Gulf Research Reports

January 1966

Habits of Juvenile Fishes in Two Rhode Island Estuaries

Mohammed Saeed Mulkana

Part of the Marine Biology Commons

Recommended Citation

The Growth And Feeding Habits of Juvenile Fishes In Two Rhode Island Estuaries

by

MOHAMMED SAEED MULKANA

TABLE OF CONTENTS

ABSTRACT

The basic purpose of this work was to gain information on the possible role of some Rhode Island estuaries as nursery grounds for young migrant and resident species of fishes.

The areas selected were, the lower Pettaquamscutt River and the lower Point Judith Pond, both in the town of Narragansett, Rhode Island. The seining operations were carried through summer and early fall of 1962 when these estuaries are heavily used as nursery grounds. Major features of the occurrence, abundance and distribution of young fishes were deduced by examining samples from seine hauls. Thirty-six species were recorded from the lower river while only twenty-four species occurred in the lower pond. The abundance of fishes rose with a rise in temperature and declined with decreasing temperature, but no correlation was observed between maximum temperature and maximum number of individuals occurring at any time. The number of species and the abundance of individual fish were highest at the seaward station (Sta. II) in the lower river. Among the selected species, the abundance of Menidia menidia *was two to three times higher at Middle Bridge (Sta. II) than at any other station. The behavior of* Pseudopleuronectes americanus, *found primarily at seaward stations, and the migrant species* Brevoortia tyrannus *observed at landward stations, is discussed.*

The species P. americanus *grew at the rate of 10 mm per month, but exhibited no variation in growth in the two estuarine systems. The populations of* B. tyrannus *from the lower Pettaquamscutt River had a growth rate that was almost twice that of populations in the lower Point Judith Pond. The growth rate of these species in Rhode Island waters compare favorably with similar data from other studies. The juvenile* M. menidia *demonstrated a higher rate of growth at seaward stations in both the areas, especially in the lower river.*

Forty-three types of prey organisms belonging to diverse taxonomic groups were identified from stomach contents of P. americanus *and thirty-nine types were noted in the gut contents of* M. menidia. *Analysis of the degree of fullness indicated markedly high percentage of full stomachs in the two study areas. However the degree of fullness was comparatively less in fish occurring in the lower pond. The scarcity of food in the lower pond, apparently forced* M. menidia *(51-80 mm) to feed upon phytoplankton as a substitute food or "forced diet". In* P. americanus *and* M. menidia *a change in diet was noted with change in size. The taxon,* B. tyrannus, *which depended upon phytoplankton and suspended organic matter, did not show any change in food with change in body size.*

While no effective predation was observed, an infection by the sporozoan parasites, Glugea hertwigi, *was marked in both* Osmerus mordax *and* P. americanus. *Low catches of* P. americanus *were perhaps due to higher infection.*

A comparison of the parameters of abundance, growth and food habits reveal that the two estuarine systems are suitable nursery grounds, and that the lower river is a more favorable nursery than the lower pond.

100

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The purpose of this work was to evaluate selected Rhode Island estuaries as nursery grounds for juvenile fishes. The juvenile stage in the life history of fishes follows the emergence from larval life to an independent young phase. At this stage survival becomes dependent on physiological and morphological fitness, availability of suitable types of food, and protective adaptations to minimize predator and parasite invasion and over-population pressure. The immature young of coastal and offshore fishes of many species spend their critical juvenile period in protected, food-rich estuaries. Often the success of stocks in a fishery is dependent on the presence of areas suitable as nursery grounds.

Greely (1939), Warfel and Merriman (1944) and Pearcy and Richards (1962), who studied the seasonal variations and ecology of juvenile and adult fishes along the New England Coast, and Shuster (1959) who conducted similar investigations in Delaware Bay estuaries, all reported a great abundance of fish-of-the-year of various species in the shallow waters of coastal ponds, estuaries, and bays. Fish's (1938-42 unpubl.) observations in Rhode Island waters point to the same conclusions. Information from all of these sources provides strong evidence that estuarine environments play a vital role in the survival and maintenance of stocks of the coastal and offshore fisheries of commercial significance.

The present work is an attempt to gain information on the role of two estuaries in Rhode Island as nursery grounds for young fishes of coastal and offshore species. Emphasis was laid on the seasonal changes of young fish populations with respect to their total and relative abundance and distributional patterns. An idea of the success of these estuaries as nurseries was gained through growth studies and analyses of the feeding habits of three species, the winter flounder, *Pseudopleuronectes americanus*, the Menhaden, *Brevoortia tyrannus*, and the Silversides, *Menidia menidia*. These species in general are benthic, pelagic and omnivorous respectively in behavior and food habits. The diverse feeding habits should provide information on the overall available food present in an environment. The average growth rate of these species should be a function of the success of the feeding niches occupied by these species.

The coast of Rhode Island has a series of salt ponds and estuaries lying both parallel and perpendicular to Rhode Island and Block Island sounds. By definition (Emery *et. al.*, 1957) coastal ponds or lagoons are former embayments which have been partially isolated from coastal waters by barrier sand bars. Some estuaries, especially along the shores of southern New England, represent drowned glacial outwash stream valleys. Rochford (1951) described estuaries as bodies of water in which chlorinity and salts and other properties are subjected to an alteration by inflow of fresh water and sea water in certain ratios during the tidal cycle. Further there exists a persistent circulation and exchange between the estuarine system and adjoining neritic waters.

The present studies were conducted in certain areas of the Pettaquamscutt River and Point Judith Pond estuaries in the town of Narragansett, Rhode Island (Fig. 1 and 2). The area under study in the lower Pettaquamscutt River lies within a "gradient zone", a zone having a distinct salinity gradient. The seining stations in Point Judith Pond were
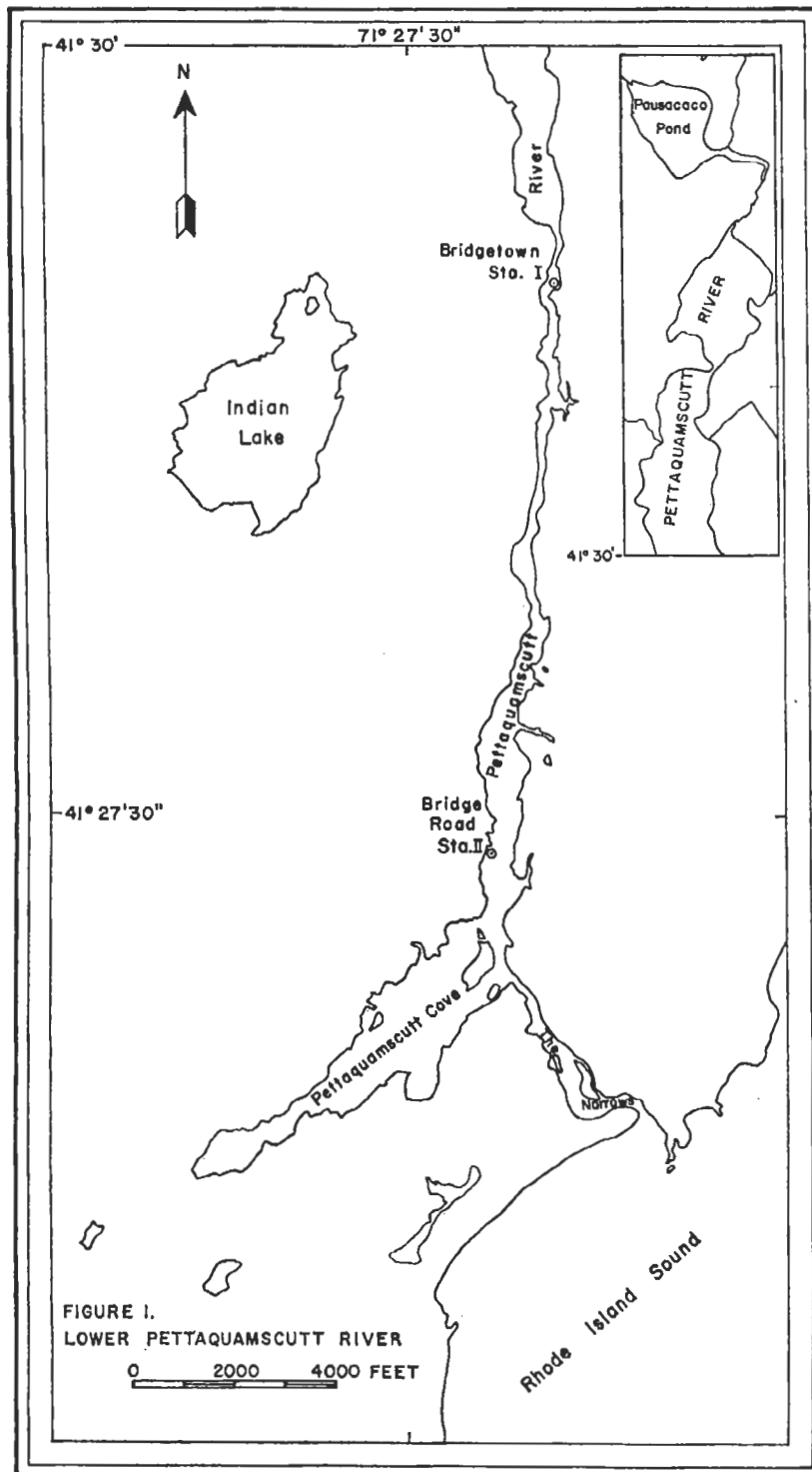
Fig. 1.   Map of Pettaquamscutt River Estuary showing location of seining stations.
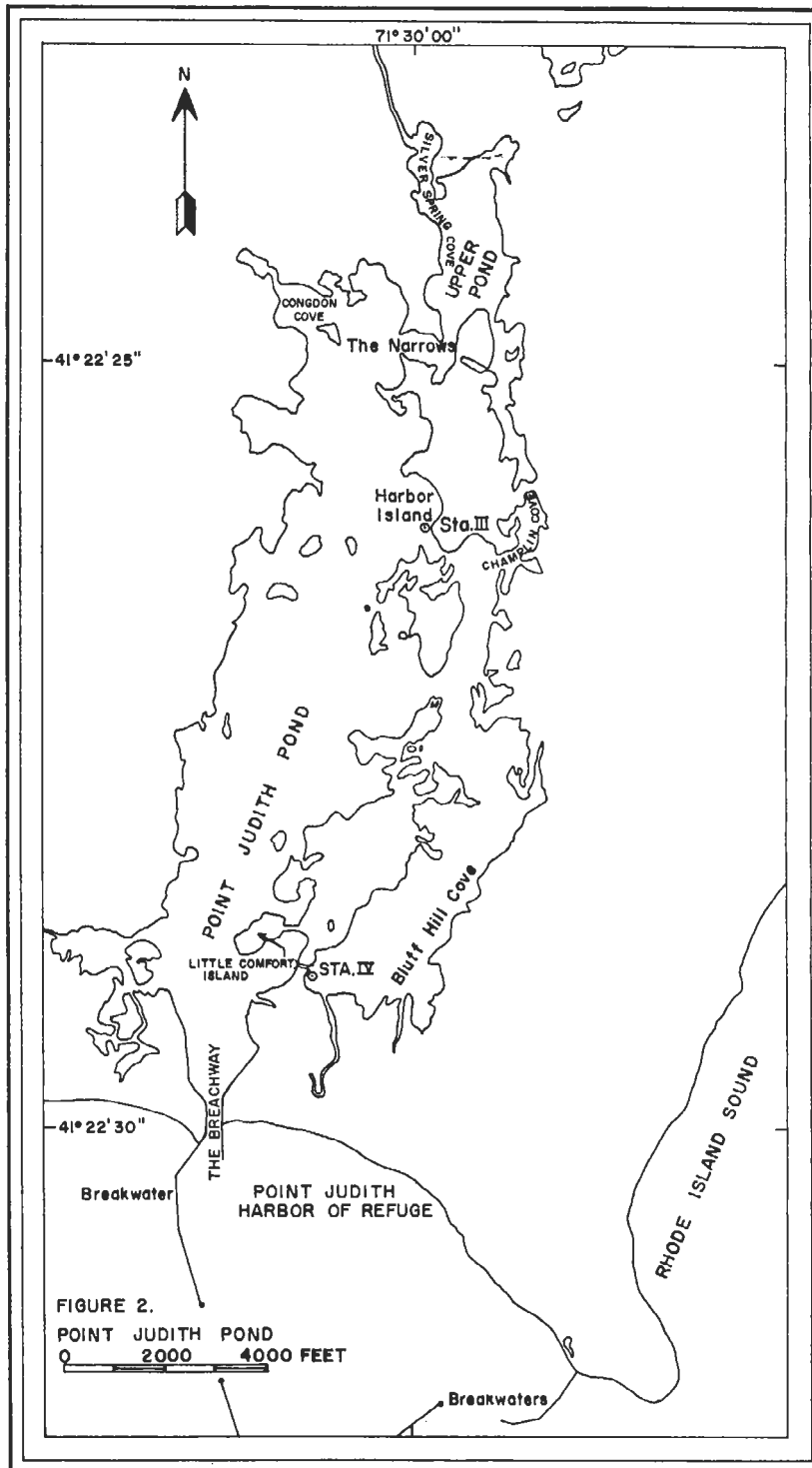
Fig. 2. Map of Point Judith Pond Estuary with locations of seining stations.

located in the lower pond, characterized as the "marine zone" according to Rochford (1951) where near-neritic conditions exist.

The river estuaries are generally considered more productive than coastal ponds and lagoons (Riley, 1937; Rochford, 1951 and Emery *et al.,* 1957). Consequently the diverse environmental conditions existing in the two estuarine systems should provide an opportunity to study the variations in abundance, average growth of young fishes and the available food in the particular feeding niches of selected species of fishes. In describing the overall occurrence and abundance of juvenile fishes some parameters for the adults of some of the smaller resident species also were included. These fishes though of no direct commercial importance, play a significant role as a food supply, as special competitors and as predators for other juvenile species of economic significance in the estuaries.

II. REVIEW OF LITERATURE

Fluctuations in fish populations have been an important concern to man since neolithic times. The pursuit of knowledge through biological investigations long remained directed towards the study of adult fishes.

Early studies by Jordan (1896-1900) in North and Middle America, Smith's (1898) investigations in the Woods Hole region, and Tracy's (1906, 1910) work in Rhode Island water all pertain to the occurrence and systematics of regional fish fauna. Quantitative studies of young fish started recently in these areas.

Hjort (1926) theorized that the numerical prominence of a year class is determined at a very early stage. Hjort's early methods and attempts to determine spawning and nursery areas brought him to the conclusion that fishes early in their life histories tend to localize in particular ecological habitats. Greely's (1939) investigation in the estuaries, creeks and oceanic inlets in Long Island Sound during the summer led him to assume that these environments may not constitute spawning areas for various species but are important rearing grounds for young fishes from remote spawning centers.

The results of the analysis of seasonal abundance and distributional patterns of young and adult fishes by Warfel and Merriman (1944) in southern New England waters point to the direct influence of temperature on immigration and emmigration of migrant species. The results manifest that factors like population density, age, depth and meterological conditions probably determine the distribution of young fishes. Adolf (1925) found that marine organisms can tolerate drastic changes in the osmotic environment more effectively than fresh water forms. Horton (1958) observed strictly marine forms in fairly brackish water environments in the upper reaches of the Pettaquamscutt River, Rhode Island, indicating that young marine immigrant species may successfully thrive in all of the salinity regimes in an estuary. Based upon the ecological studies of larvae, juvenile and adult fishes of the Mystic River estuary, Pearcy and Richards (1962) contended that estuaries may be important as spawning grounds, nurseries for juvenile fishes and feeding grounds for adult forms of resident and migrant species.

Hiatt and Strasbury (1960) analysed the relationship for 233 species of fishes in many diverse types of ecological niches in the coral reefs of the Marshall Islands. Their description of feeding types illustrates the

feeding habits and food requirements of fishes that utilize energy from different trophic levels. While this detailed study attempted to explain self-adjusted steady state equilibria existing in great varieties of reef habitats, the principles deduced may also be applicable to ecosystem studies in estuarine environments. Richards (1963) studying the feeding ecology of juvenile fishes in Long Island Sound, indicated that sporadic immigration of migrant species may not cause interspecific competition if super-abundant and well distributed food is present. Richards suggested that the mobility of prey and predator species common in a temperate marine environment, such as Long Island Sound, is an important factor indicative of the success of the various feeding niches. Ivlev's (1954a) investigation on the ecology of the feeding habits of fishes showed that with an increase in available food, the daily ration approaches a maximum ration. The application of this principle suggests that in an environment with ample food, young fishes are attracted whose fast early growth may require large quantities of food. Ricker (1946) reports that small fish eat more per unit body weight than large fish, hence the rate of feeding could affect the size of the fish. Pearcy (1962) conducted studies on the quantitative aspects of abundance, growth, survival and mortality of larvae and juvenile stages of *Pseudopleuronectes americanus* in the Mystic River Estuary. Comparing the biomass and productivity measurements of the Mystic River Estuary with that of Long Island Sound, he concluded that some estuaries are more productive than some neritic environments and serve as nursery areas for young fishes. Shuster (1959) working on the biological evaluation of the Delaware River Estuary points out that estuaries are important spawning and nursery areas and contribute effectively to the economy of the coastal fisheries.

III. METHODS AND MATERIALS

Stations:

The selection of the stations was based upon Fish's results (1938-42 Unpubl.) of seining operations in the lower Pettaquamscutt River and certain other ponds and estuaries in Rhode Island, easy access from the shore and maximum seining area available with practicable depth. Two stations were established in the lower Pettaquamscutt River and in the lower Point Judith Pond about three kilometers apart (Figs. 1, 2). The seining operations were carried out in the lower Pettaquamscutt River at the Bridgetown Bridge (Station I), and at the Middle Bridge (Station II); and in lower Point Judith Pond at Harbor Island (Station III) and at Galilee (Station IV). For brevity in the following account the study areas in each of the estuaries will be referred to as "lower pond" (lower Point Judith Pond) and "lower river" (lower Pettaquamscutt River).

Seining Operations:

Seining was carried out at selected stations only during the ebb tide. A fifteen-meter-long, shore seine with quarter-inch (6.4 mm) mesh was employed. Within the center of the seine a square of 1 mm mesh netting (2m x 2m) was fastened to ensure capture of small fishes. The seine was fished parallel to the shore from low water mark to a point 15m perpendicular to the shore, and was swept for 15m in either direction. At the end of each seine haul a capture arc was formed and the lower weighted end was drawn first thus pursing the seine to retain the catch. A strictly identical seining procedure was followed throughout the survey period. From the seine hauls numerical abundance of all species was noted.

Preservation:

A subsample of at least thirty randomly selected specimens of the more abundant species of fishes were retained for further analysis. The fishes were placed in 2% formalin. The formalin concentration was slowly increased to 10%. The procedure allowed the formalin to diffuse into the alimentary tract to stop further digestion and subsequent decomposition of the gut contents. Abdominal cavities of some fishes of selected species were incised before final preservation. The formalin was saturated with sodium tetraborate ($Na_2B_4O_7$) or calcium carbonate ($Ca Co_3$) to neutralize the acid and to keep the gut contents softened for identification.

Temperature:

Surface water temperature was measured at each station weekly 5 meters from the shore during ebb tide using a mercury thermometer to the nearest 0.2°C.

Salinity:

Surface and bottom salinity was determined by a conductivity method each week, using an electronic salinometer designed and built by J. T. Conover. Bottom water samples were taken with a sampler consisting of a polyethylene tube stoppered at both ends and equipped with a glass tube at the lower end.

The salinity of a series of surface and bottom water samples was determined along the north-south axis of both estuaries at ebb and flood tides, during one 24-hour tidal cycle on July 21, 1963. From these data salinity ratios during a complete tidal cycle were computed to aid in the zoning of the estuaries after Rochford (1951).

Precipitation:

Rainfall data were obtained from the Monthly Climatological Summary of the New England Region compiled by the U. S. Weather Bureau. The rainfall recorded by the Weather Bureau at the Hillsgrove Municipal Air Port in Providence, was used for both estuaries.

Identification and Counts:

Fishes from each sample were identified and counts were recorded and used to determine total and relative abundance. Two species, *Pseudopleuronectes americanus* and *Brevoortia tyrannus,* which occurred in significant numbers and have economic importance, and a most abundant small species, *Menidia menidia,* were selected for a detailed study. These fishes have diverse food habits and provide a good trophic picture of the environment.

Age Groups:

The separation of the young of the zero plus class of *P. americanus* and *B. tyrannus* presented no problem since the criterion of standard length, distance from snout to hypeural plate alone, is a reliable tool to distinguish zero group from older groups in these species (Pearcy, 1962, and McHugh *et al.,* 1959). To confirm this assumption for *P. americanus* in the separation of age groups, scales and otoliths were examined following the annulus interpretation given by Welsh (1924), Berry (1959) and others. For an interpretation of scales of *B. tyrannus* the writer followed criteria laid down by Hile (1948), Westman and Nigrelli (1955) and McHugh *et al.* (1959). No reliable information is available for the exact size range of the zero age group for *Menidia menidia.* Williams (1960)

considered fish of second year class as above the minimum size of 50 mm. The juvenile fish could be distinguished during early summer, but in late summer and fall an admixture of young and adult fish of overlapping size groups made it impossible to distinguish the young from the adults. The data were analysed by a graphical method (see below) which gives the size range and demonstrates the possible growth in such groups.

Growth Computations:

In view of marked fluctuations in the sample sizes of the selected species, the data were processed and computations made using an improved graphical method by Hubbs and Hubbs (1953) based upon an analysis of variance. Graphical analysis demonstrates the significance of differences between the series of samples as well as the degree of reliance on the results. The average values of standard lengths for the selected species were used to draw growth curves. For complete detail see legend for figure 13.

Food Analysis:

The food study was based on an analysis of stomach contents. It is, however, important to couple such studies with a determination of the types and abundance of food present in the environment. Due to the preliminary nature of the present work and to the time factor only stomach contents were considered in this study.

The food present in a stomach is in a less advanced state of digestion than in the intestine and permits better identification. In the absence of a well defined stomach as in the case of *Menidia menidia,* gut contents were used for food analysis. The following methods were employed for food study:

1) The occurrence method determines the palatibility of food (Allen, 1935 and Hartley, 1947).

2) The average stomach content method demonstrates the relative importance of individual prey species (Covill, 1959 and others).

3) The fullness method is a special extension of total volume method and estimates variation in quantity of food in various size groups, areas and seasons.

The size of each food organism was also measured using an ocular micrometer. All collections of each selected species from each estuary were combined, and a sample of 150 fish was taken randomly for food analysis. Fishes were categorized in three arbitrary size groups to find variations in food with respect to sizes of fishes. A fair number of stomachs or alimentary tracts from each size group, depending upon the number available, were individually dissected, the contents identified and counts made in a Sedgewick-Rafter cell or a larger improvised counting chamber under 60 X magnification. Later on stomachs or alimentary tracts were grossly studied in groups of ten. In the case of *Menidia menidia* collected from the lower Point Judith Pond, the volumes of gut contents of various size groups were determined. The gut contents which were comprised entirely of phytoplankton, were diluted, and from aliquots the number of organisms per cubic millimeter was determined.

IV. THE ENVIRONMENT

A. Topographic and Edaphic Features

1. **Topography.**

The Pettaquamscutt River Estuary represents a drowned river valley

in the post-glacial topography of a coastal plain. From its source at Pausacaco Pond in North Kingstown, the estuary extends southerly for 9 kilometers to its mouth which discharges into West Passage of Narragansett Bay. Near Sprague Bridge an arm of this estuary extends for 2.1 kilometers in a southwesterly direction ending blindly as the very shallow Pettaquamscutt Cove. The north-south axis of this estuary lies between latitude 41°26'N and 41°31'N and at longitude 71°27'30"W (Fig. 1). The river is 6 meters to 0.8 kilometers broad and has a narrow constricted mouth facing southeast. The interesting and unusual features of this estuarine system are the presence of two deep stagnant basins north of the Bridgetown Bridge which are separated from the rest of the estuarine system by shallow sills. These are kettle holes, filled with stagnant high-salinity water. Only the surface water, a few meters deep, undergoes a change in salinity during the tidal cycle. Mixing into the stagnant zone may occur when strong hurricane winds roil the river water (Jeffries and Smayda, 1954; Horton, 1958).

The Point Judith Pond is one of the largest salt ponds along the coast of Rhode Island, measuring 6.3 kilometers from the breachway at Block Island Sound to Silver Spring Cove and from 90 meters to 2.1 kilometers in width (U. S. Geological Survey, 1957). The boundaries are located between 41°22' and 41°27'N latitudes and 71°29' and 71°32'W longitudes (Fig. 2). The Saugatucket River drains into the upper Pond which opens through a narrow constricted passage, "The Narrows," into the considerably larger lower Pond. The flow of river in the lower pond is considerably less in camparison to the river inflow in the river estuary, since there is no significant salinity gradient in the greater part of the pond (Fig. 3). The lower pond is linked to Potter Pond through a narrow stream facing west and discharges southerly in Block Island Sound through the Point Judith Harbor of Refuge. The tidal flats, small coves, bars, shoals and islands are the chief topographical features in the pond estuary. Tidal amplitudes and currents in this estuary are strongly influenced by the presence of breakwaters, jetties and the irregularity of shore line and bottom contours.

2. Hydrographical Zones.

Based on the salinity conflict (modified from chlorinity conflict) after Rochford (1951), the estuaries were classified into various zones, following Rochford's assumption that ecological variations in these zones were characteristics of these environments in any estuary. Four zones were identified in the Pettaquamscutt River estuary.

a) "Marine Zone." The salinity ratio at ebb and flood observed during a tidal cycle was 1:1. According to Rochford (1951) the absence of a salinity conflict, a ratio of change, during a tidal cycle in an area helps categorize it as a "marine zone." This zone lies between the entrance from the West Passage to Sprague Bridge (Figs. 1 and 3).

b) "Tidal Zone." This zone marks the development of slight changes in salinity from ebb to flood tide and has maximum development of intertidal mud flats, and very shallow areas. The area between the northern boundary of Pettaquamscutt Cove to a kilometer towards Middle Bridge (Sta. II) has a salinity ratio of 1:1.1. In addition, Pettaquamscutt Cove having extensive intertidal mud flats, a characteristic feature of a tidal zone, may also be considered within the same domain.

110

c) "Gradient Zone." This zone demonstrates a maximum salinity conflict in this estuary, with a ratio of 2:3. The limits of this zone extend from the vicinity of Middle Bridge to the entrance of Gilbert Stuart Brook (Figs. 1 and 3). The lower portion of the river in this zone has a comparatively narrow channel, a characteristic feature of such a zone (Richford, 1951). The deep saline pockets, represented by kettle holes do not ordinarily disturb the gradient, since the water below the sills, a few meters deep, remains uninfluenced by the tidal cycle.

d) "Fresh Water Zone". No saline water is present in this zone. The entire Gilbert Stuart Brook system was considered as the fresh water zone (Fig. 3).

Only two zones could be defined in the lower Point Judith Pond. The area is dominated by the "marine zone." The salinity ratio found between ebb and flood tide was about 1:1, characteristic of this zone. In the Upper Pond the gradient and fresh water zones are present, but so constricted or small in area as to be of little importance to the estuary as a system. The lower pond however has a series of coves with well-developed extensive intertidal mud flats.

3. Edaphic and Biological Aspects.

Pettaquamscutt River. The area involved in this study lies within the "gradient zone" (Fig. 3) extending from Bridgetown Bridge (Sta. I) to Middle Bridge (Sta. II). The depth in the mid-channel at low tide is about 2 meters at Station I and 2.5 meters at Station II. The depth at the seining area of Station I varied between 0.6 m and 1.5 m. The depth at Station II was between 0.6 m and 1.2 m. McMaster (1958), in describing the bottom topography of the estuary from Bridgetown Bridge to Middle Bridge, indicated that the bottom near the Bridgetown Bridge is sandy with isolated patches of silty sand which changes to a mixture of soft silty sand and mud near the lower bridge (Sta. II). Sparse beds of *Zostera marina* occur near Bridgetown Bridge and increase in abundance down the river towards the lower station. South of Middle Bridge the bottom is composed of soft silty sand and thick stands of *Zostera marina.* The Eel grass becomes heavily epiphytized during the warm season.

The Lower Point Judith Pond. The seining stations located within the lower pond characterized as "marine zone" extend from the Bluff Hill Cove to Harbor Island (Figs. 2 and 3). The depth in this area varies between 0.6 m and 3 m. The depth at seining Station III, Harbor Island, varied between 0.6 m and 1.5 m, while at Galilee (Sta. IV) it was between 0.6 m and 1.2 m. Although the breakwater riprap minimizes the effect of waves, the north-south axis of the lower pond is markedly influenced by fast water circulation because of nearness to the open ocean. The bottom along the channel is rocky or sandy, except for inlets and coves. Along the east side of the lower pond, from Harbor Island southward, the bottom is lined with coarse sand, pebbles and cobbles especially near the shore lines of the islands centrally located in the pond basin. The Harbor Island Station has massive plant beds including *Entermorpha linza, Scytosiphon lomentaria, Ulva lactuca, Fucus vesiculosis* as well as minor plant species. The plants serve as a protection for young fish against predators and the epibiota are probably an important food source. At the lower extremity of Bluff Hill Cove (Sta. IV) the bottom consists of soft clayey silt with a high organic content which gives away to a silty sand towards the breachway. The plant life is sparse and the area is comparatively much shallower than that of the Harbor Island station (Sta. III).

111
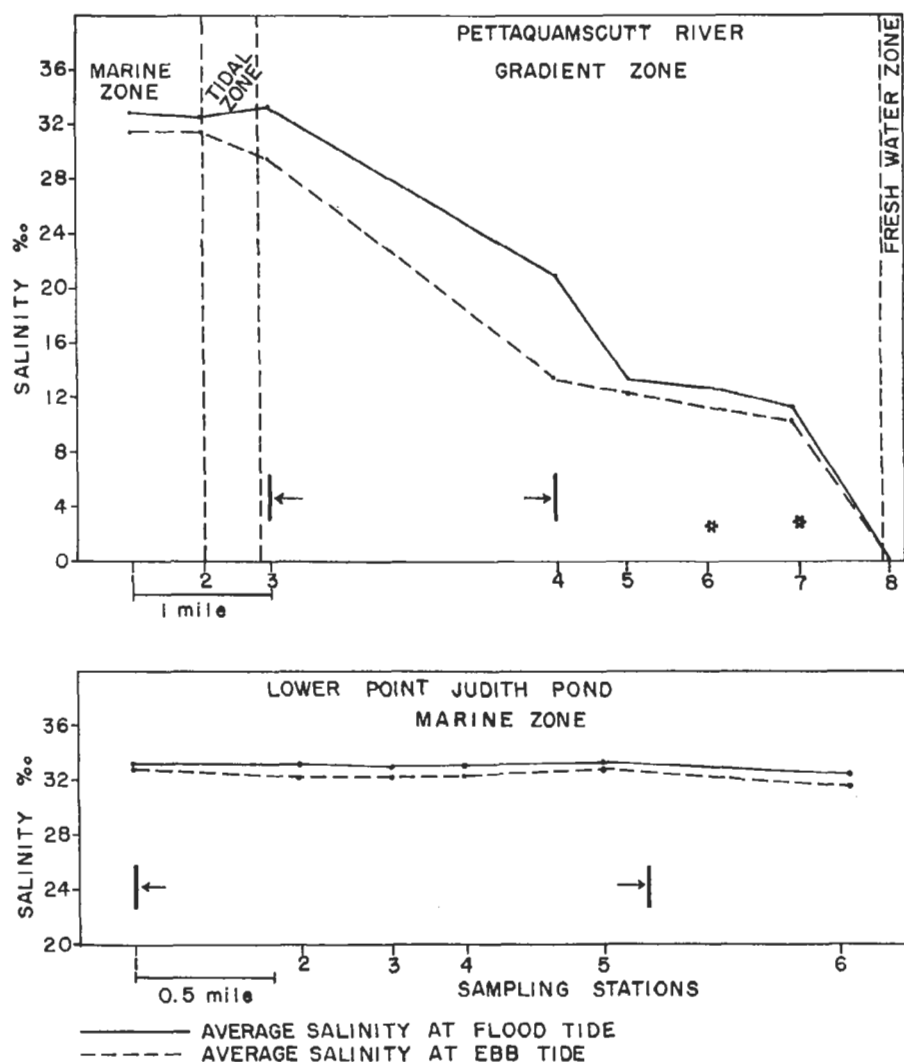
Fig. 3. Distribution of hydrographical zones in Pettaquamscutt River
and the lower Point Judith Pond estuaries (after Rochford, 1951).

LEGEND FOR FIGURE 3.

The area between the arrows in each graph indicates the study areas in the two
estuaries. The stations marked with asterisks represent deep basins separated from
one another and from the rest of the estuary by shallow sills. The vertical salinity
gradient below a few meters in depth demains stable, and stagnant conditions exist
in these salt pockets (Jeffries and Smayda, 1954; Hicks, 1958). Data for the bottom
water were taken from samples at three meters depth in these basins; consequently,
the differences in the salinity ratios at ebb and flood tide were much smaller than
they would have been if the high salinity water in the kettle holes had been considered.
The water samples were taken on July 21, 1963, which had followed a long draught
period (Climatological Data from New England Region, U. S. Weather Bureau).
The salinity values shown are abnormally high as compared with average salinity
data in these areas (Jeffries and Smayda, 1954; Hicks, 1958; Horton, 1958).

B. HYDROGRAPHY

1. Salinity.

A strong salinity gradient was observed in the lower Pettaquamscutt River, while conditions in the lower Point Judith Pond were almost neritic (Figs. 3 and 5). Considerable variations in salinity occurred especially in the lower river, the difference between 9.8 and 15.1 o/oo. The brackish water conditions exist at this station because of its nearness to a fresh water source. The range in salinity noted at the more seaward station (Sta. II) was highest, varying between 20.3 to 32.3 o/oo. The abrupt fluctuations in salinity were apparently caused by heavy precipitation during early September and October (Fig. 4). The rate of inflow of fresh water which depends upon seasonal precipitation is assumed to be the major factor influencing changes in salinity. Strong or hurricane winds very infrequently produce a significant increase in salinity by stirring up stagnant water from the upper basins (Jeffries and Smayda, 1954; Horton, 1958).

The Point Judith Pond estuary while it is narrow at the transition, the breechway, broadens considerably in the mid-region. The surface and bottom salinities in the lower pond, though not markedly diverse, indicate an apparent vertical stratification because of probable net non-tidal drift upstream at the bottom and net non-tidal drift downstream at the surface. The Point Judith Pond is a shallow estuary. Stommel and Farmer (1953) indicated possible overmixing in such estuaries, and suggested that salinity in the upstream is determined by the throttling action of the narrow transition. In the lower pond which covers three-fourths of the entire pond, the seasonal salinity variation never exceeded more than 2 o/oo at the two extremities (Sta. III and Sta. IV). The seasonal surface salinity at Harbor Island ranged between 28.5 to 31.5 o/oo. The narrow range and low variations compared with those observed in the lower Pettaquamscutt River suggest that the salinity regime of the lower pond is greatly influenced by neritic waters. Furthermore the fluctuations in salinity in the lower pond were also correlated with the precipitation (Fig. 5).

2. Temperature.

The surface temperature measured during summer and early fall at both stations in the lower river ranged between 23.8°C and 14.2°C. The temperature remained comparatively high in October at the Middle Bridge station perhaps because of the shoalness of the area (Fig. 6). The maximum temperature values were observed in August and the minimum in October.

The temperature in the lower pond maintained a fairly constant level until September 14. The seasonal range in temperature varied between 24.2°C to 14.2°C. The decrease in temperature was rapid from mid September to the last sampling date in October. Although the seaward station in the lower pond is shallower, no marked variation in temperature was apparent between the two stations (Fig. 6). The fast renewal of water, and near shore conditions may be factors in support of this constancy. The seasonal fall in temperature compared well with data from other New England estuaries such as Great Pond, Falmouth (Conover, 1958).
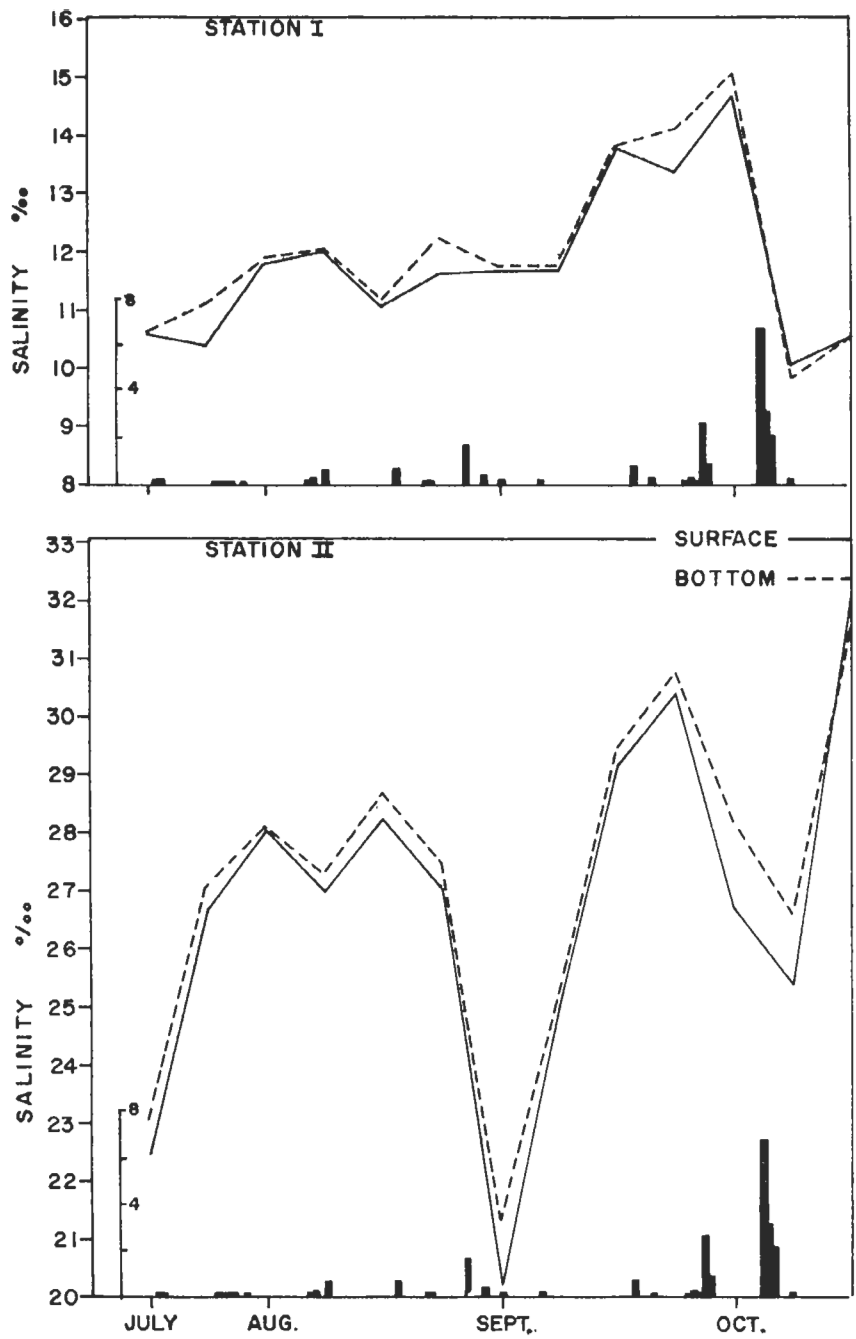
Fig. 4. Surface and bottom salinity (in o/oo) at stations I and II in the lower Pettaquamscutt River from July 11 to October 20, 1962. The vertical bars indicate rainfall in centimeters.
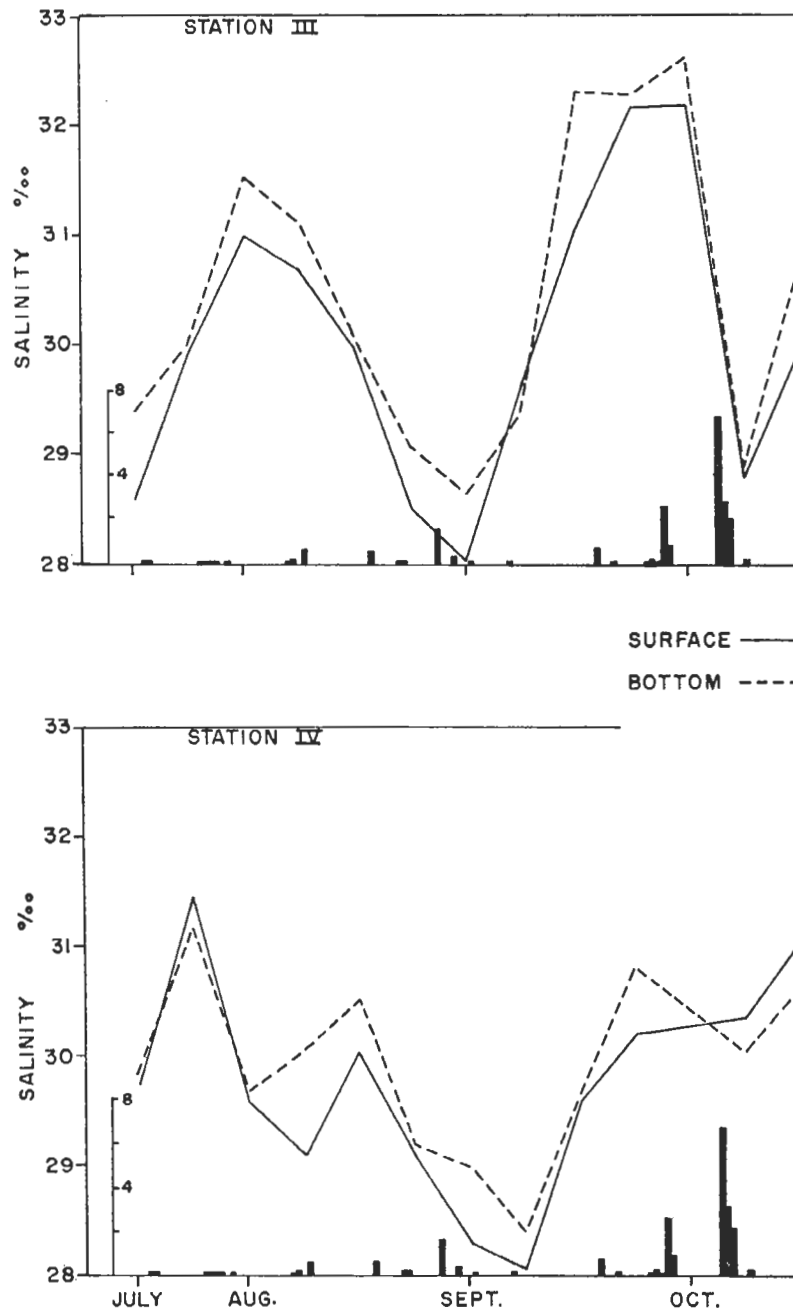
Fig. 5. Surface and bottom salinity (in o/oo) in the lower Point Judith Pond from July 11 to October 20, 1962. The vertical bars indicate rainfall in centimeters.

115

V. RESULTS

A. Occurrence and Abundance of Fishes

The juveniles and adults of forty-one species of fishes were collected from July 11 to October 20, 1962 in the lower Pettaquamscutt River and in the lower Point Judith Pond (Table I). Migrants of diadromous species contributed largely to the total number of species observed during the survey period. Thirty-six species occurred in the lower Pettaquamscutt River and twenty-four were recorded from the lower Point Judith Pond. Horton (1958) has reported juveniles and adults of 15 additional species of fishes from upper Pettaquamscutt River. His report includes the additional marine forms, *Hyporhamphus unifasciatus, Pollachius virens, Gadus callarias, Trinectes maculatus, Selene vomer, Seriola zonata, Alectis ciliaris, Trachinotus falcatus, T. carolinus* and *Roccus saxatilia,* and the fresh water taxa *Ameiurus nebulosus, Esox niger, Fundalus diaphnus,* and *Perca flavescens.* The species, *Lucania parva,* recorded from all four stations and *Trachinocephalus myops* collected at Bridgetown Bridge (Sta. I) have not been previously reported from Rhode Island estuaries or coastal ponds. The abundance and distribution of young fishes have been described under the appropriate headings below.

1. Total Abundance.

Total abundance represents the total number of juvenile and adult fishes captured at weekly intervals in each estuary (Fig. 7). The most significant observation in the lower Pettaquamscutt River was the appearance of the largest number of individuals in late July with pronounced pulses in August and a gradual decrease in numbers until the end of the seining operation in October (Fig. 7).

Variations in the total catches for each sampling period were influenced by the five dominant species *Menidia menidia, Fundulus heteroclitus, F. majalis, Apeltes quadracus* and *Cyprinodon variegatus.* Populations of *Brevoortia tyrannus* appeared at irregular intervals and when present, this species comprised the major taxon in the catches. Merriman (1947) and Shaw (1960) reported that *B. tyrannus* appears either in large numbers or not at all in a given habitat at any one time because of its precise schooling behavior.

In the lower Pond a single major pulse in total abundance of young fish occurred during late August followed by a fast decline in late October. Although the fluctuation in total abundance in both estuaries differed, one feature common to both areas was a rise in total abundance during the greater part of August, followed by a marked decline during the rest of the survey period.

2. Population Components.

During the warm season there was a complex influx into the estuaries of young fishes from two sources, the heads of the estuaries and the coastal and offshore waters. As a consequence it was necessary to group the fish populations into various components. The term "component" here is used to designate various types of migratory and resident groups. On the basis of information from reports of Bigelow and Schroeder (1953) and Pearcy and Richards (1962), Wheatland (1956) and Merriman and Sclar (1956)

116
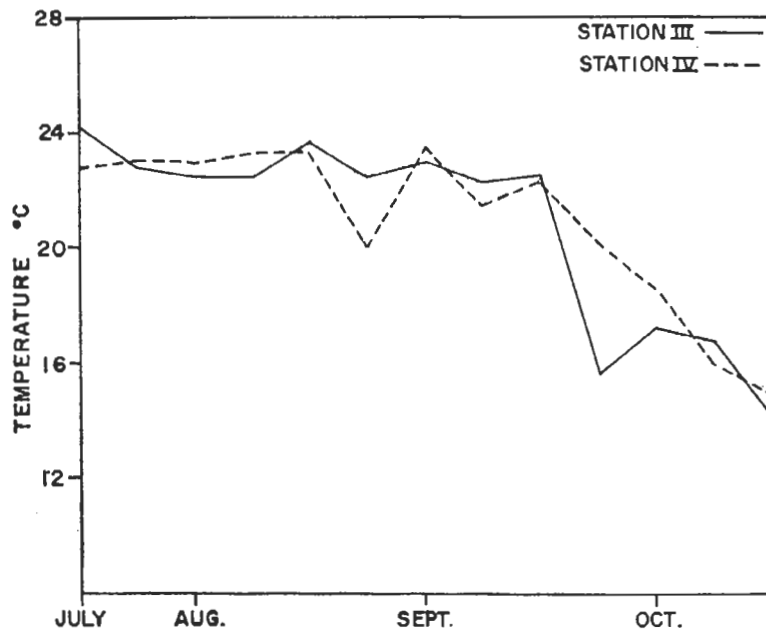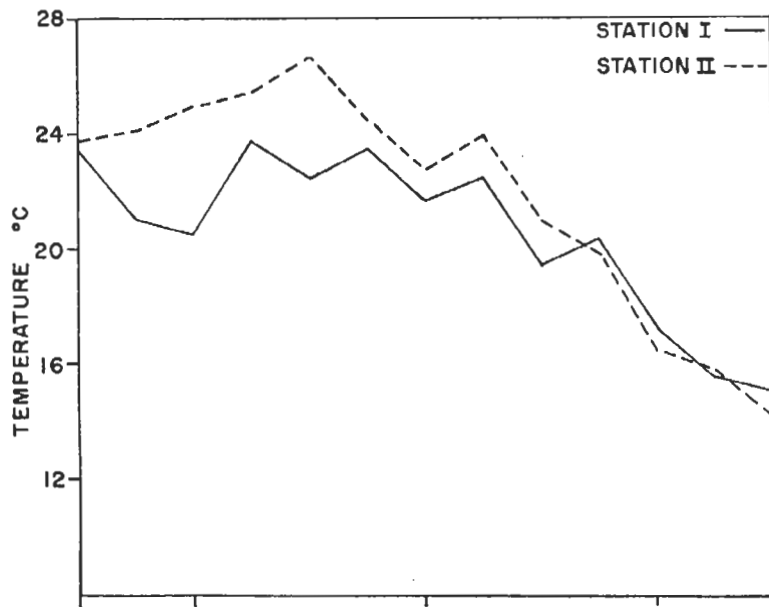
Fig. 6. Surface temperature at four seining stations in the lower Petta-
quamscutt River and the lower Point Judith Pond from July 11
to October 20, 1962.

Table I. A summary of occurrence and distribution of juvenile and adult fishes collected from four seining stations in lower Pettaquamscutt River and lower Point Judith Pond, Rhode Island, during July 11 to October 20, 1962.

Stations	Number of fishes collected	Number of recorded species	Salinity Range o/oo
I. Bridgetown Bridge	1705	27	9.8 - 15.1
II. Middle Bridge	6987	30	20.3 - 32.1
III. Harbor Island	5049	23	28.05- 32.6
IV. Galilee	5219	17	28.05- 31.5

MARINE AND BRACKISH WATER SPECIES
TOTAL ABUNDANCE OF EACH SPECIES

		STATIONS			
RESIDENT SPECIES		I	II	III	IV
1.	*Cyprinodon variegatus* (Lacépède) Sheepshead minnow	197	700	41	426
2.	*Fundulus heteroclitus* (Linnaeus) Common mummichog	235	676	996	1468
3.	*Fundulus majalis* (Walbaum) Striped mummichog	71	378	491	1315
4.	*Lucania parva* (Baird and Girard) Rain-water fish	1	2	1	2
5.	*Microgadus tomcod* (Walbaum) Tomcod	—	2	—	—
6.	*Apeltes quadracus* (Mitchill) Four-spined stickleback	23	2045	101	507
7.	*Gasterosteus aculeatus* (Linnaeus) Three-spined stickleback	6	129	519	49
8.	*Pungitius pungitius* (Linnaeus) Nine-spined stickleback	—	7	—	—
9.	*Syngnathus fuscus* (Storer) Pipefish	31	26	13	5
10.	*Roccus americanus* (Gmelin) White perch	75	—	—	—
11.	*Tautoga onitis* (Linnaeus) Tautog	—	24	59	6
12.	*Tautogolabrus adspersus* (Walbaum) Cunner	—	16	36	29
13.	*Gobiosoma bosci* (Lacépède) Naked Goby	1	—	—	—
14.	*Prionotus evolans* (Linnaeus) Striped sea robin	1	3	—	—
15.	*Myxocephalus aeneus* (Mitchill) Grubby sculpin	—	2	1	3
16.	*Menidia menidia* (Linnaeus) Silversides	718	2377	1586	1155
17.	*Pseudopleuronectes* americanus (Walbaum) Winter flounder	17	379	3	103
18.	*Opsanus tau* (Linnaeus) Toadfish	1	7	1	—

118

| | | STATIONS | | |
MIGRANT SPECIES	I	II	III	IV
1. *Brevoortia tyrannus* (Latrobe) Menhaden	162	66	922	131
2. *Clupea harengus* (Linnaeus) Sea herring	4	—	—	—
3. *Anchoa mitchilli* (Cuvier et Valenciennes) Anchovy	1	2	177	5
4. *Osmerus mordax* (Mitchill) Smelt	—	—	84	5
5. *Trachinocephalus myops* (Forster) Snake fish	1	—	—	—
6. *Strongylura marina* (Walbaum) Atlantic needlefish	—	2	—	—
7. *Urophycis chuss* (Walbaum) Squirrel hake?	—	1	—	—
8. *Lutjanus griseus* (Linnaeus) Grey Snapper	3	—	1	—
9. *Pristigenys alta* (Gill) Short big eye	1	3	—	—
10. *Pomatomus saltatrix* (Linnaeus) Bluefish	—	—	1	—
11. *Caranx crysos* (Mitchill) Hardtail	58	—	—	—
12. *Stenotomus versicolor* (Mitchill) Scup	—	—	6	—
13. *Chaetodon ocellatus* (Bloch) Butterfly fish	—	—	4	—
14. *Sphyraena borealis* (DeKay) Northern barracuda	—	—	1	—
15. *Mugil cephalus* (Linnaeus) Mullet	2	12	—	1
16. *Paralichthys dentatus* (Linnaeus) Summer flounder	1	1	—	—
17. *Alutera schoepfii* (Walbaum) Unicornfish	—	1	1	—
18. *Monocanthus hispidus* (Linnaeus) Filefish	2	36	4	9
19. *Sphaeroides maculatus* (Bloch and Schneider) Puffer	2	5	—	—

ANADROMOUS SPECIES:

| 1. *Alosa aestivalis* (Mitchill) Blueback | 11 | 16 | — | — |
| 2. *Alosa pseudoharengus* (Wilson) Alewife | 78 | 68 | — | — |

CATADROMOUS SPECIES:

| 1. *Anguilla rostrata* (LeSueur) American eel | 2 | 3 | — | — |

FRESH WATER SPECIES:

| 1. *Micropterus salmoides* (Lacépède) Largemouth bass | — | 1 | — | — |
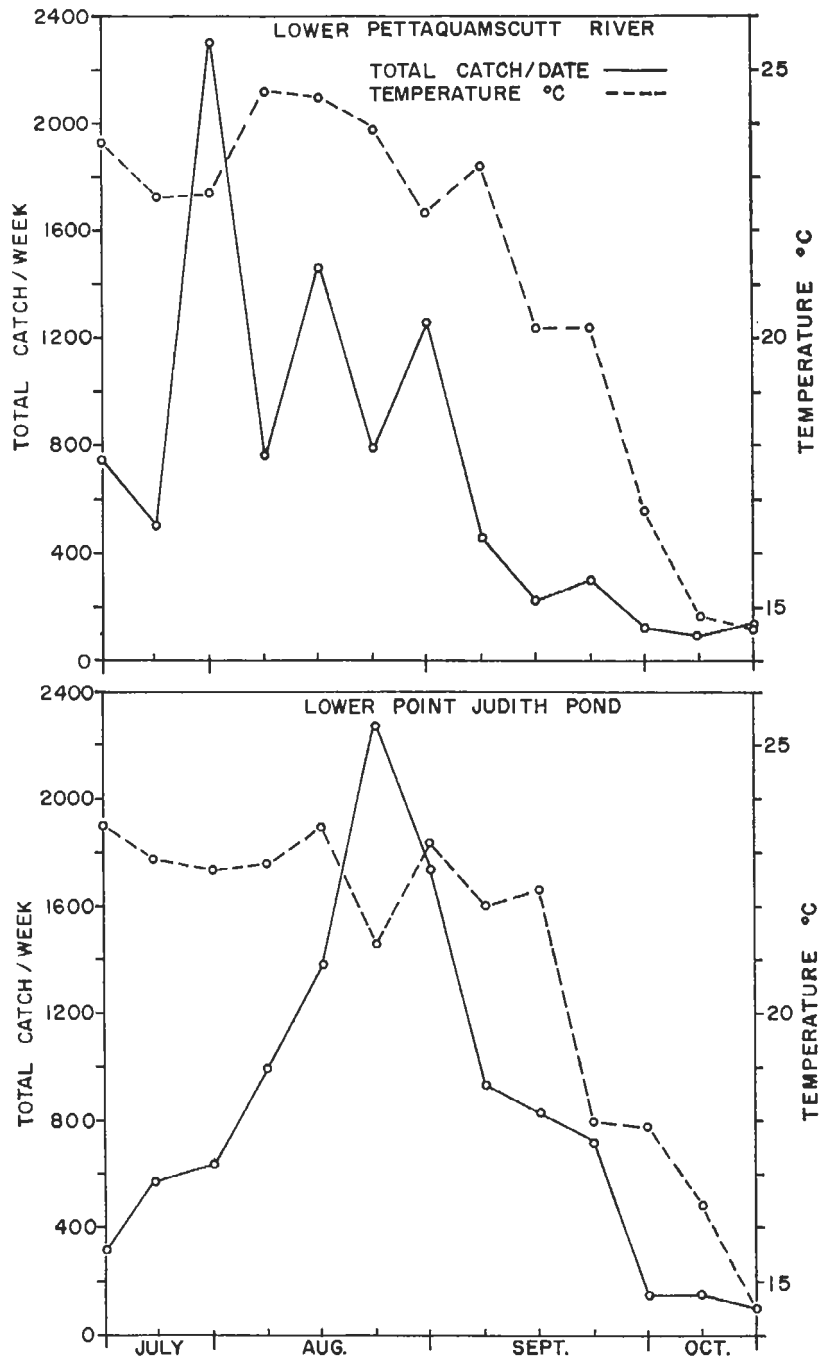
Fig. 7   Variations in total weekly catches and temperature from July 11
to October 20, 1962.

various species were grouped into the following components (Table I):
1) Resident species, species that spend a great part of their life in local estuarine environments; 2) seasonal migrants, including offshore and inshore coastal waters, immature forms as well as southern species from the lower latitudes; 3) immature fishes of anadromous species; 4) immature catadromous forms, and 5) fresh water fish.

Although there were more migrant species of fishes recorded during the survey than resident forms, the number of resident species occurring in both estuaries during the survey period was always significantly larger. In the lower Pettaquamscutt River there was a rapid increase in the number of resident species during the first month (Fig. 8). By contrast, migrant species maintained a steady population level after the first rise in the number of species. A peak in the abundance of both endemic and migrant species populations occurred in the early part of September. The highest number of resident species populations observed at any one time during the survey period was 13 (Fig. 8). However only seven migrant species were recorded during the highest pulse in September.

Only 10 migrant species were recorded from the lower pond in comparison with 17 collected from the lower river. A rapid increase in number of species in the catches was noted from July 18 to August 14. Two pulses occurred on September 14 and October 4, followed by a sharp decrease in October (Fig. 8).

3. Relative Abundance.

The analysis of relative abundance of all species of fishes, indicates the relative ranks for each major species contributing to the bulk of populations of fishes from all the seining stations (Table II). The relative abundance and rank data of three selected species indicate the ranks with respect to major species at weekly intervals (Figs. 9-11 and Table II). A common feature of these data from all collections was the presence of a few dominant species represented by a large number of individuals and a large number of subordinate species represented by few individuals.

The major species in order of abundance were *Menidia menidia, Fundulus heteroclitus, F. majalis, Apeltes, quadracus, Cyprinodon variegatus, Brevoortia tyrannus* and *Gasterosteus aculeatus,* (Table II). Other commonly occurring species were *Pseudopleuronectes americanus, Tautoga onitis, Tautogolabrus adspersus, Syngnathus fuscus,* and *Alosa pseudoharengus.* The species *Osmerus mordax* and *Anchoa mitchilli* comprised the major species on certain dates (date on file). The taxa, *Roccus americanus* and *Caranx crysos,* were common only at the landward station in the lower Pettaquamscutt River and appeared consistently.

Among the selected species, *M. menidia* was usually first in order of abundance and a major species in most of the catches in both estuaries at all stations. The fluctuations in relative abundance were more pronounced at both seaward stations (Figs. 2 and 9). Though the number of individuals in the catches was fewer at Station I (Figs. 1 and 9), these fish maintained comparatively steady population level in both estuaries at both landward stations. An apparent existing fluctuation in catches may be due to the schooling behavior of this species as reported by Shaw (1960).

121

SUMMARY

1. An extensive sampling project in Mississippi Sound and adjacent waters was carried out during the two years between November 1962 and the end of October 1964.

2. Postlarval pink shrimp were reported from this area for the first time.

3. The salinity regime in the years was very different.

4. From a total of 31 stations established, four were selected as being suitable for use in long term studies of postlarval abundance.

5. Indices of abundance developed from the catch of postlarvae at the selected stations predicted the 1964 catch of both white and brown shrimp within ten per cent.

6. Determination of the relative abundance of postlarval penaeid shrimp by season and area in Mississippi Sound and adjacent waters seems to be feasible, but reliability of the indices has not been fully established. Refinement of the indices and several more years experience will be required to refine the predictions.

REFERENCES

Baxter, Kenneth N.
    1962. Abundance of postlarval shrimp — One index of future shrimping success. Proceedings of the Gulf and Carribean Fisheries Institute, Fifteenth Annual Session, November, 1962, pp 79-87.

Collier, Albert and Joel W. Hedgpeth
    1950. An introduction to the hydrography of tidal water of Texas. Publications of the Institute of Marine Science, University of Texas, vol. 1, no. 2, pp. 125-179.

Lindner, Milton J. and William W. Anderson
    1956. Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus*. United States Fish and Wildlife Service, Fishery Bulletin 106, vol. 56, pp. 553-645.

Phleger, F. B.
    1954. Ecology of Foraminifera and Associated Micro-organisms from Mississippi Sound and Environs, Amer. Assoc. Pet. Geol. Bull., Vol. 38, no. 4, pp. 584-647.

Priddy, R. Crisler, M., Sebren, P., Powell, D., and Burford, H.
    1955. Sediments of Mississippi Sound and Inshore Water. Mississippi State Geological Survey, University of Mississippi, Bulletin 82, 53 pp.

Renfro, William C.
    1962. Small beam net for sampling postlarval shrimp. *In:* Galveston Biological Laboratory — Fishery research for the year ending June 30, 1962. United States Fish and Wildlife Service, Circular 161, pp. 86-87.

Table II. Relative abundance of the major species in order of their ranks with respect to all species collected from July 11 to October 20, 1962 from the lower Pettaquamscutt River and the lower Point Judith Pond, R. I.

| | Species | Lower Pettaquamscutt River | | | | Lower Point Judith Pond | | | |
		Station I Relative Rank %		Station II Relative Rank %		Station III Relative Rank %		Station IV Relative Rank %	
1.	Menidia menidia	42.1	1	30.4	1	31.5	1	22	3
2.	Fundulus heteroclitus	13.8	2	9.7	4	18.9	2	28.2	1
3.	Fundulus majalis	4.16	7	5.4	6	9.7	5	25.2	2
4.	Apeltes quadracus	1.35	10	28.8	2	2	7	9.4	4
5.	Cyprinodon variegatus	11.55	3	10	3	.81	10	8.1	5
6.	Brevoortia tyrannus	9.45	4	.94	9	18	3	2.5	6
7.	Gasterosteus aculeatus	.35	13	1.85	7	10.4	4	.95	8
8.	Pseudopleuronectes americanus	.99	11	5.44	5	.05	15	1.95	7
9.	Alosa pseudoharengus	4.6	5	.97	8	—	—	—	—
10.	Sygnathus fuscus	1.72	9	.37	11	.2	12	.09	12
11.	Tautoga onitis	—	—	.34	12	1.17	9	.12	11
12.	Tautogolabrus adspersus	—	—	.23	13	.7	11	.55	9
13.	Roccus americanus	4.4	6	—	—	—	—	—	—
14.	Caranx crysos	3.4	8	—	—	—	—	—	—
15.	Monocanthus hispidus	.12	16	.51	10	.07	14	.17	10

123
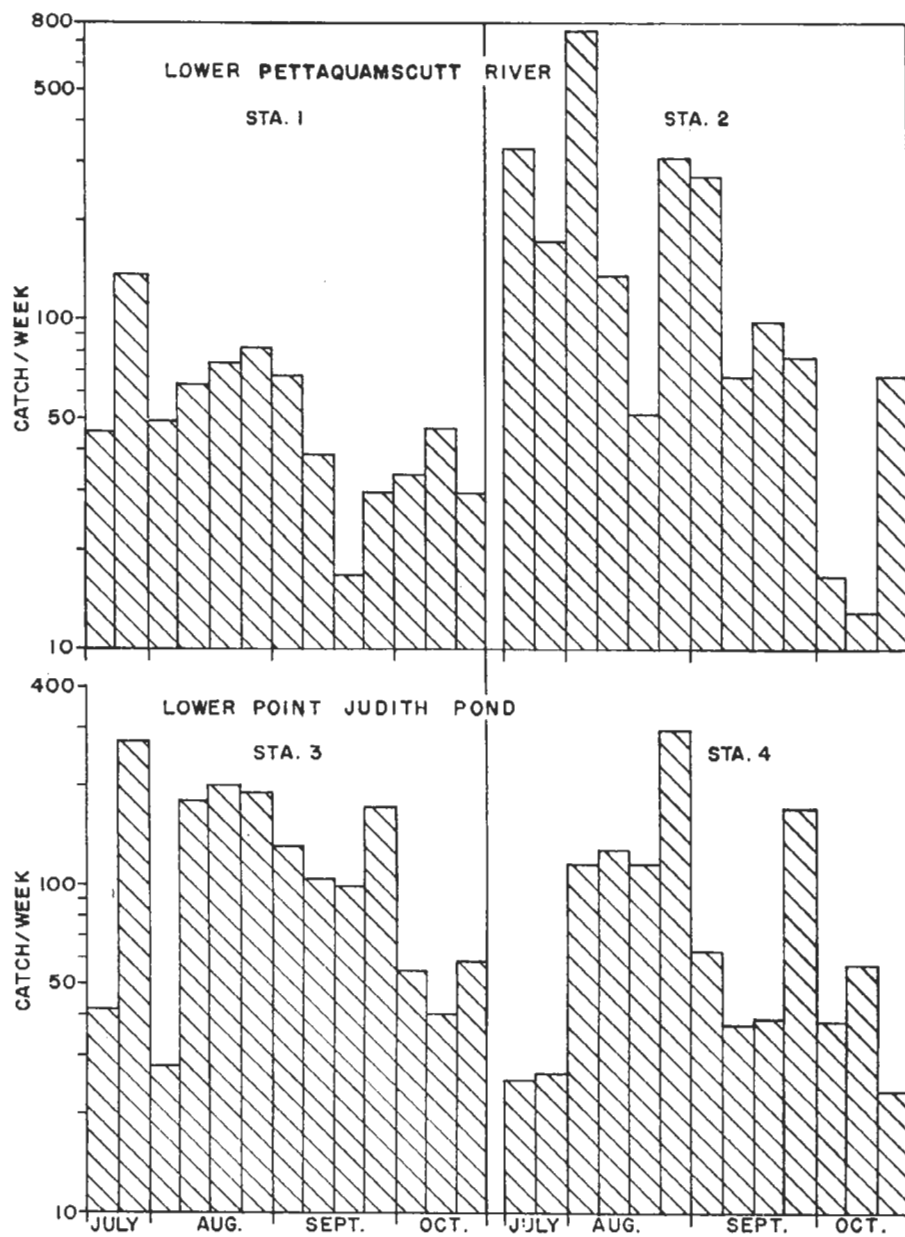
Fig. 9. Variations in weekly catches of *Menidia menidia* (Juvenile and adult) from July 11 to October 20, 1962.
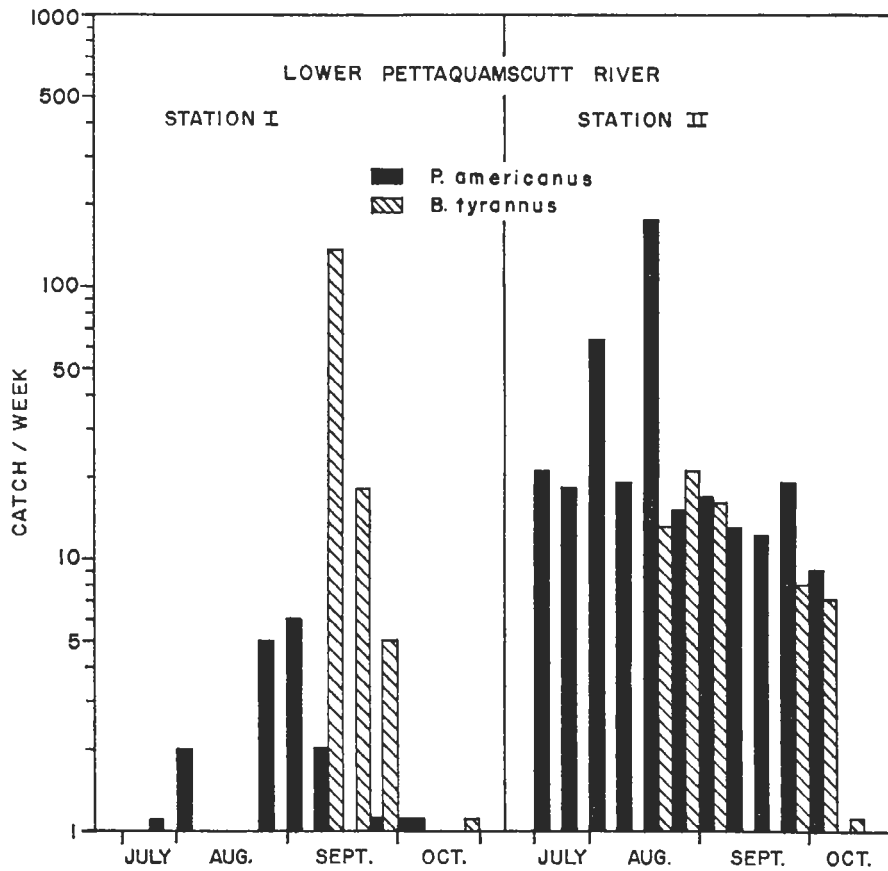
Fig. 10. Variations in weekly catches of juvenile *Pseudopleuronectes americanus* and *Brevoortia tyrannus* from July 11 to October 20, 1962 in lower Pettaquamscutt River.

125
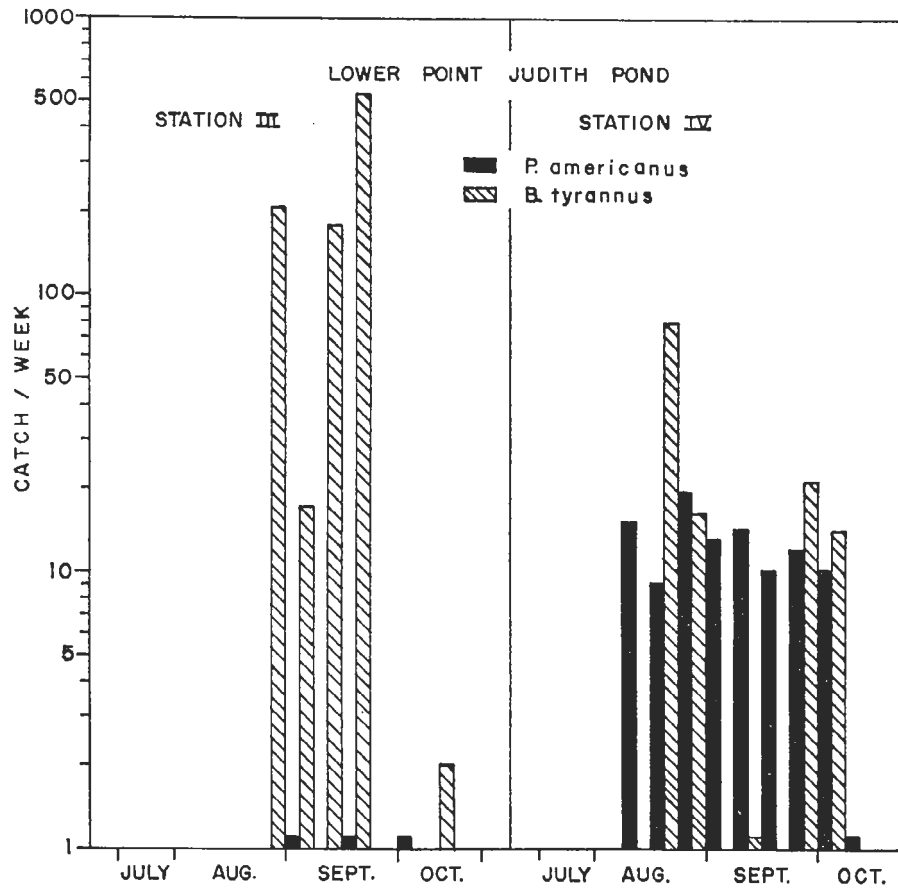
Fig. 11. Variations in weekly catches of juvenile *Pseudopleuronectes americanus* and *Brevoortia tyrannus* from July 11 to October 20, 1962, in lower Point Judith Pond.

126

The taxon, *Brevoortia tyrannus* ranked sixth in order of abundance (Table II), but the appearance of this species was extremely variable from week to week. Its greatest abundance was at the more landward station at Harbor Island in the lower Pond for most of September (Figs. 2, 10 and 11), and at the seaward station during the later half of August and early October. These fish were collected in significant numbers during mid-September at the landward station in the lower Pettaquamscutt River (Fig. 1) and at the seaward station in mid-August and early September.

Pseudopleuronectes americanus ranked eighth in abundance among the total species recorded. This taxon was relatively common at the seaward stations in both estuaries (Figs. 1, 2, 10 and 11). These fish were not numerous at the upper stations of either estuary. Only three second-year class individuals appeared at Harbor Island. The low efficiency of the "shore seine" on a rocky irregular bottom may have affected the catch record from this station.

4. Horizontal Distribution.

Disparity in distributional patterns of young fish was demonstrated by various migrant and resident species along the north-south axis of the study areas in the two estuaries. Juvenile *Brevoortia tyrannus* tended to move seaward as they grew as the season progressed. This taxon was particularly abundant at Harbor Island (Sta. III, Fig. 2) from August 28 to September 14. The size of the young fish in the first catch from this station varied between 29 and 44 mm. The mean length of the individuals in the last sample taken on September 14 was 52 mm. By early October these fish had grown to a mean size of 58 mm, but by this time they occupied the seaward station in the lower pond. McHugh *et al.* (1959) reported that populations of *B. tyrannus* move towards the sea as they grow and that consequently the mean size is greater at the seaward end of estuaries. A similar pattern of ditsribution was apparent in the lower Pettaquamscutt River. A greater number of individuals appeared at the landward station in August (Figs. 1 and 10). But the larger sized fish collected at two consecutive occasions during October were mainly from the seaward station (Figs. 1, 10 and 14).

Two anadromous species, *Alosa pseudoharengus* and *A. aestivalis*, occurred only in the river estuary (Table I). These fishes appear to populate the river from July to late September as immature emigrants. It would be expected that these species behave as other anadromous species wherein the breeding populations enter brackish or fresh water environments from the sea during spawning season, the young emigrants moving out from the estuaries as they grow. The lower Point Judith Pond, which covers more than three-fourths of the entire area, is subjected to near-seawater salinity (Figs. 4 and 5). This N/neritic condition (Fig. 3) should be adverse for spawning activities by anadromous species. Since no young fish of the two species appeared in catches throughout the survey period these observations indicate that the pond is probably not serving as a spawning area for these fishes.

The taxon, *Pseudopleuronectes americanus,* usually spawns in winter at the heads of estuaries (Bigelow and Schroeder, 1953; Perlmutter, 1939). Pearcy (1952) found that young fish move down stream as they grow. Only three individuals of the first year class appeared at Bridgetown Bridge (Sta. I, Fig. 1). A great number of the same year class fish were captured from Middle Bridge (Sta. II, Fig. 1). Fourteen second year class fish
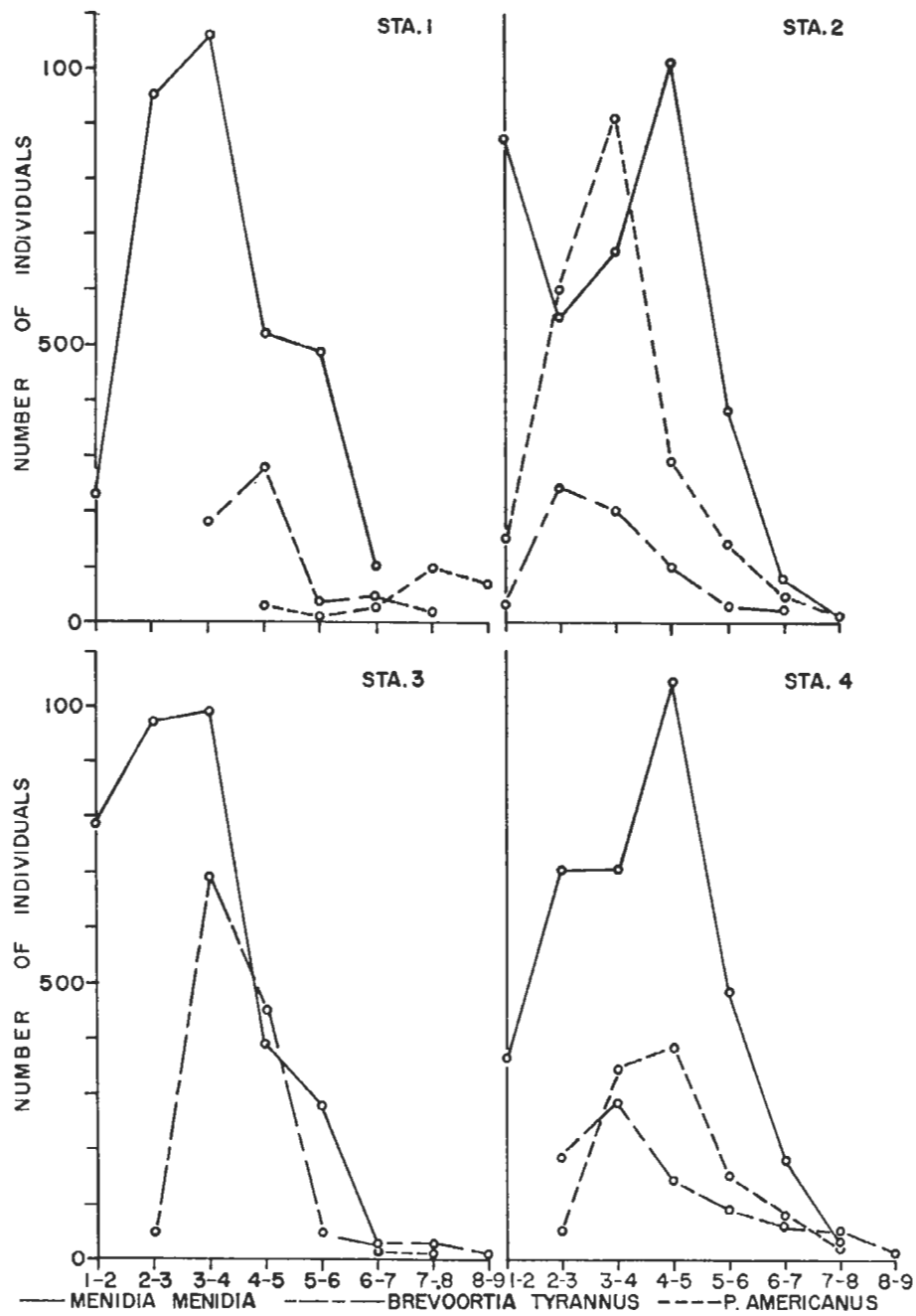
Fig. 12. Variations in class size (cms.) distribution of selected species at four seining stations.

were caught only at the landward station throughout the survey period (Figs. 1 and 12). These observations reveal that probably juvenile fish of the first year class occupy seaward stations by late summer. Second-year or older classes of fish either populate the more inland portions of estuaries (Figs. 1, 2 and 12), or wander randomly, since larger fish rarely were seen at the seaward stations in either estuary.

In lower Point Judith Pond only three specimens of *P. americanus* of the second-year class were caught at Harbor Island during the entire study period. The larger samples of this species were collected at the seaward station (Sta. IV, Fig. 2).

The species *Menidia menidia* which appeared consistently at all four stations in both the estuaries in considerable abundance, had a greater abundance of size group 40-50 mm at the more seaward stations in the two estuaries. The size group 30-40 mm was more common at the landward stations (Figs. 1, 2 and 12). Only two fish, possibly belonging to third-year class (120 mm) were collected from the landward station in the lower Point Judith Pond.

The taxa *Caranx crysos, Clupea harengus, Roccus americanus* and *Gobiosoma bosci* ocurred only at Station I (Table II, Fig. 1). A few species represented by *Strongylura marina, Microgadus tomcod, Urophycis chuss* and *Micropterus salmoides* were taken only from Middle Bridge area (Sta-II, Fig. 1), and in very small numbers. The catches of *Sphyraena borealis, Pomatomus saltatrix* and *Chastodon ocellatus* were exclusively recorded from Harbor Island. The species *Tautoga onitis* and *Tautogolabrus adspersus* never appeared at Bridgetown Bridge Station. These fishes were common and frequently were found at Middle Bridge Station and Harbor Island, exhibiting mimicking behavior in massive beds of *Zostera marina* and various types of algae (Table II, Figs. 1 and 2).

B. GROWTH

Growth is a measure of production and an important means of studying ecological variations in various types of environments. The growth study of selected species of fishes of zero-year class includes the rate of growth-in-length in the two estuarine systems under study. The average length of each sample used in graphic analysis was also employed to determine growth rates. The growth of each species has been dealt with separately.

1. *Pseudopleuronectes americanus.*

While controversy exists on the exact spawning period of this species, Pearcy (1952), Perlmutter (1939) and Bigelow and Schroeder (1953) concluded that *P. americanus* is essentially a winter spawner.

The juvenile winter flounder, consisting of 11 samples and totaling 382 individuals taken from the lower Pettaquamscutt River, provided average lengths used in comparing series of samples in computing rates of growth. The first sample collected on July 11 included juvenile fish with a mean length of 26 mm, and a size range between 15 and 44 mm. These fish were probably four to six months old at that time (Bigelow and Schroeder, 1953). The first two samples, taken at an interval of one week in July (Fig. 13) showed 50% overlap of black bars. Such a degree of overlap indicates little significance in the differences between samples and a low reliance on growth increments. This situation appears when

129
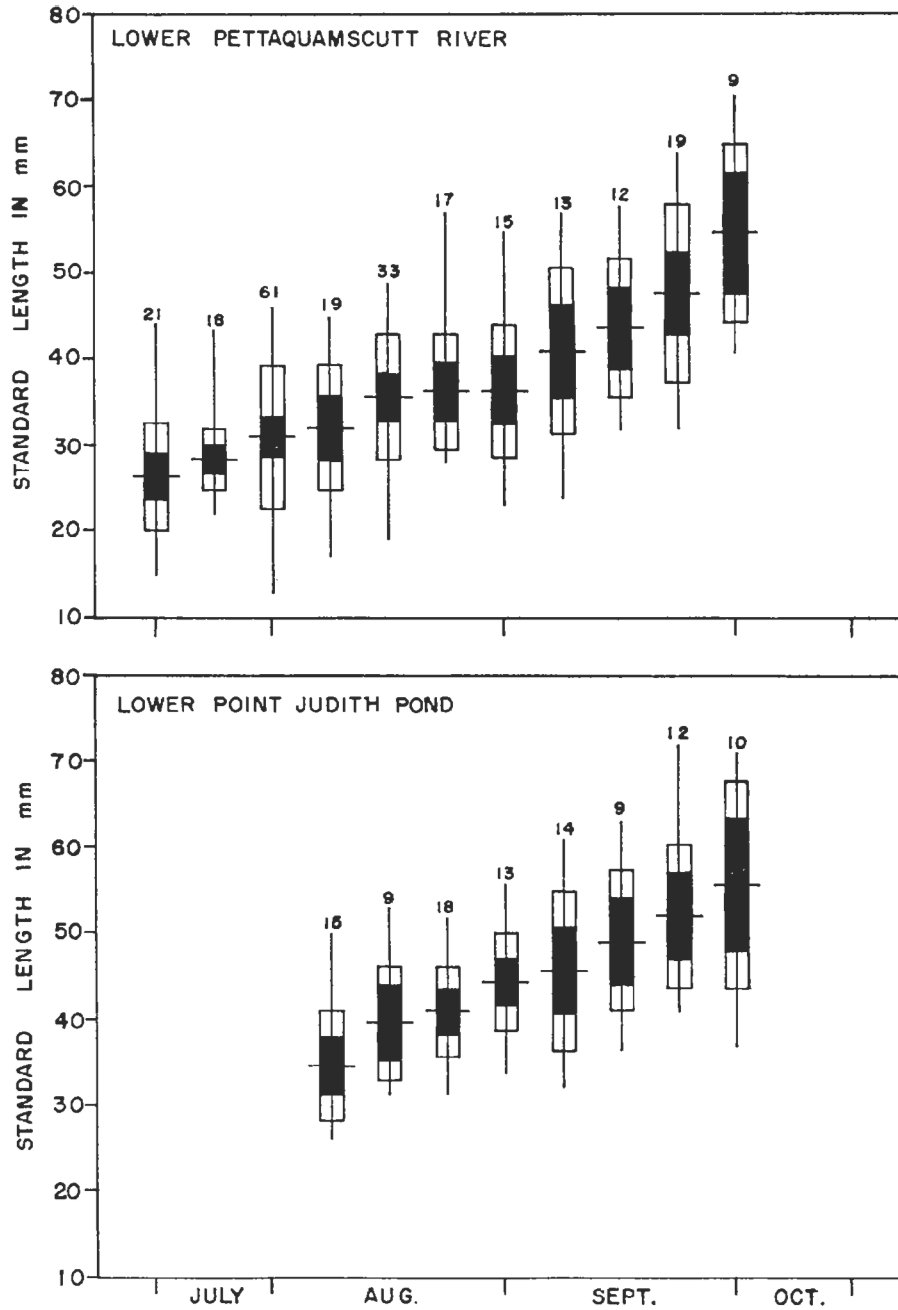
Fig. 13. Average growth of juvenile *Pseudopleauronectes americanus* collected July 11 to October 20, 1962.

The vertical lines in the histograms (Figs. 13-16) indicate size range of standard lengths in each sample. The horizontal lines are means. The black bar on either side of the mean represents two standard errors of mean (2 6 M), and the black bar and white bar combined on either side of the mean is the standard deviation (6). The standard errors express a measure of reliability, while standard deviation is a measure of dispersion. For a detailed description see Hubbs and Perlmutter (1942) and Hubbs and Hubbs (1953).

The sample sizes, given at the top of the vertical lines representing 30 or more individuals, are sub-samples from larger collections. The rest of the samples are actual sample sizes.

---

samples are compared at week intervals. But given an interval of two weeks or a month, the samples in almost all cases show less than one-third overlap. Significant differences do appear between samples and a reliance on growth increments can then be demonstrated. The samples collected during the latter half of August showed significant differences between samples.

The size of the fish when first caught in early August in the Pond estuary (Sta. IV, Fig. 2) ranged between 26 mm to 50 mm, with a mean length of 35 mm. The increase in the average length of the juvenile fish from early August to early October (Fig. 13) was between 35 and 56 mm with a growth rate of 10.5 mm per month. Though these results compare favorably with other studies (Pearcy, 1962) pertaining to this species, the single method of sampling and the small sample sizes do not lend thorough examination of differences in variations in growth between the study areas in the two estuaries. Seining operations coupled with intensive otter-trawling would probably manifest a more exact picture of growth and variations in the two environments.

2. *Brevoortia tyrannus.*

Since *B. tyrannus* has a split spawning season, it is important to know the approximate age at which the fish first appeared in catches. Kuntz and Radcliffe (1917) reported that *B. tyrannus* spawns in summer in Woods Hole and in late fall in Chesapeake Bay. Wheatland (1956) observed two peaks in egg production in this species in Long Island Sound, one in June and the other in September. Herman (1958) found that this fish spawns in Narragansett Bay from May to August and again in October. Age estimates for this species, according to scale studies by Hile (1948) and others, show all fish captured were fish-of-the-year and were approximately three to four months old when they first appeared in catches (Fig. 14). In the present study the sporadic appearance of *B. tyrannus,* a schooling species, dictated the necessity of pooling the data from both lower and upper stations in each estuary. The limitations of this decision are fully recognized by the writer.

The study of the growth rate of *B. tyrannus* in the lower Point Judith Pond was based on data from 1053 individuals from seven samples. The first sample collected on August 14 consisted of 79 fish, with a size range between 27 and 36 mm and a mean length of 33 mm. The two samples taken on August 14 and August 21, displayed significant difference, hence mean values of these samples are reliable (Fig. 14). The late

August and early September data had a marked overlap (Fig. 14). The resulting low reliance on mean length measurements is probably due to the small sample sizes. The samples collected from September 14 to October 4 showed much wider variations in the sizes of the individual fish and displayed marked overlap of black bars, with respect to weekly intervals. But in two of these samples the standard deviation is more than twice the two standard errors on either side of the means, signifying that valid differences exist between the two samples (Hubbs and Perlmutter, 1942).

The graphical analysis demonstrated two distinct groups among all the samples. As this species schools precisely according to size (McHugh, 1959), it seemed that fish appearing after September 4 represented various populations. The mean standard length of the first group collected from August 14 to September 4 increased from 31 to 38 mm, with a growth increment of 7 mm per month (Fig. 18). The first sample of the second group taken on September 14 was caught only at the landward station while the rest of the samples were taken from seaward stations (Figs. 1, 2 and 11). The increase in average length observed was from 52 to 58 mm or an increase of 6 mm in three weeks (Fig.18). McHugh *et al.* (1959) contended that schools of *B. tyrannus* of precise size groups form a distinct size gradient from one end of the estuary to the other. McHugh insisted that a single rate of growth for a given age group of such a widely ranging species occupying an estuary is not tenable. The presence of two distinct groups and catches of larger fish mainly at seaward stations during late September and October (Figs. 10-12) point to analogy with McHugh's findings. However the growth data for this species compares favorably with studies of Warfel and Merriman (1944) and McHugh *et al.* (1959)

The average lengths of seven samples consisting of 228 individuals collected from the lower Pettaquamscutt River, were used for growth study. Two distinct groups of zero-year class fish were present in this estuarine system as well (Fig. 14). The significant differences existed between samples collected from mid-August to early September. The black bars of the samples taken during the rest of September demonstrated marked overlapping thus negating the possibility of significance in differences (Fig. 14).

The mean length for all samples collected from mid-August to early September showed an increase from 25 to 43 mm (Fig. 17). This increase of 18 mm per month for the population in the lower Pettaquamscutt River estuary was more than twice the growth rate estimated for young fish collected during the same period from the lower Point Judith Pond (Figs. 17 and 18). However the growth was insignificant in the rest of the three samples which were composed of individuals of diverse size ranges. The sporadic appearance of this schooling species was another factor which created irregularity in catches and hence made it difficult to trace the exact picture of growth (McHugh *et al.*, ibid).

3. *Menidia menidia.*

There is no definite growth study of juvenile or adult *Menidia menidia.* The wide range of sizes present in all samples during the present survey created a problem in the attempt to distinguish the zero-plus group. Merriman (1947) and Bigelow and Schroeder (1953) found that sizes ranging from fry of 2.5 cm (1 inch) long to adult sizes are present during the summer months. Williams (1960) and Shaw (1960) consider the

132
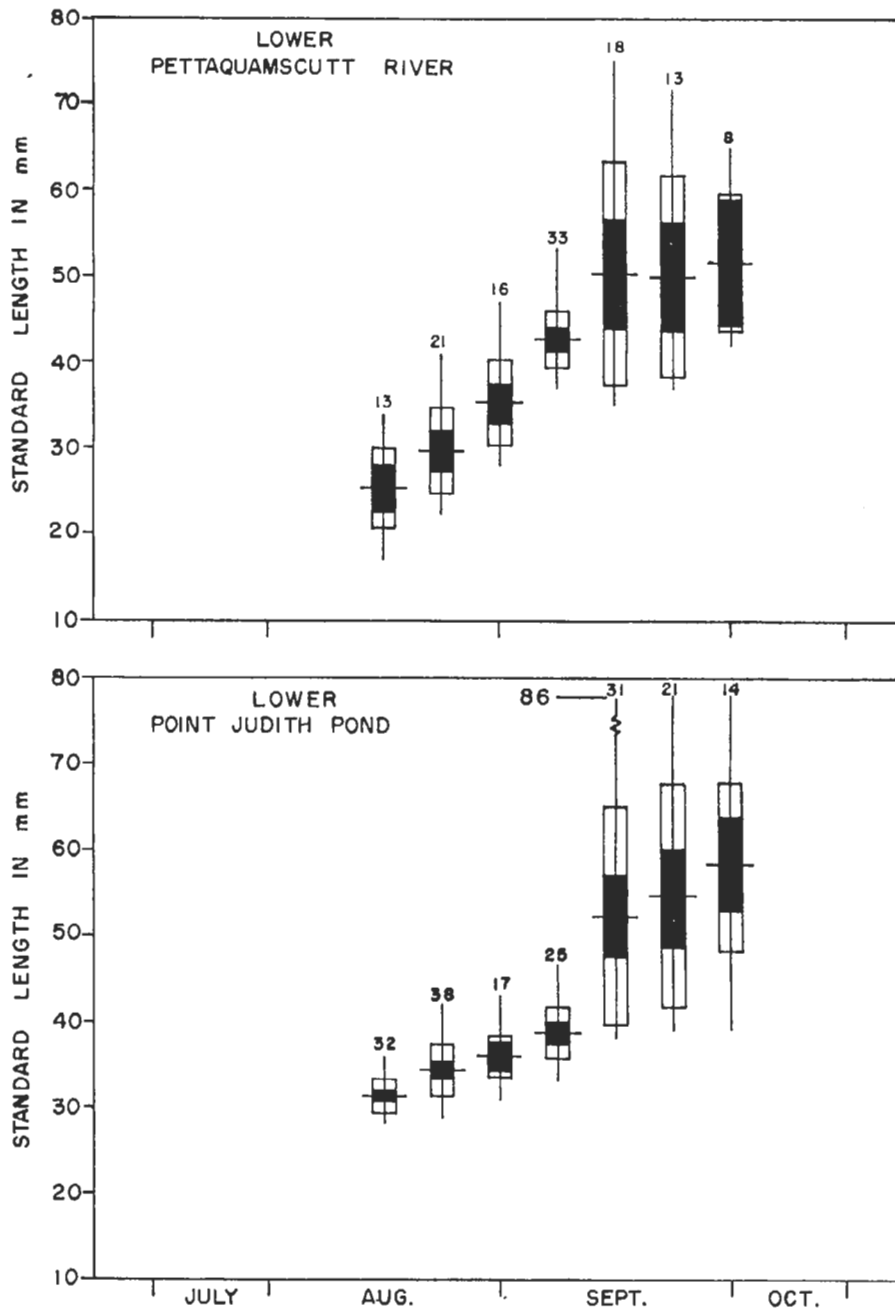
Fig. 14. Average growth of juvenile *Brevoortia tyrannus* collected from July 11 to October 20, 1962. Method of presentation is the same as given in Fig. 13.

133

minimum size of an adult fish to be 50 mm. Spawning is reported to occur from May through July (Herman, 1958) in New England waters. From July to early September juvenile fish could be separated from other age groups, because of a marked distinction in sizes. For the remaining period fast growing juvenile and slow growing adult fish occurred in a complex admixture of sizes from which the zero-plus group could not be sorted out with certainty. It is possible that the small sized fish may rapidly disappear from the estuaries, perhaps retreating to deep water in the cooler part of the season (Hildebrand and Schroeder, 1928).

Thirteen samples from Bridgetown Bridge (Sta. I, Fig. 1) consisting of over 500 fish provided data for comparison. The samples collected from July 11 to September 3 demonstrated significant differences when collected at semi-monthly or monthly intervals. The marked overlapping in samples taken from late August to early September seemed due to influx of larger numbers of small size individuals which also tended to diminish the mean growth in these samples (Fig. 15). The samples collected from September 9 to October 20 contained both juvenile and adult fish. Although significant differences were observed in these collections, the relative composition of the samples including juvenile and adult fish of uncertain age groups invalidated the mean values given.

The average length of juvenile fish rapidly increased from July 11 to September 3 attaining a size range from 19 to 35 mm. The growth increments were insignificant for three weeks from August 16 to September 3, due to an inclusion of a larger number of smaller sized individuals (data on file). The growth rate of the juvenile fish was 8 mm per month (Fig. 17). There is uncertainty in establishing a growth rate for fish taken from September 9 to October 20, because of the admixture of juvenile and adult fish of various sizes.

From 13 samples consisting of over 1500 fish from Middle Bridge (Sta. II), juvenile fish could confidently be separated out from the first eight samples. These samples taken from July 11 to August 2 demonstrated significant differences. The increase in average growth of young fish in these samples (13 to 27 mm) suggests that the growth rate is more rapid during the early juvenile phase (Figs. 15 and 17). Samples taken during early August show an overlap in black bars, probably due to the small sample sizes. The insignificant differences in collections from August 16 to September 3 is apparently due to the appearance of schools of similar sized individuals in the catches. The overall increase observed in growth from July 11 to September 3 was from 12 mm to 40 mm, or 14 mm per month (Fig. 17). Although significant differences between the samples are apparent, the problem of uncertain age group composition negated the possibility of estimating exact rates of growth for this species after September 3.

Although there were variations in average growth, the samples from the lower pond demonstrated a similar pattern of growth when compared to the catches from the lower river. The collections made from the Harbor Island (Sta. III) indicated significant differences at semi-monthly intervals (Fig. 16). The samples taken from September 4 to September 22 and October 4 to October 20, included a higher number of smaller size young fish in September samples and a higher number of larger size fish in October collections. The significance of differences between these samples
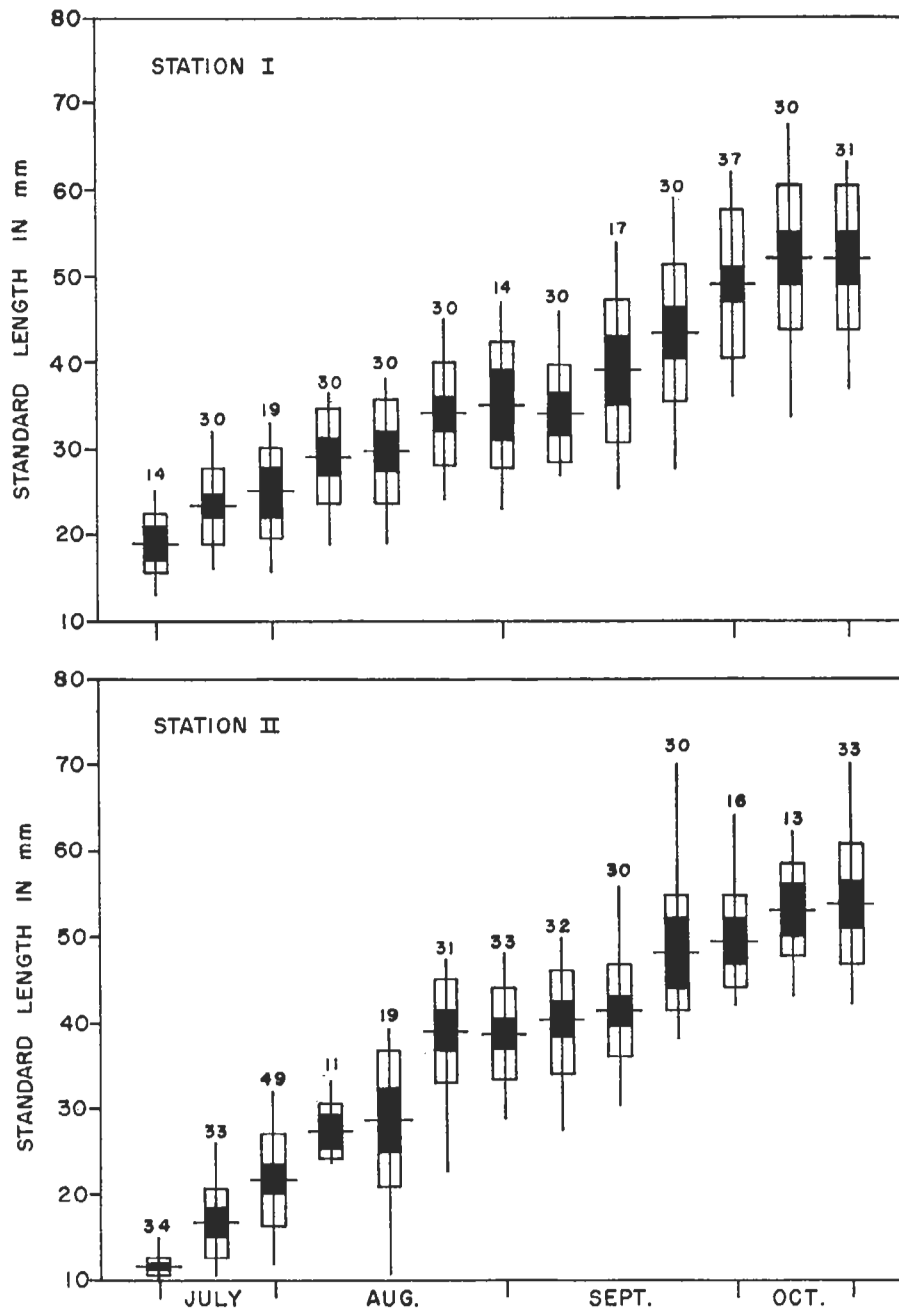
Fig. 15. Average growth of *Menidia menidia* (Juvenile and adult) collected from the lower Pettaquamscutt River from July 11 to October 20, 1962. Method of presentation is the same as given in Fig. 13.

may be misleading because of the admixture of juvenile and adult fish in the catches.

The growth rate for juvenile fish collected from July 11 to August 28 was 7 mm per month. This rate is similar to that for juvenile fish caught at the landward station (Sta. I) in the lower Pettaquamscutt River (Fig. 18). The larger size range of these young fish (Fig. 16) indicated spawning had occurred earlier at the landward station (Sta. III) in the lower Pond. The same phenomenon was noted in the lower River (Sta. I).

The juvenile fish taken from Station IV, lower Point Judith Pond, between July 11 to August 28 demonstrated significant differences between the weekly samples (Fig. 16). Hence the average growth increments are reliable. The sample taken in early August indicates an influx of comparatively small size individuals in the schools (Fig. 16). The samples collected from September 4 to October 20 differed significantly with the exception of the late September samples. These differences between average sizes probably are due to a gradual retreat of the small size fish into deeper water.

The increase in average growth noted between July 11 and August 28 in juvenile fish was 19 mm, a growth rate of 11 mm per month (Fig. 18). These figures compare favorably with data from Station II, in the lower Pettaquamscutt River. The results support the assumption that the growth rate was higher for this species at the seaward stations in both the estuaries.

C. FOOD AND FEEDING HABITS

The analysis of food based upon the stomach contents of the selected species evinced variation in abundance and varieties of prey organisms in the study areas in the two estuaries. The results provided evidence for the assumed possible differences in food resources between a "gradient zone" habitat, Lower Pettaquamscutt River, and "marine zone" habitat, Lower Point Judith Pond (Fig. 3, Tables III and V). Polychaetes were the most important dietary constituent of *Pseudopleuronectes americanus,* while crustaceans comprised the chief food of *Menidia menidia.* In the lower pond, however, 46% of group II (31-50 mm) and 100% of group III (51-80 mm) of *M. menidia* fed on phytoplankton. Heavy sporozoan infection in *P. americanus* was associated with depletion of food in the stomachs. Phytoplankton and suspended organic matter was the principle food of *Brevoortia tyrannus* and no correlation was observed between the size of fish and change in food. The juvenile fish of the species selected for food studies were separated into three size groups ranging between 10-30 mm (Group I), 31-60 mm (Group II), and 61-80 mm (Group III) to study change in food with respect to size of fishes. The minimum size of mature *M. menidia* is considered to be 50 mm (Williams, 1960): this figure was used as limit for Group II (Table V).

1. *Pseudopleuronectes americanus.*

Polychaetes were the basic food organisms, while isopods, amphipods and ostracods were the essential dietary elements of the juvenile fish. Sand, mud and fecal pellets accompanied the food. A preference for larger food organisms was noted with increasing size of the young (Fig. 19).

136
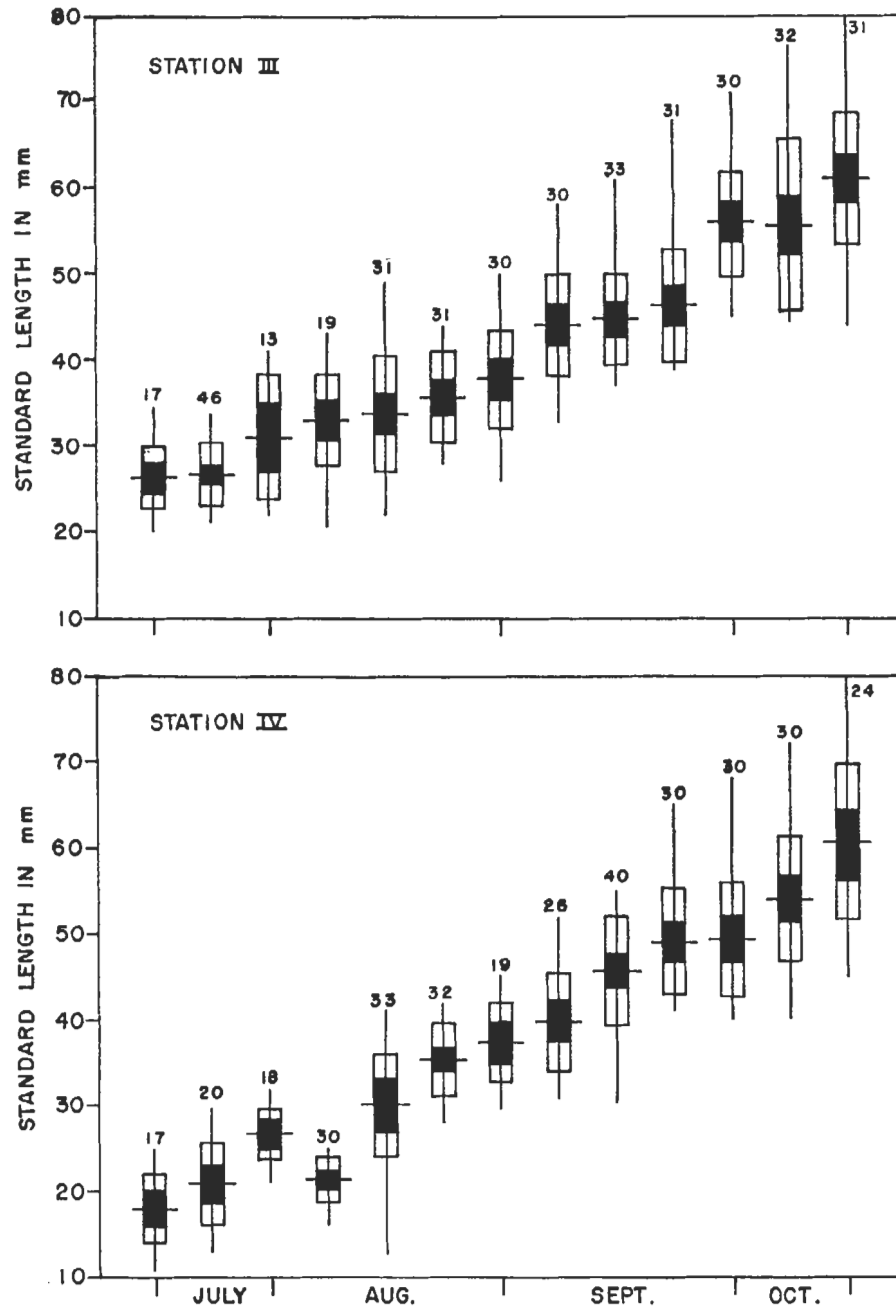
Fig. 16. Average growth of *Menidia menidia* (juvenile and adult) collected from the lower Point Judith Pond from July 11 to October 20, 1962. Method of presentation is the same as given in Fig. 13.
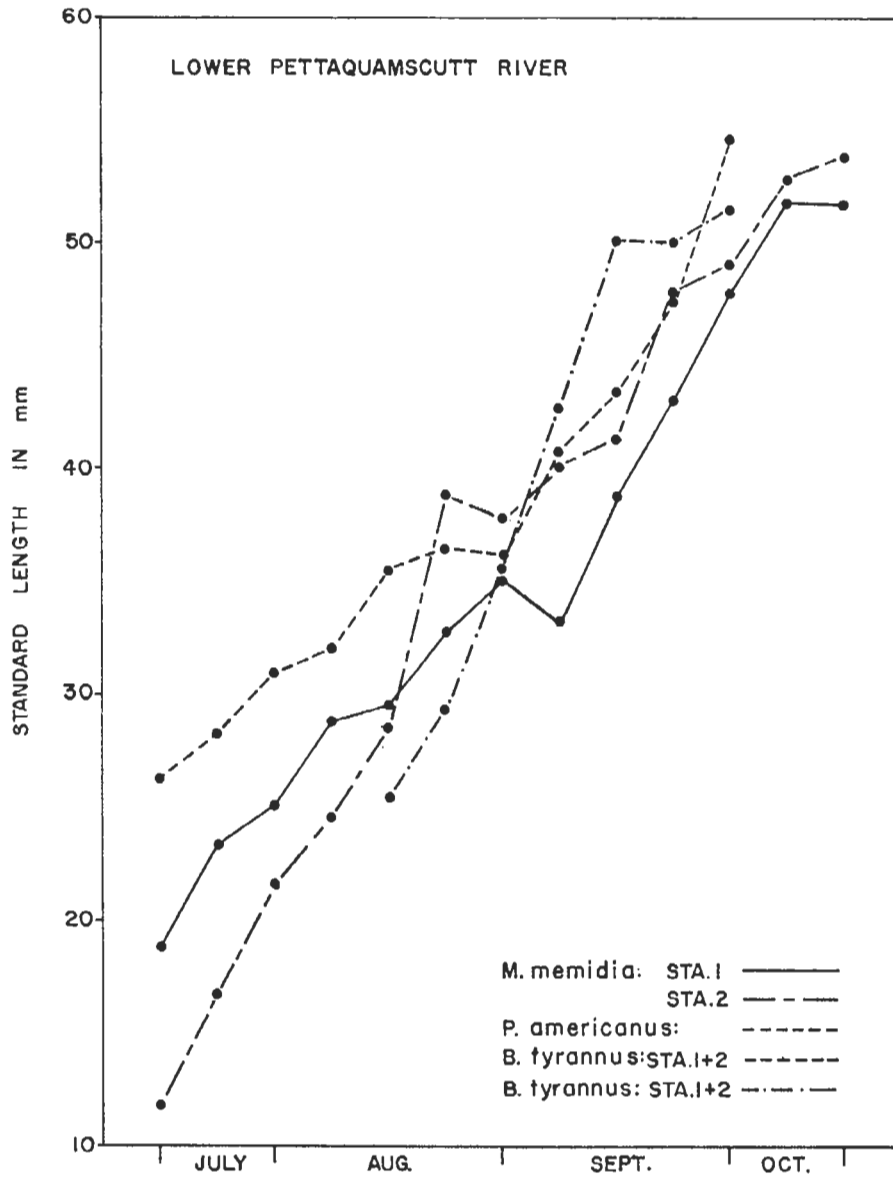
Fig. 17. Rate of growth of *Pseudopleuronectes americanus, Brevoortia tyrannus* and *Menidia menidia* seined from the lower Pettaquamscutt River from July 11 to October 20, 1962.
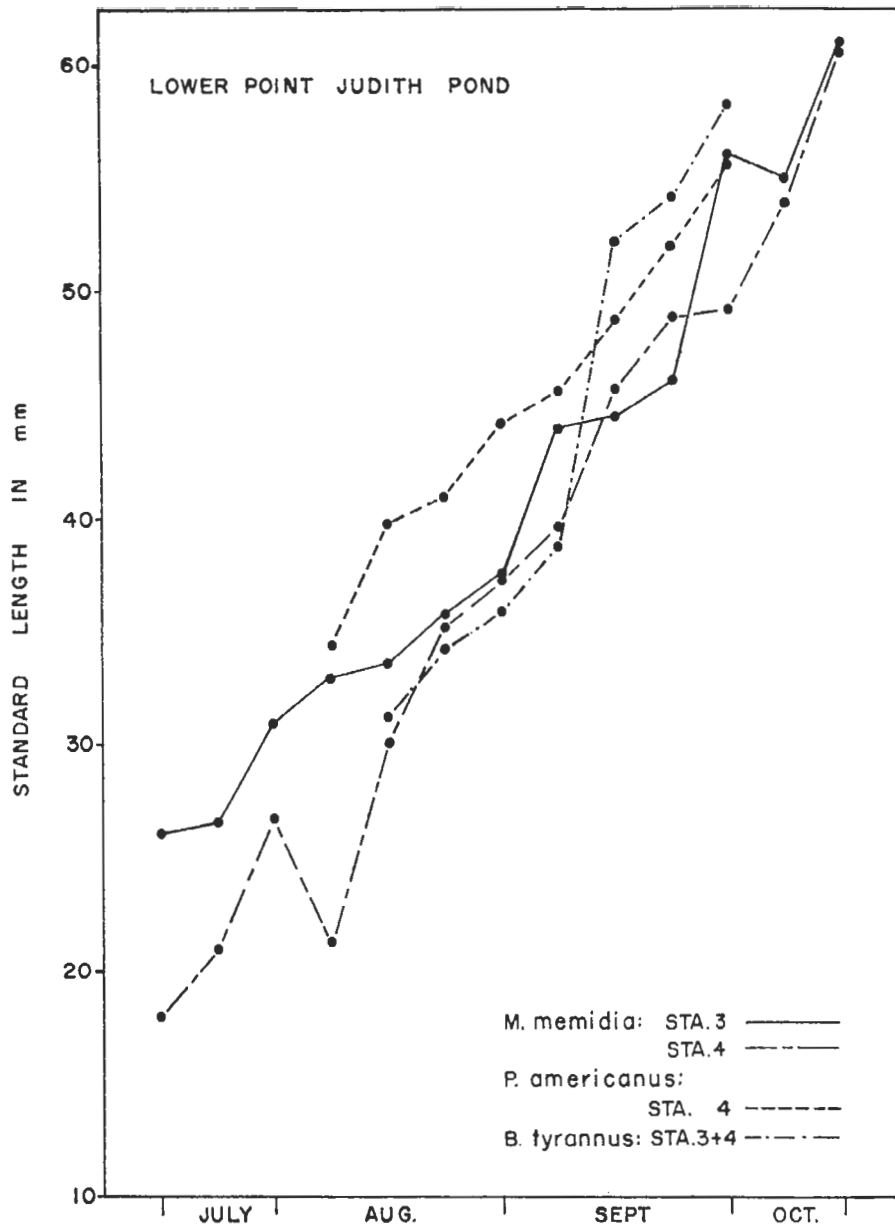
Fig. 18. Rate of growth of *Pseudopleuronectes americanus, Brevoortia tyrannus* and *Menidia menidia* seined from the lower Point Judith Pond from July 11 to October 20, 1962.

139

Table III. List of food organisms of juvenile *Pseudopleuronectes americanus* from the lower Pettaquamscutt River (Stas. I and II combined), and the lower Point Judith Pond (Sta. IV only) including average number per stomach (A/S), percentage frequency of occurrence (PF), size groups of juvenile fish (in mm) and prey size.

| Prey Species | LOWER PETTAQUAMSCUTT RIVER | | | | | | LOWER POINT JUDITH POND | | | | | | Prey size (mm) |
| | 10-30 mm | | 31-60 mm | | 61-80 mm | | 10-30 mm | | 31-60 mm | | 61-80 mm | | |
	A/S	PF	A/S	PF	A/S	PF	A/S	PF	A/S	PF	A/S	PF	
Phytoplankton	2.2	6.9	2.7	6	—	—	—	—	—	—	—	—	.05-.2
Coelenterata													
Hydroids (Broken)	—	—	—	—	—	—	—	—	—	—	3.25	25	3-5 mm
Nemertean	—	—	—	—	—	—	.25	25	.22	6.8	—	—	4.5-8
Polychaeta:-													
Prionospio malmgreni	2.1	38	.92	12	8.3	47.6	.75	25	.32	22	1	25	5-8
Neanthes succinea	—	—	.08	4	—	—	—	—	14	6.8	.75	25	5-9
Neanthes caudata	—	—	—	—	1.4	13.4	—	—	—	—	—	—	5-7
Neanthes virens	.1	1.7	.3	16	6	73.5	—	—	.24	13.6	—	—	6-15
Drilonereis longa	—	—	—	—	—	—	—	—	.05	1.7	—	—	1.3
Nephthys incisa	—	—	.12	4	.06	6.7	—	—	.05	5.1	.25	25	4.5-8
Lumbrinereis sp.	—	—	.08	2	.27	6.7	—	—	.017	1.7	—	—	6.9
Arabella sp.	—	—	.02	2	—	—	—	—	—	—	—	—	6
Spio sp.	.03	1.7	.18	4	.53	13.4	—	—	.25	11.8	—	—	5-15
Unidentified Polychaetes	.42	24.1	.86	28	10	73.5	1.25	25	.32	13	1	25	5-8
Oligochaeta	—	—	—	—	—	—	.25	25	—	—	—	—	3

Table III. (Continued)

| Prey Species | LOWER PETTAQUAMSCUTT RIVER | | | | | | LOWER POINT JUDITH POND | | | | | | Prey size (mm) |
| | 10-30 mm | | 31-60 mm | | 61-80 mm | | 10-30 mm | | 31-60 mm | | 61-80 mm | | |
	A/S	PF	A/S	PF	A/S	PF	A/S	PF	A/S	PF	A/S	PF	
Crustacea													
Cladocera:-													
Evadne nordmanni	—	—	—	—	—	—	—	—	.1	5.1	—	—	.11
Copepoda:-													
Copepodids	.06	1.7	—	—	—	—	1.5	25	—	—	—	—	.4-.5
Harpacticoida	2.55	29.3	.16	4	—	—	8.5	100	1.58	32	1.75	25	.35-.85
Ostracoda:-													
Cylindroleberis mariae	.72	10.4	.66	12	4.1	6.7	—	—	—	—	—	—	1.2-1.5
Sarsiella americana	.74	12	.22	6	.27	6.7	—	—	—	—	—	—	.9-1.2
Pontocypris edwardsi	48.3	27.6	.4	8	—	—	—	—	—	—	—	—	.6-.8
Cumacea:-													
Cyclaspis varians	.09	5.2	.08	4	—	—	—	—	—	—	—	—	3-4.5
Oxyurostylis smithi	—	—	.1	4	.06	6.7	—	—	—	—	.25	25	3-4.5
Amphipoda:-													
Ampelisca sp.	1.43	29.3	.36	12	.8	26.6	.75	50	.54	17	1.25	50	1.5-4.5
Carinogammarus mucronatus	—	—	.12	2	—	—	—	—	—	—	—	—	4-6
Microdeutopus gryllotalpa	—	—	.08	4	—	—	—	—	.15	5.1	—	—	3-4.5
Gammarus annulatus	—	—	.04	2	—	—	—	—	—	—	—	—	5.5
Corophium cylindricum	—	—	—	—	—	—	—	—	—	—	4.25	25	2-3
Lembos smithi	—	—	.36	8	.2	13.4	.5	25	.64	27.2	—	—	2-4.5

141

Table III. (Continued)

| Prey Species | LOWER PETTAQUAMSCUTT RIVER | | | | | | LOWER POINT JUDITH POND | | | | | | Prey size (mm) |
| | 10-30 mm | | 31-60 mm | | 61-80 mm | | 10-30 mm | | 31-60 mm | | 61-80 mm | | |
	A/S	PF	A/S	PF	A/S	PF	A/S	PF	A/S	PF	A/S	PF	
Uniciola sp.	—	—	.02	2	—	—	—	—	—	—	—	—	6.5
Amphithoë sp.	—	—	—	—	.2	6.7	.75	50	.2	6.6	—	—	4-7.5
Amphipod - unidentified	—	—	.2	6	.06	6.7	—	—	—	—	—	—	3-4.5
Isopoda:-													
Cyathura carinata	—	—	—	—	.27	20	—	—	—	—	—	—	4.5-8
Edotea montosa	.83	22.4	1.54	34	.27	6.7	.25	25	.57	22	—	—	2-6
Edotea triloba	.1	3.4	—	—	—	—	—	—	.05	3.39	—	—	2-6
Leptochelia savignyi	.03	1.7	—	—	3.2	6	.5	25	1.14	55.6	—	—	1-1.3
Leptochelia sp.	—	—	.42	2	.06	6.7	—	—	.12	5.1	—	—	1.5-2
Idothea viridis	—	—	.02	2	—	—	—	—	.12	5.1	—	—	6
Decapoda:-													
Crago septemspinosus	—	—	—	—	—	—	—	—	—	—	2.5	25	1.5
Chironomid larvae	—	—	.08	4	—	—	—	—	—	—	—	—	2-3.5
Gastropod larvae	.03	1.7	.04	2	—	—	—	—	.05	1.7	—	—	.05-.075
Bivalve larvae	.17	5.2	—	—	.2	13.4	1	50	—	—	—	—	.9-1.5
Invertebrate eggs	1.26	12	.44	4	—	—	2.75	50	—	—	5.25	25	.025-.15
Fish scales	.03	1.7	—	—	.3	13.4	—	—	.48	10.2	—	—	3.5-6
Total number of fish analysed	58		50		15		5		59		12		
Empty stomachs	16		8		3		1		22		2		

142

THE LOWER PETTAQUAMSCUTT RIVER: From a total of 150 fish studied, 27 had empty stomachs (Table V). The species *P. americanus* feeds normally during the daytime (Pearcy, 1962); all seine hauls were taken only during the day and the small amount of food in the stomachs of the fish probably was due to heavy sporozoan infection. Table III shows the relative importance of various food organisms.

PREY SPECIES: Among the polychaetes, *Prionospio malmgreni* (3-8 mm) was the most important food for all the three size groups of juvenile fish. Phelps (personal communication) found an abundance of this species in Charlestown Pond. *Neanthes virens* (5-15 mm), found in 73.5% of the stomachs in group III, was common as a food in other groups (Table III). A considerable number of polychaetes, fragmented and altered by digestion, were labelled "Unidentified." Other species, *Nephthys incisa, Neanthes caudata, Neanthes succinea, Arabella* sp. and *Lumbrinereis* sp. were less abundant. Often a single individual comprised the bulk of the stomach contents.

Among isopods, the second most important group of food organisms, *Edotea montosa* (2-6 mm), were frequently noted in the stomach. Isopods were relatively easy to identify because of minimum deterioration. *Leptochelia savigni* and *Leptochelia* sp., exhibiting a striking sexual dimorphism and represented mostly by females, were included among other comparatively less important isopod species (Table III).

All young fish ranging between 10-80 mm consumed *Ampelisca* sp., the most common amphipod. Pearcy (1962) reported that *P. americanus* feeds upon *Ampelisca* sp. more than any other amphipod.

Seven other amphipod species, listed in Table III, were absent in stomachs of group I juvenile fish. The amphipods *Carinogammarus, Microdeutopus, Gammarus, Lembos, Unciola* and several unidentified forms were present in the diet of group II, while group III consumed *Lembos, Unciola* as well as some unidentified forms. The ostracods, *Pontocypris edwardsi* (0.6-0.8 mm), were most significant numerically in group I (Table III). Two larger species, *Cylindroleberis mariae* (1.2-1.5 mm) and *Sariella americana* (0.9-1.2 mm), were present in all size groups. The most important components of "miscellaneous" food were harpacticoids, invertebrate eggs, chironomid larvae and fecal pellets.

VARIATION WITH SIZE: Since all collections were made during daylight no day and night variation in feeding was involved. The degree of fullness of stomachs varied with the size of the fish. The percentage of empty stomachs in group I was 21.6% while in group II, it was 13.8% (Table IV). The percentage of stomachs with traces to 25% fullness was higher in group I. In group III only 18 fish were analysed, but the percentage of stomachs with 25-100% fullness was higher than that of group I. The overall picture of stomach fullness does indicate relative increases in stomach contents as a function of body size (Table IV).

With progressive increases in size, young *P. americanus* tended to prefer larger prey organisms. In the group I juvenile fish, *Pontocypris edwardsi,* the smallest astracod species observed, averaged 48.3 per stomach. Eggs and harpacticoids were very abundant in the diet of this group. The smaller polychaete species, *Prionospio malmgreni* (5-8 mm) occurred in 38% of the stomachs with an average of 2.1 per stomach. Larger polychaetes were scarce in the diet (Fig. 19). *Ampelisca* (1.5-4.5 mm), a

143

comparatively small amphipod, was the only type observed in the diet of this group.

Table IV. Variations in relative degree of stomach fullness of three sizes (in mm) of *P. americanus collected* from the lower Petta-quamscutt River and the lower Point Judith Pond. Table includes number and percentage of stomachs with or without food.

Degree of Fullness	10-30 mm (N)	%	31-60 mm (N)	%	61-80 mm (N)	%
LOWER PETTAQUAMSCUTT RIVER						
Empty stomachs	16	21.6	8	13.8	3	16.6
Trace to 25% fullness	9	12.2	3	5.2	1	5.5
25 to 50% fullness	11	14.8	12	20.7	4	22.2
More than 50% to total fullness	38	51.4	35	60.3	10	55.5
Total	74		58		18	
LOWER POINT JUDITH POND						
Empty stomachs	1	20	22	27.1	2	14.3
Trace to 25% fullness	2	40	16	19.8	5	35.6
25 to 50% fullness	—	—	12	14.8	4	28.6
More than 50% to total fullness	2	40	31	38.3	3	21.4
Total	5		81		14	

In group II young fish the data show diminishing selection for smaller prey organisms and an increasing preference for larger organisms (Fig. 19). The stomachs in group III (61-80 mm) young fish were devoid of eggs, harpaticoids and *Pontocypris edwardsi* indicating least preference for smaller species. Though *P. americanus* is euryphagous, results of stomach analysis indicate that smaller fish tend to select smaller prey species.

Seasonal variations: During the summer months, no apparent variations in prey species with time were noted. Richards (1963) reported that all groups of prey are eaten by *P. americanus* during the summer, while in other seasons particular species such as nemerteans and hydroids are absent in their stomachs. Both of these food groups were present in the stomachs of young fish only from the salt pond estuary.

THE LOWER POINT JUDITH POND: From the lower pond 100 individuals that appeared in catches only at the seaward station were available for study. Twenty-five stomachs were found empty (Table IV), while the remaining 75 were 25% to 100% full. The depletion of food in the stomachs was associated with parasitic infection in the young fish in this estuary (see pp 78).

While polychaetes were the principle food, isopods and amphipods were among the major food items (Table III). Ostracod species were not noted in the diet of fish in the study area in this estuary. The important species and groups that comprised the bulk of the diet of young fish in
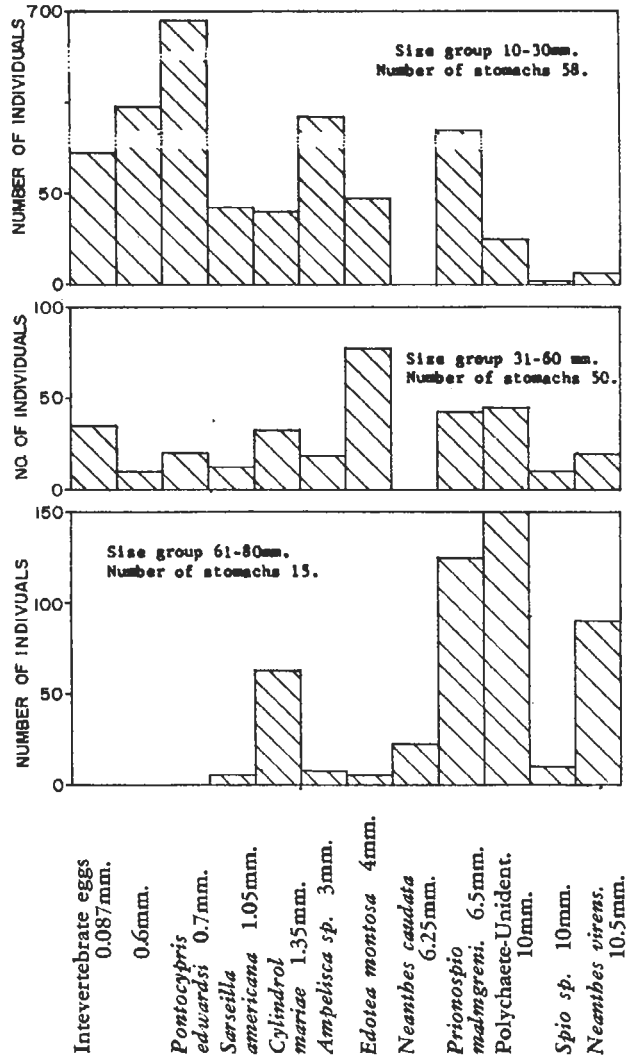
Fig. 19. Variations between different size groups of juvenile *Pseudopleuronectes americanus* and size of the prey organisms collected from the lower Pettaquamscutt River.

the lower Pettaquamscutt River were also present in the food of young fish from the lower pond. Miscellaneous food organisms in the diet including the cladoceran, *Evadne nordmanni,* nemerteans, oligochaete, actinozoa and the polychaete, *Drilonereis longa,* were noted particularly (Table III).

A remarkable feature in the pond estuary was a high percentage of empty stomachs or those with only traces of food (Table IV). According to the general size classification 81% of the young fish were categorized as group II (31-60 mm). The exact picture of size variation between young fish and their prey species could not be traced because of the high percentage of stomachs with little or no food present together with the marked inequality in number of fish in each group. An apparent scarcity in available food in the feeding niches of the lower salt pond may be one reason for a greater number of stomachs containing little or no food.

VARIATIONS BETWEEN THE ESTUARIES: The percentage of empty stomachs of young fish in the lower river was 18% as compared with 25% in the lower pond. The percentage of stomachs with traces to 25% fullness was higher in the lower pond by 14.4% (Table IV). One of the principal groups of organisms, ostracods, was entirely absent in stomachs of young fish in the lower pond. On the average there were fewer important food organisms such as polychaetes, amphipods and isopods per stomach in the lower pond (Table III). Various types of taxonomic groups represented in the diet were also few in the feeding niches of the lower pond environment.

2. *Menidia menidia.*

The species, *Menidia menidia,* demonstrated omnivorous feeding habits. In the lower Pettaquamscutt River the nature of the food varied with size of fish from a mixture of plant and animal food to a strictly carnivorous diet. In the lower Point Judith Pond the young fish were largely dependent upon plant food (Table V and VI). Forty-six per cent of group II (31-60 mm) and all of the group III (61-80 mm) fish ate plant food.

THE LOWER PETTAQUAMSCUTT RIVER: The organisms constituting the important food components of the diet of young fish (10-30 mm) were diatoms, harpacticoids, rotifers, nauplii of *Balanus* sp., and invertebrate eggs (Table V, Fig. 20). Harpacticoids, calanoid copepods, and *Balanus* nauplii comprised the principal diet of groups II and III. Amphipods, isopods and Hymenoptera were also significant as important food components of these two groups.

THE PREY ORGANISMS: While inclusion of diatoms may be considered incidental in the food of group III, these were the essential dietary components for groups I and II. The more commonly occurring species were *Gryosigma spencerii, Gyrosigma* sp., *Grammatophora marina, Nitzschia* sp., *Coscinodiscus* sp., and *Navicula* sp. Invertebrate eggs in 30% of the fish were evidently important food items in the diet of young fish (10-30 mm). Rotifers were present in 35.3% of the fish analysed, mostly of group I. The copepods recorded from the gut content were predominantly adults, including *Paracalanus parvus, Acartia tonsa, Temora longicornis,* and *Pseudocalanus minutus.* The harpacticoids occurring in the diet of 72.7% of the fish examined constituted important food components

146

Table V. List of food organisms of juvenile and adult *Menidia menidia* from the lower Pettaquamscutt River (Stas. I and II combined) and the lower Point Judith Pond (Stas. III and IV combined) including average number per gut (A/G), percentage frequency of occurrence (PR), size groups of the fish (in mm) and size of the prey species.

| Prey Species | LOWER PETTAQUAMSCUTT RIVER | | | | | | LOWER POINT JUDITH POND | | | | Prey size (mm) |
| | 10-30 mm | | 31-50 mm | | 51-80 mm | | 10-30 mm | | 31-50 mm | | |
	A/G	PF	A/G	PF	A/G	PF	A/G	PF	A/G	PF	
Phytoplankton	34.1	89	24.6	66	5.4	51.5	537	100	146	100	.05-.15
Hydroid medusae	.14	4.7	.03	2.4	—	—	—	—	—	—	1.3-1.8 mm
Rotifers	27.5	34.9	2.5	58.5	.85	21.2	—	—	—	—	.07-.1
Polychaete larvae unident.	—	—	.5	2.4	—	—	—	—	—	—	3
Crustacea											
Calanoid Copepods:-											
Acartia tonsa	2.14	14.2	3.42	31.6	31	51.1	—	—	—	—	1.1-1.3
Paracalanus parvus	1.05	11.1	11.8	20.3	31.2	30.5	—	—	—	—	.8-1.0
Temora longicornis	—	—	—	—	.06	3	—	—	—	—	1.3
Pseudocalanus minutus	—	—	—	—	11.2	27	—	—	—	—	.7-.88
Harpacticoida	18.9	71	34.5	100	13.4	70	4.4	76	13	100	.45-63
Cyclopoida:-											
Oithona similis	.76	9.5	25.6	17.1	.61	12.1	—	—	—	—	.45-.6
Copilia sp.	—	—	—	—	.06	3	—	—	—	—	3 mm
Copepod nauplii	1.4	22.2	.17	2.44	—	—	332	100	152	100	.125-.2
Copepodids	.317	11.1	.36	4.8	—	—	33.7	66.8	—	—	.3-.45

Table V. (Continued)

| Prey Species | LOWER PETTAQUAMSCUTT RIVER | | | | | | LOWER POINT JUDITH POND | | | | Prey size (mm) |
| | 10-30 mm | | 31-50 mm | | 51-80 mm | | 10-30 mm | | 31-50 mm | | |
	A/G	PF	A/G	PF	A/G	PF	A/G	PF	A/G	PF	
Ostracoda:-											
Pontocypris edwardsi	1.05	14	—	—	—	—	—	—	—	—	.5-.7
Sarsiella americana	—	—	.22	14.6	.12	6	—	—	—	—	.8-1.2
Cumacea:-											
Oxyurostylis smithi	—	—	1	4.75	—	—	—	—	—	—	2.5-4
Cyclaspis varians	—	—	—	—	.27	7.3	—	—	—	—	2.5-3.5
Amphipoda:-											
Lembos smithi	—	—	.365	9.8	.42	15	—	—	—	—	1.7-2.5
Microdeutopus gryllotalpa	—	—	.17	7.3	.06	6	—	—	—	—	2.0-3.0
Carinogammarus mucronatus	—	—	.122	7.3	.03	.01	—	—	—	—	2.7-3.3
Amphithoe sp.	—	—	.049	4.8	—	—	—	—	—	—	1.8-3.1
Ampelisca sp.	.19	6.3	.122	7.3	.97	21.2	.33	19.1	1.12	62.6	1.0-1.75
Isopoda:-											
Leptochelia savignyi	.19	7.9	.56	12.2	.21	3	—	—	.625	47	.55-1.0
Cyathura carinata	—	—	.073	4.8	.166	6	—	—	—	—	2.0-3.0
Tanais cavolinii	—	—	—	—	.18	6	—	—	—	—	1.5-2.5
Idothea viridis	—	—	.073	7.3	—	—	—	—	—	—	3.2

Table V. (Continued)

| Prey Species | LOWER PETTAQUAMSCUTT RIVER | | | | | | LOWER POINT JUDITH POND | | | | Prey size (mm) |
| | 10-30 mm | | 31-50 mm | | 51-80 mm | | 10-30 mm | | 31-50 mm | | |
	A/G	PF	A/G	PF	A/G	PF	A/G	PF	A/G	PF	
Cirripedia:-											
Balanus sp. (nauplii)	17.4	60	85	56.1	29.7	45.5	—	—	—	—	.6-1.2
Decapoda:-											
Pagurus sp. zoae	—	—	—	—	—	—	—	—	.47	9.3	.2-3.5
Decapod larvae unident.	.142	4.7	.27	7.3	.06	3	—	—	—	—	1.2-2.5
Insecta:-											
Chironomid larvae	.1	7.9	.122	9.8	.09	6	.071	4.9	—	—	2.0-3.5
Hymenoptera	—	—	.76	31.6	1.27	24.2	—	—	.03	3.1	2.5-5.5
Arachnida	.05	4.7	.025	2.44	.12	6	—	—	—	—	2.5-3.5
Bivalve larvae	.05	6.4	—	—	—	—	—	—	—	—	.6-1.2
Gastropod larvae	.49	11.1	.29	12.2	—	—	—	—	—	—	.075-.125
Invertebrate eggs	17	46	5.98	26.9	4.25	15.2	13.8	40.5	.97	31.3	.025-.05
Fecal pellets	.05	1.59	—	—	—	—	.166	7.15	.5	15.4	.15-.25
Fish scales	.86	42.9	.98	41.5	1.21	33.4	—	—	—	—	1.5-2.5
Fish eggs	.05	3.18	.315	7.3	.18	9	—	—	—	—	.8-1.1
Total number of fish analysed	69		45		36		45		34		
Empty guts	6		4		3		3		2		

149

in all size groups. The cyclopoid, *Oithona similis,* was significant in group II fish.

The isopod, *Leptochelia savignyi,* was eaten by all size groups of fish. Other isopod species consumed by young and adult fish (31-80 mm) were, *Cyathura carinata, Tanais cavolini,* and *Idothea viridis. Ampelisca* sp. was the only amphipod in the gut contents of group I fish (Table V), while the five species listed above were consumed by groups II and III. Hymenopterous insects significantly occurred in groups II and III and often comprised the bulk of the gut contents. Although the hymenoptera was well represented it is doubtful if this group, mostly represented by ants, serves as a regular source of food. These insects are probably incidentally introduced in water. The chironomid larvae, which usually occur in fresh water environments, are swept down into brackish water from the fresh water area. These were fed on by all three size groups. Decapod larvae, cumacids, gastropod larvae and fish eggs were the prominent "miscellaneous groups". The prey including larger organisms, such as amphipods, isopods and gastropod larvae were predominantly fed upon from the substratum or *Zostera* and *Ruppia* leaf blades.

VARIATION WITH SIZE: No day and night variations in feeding are known in *M. menidia.* The degree of fullness of the gut in various size groups indicates that fish were caught during the active feeding period which was always during the daylight hours (Table VI). Though the usual food for the larger group (51-80 mm) was scarce, there was an apparent indication of increase in gut fullness with increase in size of the fish (Fig. 20).

Phytoplankton as an important dietary component became less and less important with progressive growth of the young fish (Table V). In group I (10-30 mm) young fish largely depended upon small size prey organisms. Rotifers (.07-.1 mm) average 27.5 per gut while harpacticoids (.45-.63 mm), occurring in 71% of the gut, averaged 18.9 per gut. Invertebrate eggs and Balanus nauplii were present in 46% and 60% of the fish examined and averaged 17 and 17.4 per gut respectively. Other prey organisms including the larger crustaceans were insignificantly represented in the gut contents.

In group II (31-50 mm) fish phytoplankton were less important as diet, harpacticoids occurred in 100% of the fish examined, copepods and *Balanus* nauplii occurred in larger numbers as compared with the amount consumed by group I fish (Fig. 20).. Invertebrate eggs and rotifers, important dietary components of group I fish, were insignificant in group II fish. In addition some species of amphipods and isopods became increasingly important in the diet (Table V). In group II larger size prey organisms were characteristic of the diet indicating an apparent preference for larger prey with the increase in size.

The group III (51-80 mm) fish followed a similar trend in the dietary shift demonstrating greater dependence on larger food organisms. An average of 5.4 phytoplankton per gut seem to be incidently ingested along with other prey. Copepods were the most important food component. The species *Acartia tonsa* and *Paracalanus parvus* were highest in abundance in the gut contents and averaged 31 and 31.2 per gut respectively. The insects, Hymenoptera, occurred in 24.3% of the guts analysed. Isopods and amphipods were also common in this group (Table V). There was

150

Table VI. Variation in relative degree of gut fullness in three size classes of *Menidia menidia* in the lower Pettaquamscutt River and the lower Point Judith Pond. Table shows the number (N) and percentage (%) of gut with or without food. Figures with asterisk indicate fish that ate phytoplankton.

Degree of Fullness	10-30 mm (N)	(%)	31-50 mm (N)	(%)	51-80 mm (N)	(%)
LOWER PETTAQUAMSCUTT RIVER						
Empty gut	6	8.7	4	8.9	3	8.3
Traces to 25% fullness	15	21.7	11	24.4	15	41.6
25 to 50% fullness	21	30.4	7	15.6	11	30.6
More than 50% to total fullness	27	39.2	23	51.1	7	19.5
Total	69		45		36	
LOWER POINT JUDITH POND						
Empty gut	3	6.7	2	3.2	—	—
Traces to 25% fullness	5	11.1	4	6.4	—	—
25 to 50% fullness	16	35.1	15	23.8	—	—
More than 50% to total fullness	21	46.1	13	20.6	42*	100
			29*	46		
Total	45		63		42	

however no apparent change in the supply of food during the study period, covering summer and early fall.

LOWER POINT JUDITH POND: The fish in the lower pond largely depended upon phytoplankton as diet. The group I and over 50% of group II fish ate mixed plant and animal food, while 46% of group II and all the fish of size group III consumed phytoplankton.

PREY ORGANISMS: The major food items observed in the gut contents were: phytoplankton, copepod nauplii, copepodids, invertebrate eggs and to some extent harpacticoids. Inclusion of phytoplankton, as either an important component or the entire diet, was apparent in all the three size groups (Tables V and VII).

The results of the analyses of plant food (Table VII and Fig. 21B) indicate that there was an increase in volume per gut with increase in size of fish and an average of 768 cells/mm^3. The plant food consisting chiefly of littoral benthic diatoms included mostly *Gyrosigma spencerii* and *Gyrosigma* sp. in addition to less abundant species as mentioned in the description of the vegetable diet of the fish in the study area of the river estuary. Copepod nauplii averaged 332 per gut in group I and 152 in group II. Copepodids and invertebrate eggs found in over 66% and 40% respectively in size group I (10-30 mm), were insignificant in group II. There was an apparent scarcity of larger crustacea, and other taxonomic groups. The prey, *Ampelisca* sp., chironomid larvae and fecal pellets in group I were listed as "miscellaneous food" items, while in the group II,

151

LOWER PETTAQUAMSCUTT RIVER

Size group 10-30mm.
Number of fish 63.

Size Group 31-50mm.
Number of fish 41.

Size group 51-80mm.
Number of fish 33.

Phytoplankton.

Invertebrate eggs.

Nauplii - Copepods.
Balanus sp.

Nauplii -
Balanus sp.

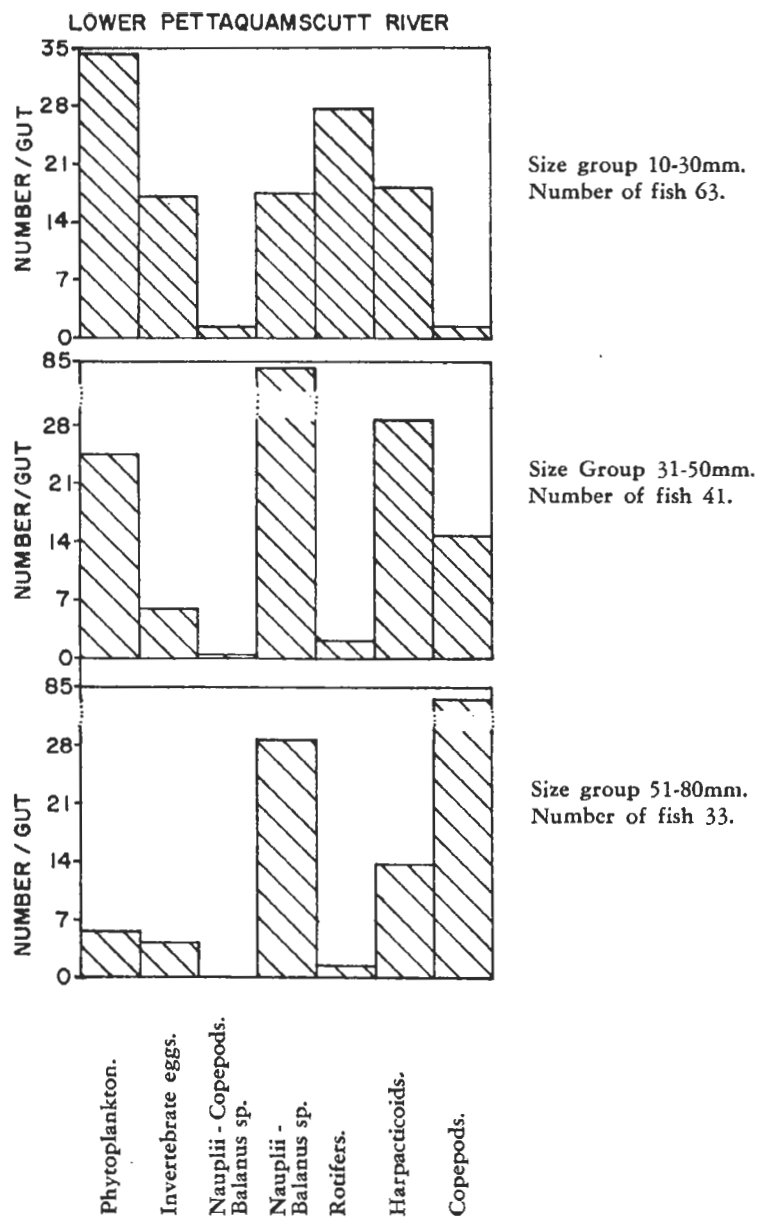Rotifers.

Harpacticoids.

Copepods.

Fig. 20. Variation between size groups of *Menidia menidia* and size of the prey species (given against each bar).

152

Table VII. The average volume and number of cells per gut in various class sizes of *Menidia menidia* that ate only phytoplankton in the Lower Point Judith Pond.

Class size in mm	Average Vol. in cc/gut	Average Number of cells/cc	Average Number of cells/gut
30-40	0.04	768,000	29,720
40-50	0.05	768,000	39,936
50-60	0.125	768,000	96,000
60-70	0.218	768,000	167,424
70-80	0.214	768,000	164,352

Leptochelia savignyi, Pagurus sp. zoeae, Hymenoptera and fecal pellets represented a similar category.

VARIATION WITH SIZE: The analysis of the gut contents showed the presence of two major food components; the minute developmental stages of crustacea and phytoplankton (Table V, Fig. 21). The microscopic mixed plant and animal food perhaps suited the feeding habits of the small size (10-30 mm) fish. The larger size fish (31-80 mm) were possibly unable to feed on minute organisms effectively in the pelagic environment, hence picked up food from the substratum as mouthfuls which contained diatoms, organic debris and fecal pellets (Tables V and VII). Brodski and Jankovskaya (1935) indicated a similar behavior in the eastern sardine, *Sardinops melanosticta,* which feeds effectively on phytoplankton in the absence of zooplankton, the normal diet of this species. A similar situation was non-existent in the lower river. Here the larger fish ate larger crustaceans and other food organisms. The inclusion of phytoplankton in their diet seemed to be incidental.

3. *Brevoortia tyrannus.*

A controversy exists regarding the nature of the primary food of *Brevoortia tyrannus.* Peck (1894) examining the food of juvenile and adult fish from Buzzards Bay, Massachusetts, during the summer period, described it as consisting of suspended organic matter and phytoplankton, with small crustaceans as supplementary food. Peck gave no quantitative data for plant matter in his food habit studies. Richards (1963) described the food of young *B. tyrannus* during winter as consisting primarily of crustaceans without any inclusion of plant food. Other workers reported that the diet was composed of oozy mud (Verrill, 1871), and others as plant debris, miscroscopic plants and small crustaceans (Goode, 1880; Bigelow and Schroeder, 1953). Richards (1963) did not account for any seasonal variation in the basic diet. By combining data and observations from this and Peck's summer studies, together with Richards' winter studies it seems evident that seasonal changes in feeding habits are indicated.

In the 150 fish of this species examined from each estuary most of the stomachs had only traces of food while the gizzards were always full (Table VIII).

The high percentage of empty stomachs may have been due to a

LOWER POINT JUDITH POND

Size group 10-30mm.
Number of fish 42.

Size group 31-50mm.
Number of fish 32.

"A"

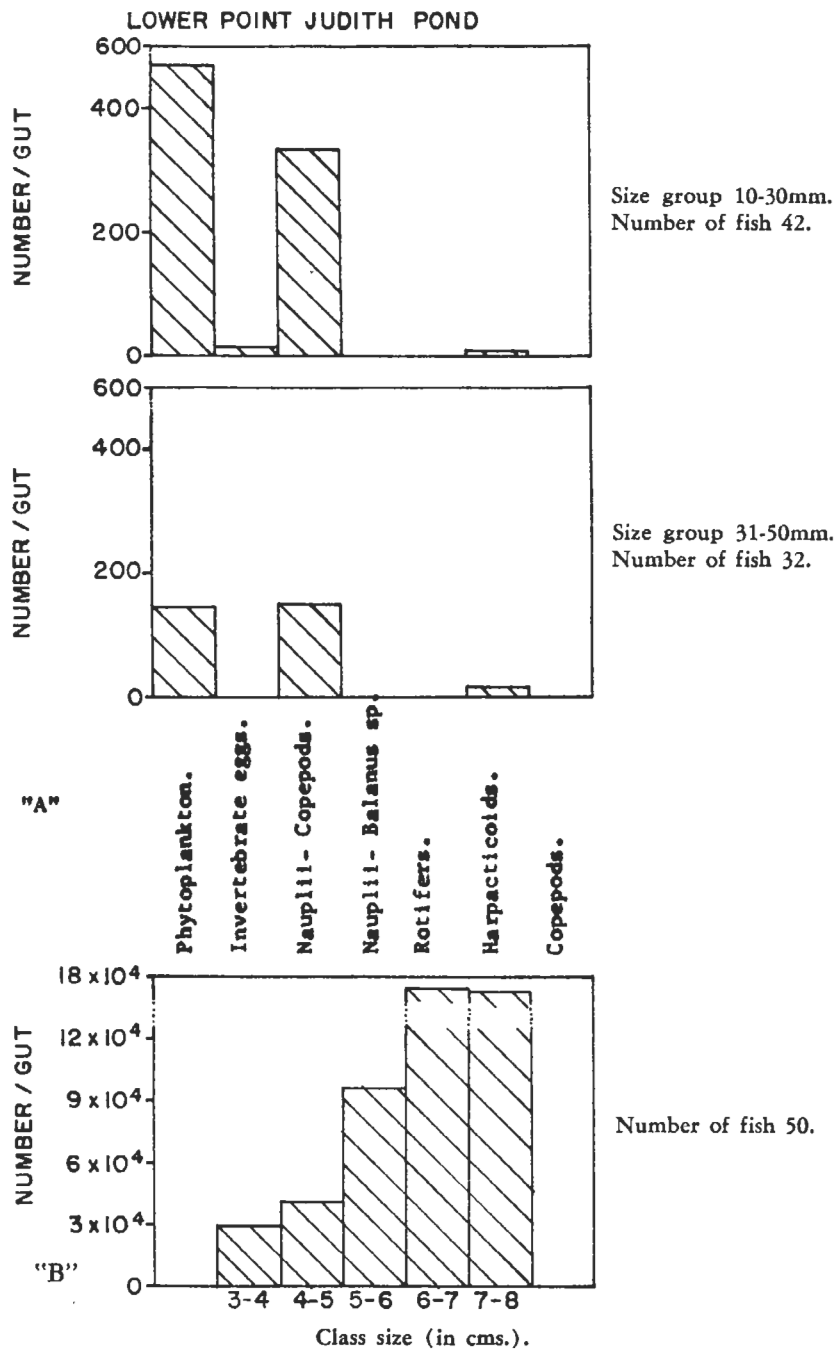Number of fish 50.

"B"

Class size (in cms.).

Fig. 21.A. Variations between size groups of *Menidia menidia* and size of the prey species.

Rig. 21.B. Variations in number of phytoplankton per gut relative to class sizes of *Menidia menidia*.

154

rapid transfer of food to the gizzards since these latter organs were always found full.

The stomach contents were comprised chiefly of unidentifiable organic matter including soft organic or so-called "oozy mud" and unicellular algae, predominantly *Peridinium* sp. Diatoms were uncommon and harpacticoids, copepod nauplii, and copepodids occurred rarely in samples from both the estuaries. Peck (1894) stated, while the only food noted was unicellular algae, polychaetes and crustaceans were altogether absent in day samplings. These observations are analogous to the findings of the present study. Fifteen different types of organisms were identified to species or genera and groups represented by dinoflagellates, *Peridinium, Dinophysis, Glenodinium,* diatoms, *Gyrosigma spencerii, Gyrosigma* sp., *Acnathes, Gramatophora, Navicula, Coscinodiscus, Rhizosolinia,* and other groups included copepod nauplii, copepodids, harpacticoids and infusorians. These organisms constituted just a small fraction of the diet in comparison to the free organic matter. There was no change in type of food with progressively increasing size of the young fish (Richards, 1963). The analogous earlier observations may have discouraged serious quantitative studies, because the material observed in summer period does not lend itself to a reliable quantitative determination.

Table VIII. Variations in the relative degree of stomach fulless of three class sizes (in mm) of juvenile *Brevoortia tyrannus* from the lower Pettaquamscutt River and the lower Point Judith Pond. Table represents number (N) and percentage (%) of stomachs with or without food.

Degree of stomach fullness	10-30 mm (N) (%)		(N) 31-60 mm	(%)	(N) 61-80 mm	(%)
LOWER PETTAQUAMSCUTT RIVER						
Empty stomach	1	3.7	18	16.1	—	—
Traces to 25% fullness	23	85.2	74	66	9	81.7
25 to 50% fullness	3	11.1	13	11.6	2	18.2
More than 50% to total fullness	--	—	7	6.3	—	—
Total	27		112		11	
LOWER POINT JUDITH POND						
Empty stomachs	2	5.3	9	9.9	—	—
Traces to 25% fullness	29	76.3	53	58.2	15	71.1
25 to 50% fullness	7	18.4	24	26.4	6	28.9
More than 50% to total fullness	—	—	5	5.5	—	
Total	38		91		21	

155

D. PREDATORS AND PARASITES

Large size fish were uncommon in the seine hauls. The stomachs of adult *Roccus americanus, Opsanus tau, Tautoga onitis, Menidia menidia* and juvenile *Caranx crysos* (40-60 mm) captured during seining were examined. Only *Opsanus tau, Caranx crysos* and *Menidia menidia* were found feeding on juvenile *Anchova mitchilli* and *Menidia menidia*. No valid picture of the overall predation can be traced because adult fishes are least vulnerable to shore seining. Piscivorous birds, *Larus* sp., the herring gull, *Sterna* sp., the common tern and *Phalacrocorax* sp., the cormorants, were observed feeding on fry throughout the survey period in the lower parts of both estuaries. Pearcy (1962) reported an abundance of cormorants in the Mystic River estuary during late summer and fall, and Steven (1933) in England showed 40% of the diet of cormorants to be flatfishes.

Infections of sporozoan parasites was surprisingly common in *Pseudopleuronectes americanus* and *Osmerus mordax*. Ectoparasites were uncommon and were only found infesting *Alosa pseudoharengus, Fundulus heteroclitus* and *F. majalis*. These were represented by *Argulus funduli, Argulus* sp. and *Caligus* sp. Endoparasites were observed in *B. tyrannus, P. americanus*, and *M. menidia* during food analysis, including nematodes, cestodes and sporozoans. The sporozoan parasite, *Glugea hertwigi*, was visible through the translucent body wall of *Osmerus mordax*, while equally heavy infection was also observed in *P. americanus*. *Glugea hertwigi* occurred as white globules attached to gut epithelium or infesting the outside walls of the alimentary tracts. In heavy infection the lumen of the alimentary tracts were either fully loaded with *Glugea* colonies or these were thickly embedded on the outside body walls. In instances of light infection a few scattered globular structures were loosely attached inside or dorsal to the alimentary tracts. In all cases of heavy infection alimentary tracts were devoid of food, and indicated greater susceptibility to other parasites. Table IX shows the degree of infection in *P. americanus*.

Table IX. Number (N) and percentage (%) of juvenile *Pseudopleuronectes americanus* infected with *Glugea hertwigi* collected from the lower Pettaquamscutt River and the lower Point Judith Pond.

Class in mm	Number of fish	Light Infection (N)	(%)	Heavy Infection (N)	(%)
LOWER PETTAQUAMSCUTT RIVER					
10-30	244	29	11.9	11	4.9
31-60	116	7	6	3	2.6
61-80	36	3	8.3	—	—
LOWER POINT JUDITH POND					
10-30	5	1	20	—	—
31-60	81	13	18	6	7.4
61-80	14	3	21.4	1	7.1

The data indicate that a considerable number of fish were infected. Through accurate estimation of mortality may require extensive sampling, these data suggest a high mortality may have occurred especially in group I (10-30 mm). Kudo (1947) and Duijn (1956) found that a host dies when heavily infected with *Glugea hertwigi* because of a degeneration of the large number of cells attacked.

VI. DISCUSSION

Spring and summer seasons mark the spawning activities in most of the species of fishes in New England waters (Merriman and Sclar, 1952; Wheatland, 1956; and Herman, 1958). Following the larval phases of growth, the young fish are faced with the problem of protection from predators and a search for abundant food. At this stage estuaries become important as nursery grounds for young fishes.

A significant influx of juvenile immigrant species from offshore and from lower latitudes and the emigration of anadromous forms was noted as temperature increased during early summer (Fig. 7). Although the abundance of fishes followed the general pattern of rise and decline in temperature, no correlation was observed between maximum temperature and maximum abundance (Fig. 7). The differential temperature tolerance in various species may be a contributing factor for a lack of correlation. Warfel and Merriman (1944) have reported that maximum temperatures are not accurate indicators of a great number of species.

Salinity is a determining factor limiting the distribution of fishes within the various segments of an estuary. The stenohaline species, especially the fresh water forms, may be limited within a narrow range of salinity. Marine forms are usually more euryhaline and are able to withstand wide ranges in salinity (Herre, 1956). A few brackish and fresh water fishes occurred in both the study areas (Table I) where salinity ranged between 10-32 o/oo and 28-32 o/oo in the lower river and the lower pond respectively. Even at Bridgetown Bridge, where salinity varied between 9.8 - 15 o/oo mostly marine forms were captured. The only fresh water species recorded was *Micropterus salmoides*, collected from the Middle Bridge area (Sta. II, Fig. 1). Adolf (1925), in discussing the tolerance of marine and fresh water organisms, suggested that marine organisms are better adapted to changes in the osmotic environment than are fresh water forms. The lack of relationship between the fluctuation in salinity and fluctuation in marine fish population is indicative of the fact that these forms can adjust to wide salinity changes in the environment. Further, the number of marine species recorded from the lower river was one and a half times higher than those captured in the lower pond (Table I) indicating an apparent preference for an area with pronounced variation in salinity (Figs. 4 and 5).

The species, *Pseudopleuronectes americanus, Brevoortia tyrannus* and *Menidia menidia*, which were used for detailed study, also gave evidence of changes in distributional behavior with respect to spawning seasons, age and thermal tolerance. The juvenile *P. americanus* of zero year class were caught mostly at lower stations in shoaler water (Table I, and pp. 15). As the larvae of this species grow they move down stream (Bigelow and Schroeder, 1953; Pearcy, 1962) and occupy stations closer to the mouth of estuaries during summer. The preference for shoaler areas with higher temperature (Figs. 6 and 12 and pp. 15) explains why a few individuals

caught at upper comparatively deeper stations in both localities were either mostly or all second year class fish. Huntsman and Sparks (1924) reported a higher incipient lethal temperature for smaller flounder than for larger ones. The difference in temperature tolerance may explain why larger fish may prefer deep water in summer.

The influx of *Brevoortia tyrannus* in the two estuaries was apparent because of the great abundance of small fish at landward stations during September. Although the schools of "precise size" individuals of this species move up and down the estuaries during the nursery period, the presence of a few fish of diverse sizes only at the seaward stations in October suggests an outward migration at this time of the year (Figs. 10 and 11).

The species, *Menidia menidia,* forms schools of similar sized individuals (Shaw, 1960) and because fish of all sizes, above 2.5 cm (1 in.), occur all the year round (Bigelow and Schroeder, 1953) patches of various size groups were found at all the stations. Because of extreme adaptability of this species to changes in temperature and salinity its abundance was markedly high at all the four stations. The measure of total abundance and distribution depends upon the reliability of catches. The catch reliability in turn may depend upon a number of factors, such as distance from the fresh water source, the tide and especially the temperature, which is the dominant factor. Day (1951) reported that any one factor cannot be the sole determinant of the distribution of organisms in estuaries. Although the total abundance and distribution are markedly influenced by temperature fluctuations, it is suspected that slight changes in temperature caused marked fluctuations in the catches (Fig. 7). The phenomenon seems to be a recurring process of overcrowding and dispersal. Such a pattern is well illustrated in the total catches in the lower Pettaquamscutt River. As Warfel and Merriman (1944) suggested, that under optimum living conditions population density may reach a super-saturation point at which time the ensuing population pressure forces a dispersal followed by another build up process.

No relationship was observed between the total number of species and the total number of individuals occurring at any one time. These data demonstrate (Fig. 7) that there were peaks in numbers of individuals occurring in late August, while the largest numbers of species in general were recorded during September in both the areas under study. The migrant species such as *Lutjanus griseus, Trachinocephalus myops* and *Chaetodon ocellatus,* enter Rhode Island waters as stray individuals from remote spawning centers quite late in summer. The late entry of these fishes contributed markedly to increases in number of species. However, because there were too few individuals, total abundance in these areas remained unaffected. Other species such as *B. tyrannus* that spawn in coastal and offshore waters, and *Alosa pseudoharengus,* that spawn in some Rhode Island estuaries appear in schools sporadically following the temperature rhythm and tend to influence the total catches.

In addition to physical and chemical variables and general migration trends of many species, the environments, characterized by various types of substrates and variable profusion of benthic plant life, serve to attract or discourage large populations of fishes. The greater number of species and individuals of most species preferred habitats at Harbor Island, in the lower pond and at Middle Bridge, in the lower river, where luxurious

growth of Zostera-algal communities occur. These habitats especially in the Middle Bridge area, in the lower river, apparently provide plant cover and abundant food supply, the primary needs of the juvenile fishes, and are therefore, major attractions to large populations of considerable number of species of young fishes (Table I). A fewer species of young fishes frequented the Bridgetown Bridge area, in the lower river, and the seaward station, in the lower pond, where a paucity of plant life prevails. The data for growth and food studies of young fishes were combined for both the stations in each estuary. Hence, these data represent the consequences of all the environmental influences in each estuarine system. A higher profusion of benthic plant life in the Middle Bridge area, is reflected in beter conditions for growth of young fishes and greater abundance of food in the lower river as compared to those in the lower pond.

Another useful aspect of the habitats with profusion of benthic plant life, is a case of mimicry exhibited by species including *Tautoga onitis* and *Tautogolabrus adspersus,* a useful adaptation for protection in these habitats.

The growth studies were conducted during summer season, the period of thermal maximum. The higher temperature results in increased metabolic activity (Prossor and Brown *et al.,* 1962), and particularly influences the rate of growth in poikilothermic animals including fishes (Rounsefell and Everhart, 1953).

Although the lower river was preferred by most species and held a greater abundance of prey organisms, no variation in average growth was observed for *P. americanus* in both the study areas. Probably due to small sample sizes the variation in growth did not become apparent. However, the growth increments were significant (Figs. 13, 17 and 18). The average growth of the young fish from the lower river and the lower pond compares favorably with growth of juvenile *P. americanus* in the Mystic River estuary, an area considered to be highly productive (Pearcy, 1962).

The statistical analysis of growth data of juvenile *B. tyrannus* showed that two distinct groups in each estuarine system studied (Fig. 14) The first group, appearing from mid-August to mid-September comprising four samples of "precise size" individuals, showed significant and statistically adequate growth in each of the study areas. The rate of growth per month for this species in the lower river was double that of the fish from the lower pond (Fig. 14). Although there is marked irregularity in sample sizes because of the schooling habit of this species, comparative food studies of the feeding niches also reflect the better environmental conditions in the lower river. The rest of the samples were composed of individuals with diverse size range which perhaps had strayed off from the various schools during emigration. The growth rates in such samples markedly differed from the previous samples (Figs. 17 and 18). McHugh *et al.* (1959) have found that a single rate of growth for this widely ranging species in an estuary is untenable.

Although no comparable growth study of *Menidia menidia* is available, the growth data of this small sized species (Figs. 15-18) indicate that significant growth increments occur from early July to early September. Indications of variation in growth were observed in the two estuarine environments, and between the two stations within each individual estuary (Figs. 15-18). The higher rate of growth in the lower river is indicative of a higher productivity in comparison to that of the lower pond. This

159

correlation is also corroborated by environmental and food habit studies (Table V and pp. 15). The differences in variation occurring between the stations in each estuary were probably due to late spawning at seaward stations. The higher rate of growth at seaward stations (Figs. 17 and 18) indicated smaller fish of the same year class grow faster.

The success of feeding niches in the two estuarine systems studied depends upon the presence of abundant, palatable food and habitat conditions. The food resources in the lower Pettaquamscutt River, an area with conditions varying from neritic to brackish water and profusion growth of plant life with attendant epibiota, were comparatively abundant and suited to the food habits of all size groups of progressively growing fishes. In the lower Point Judith Pond where neritic conditions prevail, the less abundant animal food was reflected in the low diversity of prey organisms (Tables III and V). The higher percentage of empty stomachs in *Pseudopleuronectes americanus* and presence of phytoplankton as substitute diet or "forced diet" in the gut contents of *Menidia menidia* may account for the low efficiency of the trophic environment in the lower pond. The food study of the individual species further illustrated this variation in the trophic picture.

The prey of *P. americanus* represented a wide variety of organisms from both the pelagic and benthic environments (Table III). Although *P. americanus* is a euryphagous species (Pearcy, 1962), the three arbitrarily selected groups from the lower river demonstrated a preference for larger and more varied types of food organisms, with increase in size (Fig. 19 and Table III). The small juvenile fish (10-30 mm) largely ate harpacticoids, *Pontocypris edwardsi,* invertebrate eggs, and few species of larger organisms. The inclusion of large sizes and the diverse nature of the prey including polychaetes, amphipods and isopods in the diet of young fish of size groups 31-60 mm and 61-80 mm is doubtless due to a greater adaptability of the larger young fish to capture larger and more varied types of food organisms. The stomach fullness method indicated a greater percentage of full stomachs, noted in the lower river, as function of size.

While the essential dietary components were present in the food components of *P. americanus* from the lower pond, the quantity and diversity in the prey organisms was low in comparison to those occurring in the lower river (Table III). Shelbourne (1953) in the plaice, *Pleuronectes platessa,* and Pearcy (1962) in *P. americanus* have observed diurnal feeding behavior. Since the catches represent day samplings, a high percentage of stomachs with little or no food, observed in the lower pond, indicate that there was a low abundance of prey organisms. Any interpretation on the basis of higher digestive rates in one estuary than the other may be erroneous as the fish of the same species were caught at the same time of the day, with lesser food in the stomachs in one environment as compared to that in the other environment. From these observations it would seem that in some river estuarine systems with a distinct salinity gradient, environmental conditions are apt to be more successful in terms of feeding niches for young fish than the estuarine environments with near neritic conditions such as the lower pond. Pearcy (1962) compared his results of production of young *P. americanus* from the Mystic River estuary with those of Richards (1963) from Long Island Sound and contended that seventy times higher values for the estuary point to higher productivity in the small estuaries as compared to the near Sound area.

The data obtained for *Menidia menidia,* an omnivorous fish, allowed further insight into the trophic environment of the feeding niches, in both the study areas. While the diet of this species in the lower river contained a mixture of plants and animals, the fish demonstrated largely or wholly a dependence upon phytoplankton in the lower pond. The food of *M. menidia* which was rich in phytoplankton for small size (10-30 mm) fish in the lower river, essentially was composed of phytoplankton, rotifers, harpacticoids and calanoid copepods, *Balanus* nauplii and invertebrate eggs. With a successive increase in the size of the fish, the phytoplankton in the diet became negligible. Calanoids, harpacticoids and *Balanus* nauplii were the important food components for larger fish (31-80 mm). It seems that the smaller fish preyed upon minute and less mobile food organisms including phytoplankton. Later with increased size and speed these fish could feed on a great variety of larger and more mobile food organisms. Bhattacharyya (1957) reported a similar gradual dietary change from vegetable food to a carnivorous diet in postlarval herring (35 mm).

The small size fish consumed more phytoplankton in the lower pond due to an apparent lack of minute prey organisms (Table V). Forty-six per cent of the size group 31-50 mm and all of size group 51-80 mm fish ate plant food. One possible interpretation may be that due to a scarcity of carnivorous food, the fish would be forced to seek a substitute diet or so-called "forced diet." In this case the substitute diet was phytoplankton, primarily benthic littoral diatoms, fecal pellets and detrital material (Brodski and Jankovskaya, 1935). There is no information to the author's knowledge concerning the nutritive value of such food. However there was indication of comparatively slow rate of growth in the pond estuary where fish largely depended upon phytoplankton. The excessive grazing by these fish on plant food, the only available substitute, may be preparatory for the winter season, when active feeding is probably minimal.

There is no well defined study on the food habits of *Brevoortia tyrannus.* Controversy exists on the nature of its primary food and feeding habits. The results of the present study and comparison with other available data on the food habits of this species indicate that the primary food during summer and fall is phytoplankton and suspended organic matter while in winter crustaceans constitute the basic diet (Peck, 1894; Richards *et al.,* 1963). The diet of this species according to the present study includes dinoflagellates, diatoms, and a very large fraction of unidentifiable organic matter (see pp. 76). The average and percentage occurrence methods employed for analysis of food for other species were obviously not useful for this type of material. The stomach fullness method showed most of the stomachs were empty or traces to 25% full (Table VIII). Gizzards and intestines were always full which indicated that food transfer from stomach to the gizzards probably took place in a very short time.

Since the diet of *B. tyrannus* in summer and fall included phytoplankton and suspended organic matter, its abundance in the pond estuary can immediately be realized from the food habits of *M. menidia.* Furthermore the rates of growth in both estuarine systems favorably compare with data from other studies (Welsh *et al.,* 1924; McHugh *et al.,* 1959) and indicate that the nutrition for this species must have been adequate in both environments.

The predators and most parasites did not seem to harm the populations of young fishes. However the sporozoan parasites, *Glugea hertwigi,*

161

common in *Osmerus mordax* and *P. americanus,* indicated harmful effects in the latter species. The comparative higher infection and markedly low catches of *P. americanus* in the lower pond to an extent of almost one-fourth the collections from the lower river point to possible mortality that may have incurred (Tables I and IX). Almost total depletion of food in heavily infected stomachs indicated feeding may have been adversely affected by presence of these parasites, but average growth in both the study areas did not show any variation, possibly due to an inequality in sample sizes. But in all cases of heavy infection, the digestive tissues were found badly attacked and showed signs of obliteration. Kudo (1947) and Duijn (1956) found dead and dying cells in infected tissues in fishes caused by *Glugea hertwigi* and allied species, and have reported that the host dies in advanced stages of the disease. While there are indications of some mortality caused by the infection, at the present preliminary state of study exact estimates are not possible. This problem needs a thorough investigation to determine the extent of mortality caused by these parasites.

The results show that in this instance a river estuarine system with greater river influences is a more important nursery area than a pond estuarine system with neritic conditions. The conclusions derived from the present study provide some basis for launching detailed and comprehensive future ecological studies of young fishes in other estuaries along the coast of Rhode Island, Narragansett Bay and its tributaries. These estuaries probably play an important role in maintaining the bay and coastal fisheries.

VII. SUMMARY

1. Shore seining of juvenile fishes was carried out in the lower Petta-quamscutt River and the lower Point Judith Pond from July 11 to October 20, 1962.

2. Based on the salinity "conflict" during a tidal cycle the lower Petta-quamscutt River is characterized as a "gradient zone" having a distinct salinity gradient while the lower Point Judith Pond (Figs. 1 and 2) is characterized as a "marine zone" which has near neritic conditions.

3. In a total of 41 species of young fishes 36 were recorded from the lower river and 24 from the lower pond. Fifteen species in the lower river and 11 in the lower pond appeared consistently; the rest appeared sporadically or were rare. Sixteen species recorded from the lower river and four from the lower pond were found only in those localities and not the other.

4. The abundance and diversity of various species of young fishes provided evidence that these two estuarine environments are heavily used as nursery grounds.

5. The abundance of young fishes fluctuated with the rise and decline in temperature. The greatest abundance of fishes was observed in mid-August while a few individuals of resident species remained in catches in late October.

6. No correlation between changes in salinity and in abundance of fishes was noticed. But anadromous, catadromous and certain other species (Table I) occurred only in the river estuary, where the salinity gradient extends from near neritic conditions to a fresh water environment.

162

7. There was no relationship observed between maximum abundance of fishes and maximum number of species appearing at any one time. Peaks in abundance of fishes were recorded in late July and August while peaks in species occurred in September.

8. The growth computations of certain selected species demonstrated that weekly intervals are too short to deduce satisfactory growth rates. Semimonthly or monthly intervals exhibited significant rates of growth. The estimation of an accurate rate of growth of *Menidia menidia* appearing in September and October was not possible because of an admixture of fish of uncertain age groups.

9. The abundance and diversity of taxonomic groups of food organisms was greater in the Pettaquamscutt River estuary.

10. Young *P. americanus* and *M. menidia* demonstrated change in preference for larger prey organisms with the change in size of the young fishes in both estuarine systems. Juvenile *B. tyrannus* consumed the same type of diet irrespective of increases in size.

11. Both juvenile and adult *M. menidia* depended largely on phytoplankton as food in the pond estuary. An apparent scarcity of carnivorous food motivated the larger fish to substitute phytoplankton as "forced diet."

12. The lower Pettaquamscutt River has greater river influences, and a higher profusion of benthic plant life than the lower Point Judith Pond. The environmental conditions observed in the lower river indicate that the former estuarine system is more favorable as a nursery ground for the young fishes.

13. While predators and most parasites did not demonstrate any noticeable harm to fish populations, infection by the sporozoan parasite *Glugea hertwigi*, was a possible cause of low catches of *P. americanus* particularly in the lower pond.

14. Based on the analyses of results, the parameters of abundance growth and food habits of selected species indicated the lower river estuary as the more favorable nursery ground.

VIII. ACKNOWLEDGEMENTS

IX. BIBLIOGRAPHY

Adolf, E. F. 1925. Some physiological distinctions between fresh and marine organisms. Biol. Bull., 48: 327-335.

Allen, K. B. 1935. The food and migration of the Perch (*Perca fluviatilis*) in Windermere. Jour. Anim. Ecol., 4: 246-273.

Berry, R. J. 1959. Critical growth studies of winter flounder *Pseudopleuronectes americanus* (Walbaum), in Rhode Island waters. M. S. dissertation, University of Rhode Island.

Bhattacharyya, R. N. 1957. The food and feeding habits of larval and post-larval herring in the Northern North Sea. Jour. Mar. Res. (Lond.), 3: 1-15.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull., U. S. Fish Wild. Serv., 53(74): 577 pp.

Brodski, K. A. and A. J. Jankovskaya. 1935. Contribution to the knowledge of food of the far eastern sardine. Bull. Far East. Br. Acad. Sci. U.S.S.R., No. 13: 102-114. (Translated by A. S. Loukashkin, Calif. Acad. Sci., San Fran.).

Brown, C. L. 1962. On the ecology of Aufwuchs of *Zostera marina* in Charlestown Pond, Rhode Island. M.S. dissertation, University of Rhode Island.

Conover, J. T. 1958. Seasonal growth of benthic marine plants as related to environmental factors in an estuary. Publ. Inst. Mar. Sci., (Univ. Texas), 5: 97-147.

Covill, R. W. 1959. Oceanography of Long Island Sound. Food and feeding habits of larvae and post-larvae of *Ammodytes americanus*. Bull. Bingham Oceanogr. Coll., 17(1): 125-146.

Crisp, D. J. 1926. The planktonic stages of the Cirripedia *Balanus balanoides* (L) and *Balanus balanus* (L) from North Temperate waters. Crustaceana, 3(3): 207-221.

Cupp, E. E. 1943. Marine plankton diatoms of the West Coast of North America. Bull. Scripps Inst. of Oceanogr., 5(1): 1-238.

Day, J. H. 1951. The ecology of the South African Estuaries. Transac. Roy. Soc. S. Africa., 33: 53-91.

Duijn, C. V., Jr. 1956. Diseases of Fishes. Water Life. Dorset House, Stamford St., London. 174 pp.

Emery, K. O., R. E. Stevenson and J. W. Hedgpeth. 1957. Estuaries and Lagoons. I. Physical and chemical characteristics. Treatise on Marine Ecology and Paleoecology, Vol. I Ecology. Geol. Soc. Amer. Memoir, 67: 673-750.

Fish, C. J. 1925. Seasonal distribution of the plankton of the Woods Hole region. Bull. U. S. Bur. Fish., 41: 91-179.

Goode, G. B. and W. O. Atwater. 1880. A History of the Menhaden with an Account of the Agricultural Uses of the Fish. Orange Judd Co., New York. 529 pp.

Greeley, J. R. 1939. Fishes and habitat conditions of the shore zones based upon July and August seining investigations. A biological survey of the salt waters of Long Island, 1938 pt. II, No. XV. Suppl 28th Ann. Rept. New York Conserv. Dept. :79-99.

Hartley, P. H. T. 1947. Food and feeding relationship in a community of fresh water fishes. Jour. Anim. Ecol., 17: 1-14.

Hatanaka, Masayoshi, Masaya Kosaka and Yuji Sato. 1956. Growth and food consumption in Plaice. Part I. *Limanda yokohamae* (Günther). Tohuku J. Agric. Res., 7: 157-162.

Herre, A. W. C. T. 1956. Marine fishes in fresh water. Science, 123(3206): 1035.

Herman, S. S. 1958. The planktonic fish eggs and larvae of Narragansett Bay. M.S. dissertation, University of Rhode Island.

Hiatt, R. W. and D. W. Strasburg. 1960. Ecological relationship of the fish fauna in coral reefs of the Marshall Islands. Ecol. Monogr., 30: 65-127.

Hicks, S. D. 1958. Distribution of Salinity in Pettaquamscutt River. Pettaquamscutt River Investigation, Div. Fish and Game and Narragansett Mar. Lab., 1-4.

Hildebrand, S. F. and W. C. Schroeder. 1927. Fishes of Chesapeake Bay. Bull. U. S. Bur. Fish., 43(1): 1-366.

Hile, Ralph. 1948. Standardization of methods of expressing lengths and weights of fish. Trans. Amer. Fish. Soc., 75: 157-164.

Hjort, Johan. 1926. Fluctuation in the year class of important food fishes. Jour. Cons. Int. Explor. Mer., 1: 5-39.

Horton, D. B. 1958. The occurrence and distribution of fish in Upper Pettaquamscutt River as related to certain chemical and physical variables. M.S. dissertation, University of Rhode Island.

Hubbs, C. L. and A. Perlmutter. 1942. Biometric comparison of several samples, with particular reference to social investigations. Amer. Nat., 76: 582-592.

Hubbs, C. L. and C. Hubbs. 1953. An improved graphical analysis and comparison of series of samples. Systematic Zool., 2: 49-57.

Huntsman, A. G. and M. I. Sparks. 1924. Limiting factors for animals. 3. Relative resistance to high temperature. Contr. Canada Biol., N.S. 2(6): 95-114.

Ivlev, V. S. 1945. Density and character of food distribution as factors determining the size of the ration in fishes. Zool. Zhurnal, 24(2): 112-125.

Jeffries, H. P. and T. J. Smayda. 1954. Late winter and early spring plankton populations in the Pettaquamscutt River, a brackish estuary in Rhode Island. Unpubl. Report, Narragansett Marine Laboratory.

⸻⸻⸻. 1962. Salinity-space distribution of the estuarine copepod genus *Eurytemora*. Int. Rev. Hydrobiol., 47(2): 291-300.

Jordan, D. S. and B. W. Evermann. 1896-1900. The fishes of North and Middle America. Bull. U. S. Nat. Mus., No. 47. 1-4: 1-3313.

Kudo, R. R. 1947. Protozoology. 3rd Edition. Charles C. Thomas Publisher, Springfield, Illinois.

Kuntz, A. and L. Radcliffe. 1917. Notes on the embryology and larval development of twelve teleostean fishes. Bull. U. S. Bur. Fish., 35: 87-134.

McHugh, J. L., R. T. Oglesby, and A. L. Pacheco. 1959. Length, weight, and age composition of the menhaden catch in Virginia waters. Limm. Oceanogr., 4(2): 145-162.

McMaster, R. L. 1958. Distribution of bottom sediments. Pettaquamscutt River Investigation. Div. Fish and Game and Narr. Mar. Lab. Feb. 14, 1958, 3 pp.

Merriman, D. 1947. Notes on the mid-summer ichthyfauna of a Connecticut beach at different tide levels. Copeia, 4: 281-286.

Merriman, D. and R. C. Sclar. 1952. The pelagic fish eggs and larvae of Block Island Sound. Bull. Bingham Oceanogr. Coll., 13(3): 165-219.

Miner, Roy W. 1950. Field Book of Sea Shore Life. G. P. Putnam's Sons, New York. 888 pp.

Morris, R. W. 1955. Some considerations regarding the nutrition of marine fish larvae. Jour. int. Explor. Mer., 20: 255-265.

Pearcy, W. G. 1962. Ecology of young winter flounder in an estuary. Bull. Bingham Oceanogr. Coll., 18(1): 1-77.

Pearcy, W. G. and S. W. Richards. 1962. Distribution and ecology of fishes of Mystic River estuary, Conn. Ecology. 43(2): 248-259.

Pearse, A. S., H. J. Humm and G. W. Wharton. 1942. Ecology of sand beaches at Beaufort, North Carolina. Ecol. Monogr., 12: 135-190.

Peck, J. I. 1894. On the food of the menhaden. Bull. U. S. Fish Comm., (1893), 13(16): 113-126.

Perlmutter, Alfred. 1939. An ecological survey of young fish eggs identified from tow-net collections. A biological survey of the Salt Waters of Long Island, 1938, Pt. II, No. XV. Suppl. 28th Ann. Rept.: New York Conserv. Dept. 11-17.

_____. 1947. The black flounder and its fishery in New England and New York. Bull. Bingham Oceanogr. Coll., 9(2): 1-99.

Pettibone, M. H. 1963. Marine polychaete worms of the New England region. Smithsonian Inst., U. S. National Museum. Pub. No. 227, Part 1, 356 pp.

Prosser, C. L. and F. A. Brown, Jr. 1961. Comparative Animal Physiology. W. B. Saunders Company, Phila. 688 pp.

Richards, S. W. 1963. The demersal fish populations of Long Island Sound. Bull. Bingham Oceanogr. Coll., 18(2): 1-101.

Richardson, Harriet. 1905. A monograph of the isopods of North America. Bull. U. S. Nat. Mus., No. 54: 1-727.

Ricker, W. E. 1946. Production and utilization of fish populations. Ecol. Monogr., 16: 373-392.

Riley, G. A. 1937. The significance of Mississippi River drainage for biological conditions in the northern Gulf of Mexico: Jour. Mar. Res., 1(1): 60-74.

Rochford, D. J. 1951. Studies in Australian hydrography. I. Introductory and comparative features. Austr. J. Mar. Fresh. Res., 2(1): 1-116.

Rose, M. 1933. Faune de France, Copepodes pelagique. Paul Lechevalier, Paris. 372 pp.

Rounsefell, G. A. and W. E. Everhart. 1953. Fishery Science. Its methods and applications. John Wiley and Sons. New York. 444 pp.

Shaw, Evelyn. 1960. The development of schooling behavior in fishes. Physiol. Zool., 33: 79-86.

Shelbourne, J. E. 1953. The feeding habits of plaice post-larvae in the Southern Bight. J. Mar. Biol. Ass. U.K., 32: 149-159.

Shuster, C. N., Jr. 1959. A biological evaluation of the Delaware Bay estuary. Information Series, Publ. No. 3, University of Delaware Marine Lab. 1-77 pp.

Smith, H. M. 1898. The fishes found in the vicinity of Woods Hole. Bull. U. S. Fish. Comm., 1897. 17: 85-111.

Steven, G. A. 1933. The food consumed by Shags and Cormorants around the shores of Cornwall (England). J. Mar. Biol. Ass. U.K., 19: 277-292.

Stommel, H., and H. G. Farmer. 1953. Control of salinity in an estuary by transition. Jour. Mar. Res., 12(1): 13-20.

Tracy, H. C. 1906. A list of the fishes of Rhode Island. 36th Ann. Rept. Comm. of Inland Fisheries, Rhode Island: 38-99.

——————. 1910. Annotated list of fishes known to inhabit the waters of Rhode Island. 40th Ann. Rept. Comm. of Inland Fisheries, Rhode Island: 35-176.

Verril, A. E. 1871. On the food and habits of some marine fishes. Amer. Nat., 5: 399.

Warfel, H. E. and D. Merriman. 1944. Studies on the marine resources of south New England. 1. An analysis of the fish population of the shore zone. Bull. Bingham Oceanogr. Coll., 9(2): 1-91.

Welsh, W. W., and C. M. Breder, Jr. 1924. Contribution to life histories of Sciaenidae of the eastern United States Coast. Bull. U. S. Bur. Fish., 39: 141-201.

Westman, J. R., and R. F. Nigrelli. 1955. Preliminary studies of menhaden and their mass mortalities in Long Island Sound and New Jersey waters. N. Y. Fish. and Game. Jour., 2: 142-153.

Wheatland, S. B. 1956. Oceanography of Long Island Sound, 1952-1953. VII. Pelagic fish eggs and larvae. Bingham Oceanogr. Coll., 15: 234-314.

Wilson, C. B. 1932. The copepods of the Woods Hole region. Bull. Nat. Mus., No. 158. 635 pp.