10			4		1	1			
11				3	10	1			
12					11	1			
13					23	1			
14					39	1			
15					15	4			
16					11	4			
17					8	2			
18					2				
19					2				
20					1			1	
21					1				
22						1			1
23								1	
Number	1	42	57	30	179	20	0	2	2
Mean Length	4	7	8	8	11	14	-	(22)	(15)

[1] Includes specimens caught on hook and line.

Table 26. Frequency of occurrence of food items in the stomachs of 152 Bluefish, Pomatomus saltatrix, total length 4 to 23 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)																				Total
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Invertebrates																					
Arthropoda																					
Crustacea (remains)				2		1															3
Mysidacea																					
Neomysis	4	2	5	3								2	2	2	1				1		22
Decapoda			1	1																	2
Crangon			2	4	1	1					1									1	10
Paleomonetes						1															1
zoea larvae			1																		1
Vertebrates																					
Fishes	1		7	3	9	4	2	3	2		1	3	4	1		1	1			1	43
Menidea			3	5	12	3	3	1			1	4	3								35
Anchoa				1		1		1	1				1								5
Gobiosoma					1																1
Fundulus					1																1
Carangidae													1						1		2
Clupeidae			1	1	1	1		1						1							6
post-larval fish				1	2		1														4
Miscellaneous																					
plant detritus		1																			1
unidentified tissue			1		2	2		1		2	2										10
Empty				3	5	2	2	2	1	2	5	3	1	1			1				29
Number of stomachs examined	6	2	14	20	29	14	8	9	4	4	10	11	8	5	1	1	2		3	1	

Table 27. Length frequencies of 82 Crevalle Jack, Caranx hippos, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	June		July		August		September		October	
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
2			1			3				
3		3	11	5	1	1			1	
4			4	3		4				
5										
6						1			6	1
7									5	
8										
9									1	
10						2				
11						8				
12						13				
13						7				
14										
15										
16							1			
Number	0	3	16	8	1	39	1	0	13	1
Mean Length	-	3	3	3	3	10	16	-	6	6

Table 28. Frequency of occurrence of food items in the stomachs of 40 Crevalle Jack, Caranx hippos, total length 3 to 16 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)												Total
	3	4	5	6	7	8	9	10	11	12	13	16	
Invertebrates													
Arthropoda													
Crustacea	5									1			6
Mysidacea													
Neomysis	5	1			1								7
Decapoda		1		1				1		1			4
Crangon	1												1
Paleomonetes									3	1	1		5
Vertebrates -(Fishes)									1	1		1	3
Gobiidae					1								1
Engraulidae													
Anchoa					1								1
Atherinidae					1								1
Miscellaneous													
sand		1											1
soft remains	3	2			1								6
Empty	1	1		3	1		1						7
Number of stomachs examined	15	5	-	4	4	-	1	1	3	5	1	1	

Table 29. Length frequencies of 620 Silver Perch, Bairdiella chrysura, collected in the shore zone of the Delaware River estuary area, 1958-1960

Total length (cm.)	July		August		September		October		November
	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15
0-1		2							
1	8	69		1					
2	77	41	20						
3	46	27	22	9			3		
4	9	36	3	29			19		
5	3	34	3	26	16		2		
6		5	3	4	23		1		
7			9	2	8		4	2	1
8			2	10			3	1	1
9				5	1		1	4	
10				7	1			5	
11				5				4	
12								3	
Number	143	214	62	98	49	0	33	19	2
Mean Length	2	3	4	6	6	-	5	10	8

Table 30. Frequency of occurrence of food items in the stomachs of 221 Silver Perch, Bairdiella chrysura, total length 2 to 19 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)														Total
	2	3	4	5	6	7	8	9	10	11	12	16	17	19	
Invertebrates															
Nematoda		2													2
Annelida															
Polychaeta							2								2
Mollusca															
Gastropoda							1								1
Arthropoda						1									1
Crustacea		7	5	3	3	3	1	2	1	2					27
Mysidacea		19	19	24	9	9	5	4	6	4	2				101
Decapoda															
Cragonidae		1	1	3		1	5	2	7	7	3	2			32
Isopoda		4		4	1				1						10
Amphipoda		2	2	5		1	1								11
Gammarus	1	5	4	7	2		2								21
Corophium		3	6	3					1						13
Copepoda		5	5	4											14
Crustacean megalops		2	5	6	1		1		1						16
Xiphosura - Limulus							1								1
Invertebrate eggs				1											1
Vertebrates															
Fishes		1	1	1	1				1						5
post larvae		1		2	1	1									5
Clupeidae post larvae					1										1
Miscellaneous															
sand, stones, gravel		2	2	1			1								6
Empty	1	8	1	3	1		1	3	3	1					22
Number of stomachs examined	2	44	34	44	25	15	16	10	13	11	3	2	1	1	

Table 31. Length frequencies of 1105 Weakfish, Cynoscion regalis, collected in the shore zone of the Delaware River estuary area, 1958-1960. [1]

Total length (cm.)	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Oct. 1-15	Oct. 16-31	Nov. 1-15
1	2						
2	78		1	25			
3	77	2		17			
4	114	8	4	13			1
5	196	7	32	5		1	7
6	112	2	56	8		4	14
7	29	4	24	29		4	4
8	10	4	5	23		7	4
9	2	4	1	16		23	4
10		1		14	2	23	
11				4		16	3
12				1		6	
13				1		1	
14							
15							1
Number	620	82	123	156	2	85	37
Mean Length	4	6	6	6	10	10	7

[1] Includes several collections from trawls taken in deeper water in July and November.

Table 32. Frequency of occurrence of food items in the stomachs of 220 Weakfish, *Cynoscion regalis*, total lengths 2 to 15 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)															Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Invertebrates																
Annelida																
Polychaeta (tubes)							1									1
Arthropoda																
Crustacea (remains)							2	1			1					4
Mysidacea																
Neomysis	1	2		11	24	21	29	14	7	9	3	1	1			123
Decapoda																
Crangon					2	1	2	3	5	4	6	3	1			27
Paleomonetes									1	2						3
decapod larvae				2	5	1	4									12
unidentified					1				3							4
Isopoda				1	1		1	2	1	1						7
Amphipoda																
Gammaridae									1							1
Gammarus						2	4	1	1		1					9
Corophium					1		2	1								4
unidentified					1	1	2	2								6
Copepoda				1	2	3	1									7
Insecta																
larvae								1		1						2
unidentified							2									2
Xiphosura (*Limulus*)						1	2	6		1	1					11
Vertebrates																
Fishes																
Anchoa						1	1		1	1						4
Menidia post larvae								1		2						3
unidentified					1			3	3		1		1		1	10
Miscellaneous																
sand					1						1					2
plant detritus						3	3	3								9
Empty				3	8	2	4	4	2	3	2					28
Number of stomachs examined	1	2		17	39	31	41	30	18	20	14	4	2	0	1	

Table 33. Length frequencies of 423 Northern Kingfish, Menticirrhus saxatilis, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	July		August		September		October	
	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
1	6							
2	3	2	12	1			28	3
3	1	14	6	1			68	9
4	1	37	4	3	2		49	23
5		21	8	4			22	22
6		3	5	5			13	3
7		1	6		1		2	2
8				2	1		2	2
9		2		3	2		1	
10		1		3			1	1
11		1		2			1	
12				1			1	
13					2			1
14					1			
15							1	
Number	11	82	41	25	9	0	189	66
Mean Length	2	4	4	7	9	-	4	5

Table 34. Frequency of occurrence of food items in the stomachs of 119 Northern Kingfish, Menticirrhus saxatilis, total lengths 1 to 14 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)														Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Invertebrates															
Nematoda		4	1	1	1										7
Annelida		1													1
Polychaeta			1	5	5	3	1	5	4	2	2				28
Bryozoa					2										2
Platyhelminthes															
Cestoda					1										1
Arthropoda					1										1
Crustacea				8	2	2							1		13
Mysidacea	1	9	6	11	12	4	1								44
Decapoda															
Brachyura (adults and larvae)				1	1								1		3
Cragonidae				2	1			1	4		2	1			11
Paleomonidae											1				1
Isopoda			3	1	2	1									7
Amphipoda		1	1	3	10	1			2						18
Gammarus				1	6	1	1		1						10
Crustacean eggs					2										2
Copepoda		1		2	12	1		1							17
Insecta											1				1
Diptera		1			1										2
Xiphosura (Limulus)				1						1					2
Balanoglossus				1											1
Vertebrates															
Fishes				3	1			1	1					1	7
Gobiidae										1			1		2
Clupeidae					1			2				1	1	1	6
Miscellaneous															
gravel, sand				3	1	3		3	3	1	2				16
Unidentified eggs				1	2										3
detritus								1							1
plant detritus					1			1	1						3
fish scales		1	2	2	1	1				1					8
Empty					2		3	2							7
Number of stomachs examined	1	10	7	27	27	8	5	13	8	5	4	1	2	1	

Table 35. Length frequencies of 120 Black Drum, Pogonias cromis collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	July		August		September		October	
	1-15	16-31	1-15	15-31	1-15	16-30	1-15	16-31
1	1							
2	1		1					
3	1							
4								
5	2	1					1	
6	10		1					
7	8	1	1					
8	3	5	1	1				
9	1	1						
10	1		1	4				
11				4				
12			1	6	1			
13			1	5				
14			1	13				
15				17	1			2
16				9				
17				6				1
18				3			1	
19				1				
Number	28	8	8	69	2	0	2	3
Mean Length	6	8	9	14	14	-	12	16

Table 36. Frequency of occurrence of food items in the stomachs of 79 Black Drum, Pogonias cromis, total lengths 3 to 19 centimeters, collected in the shore zone area of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)																	Total
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Invertebrates																		
Annelida (remains)			1										1					2
tubes												1	1					2
Polychaeta			1	1	2	3		1		2	1	3	7	2	1	1		25
Mollusca (shell)								1				1		1		1		4
Pelecypoda						1		2	1			3	4	2	2	1		16
Mercenaria												1	1	2				4
Mya															1			1
Mytilus								1										1
Crassostrea											1		1		2	1	1	6
Arthropoda								1										1
Crustacea				1	1	1			1		2					1		7
Decapoda								1							1			2
Brachyura													1					1
Crangon						1		1					1		2			5
Isopoda (Edotea)			1															1
Amphipoda			1							1								2
Gammaridae	1																	1
Gammarus			2		1	1												4
Insecta																		
Orthoptera									1									1
Vertebrates																		
Fishes						2			1	1		1	1					6
Menidia													1		1			2
Clupeidae											1							1
fish scales						1										1		2
Miscellaneous																		
sand, stone, gravel				1		1				1	2	4	2					11
detritus			1											1				2
plant remains												1						1
Empty				1		1		1		4		1	3			1		12
Number of stomachs examined	1		3	2	3	6		7	4	7	3	9	16	6	7	4	1	

Table 37. Length frequencies of 209 Northern Sennet, Sphyraena borealis, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	June		July		August	
	1-15	16-30	1-15	16-31	1-15	16-31
5		24	16	2	1	7
6	1	23	82	1	1	2
7			32	1	2	1
8			7		2	
9			1			
10			1			
11			2			
Number	1	47	141	4	6	10
Mean Length	6	5	6	5	7	5

Table 38. Frequency of occurrence of food items in the stomachs of 85 Northern Sennet, Sphyraena borealis, total lengths 5 to 11 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)							Total
	5	6	7	8	9	10	11	
Invertebrates								
Arthropoda			1					1
Crustacea								
Mysidacea	8	5	1	1				15
Decapoda		1						1
Isopoda		1						1
Vertebrates								
Fishes (unidentified)	3	21	2	3			1	30
Atherinidae								
Menidia	2	5	4	1			1	13
Engraulidae								
Anchoa	1		2					3
Clupeidae								
Alosa	2	2	1					5
Sphyraenidae								
Sphyraena borealis			2					2
Gobiidae								
Gobiosoma		1						1
fish larvae		5						5
Empty	3	5	7			1		16
Number of stomachs examined	18	41	18	5	0	1	2	

Table 39. Length frequencies of 469 Striped Mullet, Mugil cephalus, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	June		July		August		September		October	
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
2	18	22		1						
3	76	255	4	4						
4	7									
5	14		3	1						
6			15							
7			1							
8				2						1
9				2	1					
10					4					2
11				1	10					1
12				1	4					
13			2		4					
14			3		1					
15					1	2				
16										
17						2				
18						3				
19						1				
Number	115	277	28	12	25	8	0	0	0	4
Mean Length	3	3	7	6	12	17	-	-	-	10

Table 40. Length frequencies of 355 White Mullet, Mugil curema, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	June		July		August		September		October	
	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
2	5		9	15						
3	8	1	45	50						
4				5						
5				5						
6				141						1
7				47						2
8					1					4
9					3					6
10										2
11										1
12						1(1)				
13						3(1)				
Number	13	1	54	263	4	4	0	0	16	
Mean Length	3	3	3	5	9	13	-	-	9	

(1) night collection

Table 41. Length frequencies of 5357 Atlantic Silverside, *Menidia menidia*, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	Jan.	February		March	April		June	
	1-15	1-15	16-28	15-31	1-15	16-30	1-15	16-30
0-1								1
1							8	45
2			1			1	2	286
3								115
4		1	1	8		7		23
5	6	6	2	59	2	4	1	4
6	12	11	4	100	1	15	6	26
7	13	9	8	86	1	11	22	53
8	10	7	21	55	3	5	28	83
9	8	6	44	23	3	3	28	55
10	7	2	32	7		1	20	33
11	1	1	3	7			5	12
12	1						3	1
13				1				
Number	58	43	116	346	10	47	123	737
Mean Length	7	7	9	7	7	6	8	4

Table 41. continued

July		August		October		Nov.	Dec.
1-15	16-31	1-15	16-31	1-15	16-31	1-15	16-31
6	4	10	2				
35	127	38	13	3			
57	219	45	42	16	6	2	3
35	205	136	115	52	18	4	2
16	145	191	157	80	39	21	34
40	54	232	122	90	58	29	37
88	10	186	114	84	44	26	12
81	8	35	87	85	25	11	15
69	14	14	45	62	27	4	6
31	15	7	18	36	5		13
4	12	3	14	10	1		5
	2	2	4				1
	1		1				
462	816	899	734	518	223	97	128
6	4	5	6	7	6	6	7

Table 42. Frequency of occurrence of food items in the stomachs of 193 Atlantic Silverside, Menidia menidia, total lengths 5 to 12 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)								Total
	5	6	7	8	9	10	11	12	
Invertebrates									
Annelida (Polychaeta)					1	1			2
polychaete tubes			1				1		2
Mollusca (valve)						1			1
Arthropoda (remains)			1	1	2	2			6
Crustacea	2	2	5	4	5	2	1		21
Mysidacea									
Neomysis			1	6	6	2	4		19
Cladocera		2	2	3			1		8
Decapoda (remains)					2	1			3
Callinectes			1						1
Emerita								1	1
Crangon				1					1
megalops larvae		1	1				1		3
zoea larvae		2	1	1					4
Isopoda		1	2	1	1		2		7
Amphipoda		3		5	5	4		1	18
Gammarus			1	2	6	2			11
Corophium				1	1				2
Copepoda	2	9	5	4	8	4	1		33
Xiphosura (Limulus) larvae		1		1	6	4	1		13
eggs	1			4	3				8
Insecta		3	4	6	4	1	1		19
Diptera		2		2					4
Hemiptera					1				1
invertebrate eggs (unidentified)							1		1
Vertebrates									
Fishes (remains)			1	4		2		1	8
Anchoa sp.			1		1	2			4
Gobiidae				1					1
eggs				2					2
Miscellaneous									
fish scales						2			2
sand	1	2	1	2					6
unidentified detritus			1						1
" flesh	1	2	3	2			1	1	10
Empty	1	4	5	4	2	5			21
Number of stomachs examined	7	25	32	48	41	25	12	3	

Table 43. Length frequencies of 38 Summer Flounder, Paralichthys dentatus, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	May		June		July		August		September		October	
	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
4			1									
5												1
6			2	1	1			1				
7			1		1			1				
8				3	1							
9				4								
10				3			1					
11				1	1							
12				1								
13						1	1					
14						1						
15												
16						1		1				
17	1	1								1		1
18												
19	1											2
20											1	
Number	2	1	4	13	4	3	2	3	0	1	1	4
Mean Length	18	17	6	9	8	14	12	10	-	17	20	15

Table 44. Frequency of occurrence of food items in the stomachs of 26 Summer Flounder, Paralichthys dentatus, total lengths 5 to 21 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.) 5	7	8	9	10	11	12	13	14	16	18	20	21	Total
Invertebrates														
Annelida														
Polychaeta (remains)	1		1			1								3
Crustacea (unidentified)	1								1	1		1		4
Decapoda											3		2	5
Crangon									1					1
Pagurus														
Mysidacea		2	3		8									13 (8*)
Neomysis		1*	1*	3*	2*		1*							
Amphipoda														
Gammaridae			1											1
Isopoda														
Edotea			2											2
Arachnoidea														
Xiphosura														
Limulus (eggs and larvae)			1				1*							1 (1*)
Vertebrates														
Fish (unidentified)			1									1	2	4
Menticirrhus													1	1
Gobiosoma				1*										(1*)
Menidia									3	1				4
Miscellaneous														
Sand			1							1				2
Empty								1			1			2
Number of stomachs examined	2	2	4	3	3	1	2	1	2	2	2	1	1	

* (indicates stomach full but individual organisms were not counted)

Table 45. Length frequencies of 119 Windowpane Flounder, Scophthalmus aquosa, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	Feb. 1-15	Feb. 16-28	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31
5			5	3				
6	1		15	11				
7	1		21	11				1
8			12	3		1		1
9			6	2	2			4
10			3			1		1
11			2					2
12					3	1		3
13					1			2
14								
15								
16								
17								
Number	2	0	64	30	6	3	0	14
Mean Length	6	-	7	6	11	10	-	10

Table 46. Frequency of occurrence of food items in the stomachs of 31 Windowpane Flounder, Scophthalmus aquosus, total lengths 5 to 17 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)										Total
	5	6	7	8	9	10	11	12	13	17	
Invertebrates											
Arthropoda											
Crustacea											
Mysidacea											
Neomysis	1	1	6		5	3	1	4	4	1	26
Decapoda											
Crangon					2				1		3
Copepoda		2									2
Vertebrates											
Fishes									1		1
Miscellaneous											
sand										1	1
Empty		1		1							2
Number of stomachs examined	1	4	6	1	6	3	1	3	4	2	

Table 47. Length frequencies of 625 Winter Flounder, *Pseudopleuronectes americanus*, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Total length (cm.)	March	June		July		Aug.		Oct.		Nov.
	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-31	1-15
2			1							
3			3							
4		1	13	2	3	4				
5		5	18	1	9	7	6			
6		5	10	7	20	12	29			
7		2	6	3	6	17	67	1	1	
8	1		1	5	1	12	107			
9				2	1	5	106			
10						1	79	1		
11							30	2	1	
12				1			3	1		2
13							2		1	1
Number	1	13	52	21	40	58	429	5	3	3
Mean Length	8	6	5	7	6	7	8	10	10	12

Table 48. Frequency of occurrence of food items in the stomachs of 95 Winter Flounder, *Pseudopleuronectes americanus*, total lengths 3 to 13 centimeters, collected in the shore zone of the Delaware River estuary area, 1958-1960.

Stomach Contents	Total length (cm.)												Total
	2	3	4	5	6	7	8	9	10	11	12	13	
Invertebrates													
Annelida			2	1		2	1						6
Oligochaeta				1						1			2
Polychaeta		3	2	7	11	8	3	2	3	3	1	1	44
Nereidae						2							2
annelid tubes			1		1								2
Bryozoa				1									1
Mollusca													
Pelecypoda													
Mytilus						1							1
Arthropoda													
Crustacea				2		3							5
Mysidacea						1							1
Decapoda									1				1
larvae					1		1					1	3
Isopoda					2	1			1	3			7
Edotea			1		1	3	1			1		1	8
Amphipoda				1	1					1			3
Gammarus					1			1	1	1			4
Copepoda			2				1						3
Ostracoda				1									1
Xiphosura (*Limulus*) eggs						1							1
larvae						1							1
Vertebrates													
fish eggs				1									1
Miscellaneous													
fecal pellets				1	1	1	2						5
sand			1	1	2	5	2						11
detritus				1	2	2	2	1		1			9
plant detritus					2								2
Empty		1	1	3	8		2	1	1		1		18
Number of stomachs examined		4	9	15	26	17	8	4	4	5	2	1	

Table 49. Summary of major food items of 1857 specimens of 17 fish species taken in the shore zone of the Delaware River estuary area, 1958-1960. The number of stomachs in which each food item was found and the total length range (in centimeters) of each fish species are recorded.

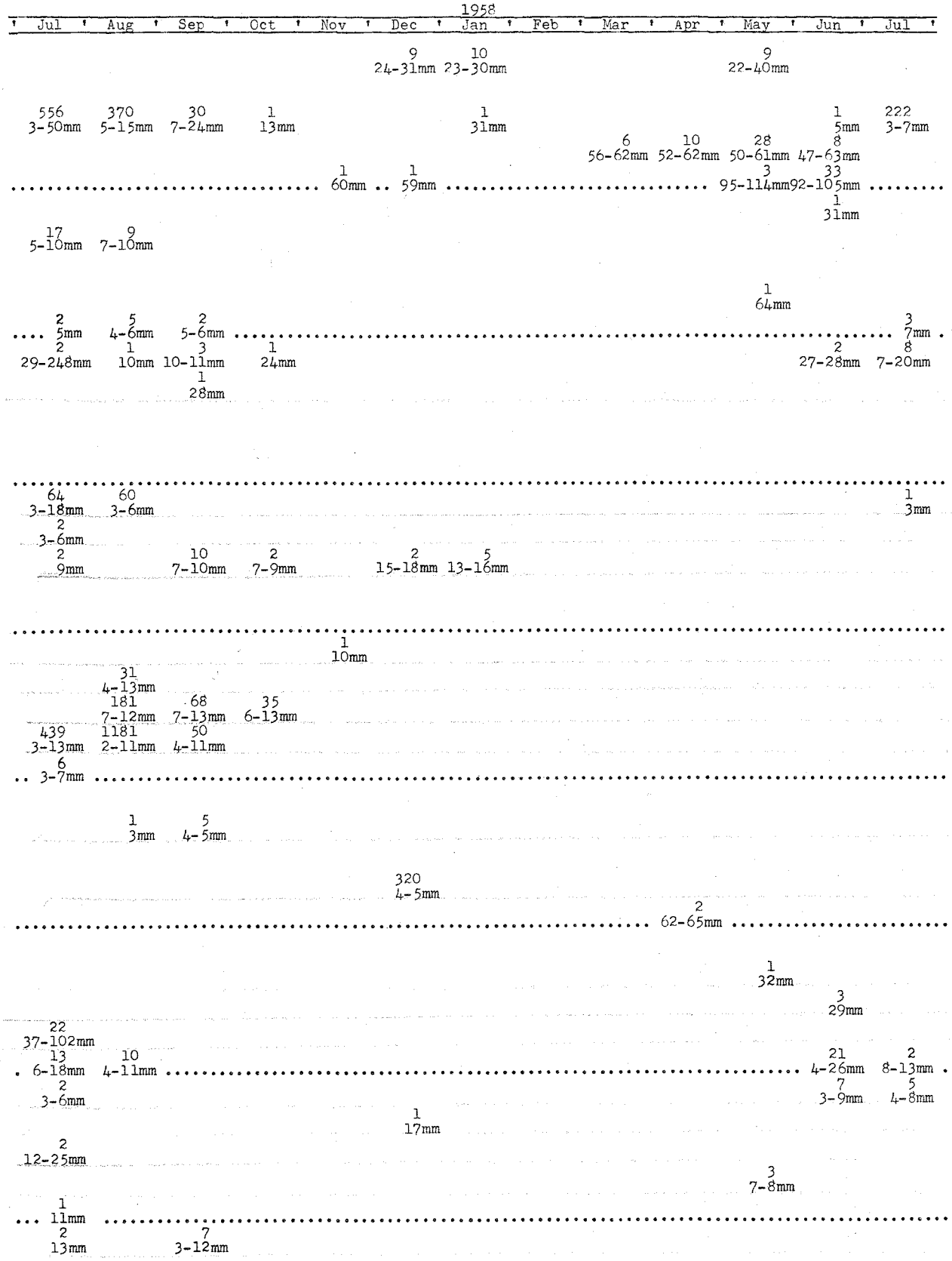
Major food item:	Anguilla rostrata (Table 15)	Fundulus heteroclitus (Table 17)	Fundulus majalis (Table 19)	Roccus americanus (Table 22)	Roccus saxatilis (Table 24)	Pomatomus saltatrix (Table 26)	Caranx hippos (Table 28)	Bairdiella chrysura (Table 30)	Cynoscion regalis (Table 32)	Menticirrhus saxatilis (Table 34)	Pogonias cromis (Table 36)	Sphyraena borealis (Table 38)	Menidia menidia (Table 42)	Paralichthys dentatus (Table 44)	Scophthalmus aquosus (Table 46)	Pseudopleuronectes americanus (Table 48)	Trinectes maculatus	No.	%
Annelida	5	4	8	9	6			2	1	29	29		4	3		56	8	164	9
Crustacea (remains)	1			8	29	3	6		20	15	7		21	4		5	1	120	6
Mysidacea	3			18	98	22	7	101	123	44		15	19	21	26	1		498	26
Decapoda	2	1	2	6	11	3	4	16	16	3	3	1	12	1		4		83	4
Palaemonetes				1	29	1	5		3	1								40	2
Crangon				3	35	10	1	32	27	11	5		1	5	3			128	7
Isopoda	1		2	4	3			10	7	7	1	1	7	2		15		60	3
Amphipoda (Gammaridae)		5		27	51			21	10	10	5		11	1		4		145	8
Corophium								13	4				2					19	1
other species	2	8	3	5	8			11	6	18	2	1	18			3		85	5
Cladocera				3									8					11	1
Copepoda				17	6			14	7	17			33		2	3		99	5
Xiphosura	16		54	3	21			1	11	2			21	2		2		133	7
Insecta	3		4	1	2				4	3	1		24					42	2
Mollusca		1						1			28		1			1		32	2
Fishes (other)	2	4	3	3	11	51	4	10	10	8	8	38	11	6	1	1		171	9
Atherinidae	3	1			2	35	1		3		2	13		4				64	3
Engraulidae					7	5	1		4			3	4					24	1
Clupeidae					2	6		1		6	1	5						21	1
Plant		17			3	1		1	9	3	1		1			2		38	2
Detritus	1	15	4	3						1	2		1			9		36	2
Empty	20	12	12	26	23	29	7	22	28	7	12	16	21	2	2	18	3	260	14
% empty stomachs	43	18	19	22	8	19	18	10	13	6	15	19	11	8	6	19	20		
No. of stomachs examined	47	67	64	116	279	152	40	221	220	119	79	85	193	26	31	95	15	1857	
Range in total length (in cm.)	6-49	3-10	3-14	3-23	4-31	4-23	3-16	2-19	1-14	1-14	3-19	5-11	5-12	5-21	5-17	3-13	4-13		

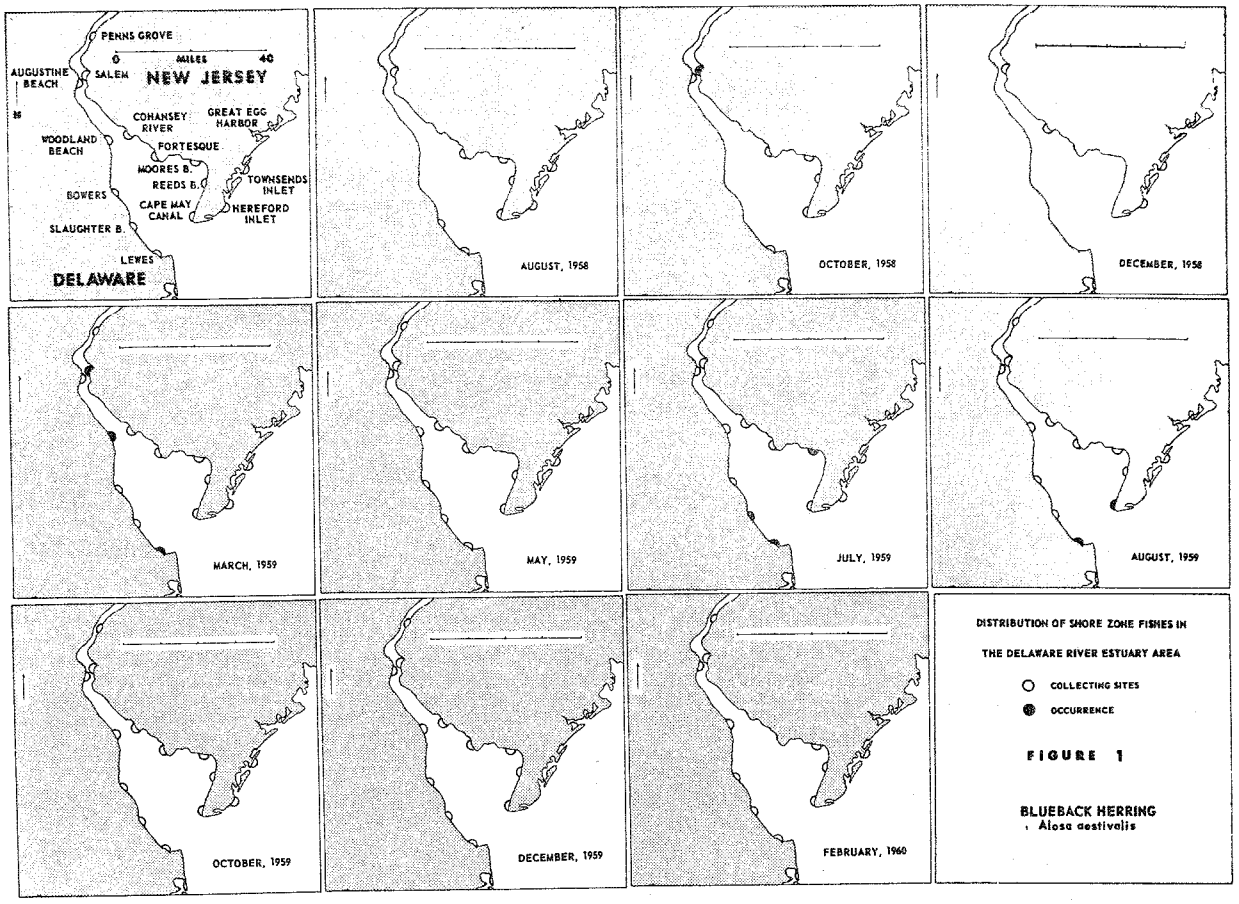
Table 50. Larvae and juveniles from 41 genera, with 43 or more species, identified by de Sylva and Smith (NSF - Ichthyoplankton Project) from zooplankton collections made by Hopkins (1958) at Indian River Inlet, Delaware. The collections were at night, on flooding tides, at biweekly intervals from July 1956 through July 1958 (University of Delaware Research Foundation Inc. grant to Shuster).

		1956						1957						
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
	Atlantic Menhaden *Brevoortia tyrannus*					6 16-32mm	17 24-33mm	17 15-36mm	16 20-30mm	2 17-33mm	59 19-30mm			
*	Atlantic Herring *Clupea harengus*				3 9-14mm		2 31mm							
	Bay Anchovy & Striped Anchovy *Anchoa sp.* (*mitchilli* & *hepsetus*)	77 5-10mm	401 3-20mm	196 4-20mm	20 11-24mm	14 15-30mm		3 23-26mm	6 21-31mm				68 5-8mm	
	American Eel *Anguilla rostrata*							16 46-61mm	15 49-61mm		14 49-62mm	4 54-60mm	1 53mm	
(*)	Conger Eel *Conger oceanicus*							1 51mm			10 90-100mm			
	Atlantic Needlefish *Strongylura marina*													
	Striped Killifish *Fundulus majalis*											9 5-9mm	20 6-10mm	
*	Cods *Gadus sp.*										1 43mm			
	Spotted Hake *Urophycis regius*	1 13mm												
*	Spotted Seahorse *Hippocampus erectus*		6 4-5mm											
	Northern Pipefish *Syngnathus fuscus*	3 10-11mm	7 8-12mm	2 11-54mm	2 10-12mm							1 7mm	1 30mm	
	Bluefish *Pomatomus saltatrix*		1 4mm											
*	Banded Rudderfish *Seriola zonata*		1 3mm											
(*)	Rough Scad *Trachurus lathami*												3 3-5mm	
	Silver Perch *Bairdiella chrysura*		3 4-10mm											
	Weakfish *Cynoscion regalis*	5 3-12mm	33 3-12mm	1 6mm									439 3-6mm	
	Northern Kingfish *Menticirrhus saxatilis*	1 3mm	8 3-6mm										2 4-5mm	
	Atlantic Croaker *Micropogon undulatus*	1 6mm	7 3-7mm	73 4-11mm	20 5-13mm	26 12-20mm	10 16-19mm	3 22-37mm	4 22-37mm					
*	Scup *Stenotomus chrysops*												1 4mm	
*	Tautog *Tautoga onitus*												1 4mm	
(*)	Darter Goby *Gobionellus boleosoma*	3 3-8mm	78 3-10mm											
	Gobies *Gobionellus sp.*			16 5-10mm										
	Naked Goby *Gobiosoma bosci*	494 6-12mm	750 4-12mm		84 5-12mm								6 5-8mm	
	Seaboard Goby *Gobiosoma ginsburgi*	8 12-13mm	361 5-12mm	375 6-12mm	165 4-11mm	1 27mm			1 40mm					
	Gobies *Gobiosoma sp.*			229 3-12mm	154 5-10mm								1 3mm	
(*)	Green Goby *Microgobius thalassinus*	1 2mm												
	Searobins *Prionotus sp.*	4 4-5mm	23 3-9mm	13 5-10mm									4 3-4mm	
(*)	Sculpins *Myoxocephalus sp.*							1 6mm						
*	Sand Lances *Ammodytes sp.*						113 4-5mm		1 4mm		3 6-30mm			
	Striped Cusk-eel *Rissola marginata*										1 33mm			
*	Butterfish *Poronotas triacanthus*		2 3-9mm											
	Striped Mullet *Mugil cephalus*													
	White Mullet *Mugil curema*													
	Silversides *Membras sp.*										1 5mm			
	Atlantic & Tidewater Silversides *Menidia sp.* (*menidia* & *beryllina*)	10 5-9mm	64 3-51mm	3 15-17mm							4 4-5mm	18 3-21mm	15 3-11mm	
	Windowpane *Scophthalmus aquosus*					1 20mm						3 3-6mm		
	Summer Flounder *Paralichthys dentatus*					3 13-15mm	2 10-15mm	7 10-16mm	2 11-15mm		4 8-18mm			
*	Fourspot Flounder *Paralichthys oblongus*													
	Winter Flounder *Pseudopleuronectes americanus*										44 4-9mm			
(*)	Blackcheek Tonguefish *Symphurus plagiusa*													
	Northern Puffer *Sphaeroides maculatus*	1 3mm												

* 15 species not reported in Tables 11 and 12; those indicated by parentheses (*) were not included in the annotated list.

Table 50. continued

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GREAT EGG HARBOR
WOODLAND BEACH
FORTESQUE
MOORES B.
REEDS B.
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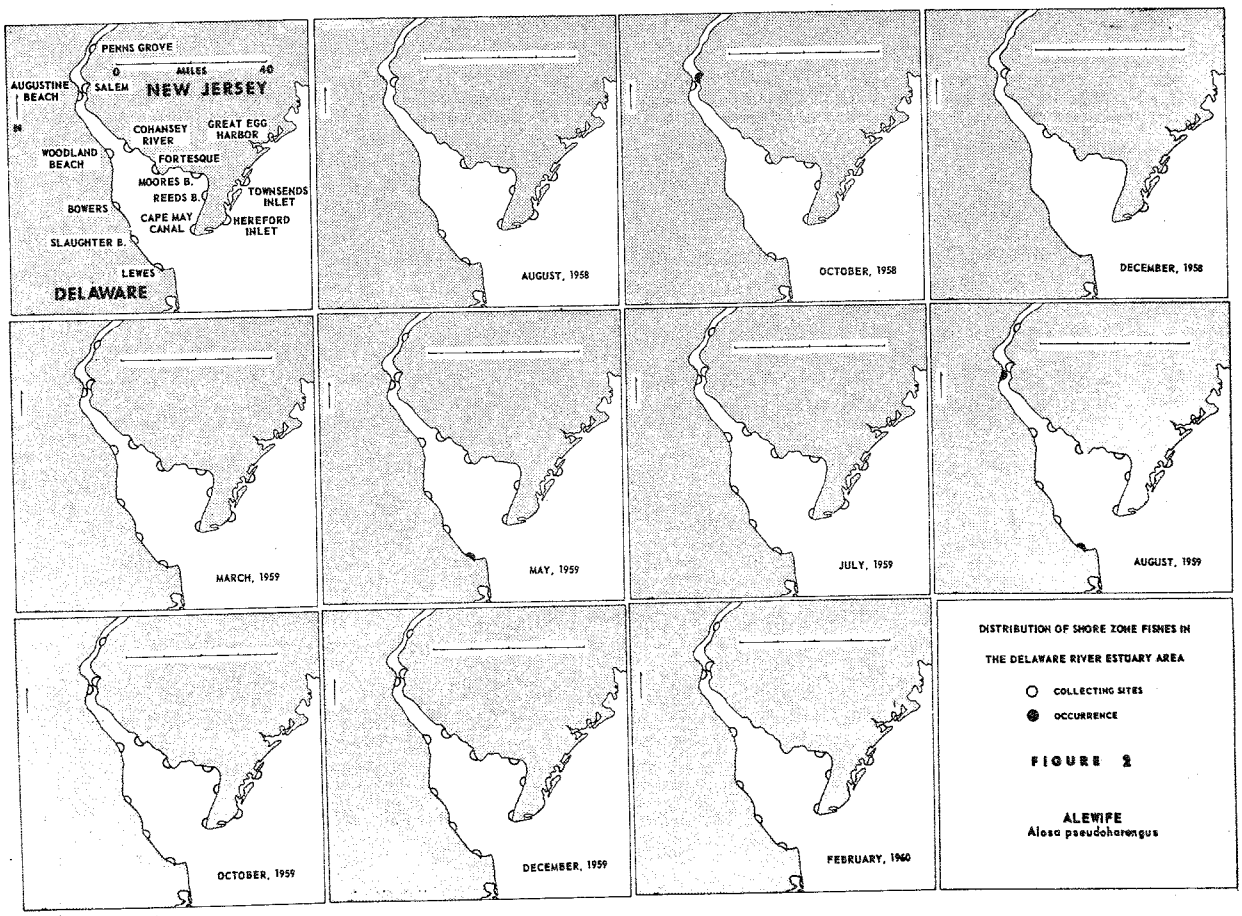
DISTRIBUTION OF SHORE ZONE FISHES IN
THE DELAWARE RIVER ESTUARY AREA
COLLECTING SITES
OCCURRENCE
FIGURE 1
BLUEBACK HERRING
Alosa aestivalis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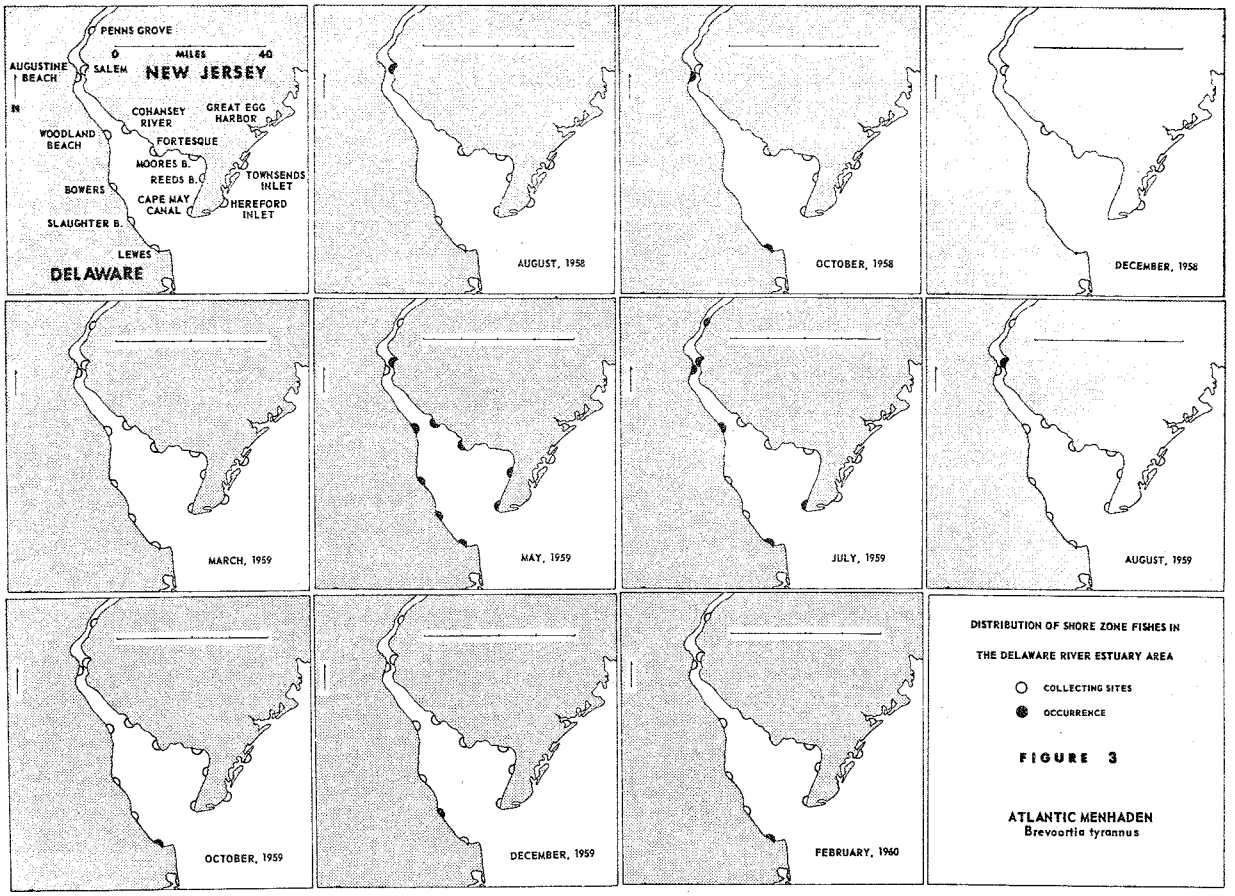
OCCURRENCE
FIGURE 2
ALEWIFE
Alosa pseudoharengus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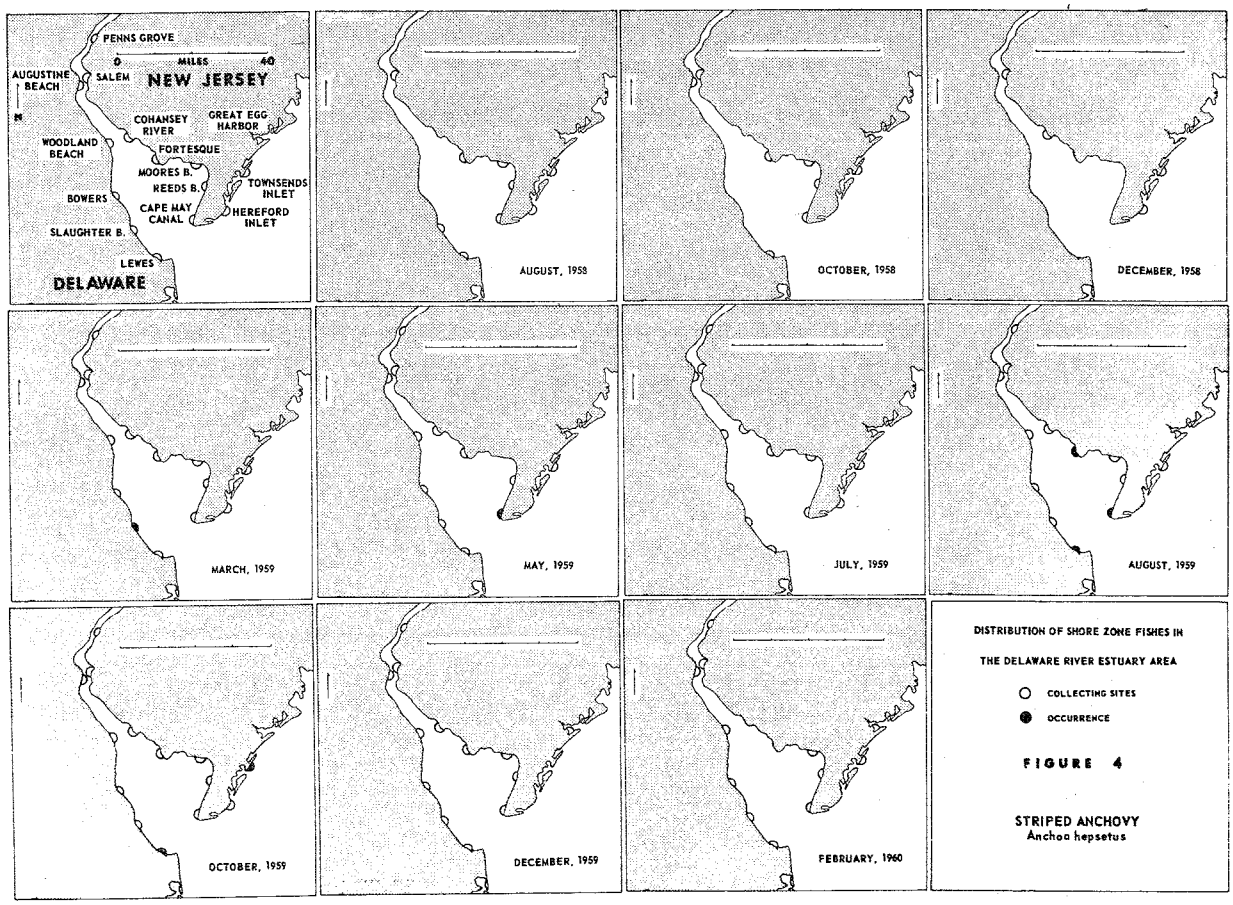
DISTRIBUTION OF SHORE ZONE FISHES IN
THE DELAWARE RIVER ESTUARY AREA
COLLECTING SITES
OCCURRENCE
FIGURE 3
ATLANTIC MENHADEN
Brevoortia tyrannus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THE DELAWARE RIVER ESTUARY AREA
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OCCURRENCE
FIGURE 4
STRIPED ANCHOVY
Anchoa hepsetus

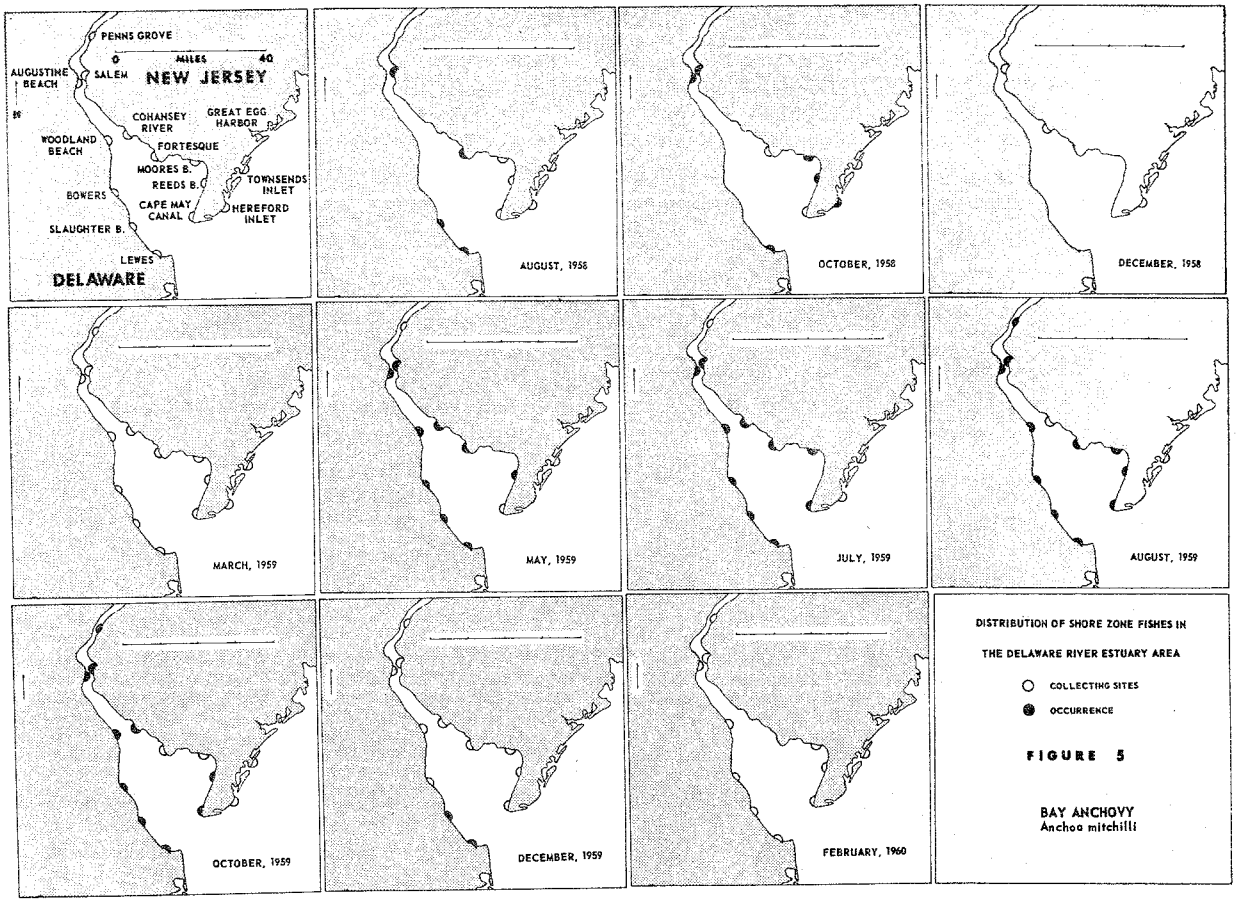


FIGURE 5

BAY ANCHOVY
Anchoa mitchilli

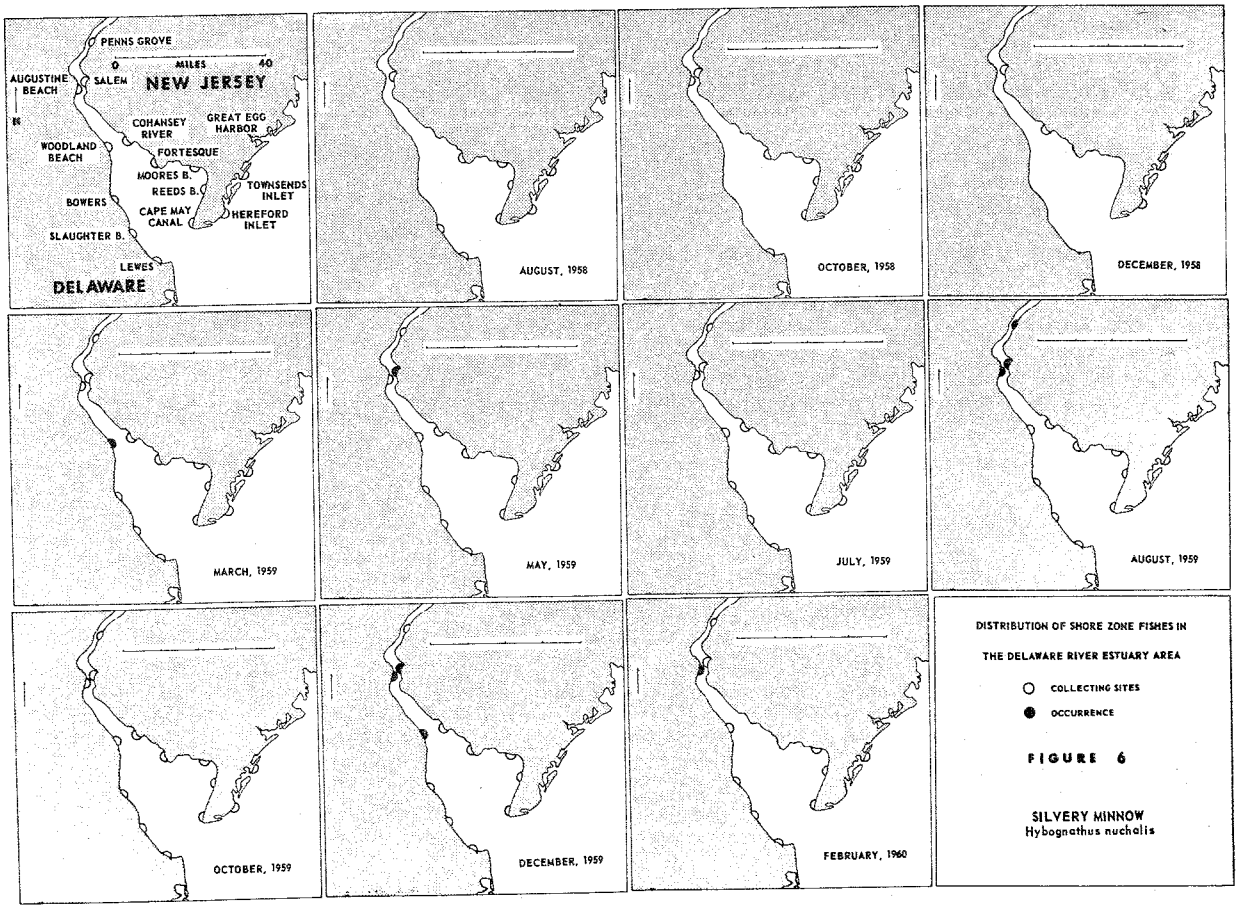


FIGURE 6

SILVERY MINNOW
Hybognathus nuchalis

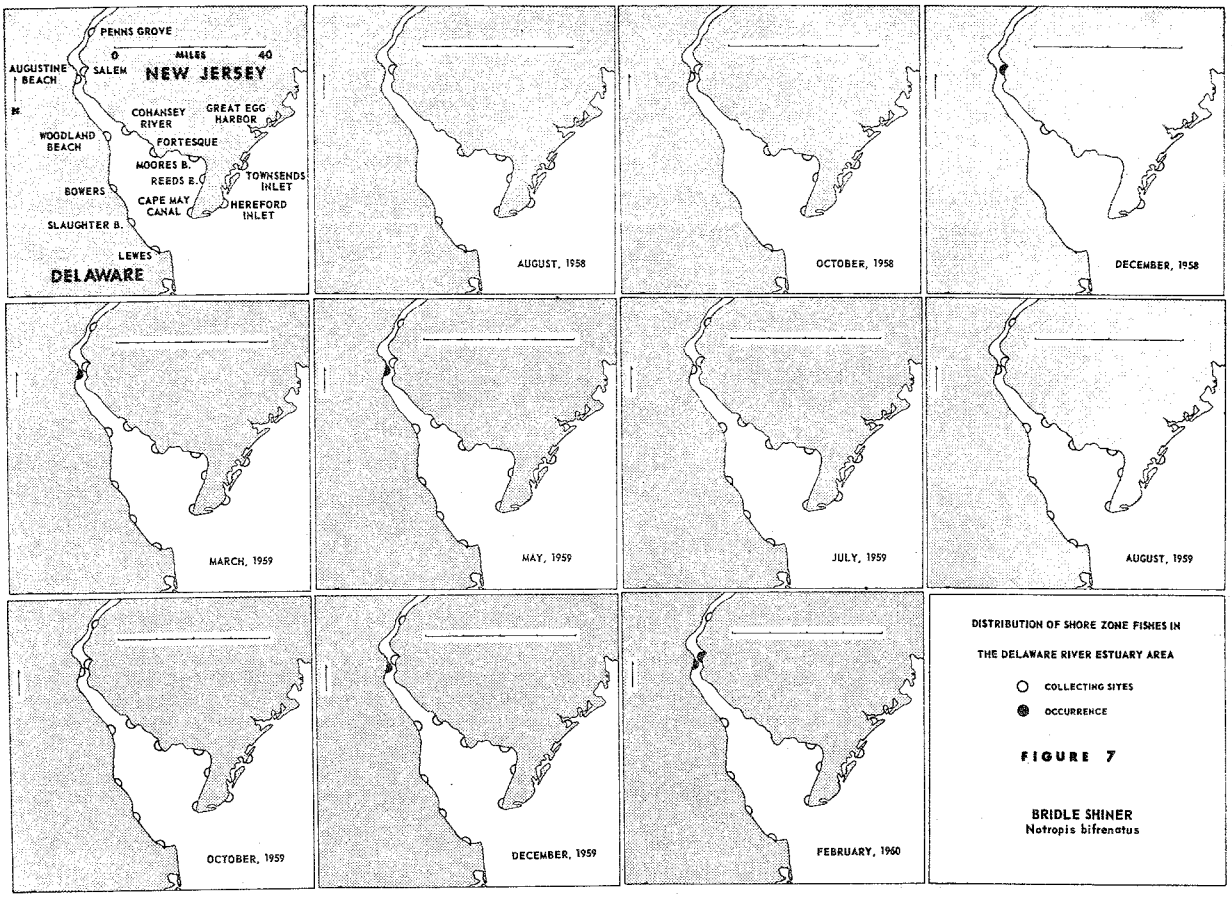


FIGURE 7

BRIDLE SHINER
Notropis bifrenatus

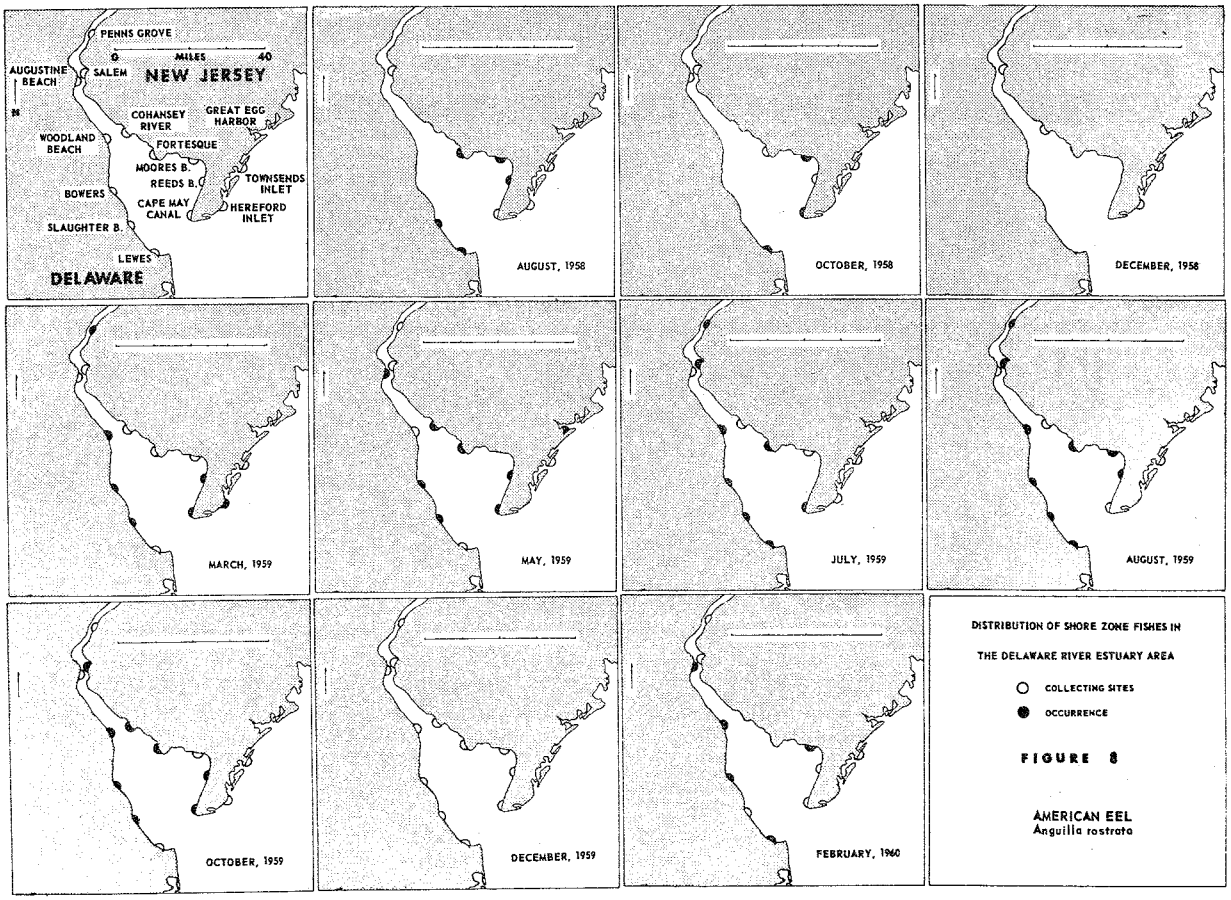


FIGURE 8

AMERICAN EEL
Anguilla rostrata

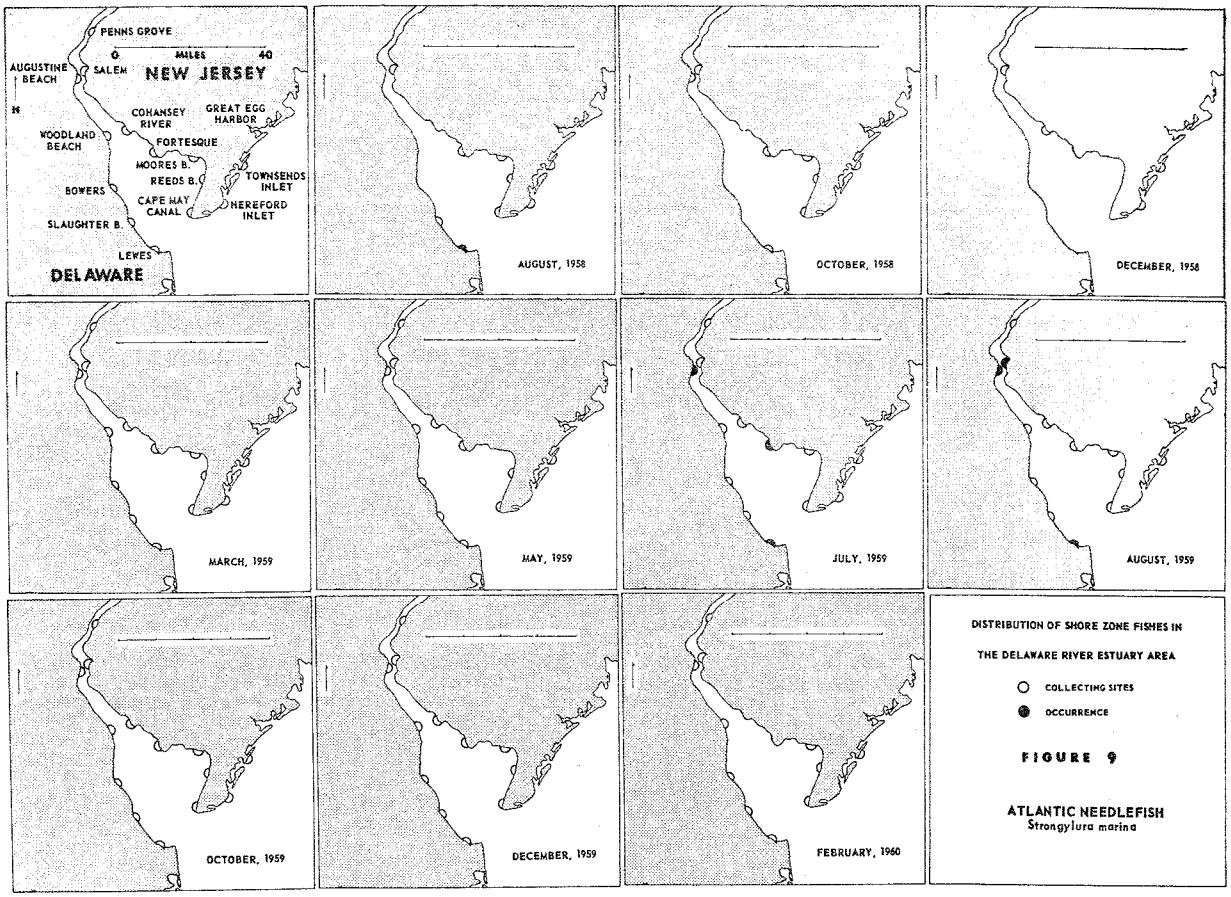


FIGURE 9

ATLANTIC NEEDLEFISH
Strongylura marina

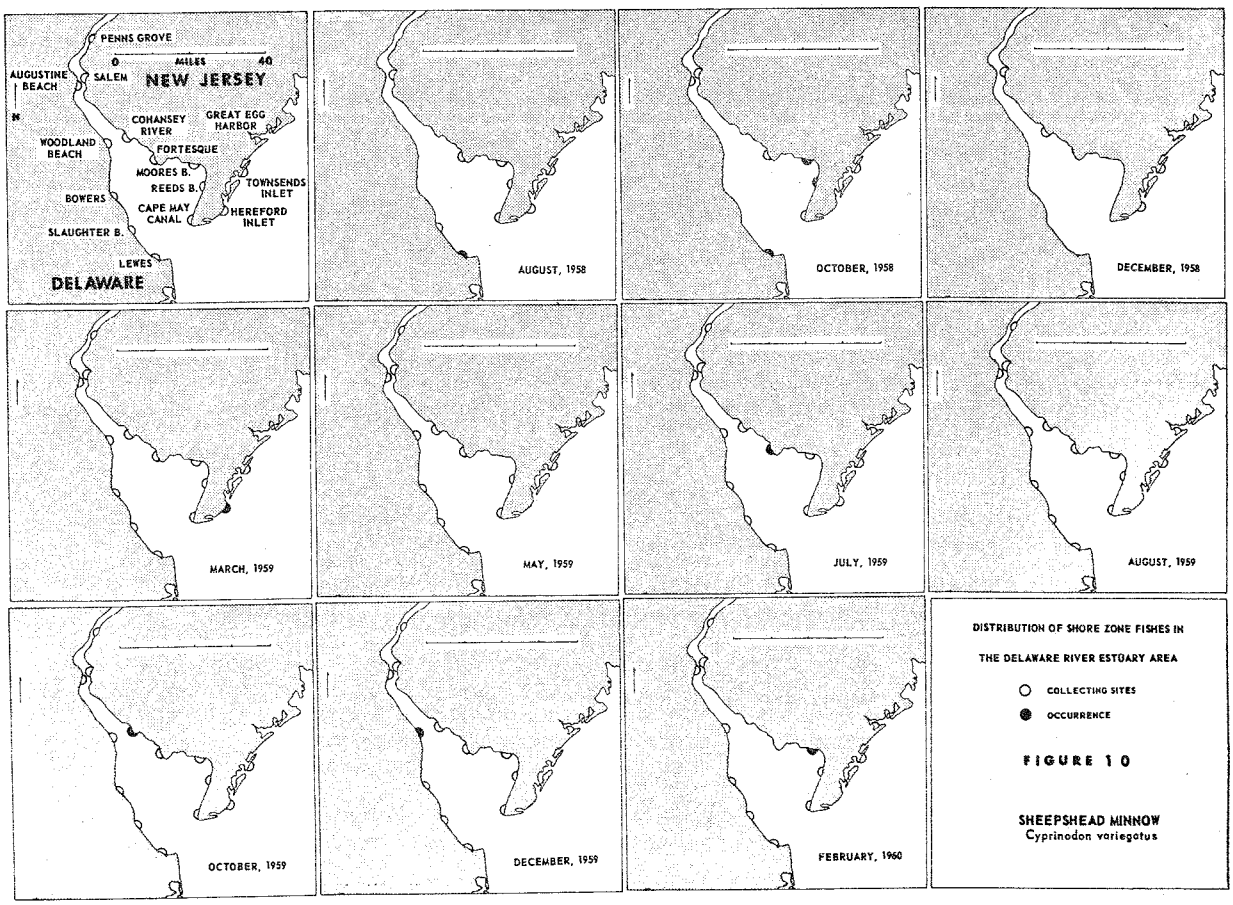
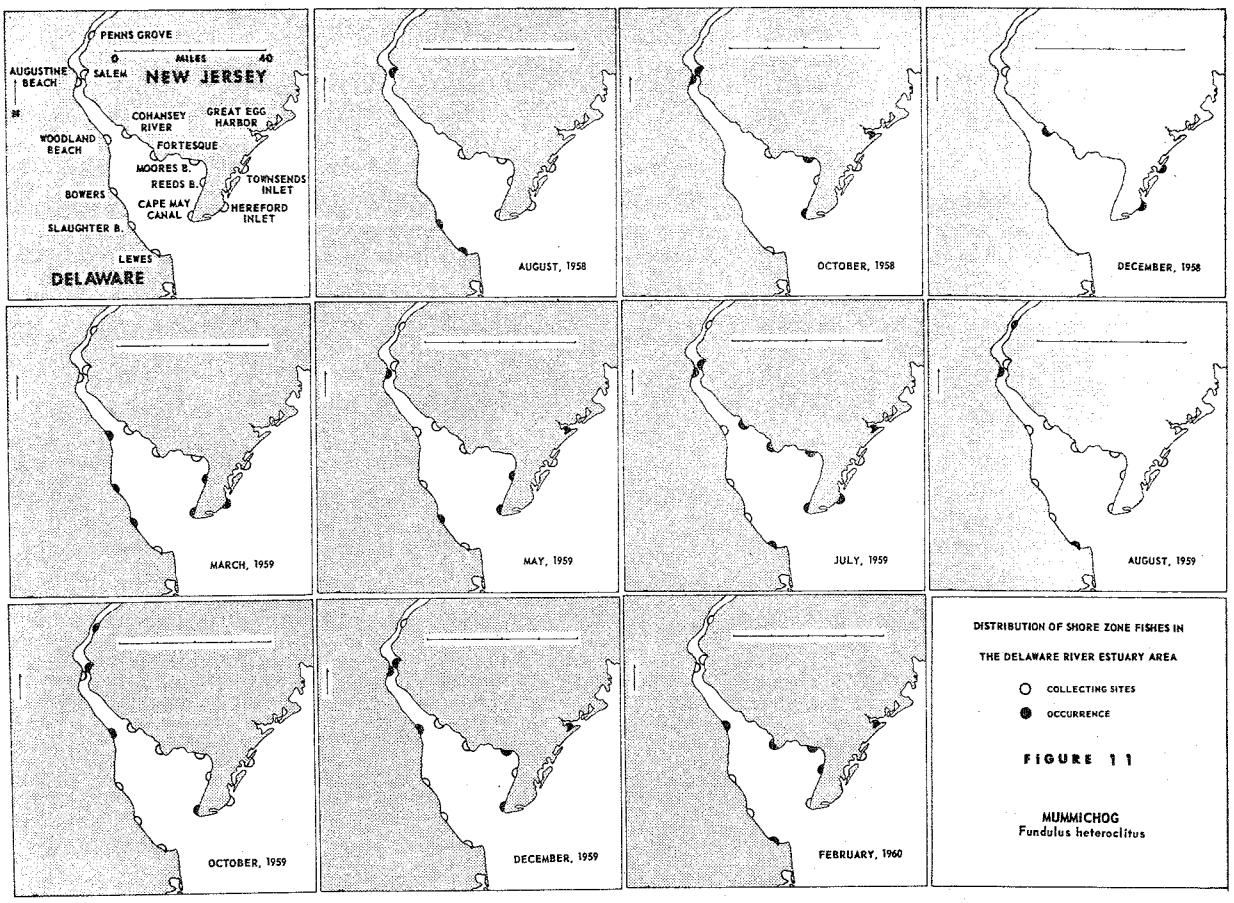


FIGURE 10

SHEEPSHEAD MINNOW
Cyprinodon variegatus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OCCURRENCE
FIGURE 11
MUMMICHOG
Fundulus heteroclitus

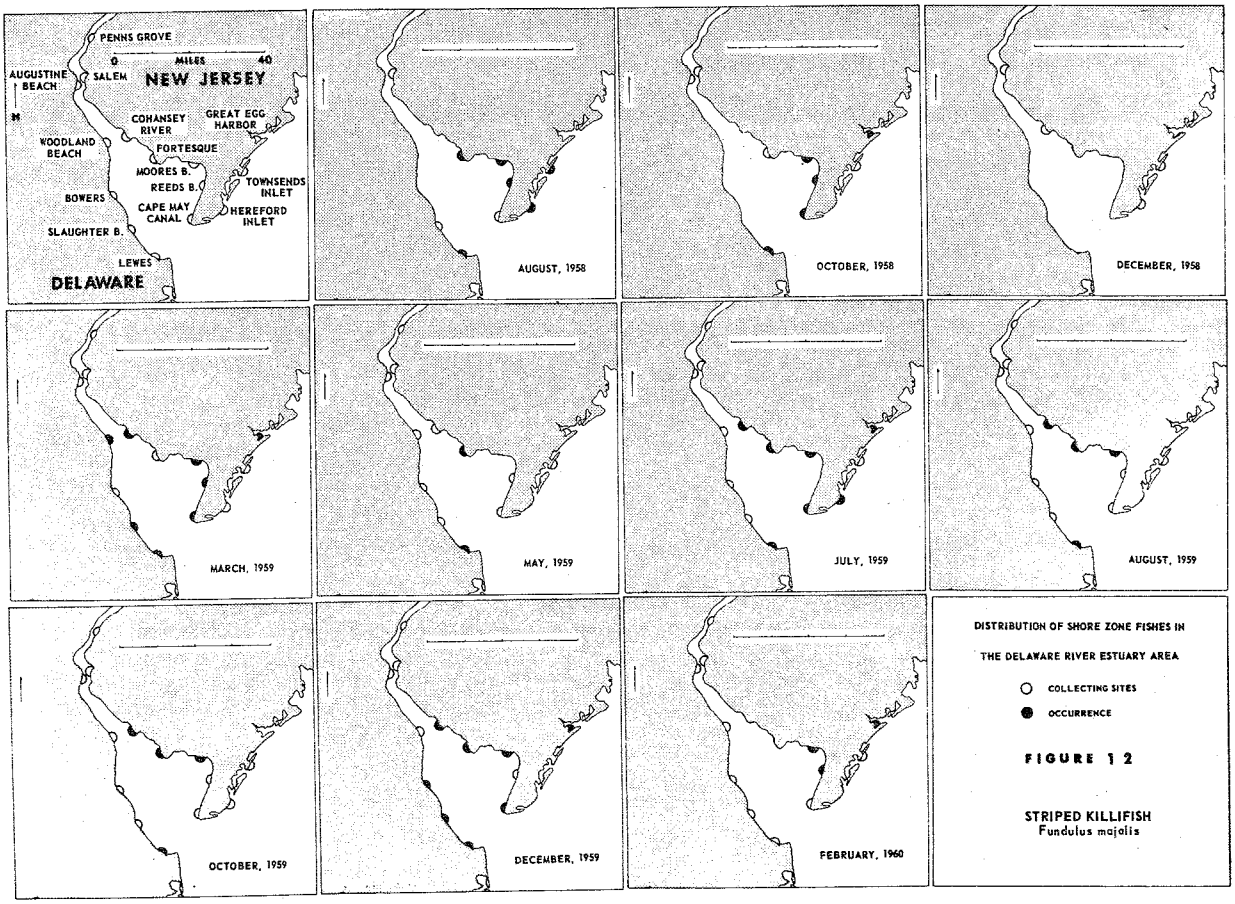
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FIGURE 12
STRIPED KILLIFISH
Fundulus majalis

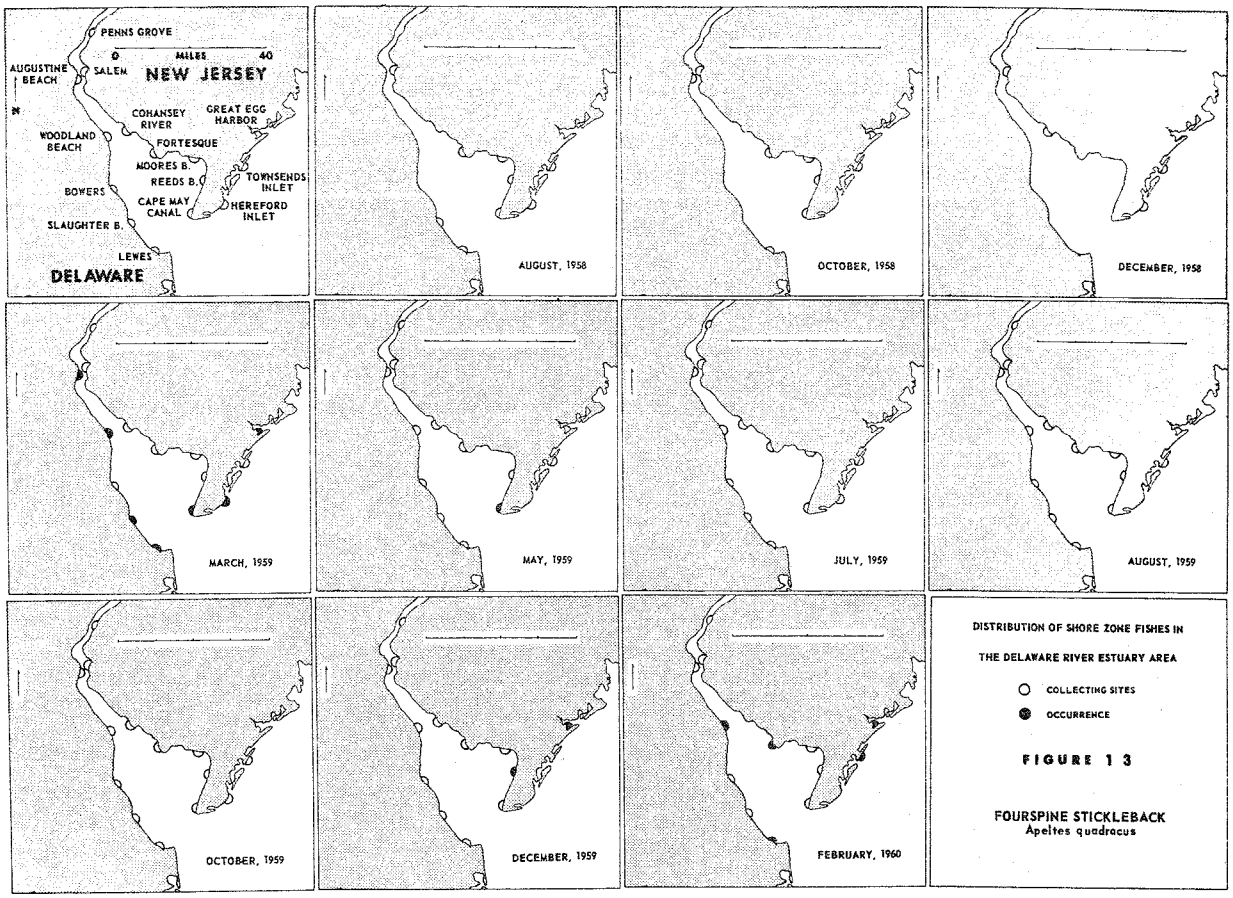


FIGURE 13

FOURSPINE STICKLEBACK
Apeltes quadracus

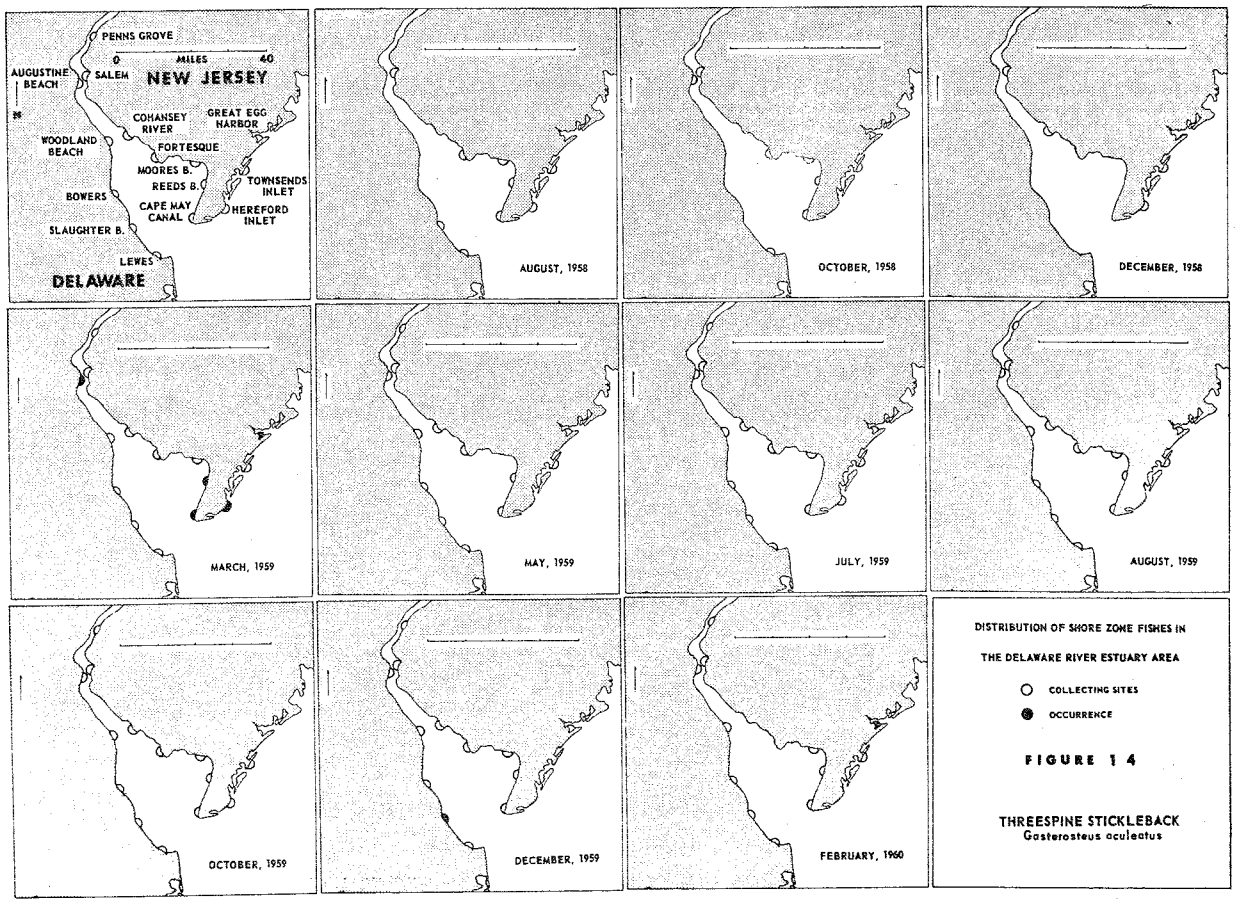
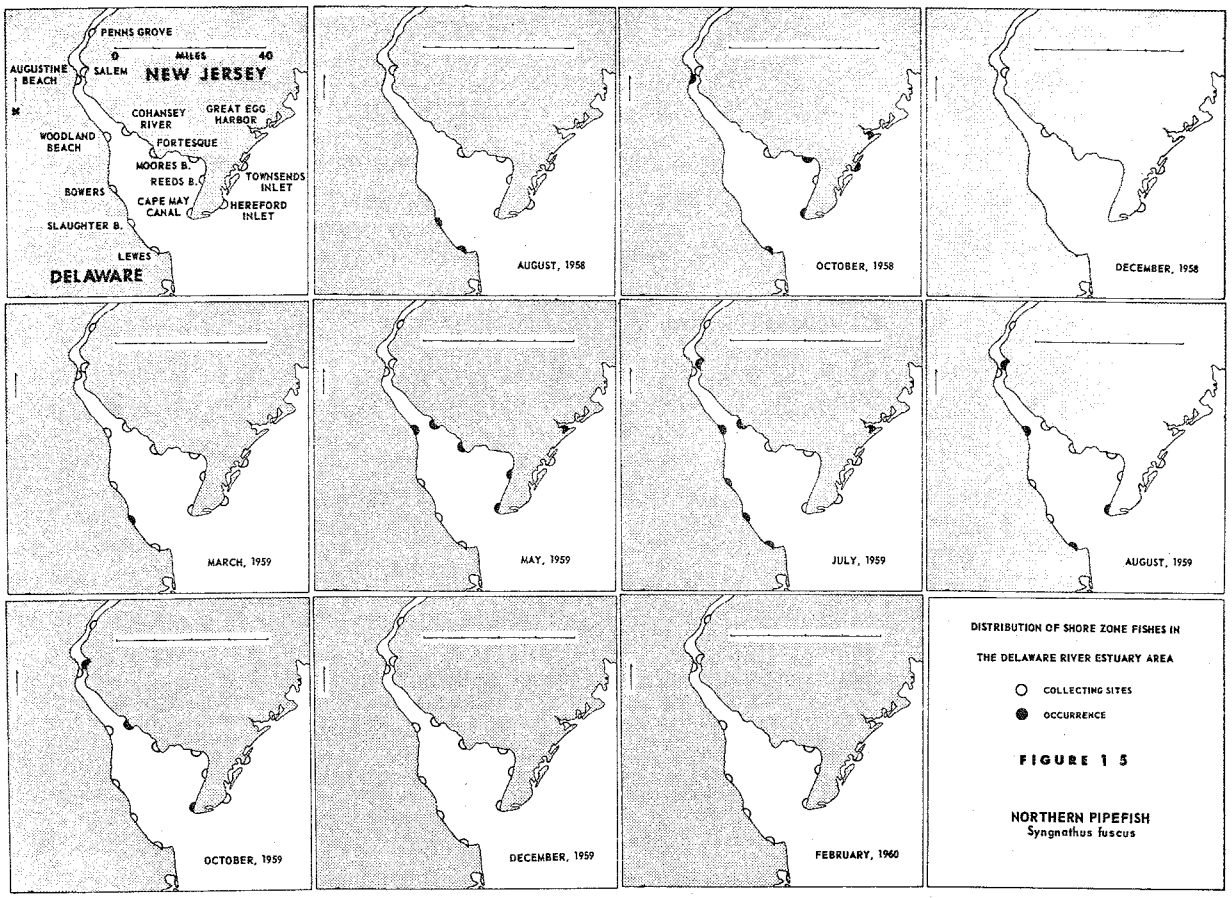


FIGURE 14

THREESPINE STICKLEBACK
Gasterosteus aculeatus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OCCURRENCE
FIGURE 15
NORTHERN PIPEFISH
Syngnathus fuscus

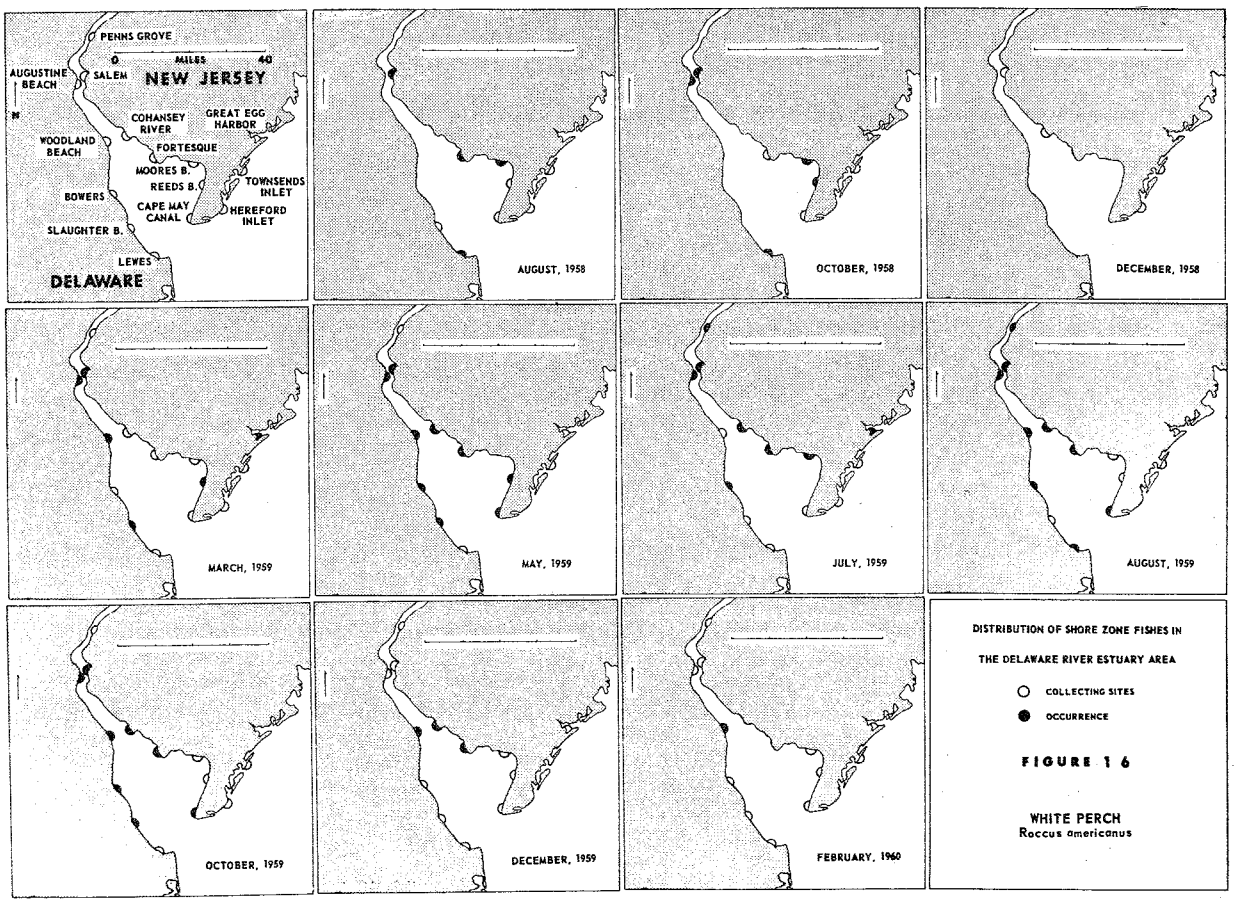
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FIGURE 16
WHITE PERCH
Roccus americanus

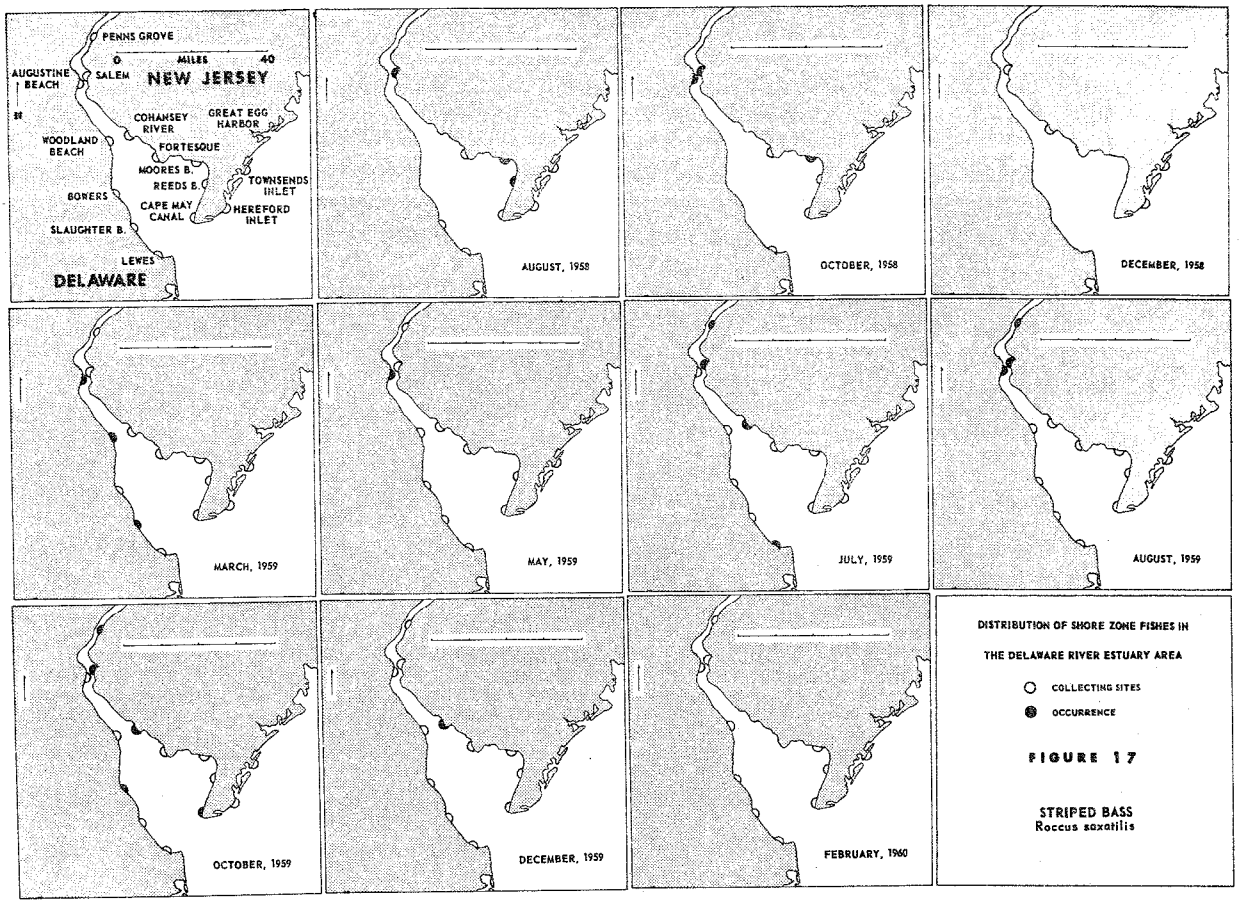


FIGURE 17

STRIPED BASS
Roccus saxatilis

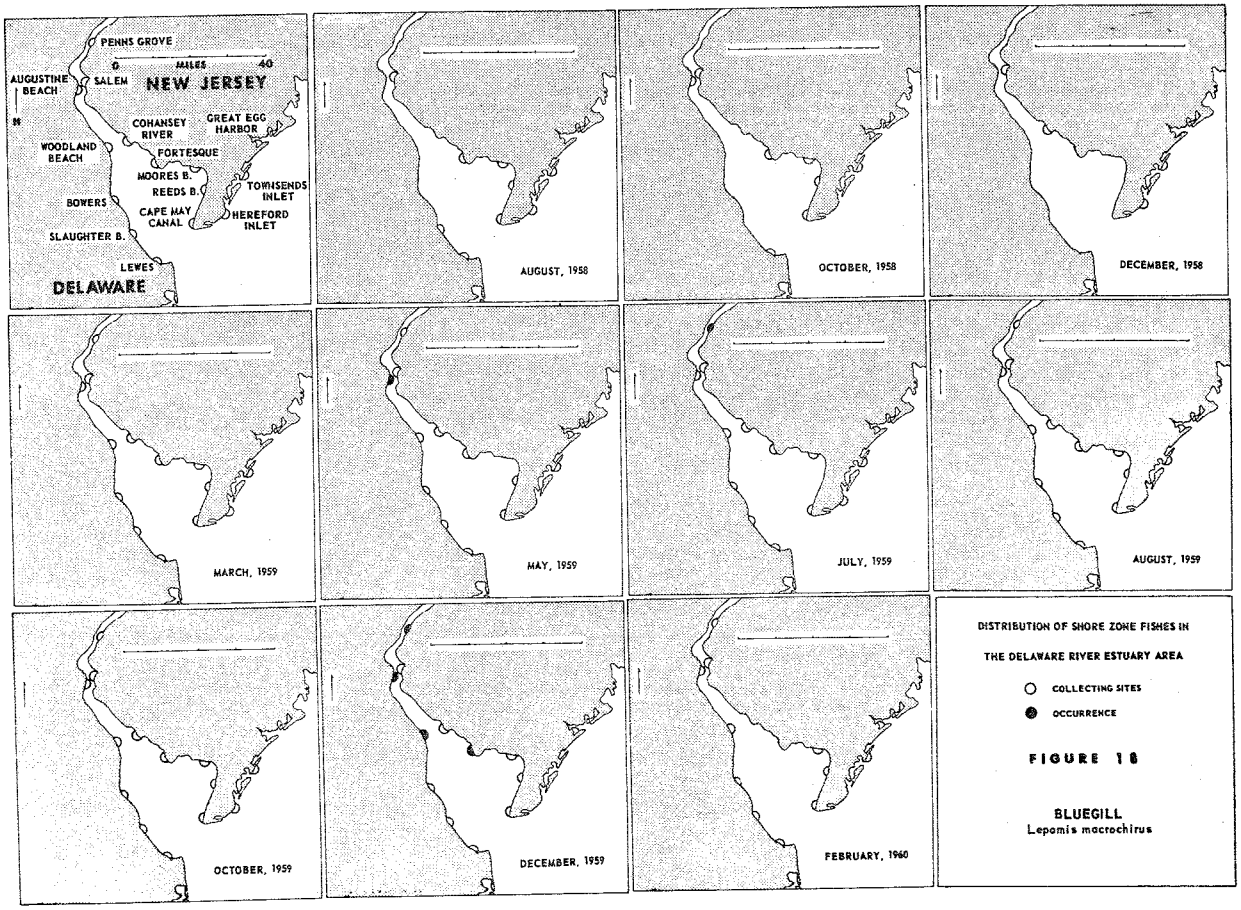


FIGURE 18

BLUEGILL
Lepomis macrochirus

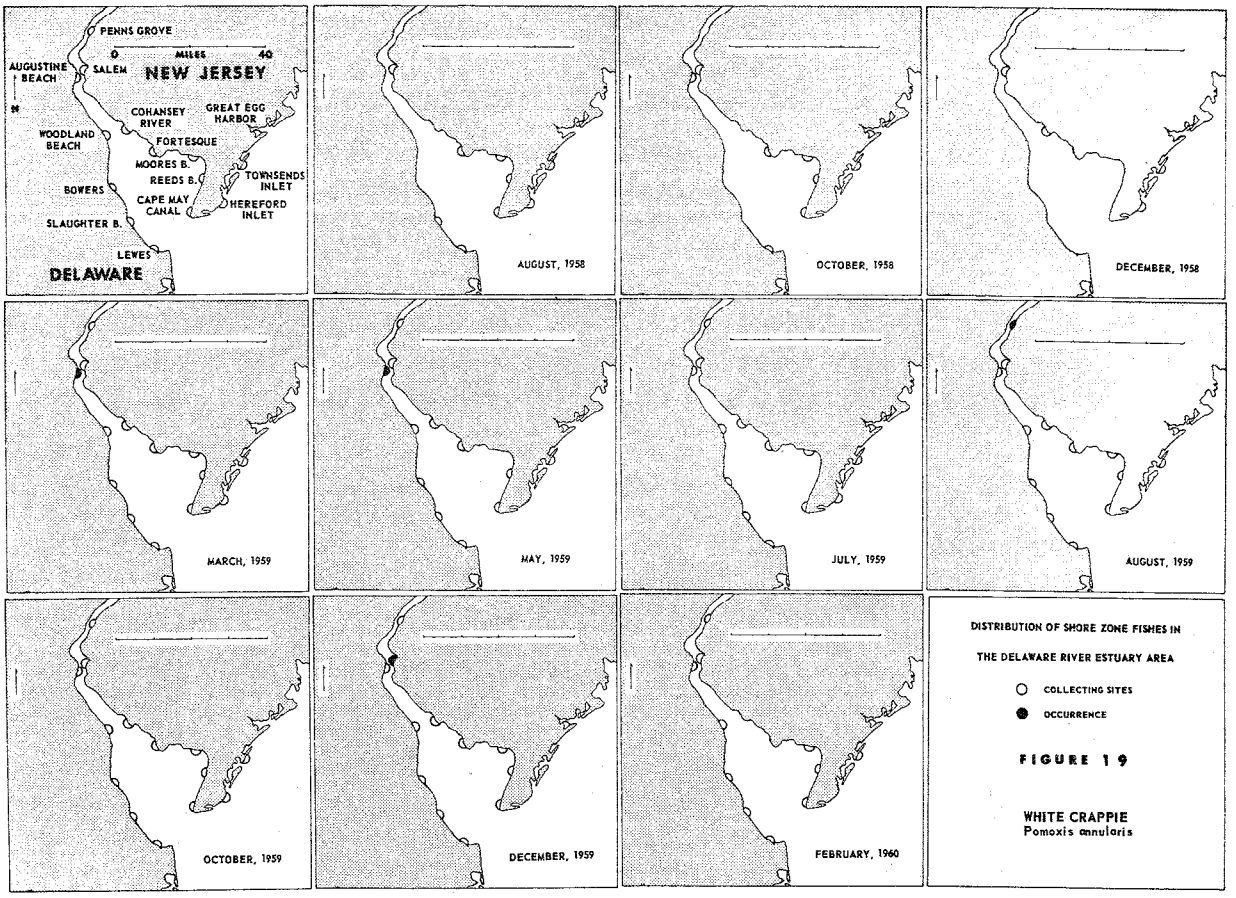


FIGURE 19

WHITE CRAPPIE
Pomoxis annularis

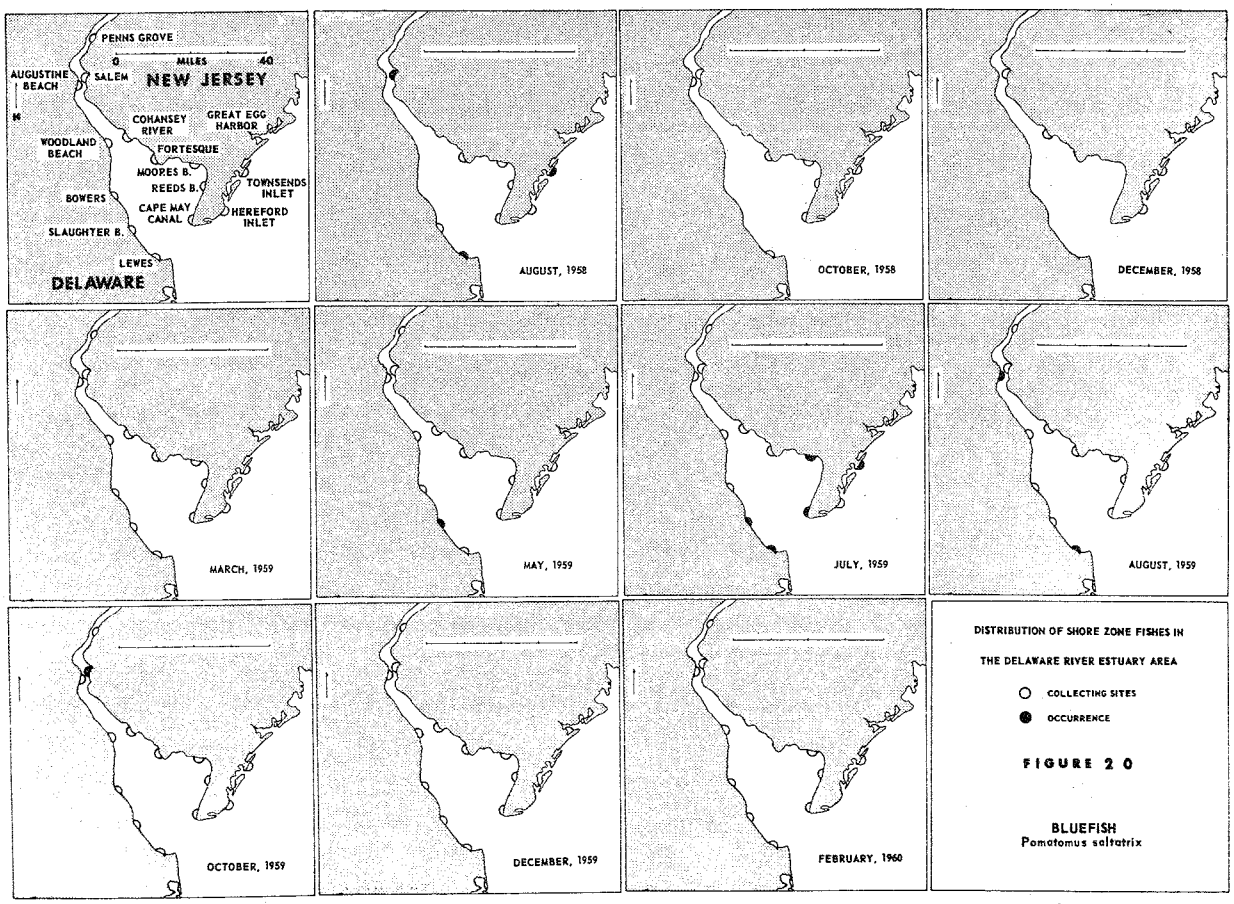
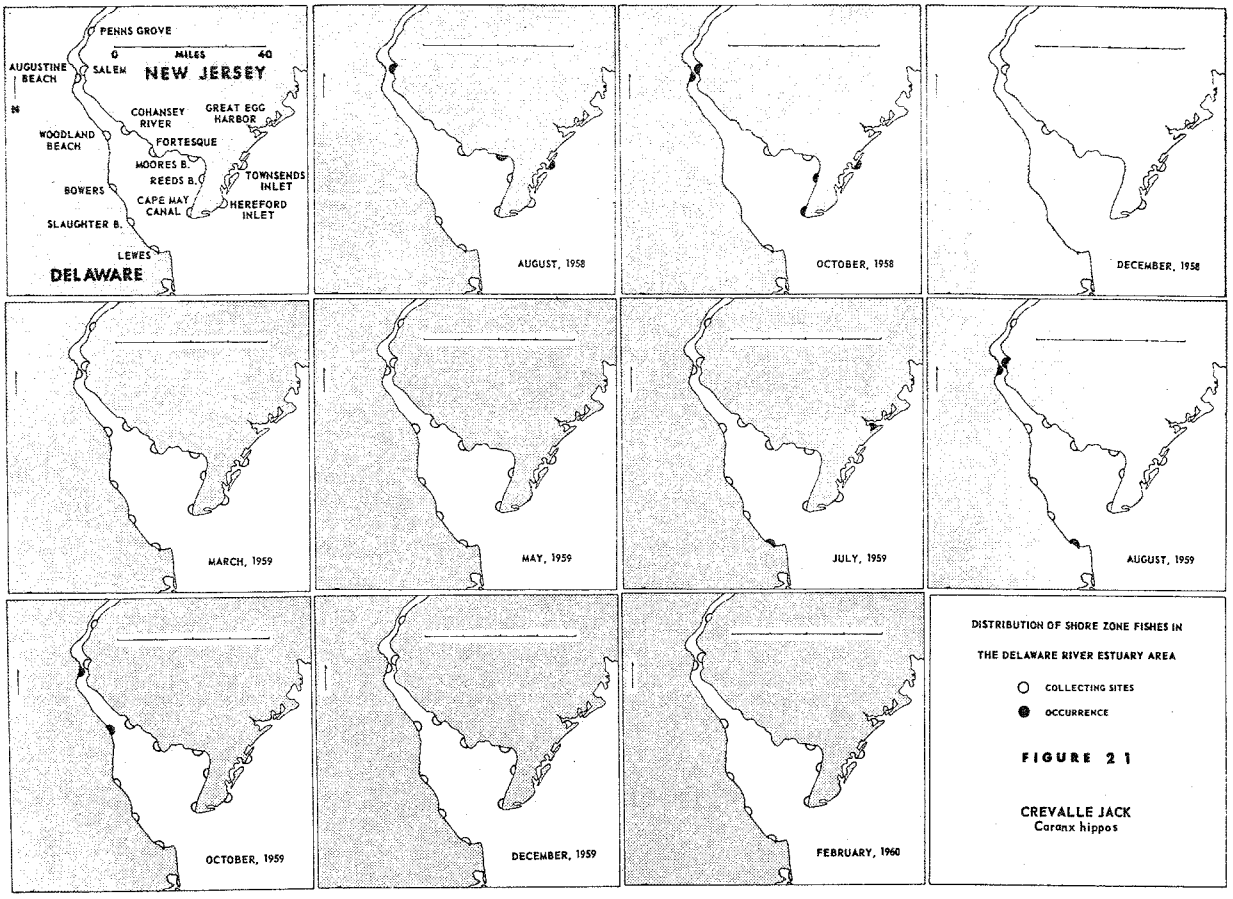


FIGURE 20

BLUEFISH
Pomatomus saltatrix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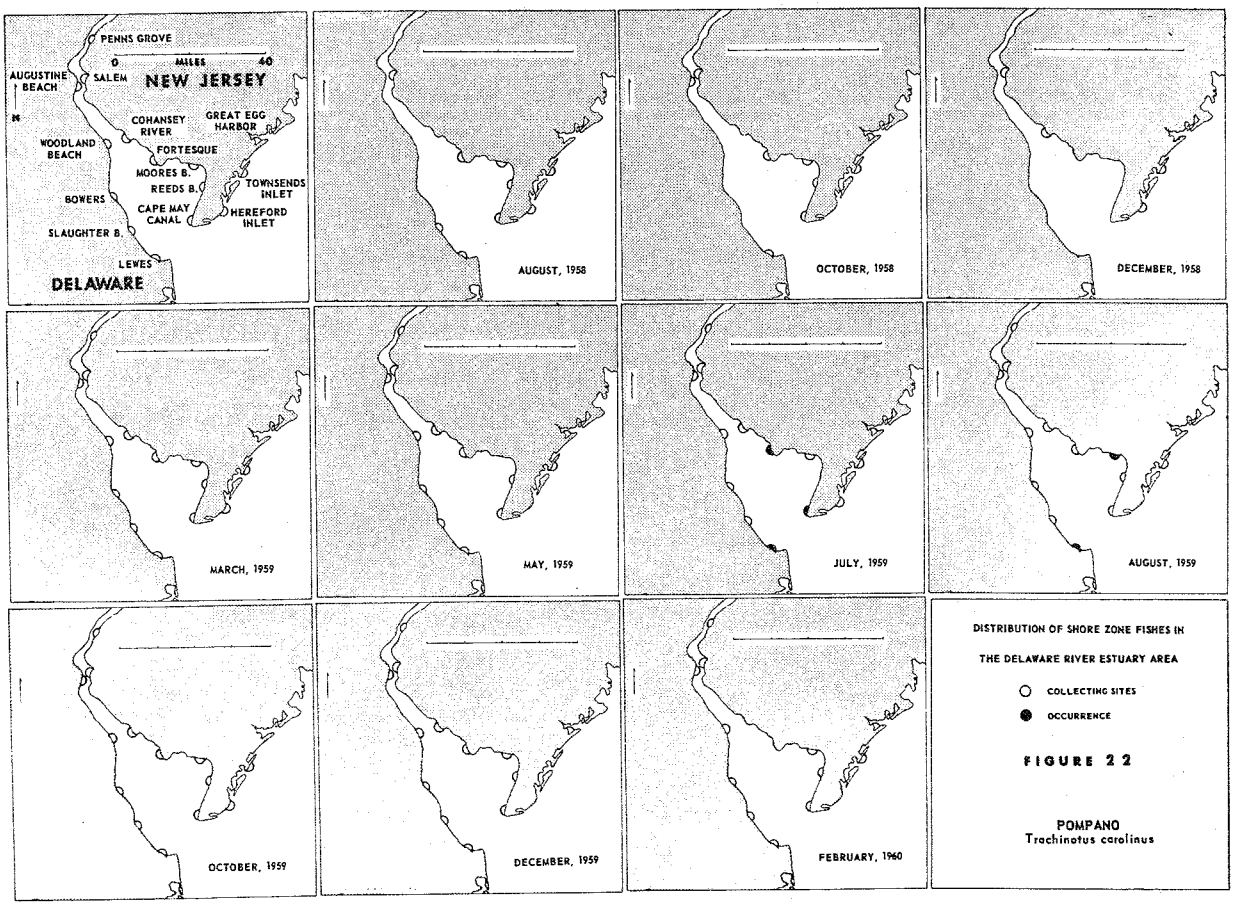
OCCURRENCE
FIGURE 21
CREVALLE JACK
Caranx hippos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THE DELAWARE RIVER ESTUARY AREA
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OCCURRENCE
FIGURE 22
POMPANO
Trachinotus carolinus

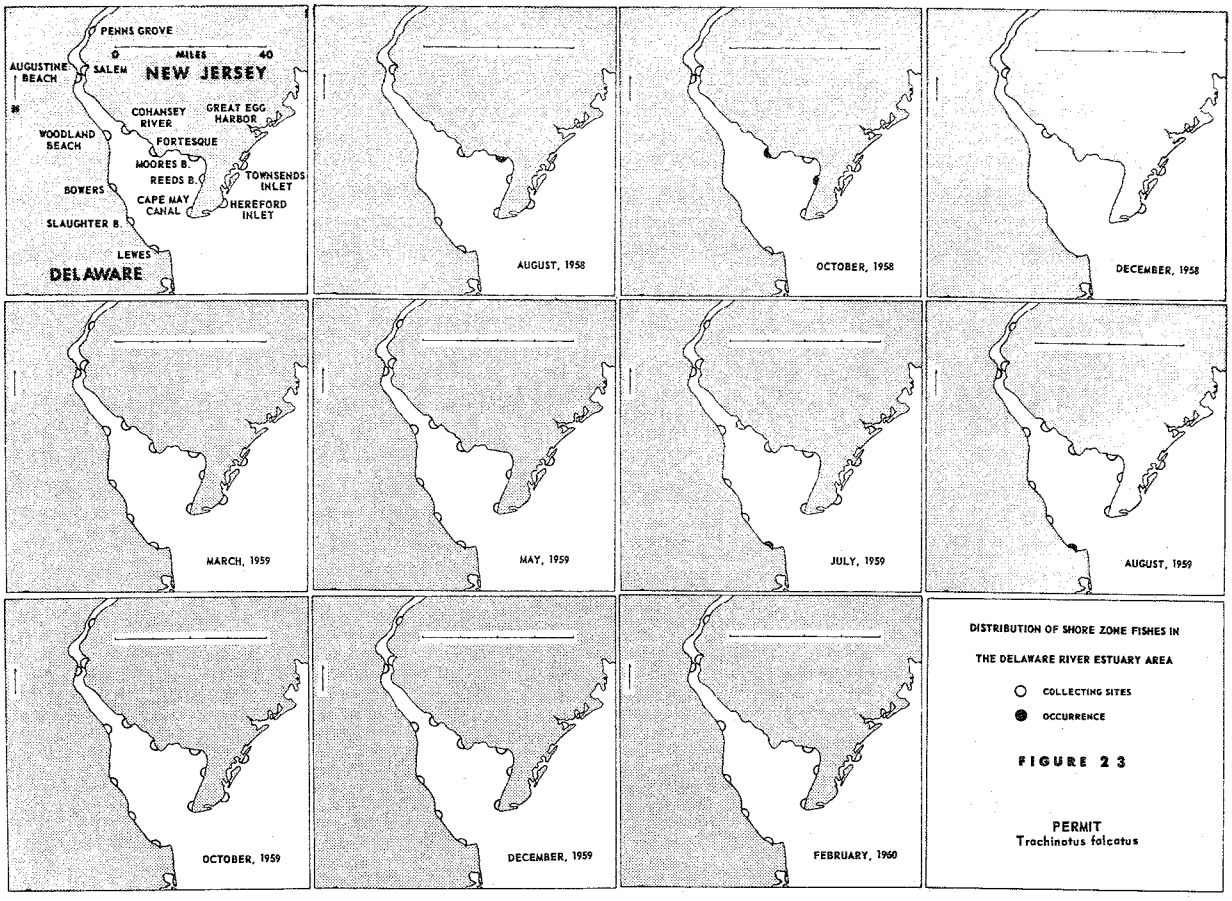


FIGURE 23

PERMIT
Trachinotus falcatus

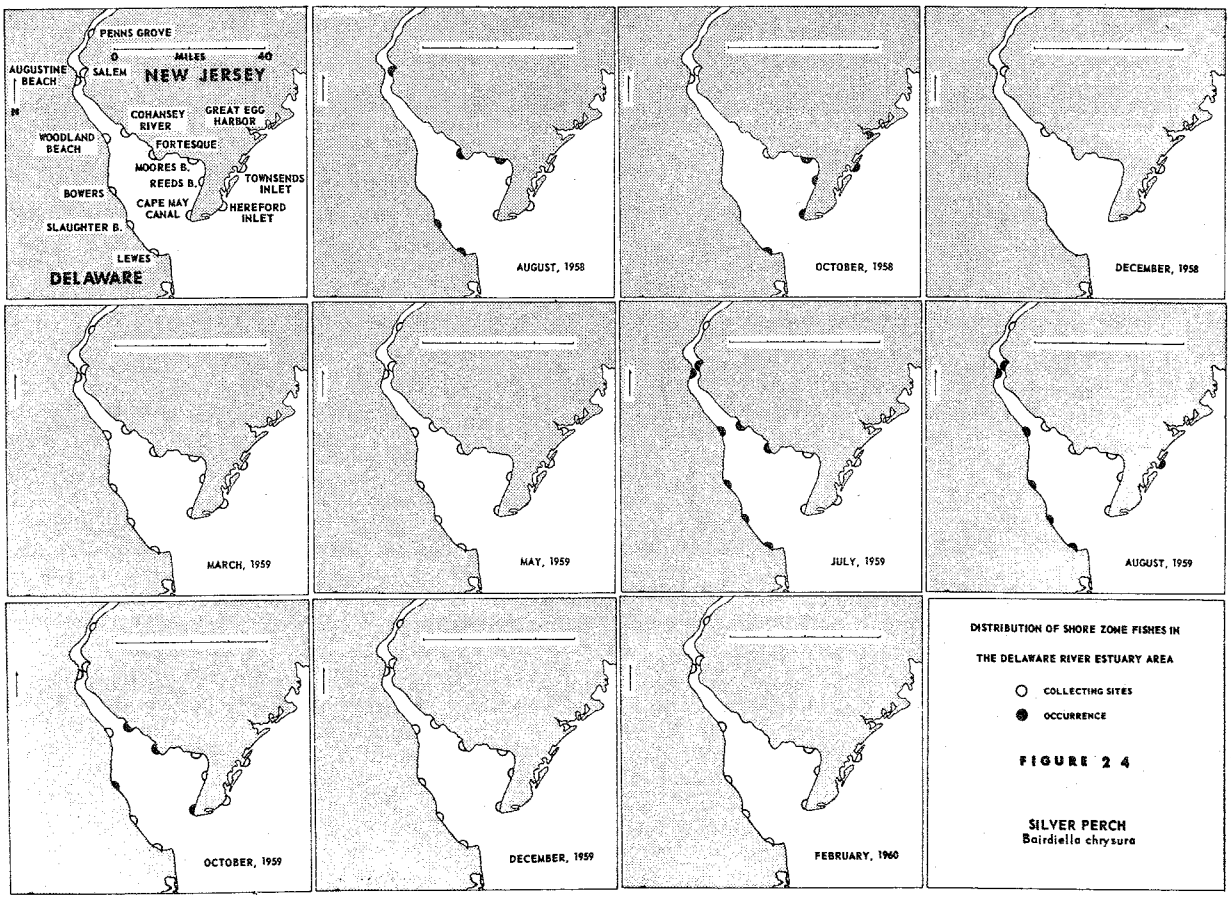


FIGURE 24

SILVER PERCH
Bairdiella chrysura

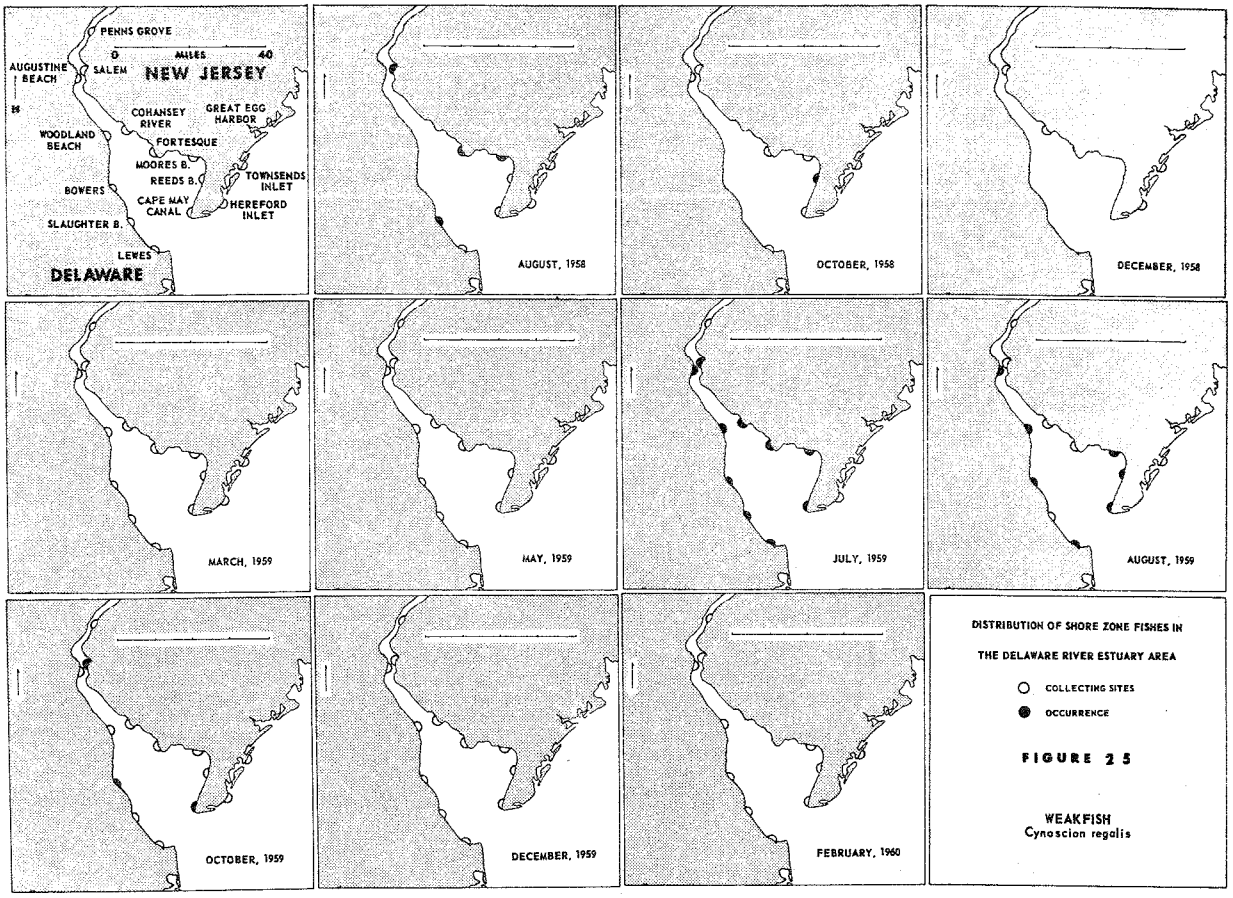


FIGURE 25

WEAKFISH
Cynoscion regalis

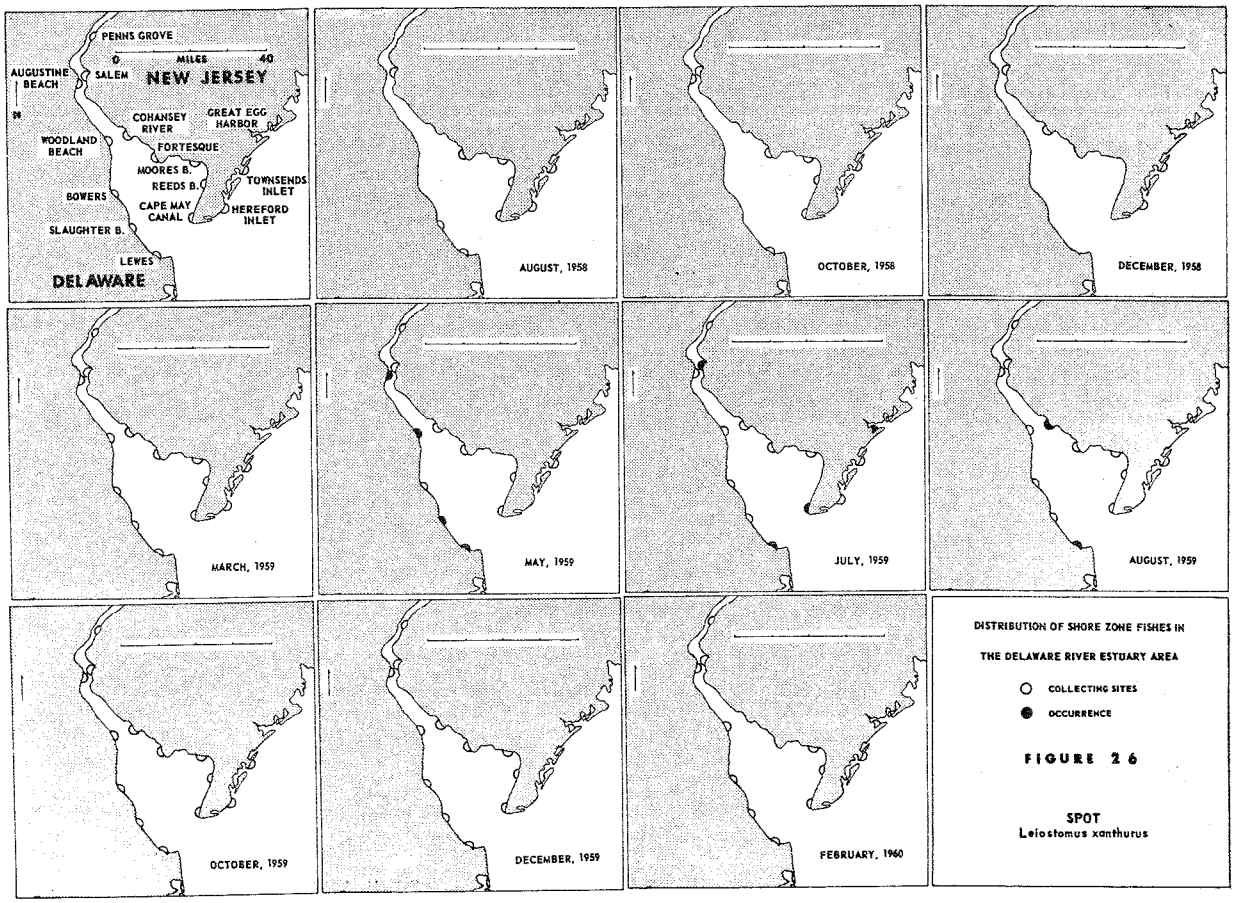


FIGURE 26

SPOT
Leiostomus xanthurus

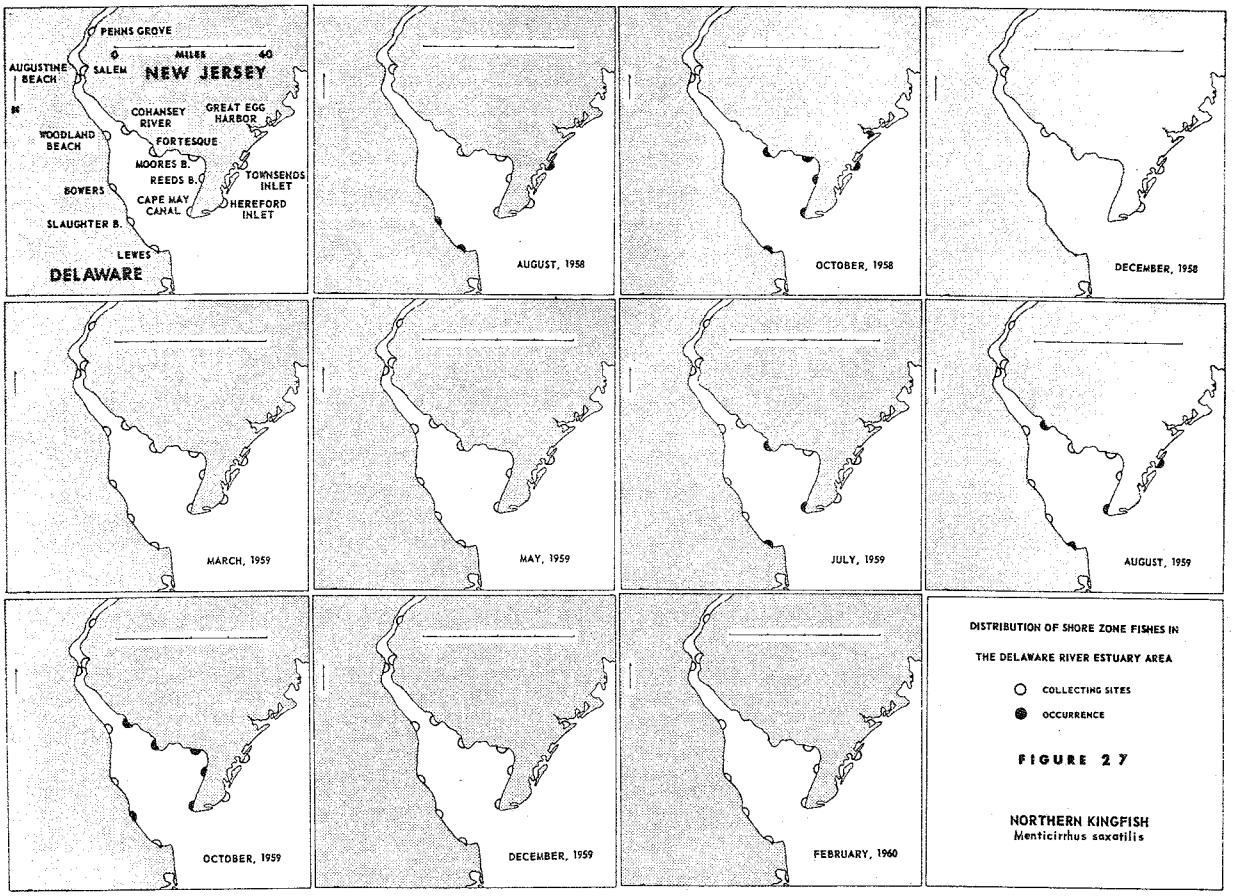


FIGURE 27

NORTHERN KINGFISH
Menticirrhus saxatilis

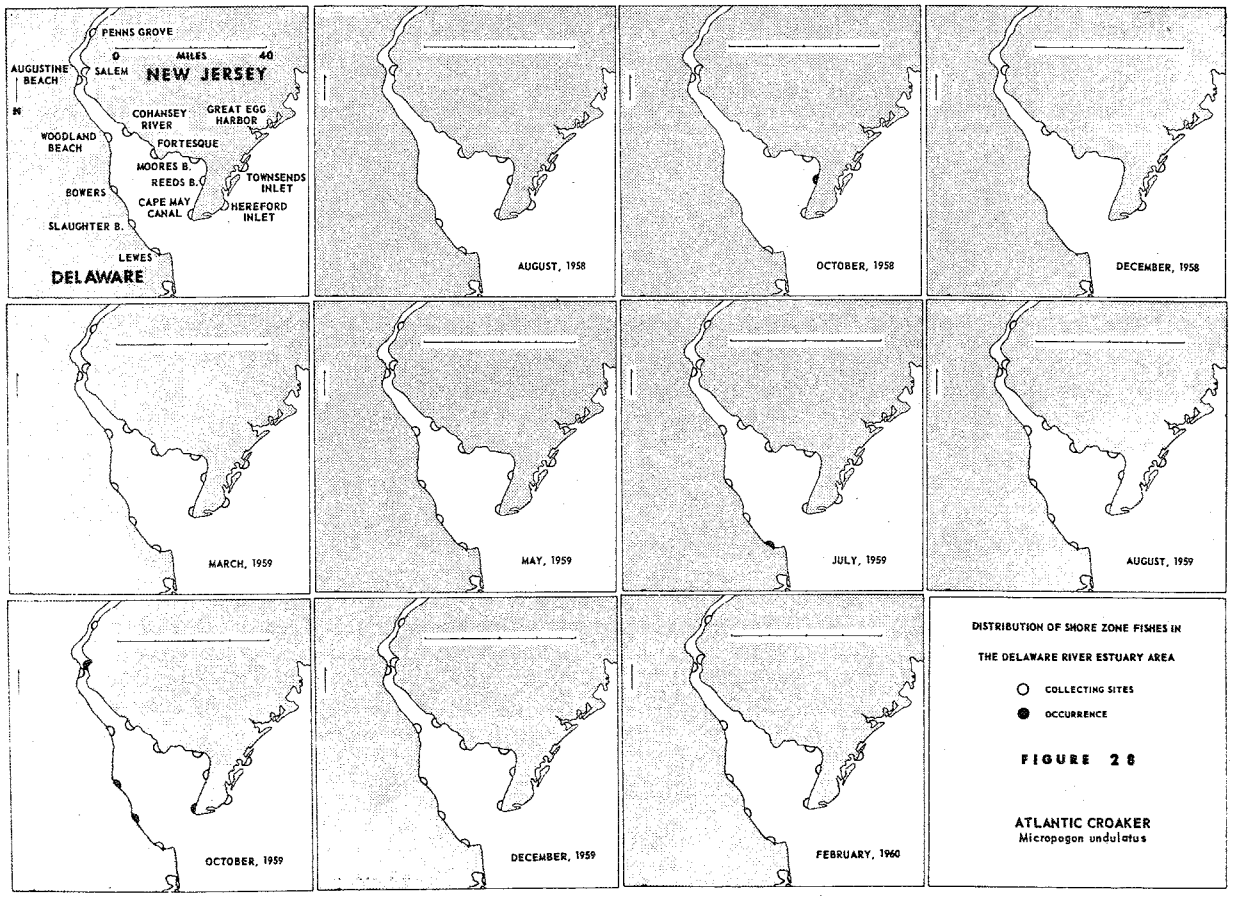


FIGURE 28

ATLANTIC CROAKER
Micropogon undulatus

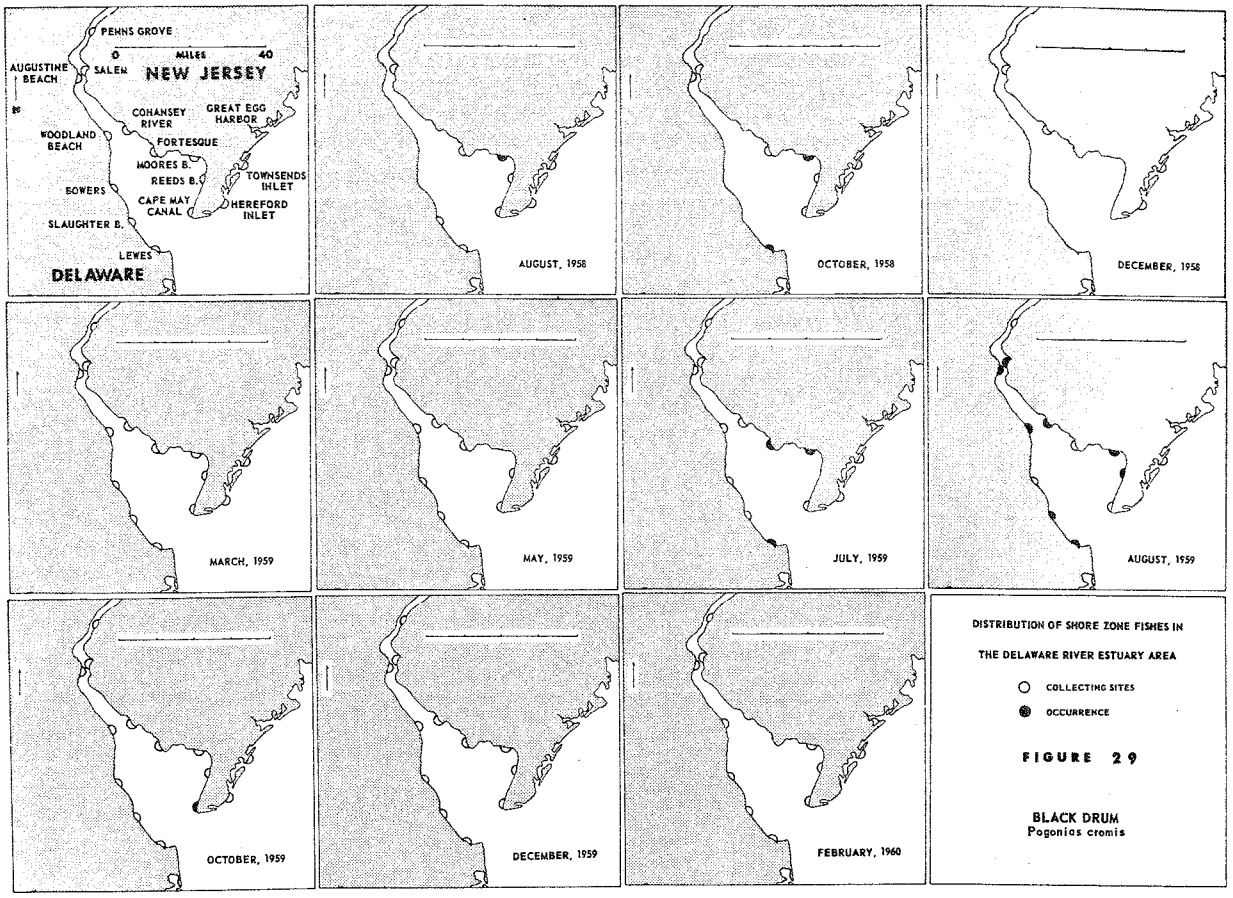


FIGURE 29

BLACK DRUM
Pogonias cromis

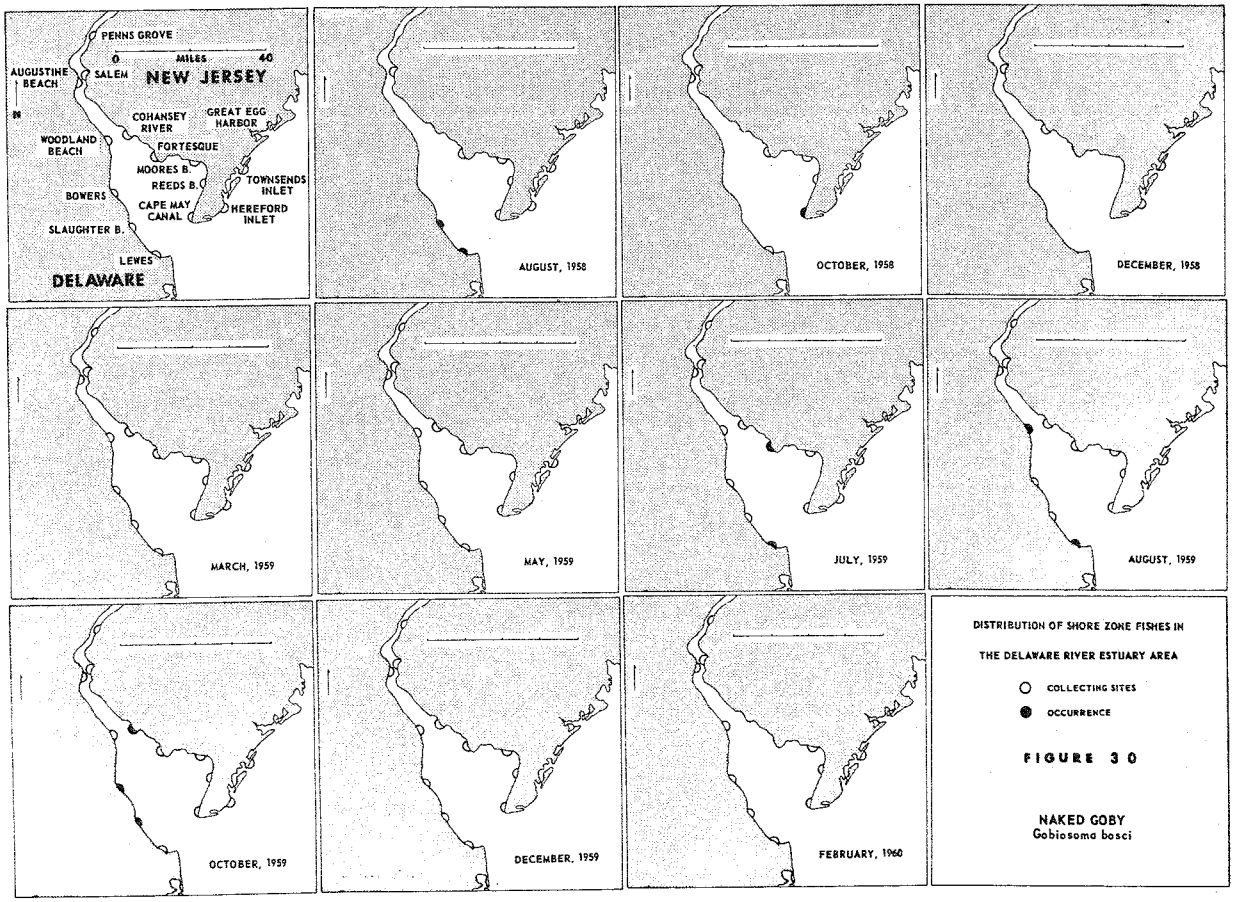


FIGURE 30

NAKED GOBY
Gobiosoma bosci

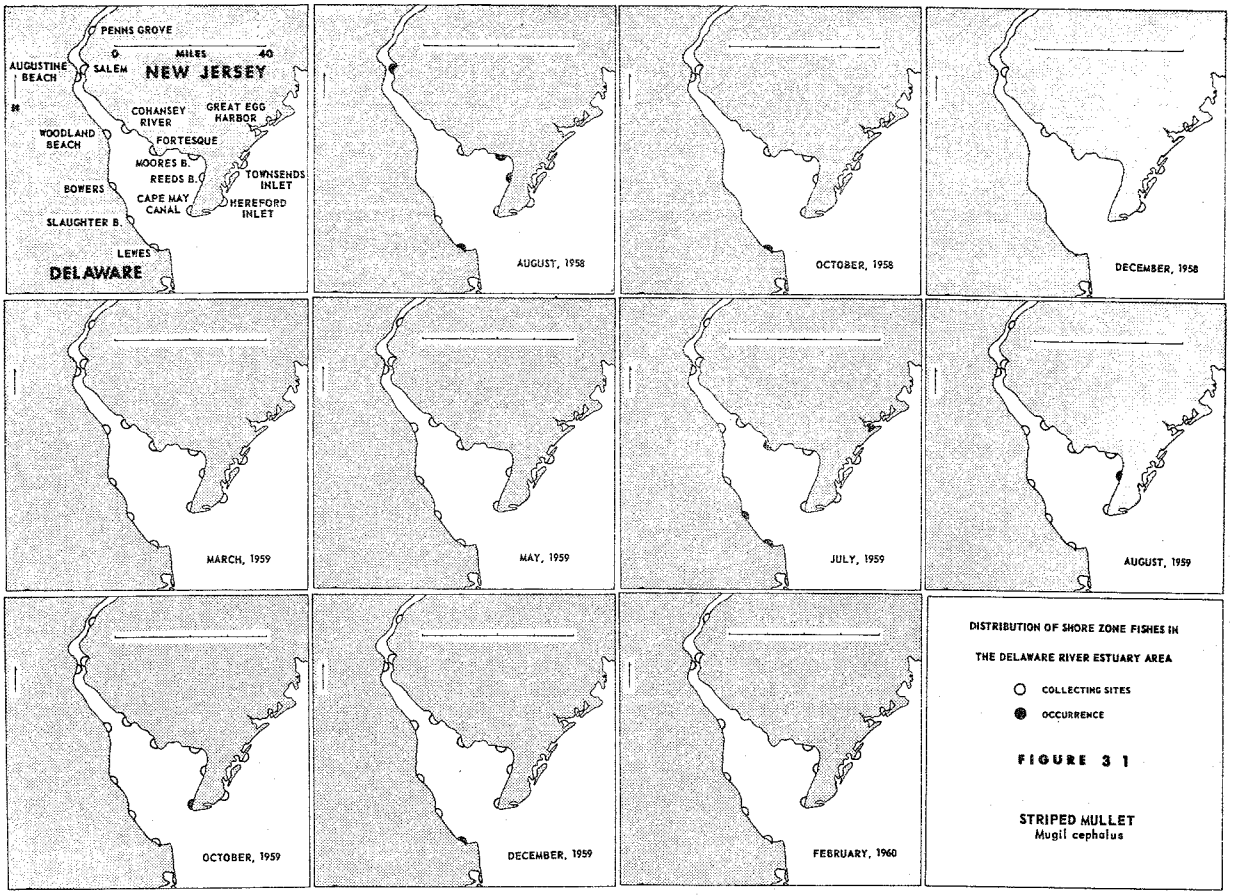


FIGURE 31

STRIPED MULLET
Mugil cephalus

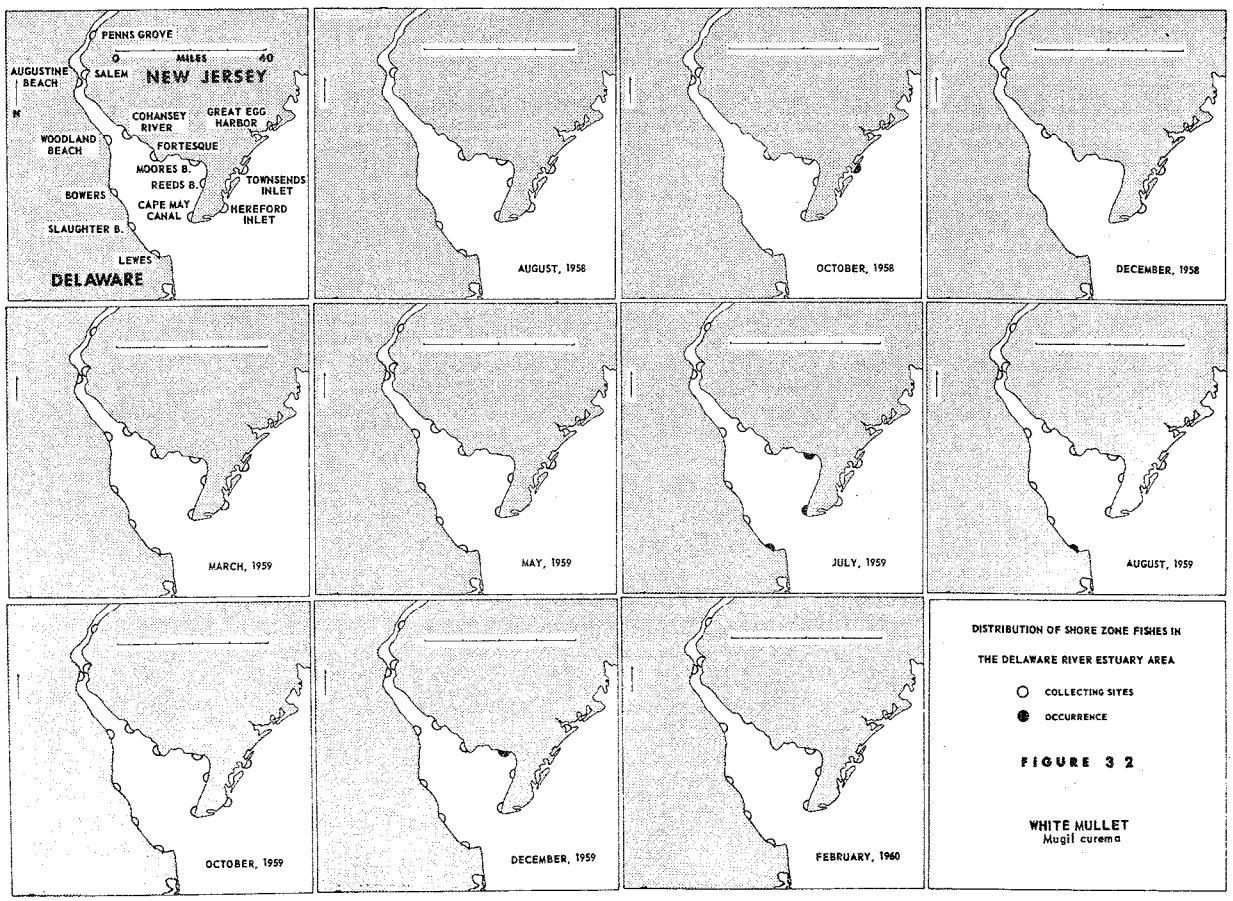


FIGURE 32

WHITE MULLET
Mugil curema

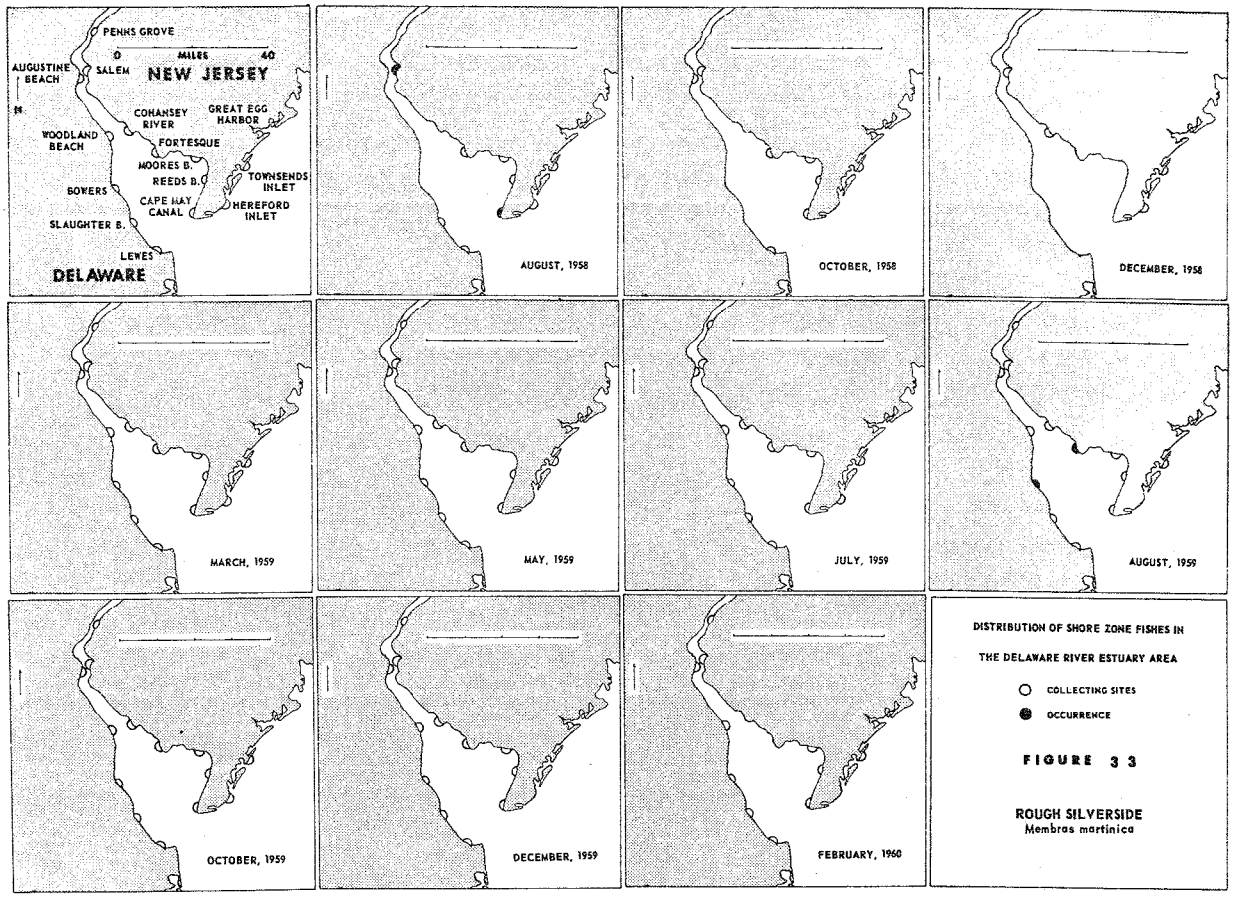


FIGURE 33

ROUGH SILVERSIDE
Membras martinica

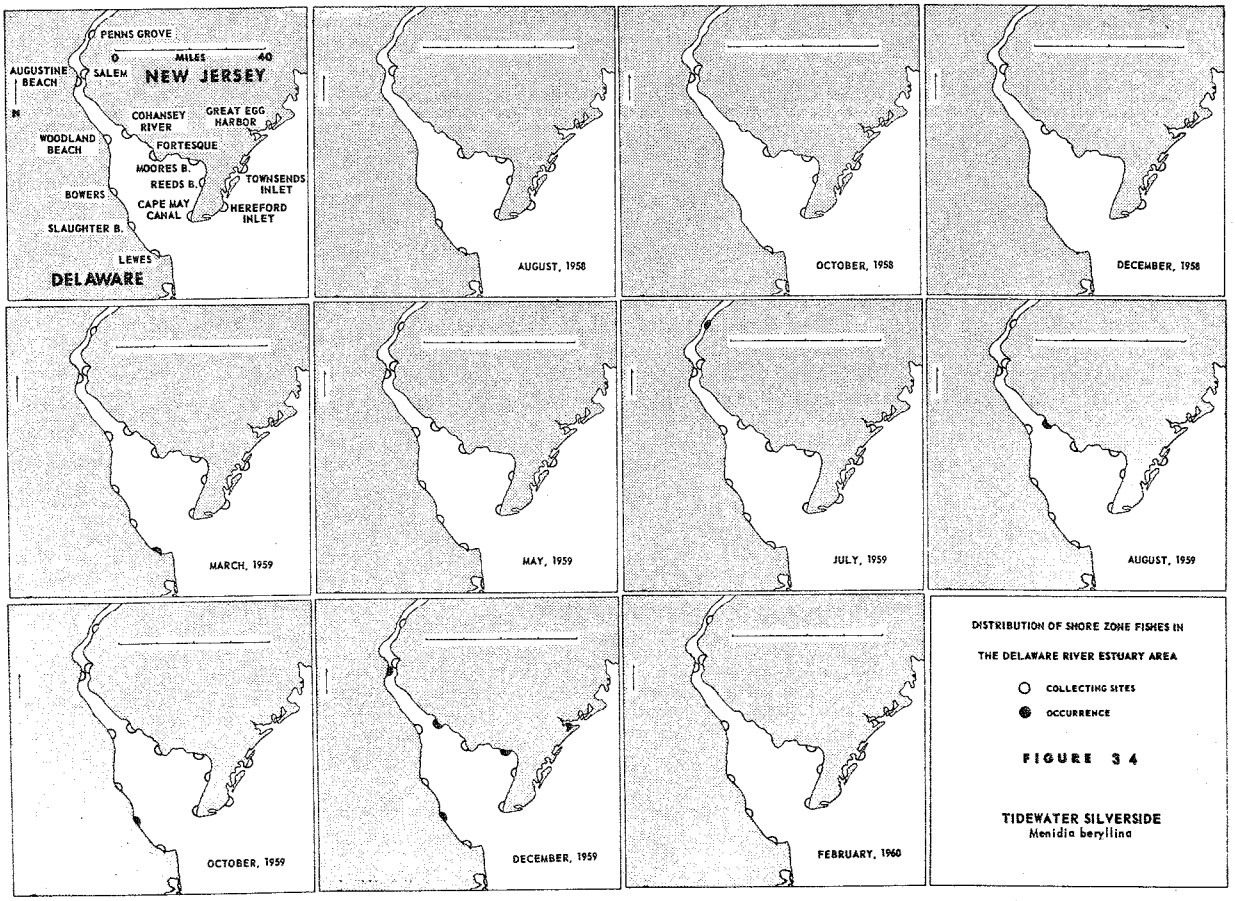


FIGURE 34

TIDEWATER SILVERSIDE
Menidia beryllina

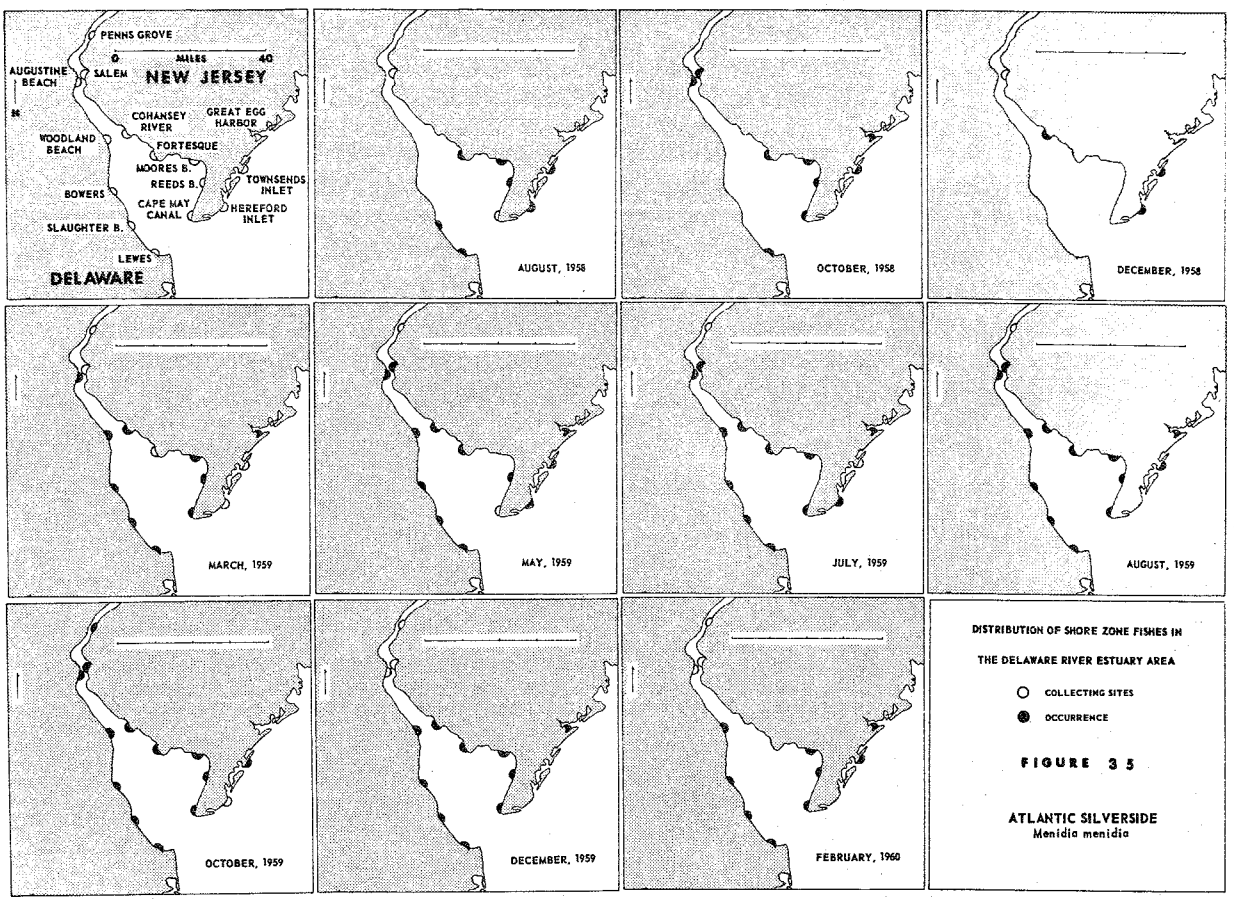


FIGURE 35

ATLANTIC SILVERSIDE
Menidia menidia

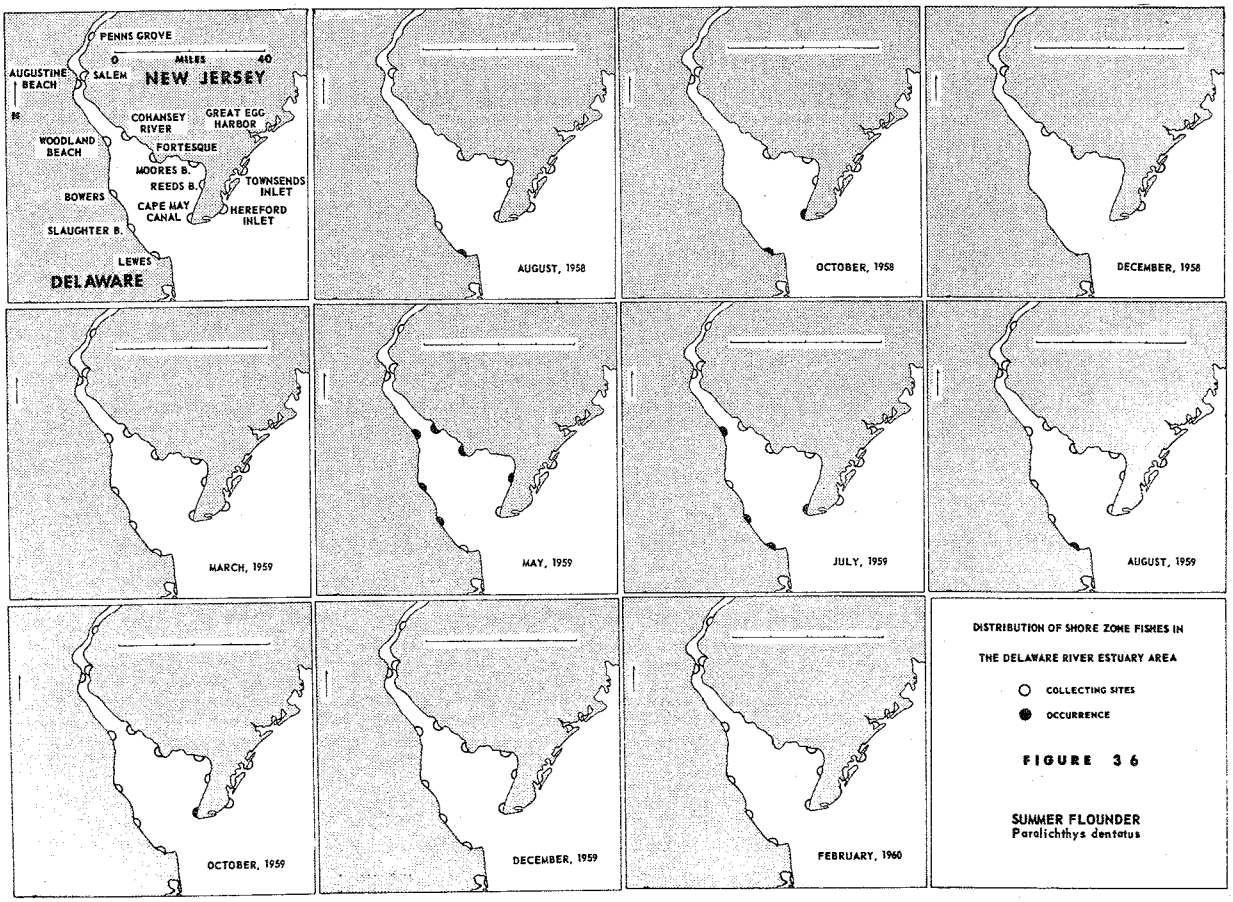
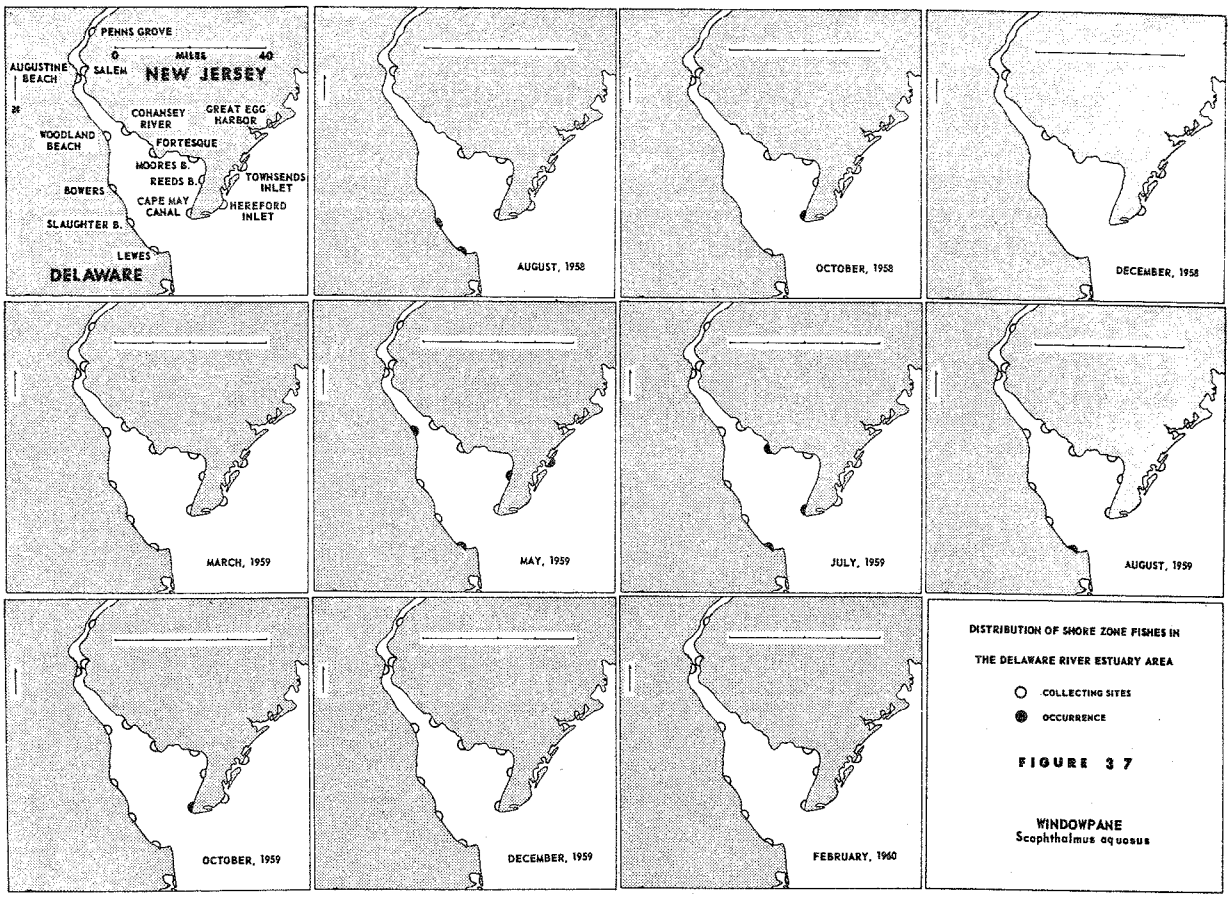
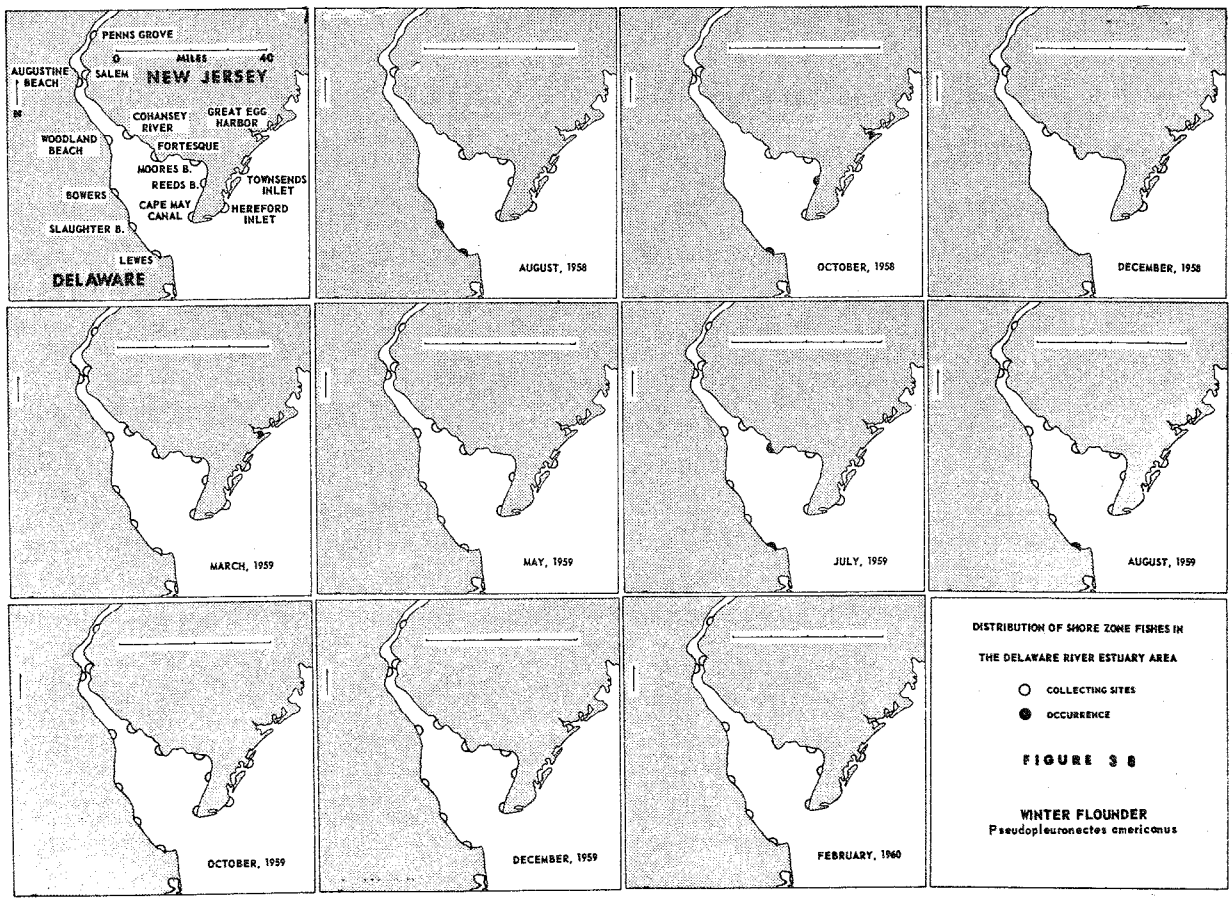


FIGURE 36

SUMMER FLOUNDER
Paralichthys dentatus


PENNS GROVE
0 MILES 40
AUGUSTINE BEACH
SALEM
NEW JERSEY
COHANSEY RIVER
GREAT EGG HARBOR
WOODLAND BEACH
FORTESQUE
MOORES B.
REEDS B.
TOWNSENDS INLET
BOWERS
CAPE MAY CANAL
HEREFORD INLET
SLAUGHTER B.
LEWES
DELAWARE
AUGUST, 1958
OCTOBER, 1958
DECEMBER, 1958
MARCH, 1959
MAY, 1959
JULY, 1959
AUGUST, 1959
OCTOBER, 1959
DECEMBER, 1959
FEBRUARY, 1960
DISTRIBUTION OF SHORE ZONE FISHES IN
THE DELAWARE RIVER ESTUARY AREA
COLLECTING SITES
OCCURRENCE
FIGURE 37
WINDOWPANE
Scophthalmus aquosus


PENNS GROVE
0 MILES 40
AUGUSTINE BEACH
SALEM
NEW JERSEY
COHANSEY RIVER
GREAT EGG HARBOR
WOODLAND BEACH
FORTESQUE
MOORES B.
REEDS B.
TOWNSENDS INLET
BOWERS
CAPE MAY CANAL
HEREFORD INLET
SLAUGHTER B.
LEWES
DELAWARE
AUGUST, 1958
OCTOBER, 1958
DECEMBER, 1958
MARCH, 1959
MAY, 1959
JULY, 1959
AUGUST, 1959
OCTOBER, 1959
DECEMBER, 1959
FEBRUARY, 1960
DISTRIBUTION OF SHORE ZONE FISHES IN
THE DELAWARE RIVER ESTUARY AREA
COLLECTING SITES
OCCURRENCE
FIGURE 38
WINTER FLOUNDER
Pseudopleuronectes americanus

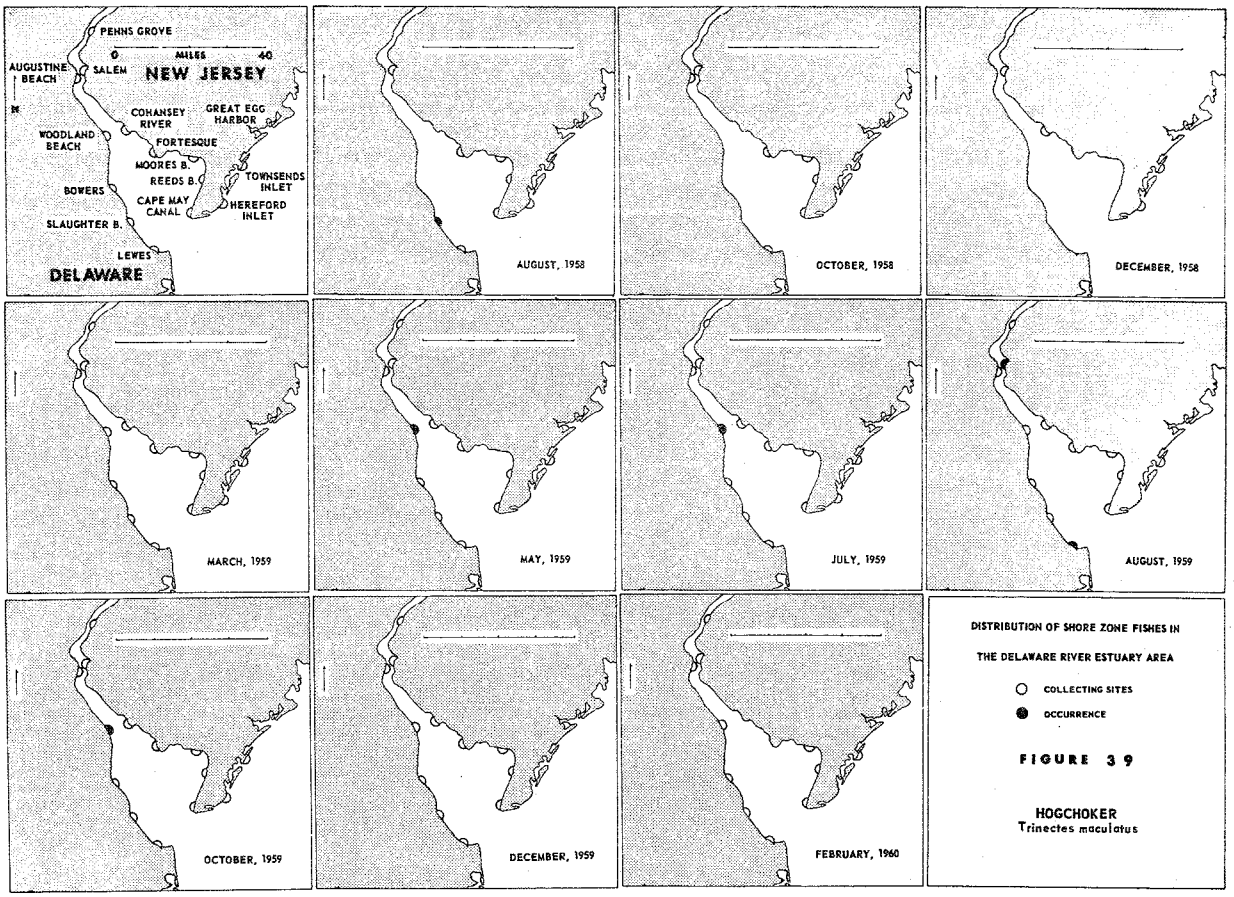


FIGURE 39

HOGCHOKER
Trinectes maculatus

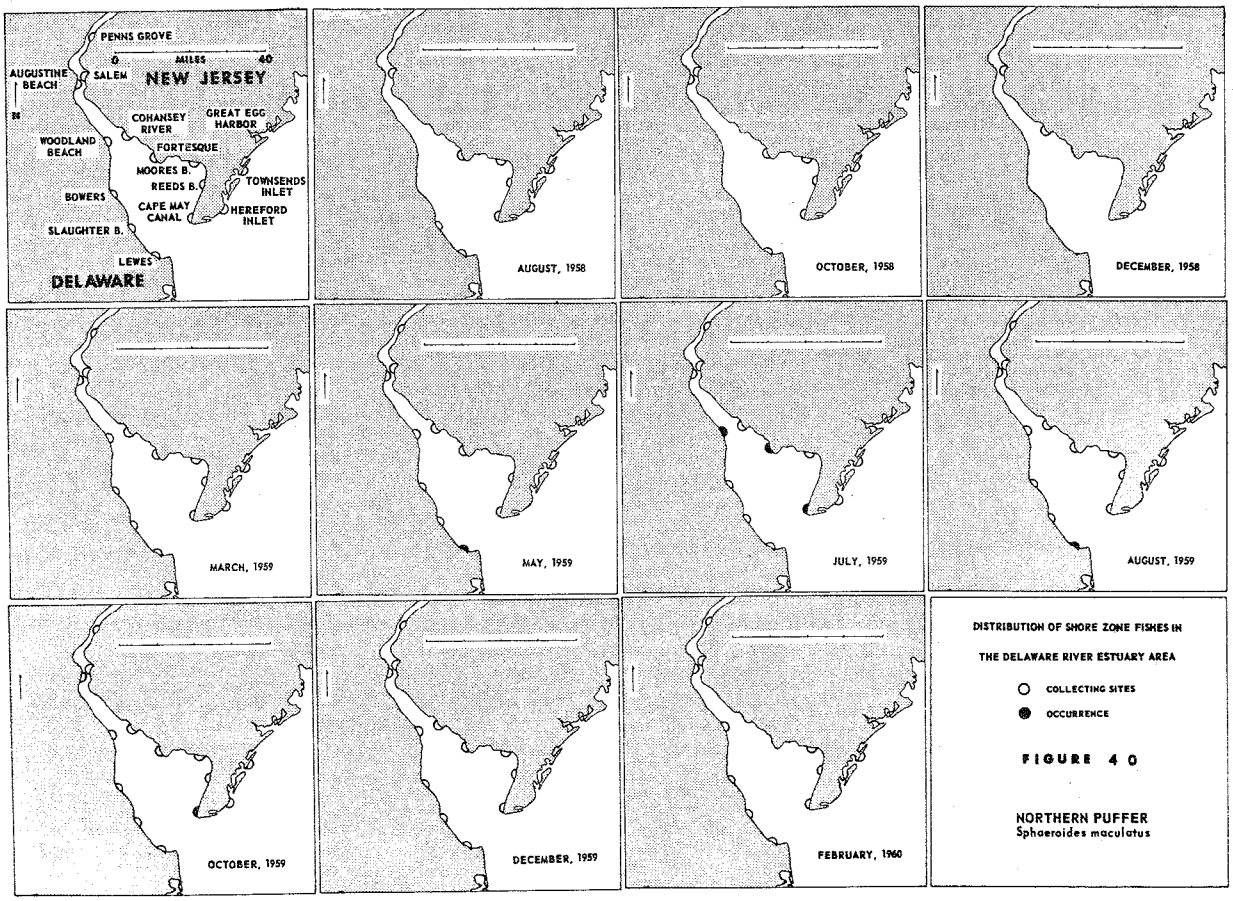
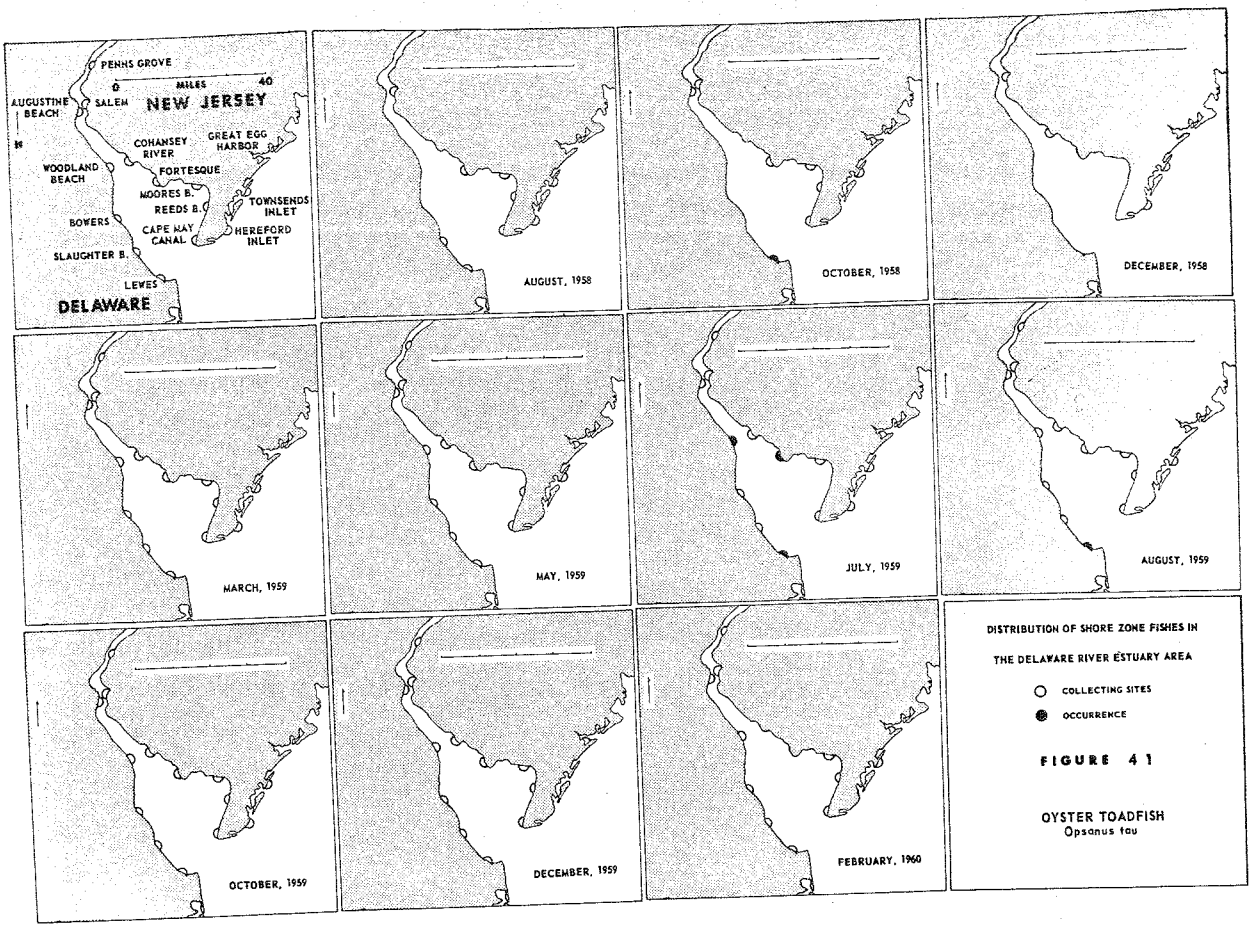


FIGURE 40

NORTHERN PUFFER
Sphaeroides maculatus


PENNS GROVE
0 MILES 40
AUGUSTINE BEACH
SALEM
NEW JERSEY
COHANSEY RIVER
GREAT EGG HARBOR
WOODLAND BEACH
FORTESQUE
MOORES B.
REEDS B.
TOWNSENDS INLET
BOWERS
CAPE MAY CANAL
HEREFORD INLET
SLAUGHTER B.
LEWES
DELAWARE
AUGUST, 1958
OCTOBER, 1958
DECEMBER, 1958
MARCH, 1959
MAY, 1959
JULY, 1959
AUGUST, 1959
OCTOBER, 1959
DECEMBER, 1959
FEBRUARY, 1960
DISTRIBUTION OF SHORE ZONE FISHES IN
THE DELAWARE RIVER ESTUARY AREA
COLLECTING SITES
OCCURRENCE
FIGURE 41
OYSTER TOADFISH
Opsanus tau

INDEX TO THE SPECIES OF FISHES COLLECTED IN THE REGION OF THE DELAWARE RIVER ESTUARY, 1951-1960.

(Those species marked by an asterisk (*) have been collected mainly by Dr. Franklin C. Daiber and his students, starting in 1951, for use in a University of Delaware Marine Laboratories research-teaching collection which is housed in Wolf Hall.)

ANGUILLIDAE - Freshwater Eels

* American Eel *Anguilla rostrata* (LeSueur)	P 9, 22, 23; T 7-12, 14-15, 49-50; F 8.

CONGRIDAE - Conger Eels

* Conger Eel *Conger oceanicus* (Mitchill)	T 50.

BELONIDAE - Needlefishes

Flat Needlefish *Ablennes hians* (Valenciennes)	P 23.
* Atlantic Needlefish *Strongylura marina* (Walbaum)	P 23; T 7-9, 11-12, 50; F 9.
Houndfish *Strongylura raphidoma* (Ranzani)	P 23.

HEMIRAMPHIDAE - Halfbeaks

* Halfbeak *Hyporhamphus unifasciatus* (Ranzani)	P 23; T 12.

CYPRINODONTIDAE - Killifishes

* Sheepshead Minnow *Cyprinodon variegatus* Lacepède	P 20, 23, 25; T 7-12; F 10.
* Banded Killifish *Fundulus diaphanus* (LeSueur)	P 24; T 7-11.
* Mummichog *Fundulus heteroclitus* (Linnaeus)	P 20, 24, 25; T 7-12, 16-17, 49; F 11.
* Striped Killifish *Fundulus majalis* (Walbaum)	P 20, 24, 25; T 7-12, 18-19, 49-50; F 12.
Spotfin Killifish *Fundulus luciae* (Baird)	P 25; T 8, 12.
* Rainwater Killifish *Lucania parva* (Baird and Girard)	P 25; T 7-12.

POECILIIDAE - Livebearers

Mosquitofish *Gambusia affinis* (Baird and Girard)	P 25; T 7, 10.

GADIDAE - Codfishes and Hakes	T 50.
Fourbeard Rockling *Enchelyopus cimbrius* (Linnaeus)	P 25.

CHAETODONTIDAE - Butterflyfishes

* Spotfin Butterflyfish — P 36; T 7-8.
  Chaetodon ocellatus (Bloch)

LABRIDAE - Wrasses

* Tautog — P 37; T 7-10, 50.
  Tautoga onitis (Linnaeus)
* Cunner — P 37.
  Tautogolabrus adspersus (Walbaum)

TRICHIURIDAE - Cutlassfishes

* Atlantic Cutlassfish
  Trichiurus lepturus (Linnaeus)

SCOMBRIDAE - Mackerels and Tunas — P 32, 37.

* Little Tuna
  Euthynnus alletteratus (Rafinesque)
* Atlantic Mackerel — P 37.
  Scomber scombrus (Linnaeus)
* Atlantic Bonito — P 32, 37.
  Sarda sarda (Bloch)

ISTIOPHORIDAE - Billfishes

White Marlin — P 19, 32, 37, 44.
  Makaira albida (Poey)
Blue Marlin — P 37.
  Makaira nigricans Lacépède

XIPHIIDAE - Swordfishes

Swordfish — P 38.
  Xiphias gladius (Linnaeus)

GOBIIDAE - Gobies

Darter Goby — T 50.
  Gobionellus boleosoma (Jordan and Gilbert)
* Naked Goby — P 38; T 7-12, 50; F 30.
  Gobiosoma bosci (Lacépède)
Seaboard Goby — P 38; T 7-8, 10-12, 50.
  Gobiosoma ginsburgi (Hildebrand and Schroeder)

Green Goby *Microgobius thalassinus* (Jordan and Gilbert)	T 50.
TRIGLIDAE - Searobins	P 51; T 50.
* Northern Searobin *Prionotus carolinus* (Linnaeus)	P 38; T 7-10, 12.
* Striped Searobin *Prionotus evolans* (Linnaeus)	P 39; T 7-8.
COTTIDAE - Sculpins	
Myoxocephalus sp.	T 50.
* Longhorn Sculpin *Myoxocephalus octodecemspinosus* (Mitchill)	
DACTYLOPTERIDAE - Flying Gurnards	
* Flying Gurnard *Dactylopterus volitans* (Linnaeus)	P 39.
AMMODYTIDAE - Sand Lances	T 50.
* American Sand Lance *Ammodytes americanus* De Kay	P 39; T 7-10.
URANOSCOPIDAE - Stargazers	
* Northern Stargazer *Astroscopus guttatus* (Abbott)	P 39; T 7-12.
* Southern Stargazer *Astroscopus y-graecum* (Cuvier)	
BLENNIIDAE - Combtooth Blennies	
* Striped Blenny *Chasmodes bosquianus* (Lacépède)	P 39.
OPHIDIIDAE - Cusk-eels	
* Striped Cusk-eel *Rissola marginata* (De Kay)	P 40; T 7-12, 50.

STROMATEIDAE - Butterfishes

* Barrelfish *Palinurichthys perciformis* (Mitchill) * Butterfish *Poronotus triacanthus* (Peck)	P 15, 40; T 50.

SPHYRAENIDAE - Barracudas

* Northern Sennet *Sphyraena borealis* (De Kay)	P 19, 40; T 7-12, 37-38, 49.

MUGILIDAE - Mullets

* Striped Mullet *Mugil cephalus* (Linnaeus)	P 40, 41; T 7-12, 39, 50; F 31.
* White Mullet *Mugil curema* Valenciennes	P 41; T 7-12, 40, 50; F 32.

ATHERINIDAE - Silversides

	P 53.
* Rough Silverside *Membras martinica* (Valenciennes)	P 41; T 7-11, 50; F 33.
* Tidewater Silverside *Menidia beryllina* (Cope)	P 2, 7, 36, 41; T 7-12, 50; F 34.
* Atlantic Silverside *Menidia menidia* (Linnaeus)	P 2, 6, 7, 20, 36, 42; T 7-12, 41-42, 49-50; F 35.

BOTHIDAE - Lefteye Flounders

* Smallmouth Flounder *Etropus microstomus* (Gill)	P 42; T 7-12.
* Summer Flounder *Paralichthys dentatus* (Linnaeus)	P 42, 43; T 7-12, 43-44, 49-50; F 36.
* Fourspot Flounder *Paralichthys oblongus* (Mitchill)	P 43; T 50.
* Windowpane *Scophthalmus aquosus* (Mitchill)	P 43, 51; T 7-12, 45-46, 49-50; F 37.

PLEURONECTIDAE - Righteye Flounders

Yellowtail Flounder *Limanda ferruginea* (Storer)	P 43
* Winter Flounder *Pseudopleuronectes americanus* (Walbaum)	P 43, T 7-12, 47-50; F 38.

SOLEIDAE - Soles

* Hogchoker — P 44, 51; T 7-12, 49; F 39.
  Trinectes maculatus (Bloch and Schneider)

CYNOGLOSSIDAE - Tonguefishes

* Blackcheek Tonguefish — T 50.
  Symphurus plagiusa (Linnaeus)

ECHENEIDAE - Remoras

* Sharksucker — P 44.
  Echeneis naucrates Linnaeus
* Marlinsucker — P 44.
  Remora osteochir (Cuvier)

BALISTIDAE - Filefishes and Triggerfishes

* Orange Filefish — P 44.
  Alutera schoepfi (Walbaum)
* Gray Triggerfish — P 45.
  Balistes capriscus Gmelin

TETRAODONTIDAE - Puffers

* Smooth Puffer — P 45.
  Lagocephalus laevigatus (Linnaeus)
* Northern Puffer — P 45; T 7-12, 50; F 40.
  Sphaeroides maculatus (Bloch and Schneider)

DIODONTIDAE - Porcupinefishes

* Striped Burrfish — P 45.
  Chilomycterus schoepfi (Walbaum)

BATRACHOIDIDAE - Toadfishes

* Oyster Toadfish — P 45; T 7-12; F 41.
  Opsanus tau (Linnaeus)

LOPHIIDAE - Goosefishes

* Goosefish — P 46.
  Lophius americanus (Valenciennes)

SPECIES OF FISHES COMMON IN THE DELAWARE BAY AREA

(Drawings by Nancy Schenck Smith)

Smooth Dogfish
Mustelus canis

x1/10

Bay Anchovy
Anchoa mitchilli

x2/3

Atlantic Menhaden
Brevoortia tyrannus

x1/6

Atlantic Silverside
Menidia menidia

x1/2

Clearnose Skate
Raja eglanteria

x1/10

Bluntnose Stingray
Dasyatis sayi

x1/8

Bluefish
Pomatomus saltatrix

x1/10

Weakfish
Cynoscion regalis

x1/6

Spotted Hake
Urophycis regius

x1/5

Northern Puffer
Sphaeroides maculatus

x1/4

Scup
Stenotomus chrysops

x1/4

American Eel
Anguilla rostrata

x1/15

Striped Killifish
Fundulus majalis

x1/2

Striped Bass
Roccus saxatilis

x1/10

Tautog
Tautoga onitis

x1/7

Black Sea Bass
Centropristes striatus

x1/6

Northern Searobin
Prionotus carolinus

x1/6

Atlantic Needlefish
Strongylura marina

x1/8

Striped Cusk-Eel
Rissola marginata

x1/4

Northern Sennet
Sphyraena borealis

x1/4

Northern Stargazer
Astroscopus guttatus

x1/6

Summer Flounder
Paralichthys dentatus

x1/7