# BULLETIN OF THE BINGHAM OCEANOGRAPHIC COLLECTION

The *Bulletin of the Bingham Oceanographic Collection,* established by Harry Payne Bingham (Yale 1910) in 1927, published scientific articles and monographs on marine and freshwater organisms and oceanography for the Bingham Oceanographic Collection at Yale University.

The series ceased independent publication after Volume 19, Article 2, and was merged into the *Bulletin of the Peabody Museum of Natural History* monograph series after 1967.

See also the Bingham Oceanographic Collection Archives,
Invertebrate Zoology, Yale Peabody Museum, in the Archives at Yale:
https://archives.yale.edu/repositories/15/resources/11140



Yale PEABODY MUSEUM OF NATURAL HISTORY

P.O. Box 208118 | New Haven CT 06520-8118 USA | peabody.yale.edu

BULLETIN

OF

THE BINGHAM OCEANOGRAPHIC COLLECTION

PEABODY MUSEUM OF NATURAL HISTORY
YALE UNIVERSITY

VOL. IX, ART. 2

# STUDIES ON THE MARINE RESOURCES OF SOUTHERN NEW ENGLAND

# I. AN ANALYSIS OF THE FISH POPULATION OF THE SHORE ZONE

BY HERBERT E. WARFEL AND DANIEL MERRIMAN
*Bingham Oceanographic Laboratory*

*Issued October, 1944*
*New Haven, Conn., U. S. A.*

PUBLISHED BY

BINGHAM OCEANOGRAPHIC LABORATORY

"Founded for the Purpose
of Oceanographic Research"

# STUDIES ON THE MARINE RESOURCES OF SOUTHERN NEW ENGLAND

# I. AN ANALYSIS OF THE FISH POPULATION OF THE SHORE ZONE[1]

By Herbert E. Warfel and Daniel Merriman
*Bingham Oceanographic Laboratory*

## CONTENTS

| | Page |
|---|---|
| Abstract | 2 |
| Introduction | 3 |
| The Locality | 4 |
| Methods | 5 |
| Analysis of the Fish Population by Species | 7 |
| *Menidia menidia notata* | 9 |
| *Pseudopleuronectes americanus* | 16 |
| *Syngnathus fuscus* | 23 |
| *Fundulus heteroclitus* and *majalis* | 29 |
| *Brevoortia tyrannus* | 35 |
| *Spheroides maculatus* | 38 |
| *Microgadus tomcod* | 42 |
| *Cynoscion regalis* | 44 |
| *Scophthalmus aquosus* | 48 |
| *Menticirrhus saxatilis* | 50 |
| *Clupea harengus* | 51 |
| *Myoxocephalus aeneus* | 53 |
| *Pomatomus saltatrix* | 55 |
| *Prionotus evolans evolans* | 55 |
| *Anchoa mitchilli* | 56 |
| *Bairdiella chrysura* | 57 |
| *Tautoga onitis* | 58 |
| *Synodus foetens* | 59 |
| The Less Abundant Species | 59 |

[1] The authors acknowledge with gratitude the cooperation of the Connecticut State Board of Fisheries and Game and the Woods Hole Oceanographic Institution, without whose generous support these studies could not have been completed at this time.

*Page*

PHYSICAL ASPECTS OF THE ENVIRONMENT . . . . . 61
Temperature . . . . . 61
Salinity . . . . . 66
Light . . . . . 66

ANALYSIS OF THE FISH POPULATION AS A WHOLE . . . . . 68
Major Categories . . . . . 68
Geographical Distribution . . . . . 68
Size . . . . . 74
Size Stratification . . . . . 75
Abundance . . . . . 76
Relative Abundance . . . . . 80
Total Abundance . . . . . 83

## ABSTRACT

Regular biweekly haul-seine collections of fishes were made at Morris Cove, New Haven Harbor, Connecticut, from July 1942 through June 1943. The objectives were: 1. to determine the precise nature of the population; 2. to reveal methods needed for more detailed analyses of the life histories of the different fishes encountered; 3. to gather as much data as possible on the smaller inshore species—this information to form the basis for further studies of those fishes that are commercially important, either directly or indirectly. The collections involved 16,525 individuals distributed among 32 species.

An analysis of the fish population by species includes discussions of each of the 18 most abundant forms, of which the commonest were *Menidia menidia notata*, *Pseudopleuronectes americanus*, *Syngnathus fuscus*, *Fundulus heteroclitus* and *majalis*, and *Brevoortia tyrannus*. Length-frequency curves and life-history data are presented, and the problems arising from the spatial and temporal differences in the spawning of many of the individual species, as well as the resultant intermixture of the young produced at different periods and in different areas are emphasized.

There were definite relationships between temperature and the population of fishes as a whole as well as the component species. Low winter temperatures apparently excluded all species. Salinity was not a limiting factor. Abundance appeared to be conditioned in part by the degree of turbidity.

An analysis of the fish population as a whole includes classification on the basis of geographical distribution and size. Evidence is presented that the shore-zone fishes are definitely limited as to the size at which they occupy this biotope. With few exceptions the different species are not found in the area after they reach approximately 100 mm. This size stratification holds regardless of age.

That the sandy-bottom, shallow-water shore zone under consideration is a definite ecological entity is clear from the highly characteristic population of fishes it contained. The discussion of abundance involves consideration of a constantly shifting population of apical dominants at the peak of an Eltonian pyramid. In any ecosystem organized in trophic levels there are apical, intermediate, and basal dominants. The apical dominant includes the species of the highest level controlling the

biocoenosis. The basal dominant includes the controlling organisms at the lowest level. Normally the apical dominant will be the largest common predator, the basal dominant the major photosynthetic species. The composition of the aggregation of fishes here considered is never twice the same and the precise make-up of the peak of the Eltonian pyramid thus varies correspondingly.

The numbers of fishes are considered in terms of *relative* and *total* abundance. The former approach indicates the relative position of the various species on any given date, and when summarized gives a true expression of positional values regardless of the influence of extraordinary numbers of individuals present on any one day. The latter approach indicates the fluctuations in total numbers collected on one day; when summarized, the total abundance of a single species in terms of the percentage of the whole of the collections for the entire study is shown. Analysis of the total abundance of the species by collection dates suggests a possible effect of population pressure on the number of individuals, *i. e.*, the population of fishes showed a tendency to build up to maximal levels, with subsequent sudden dispersal, after which the numbers increased again until the quantities were sufficient to cause repetition of this cycle of events. Summarization of the data shows that the species occupying the first six ranks of relative abundance made up 92% of the volume of all the collections, but dominated the individual collections, and hence the fish population of the biotope, only 63% of the time.

## INTRODUCTION

The present analysis is based on regular, biweekly haul-seine collections of fishes from Morris Cove, New Haven Harbor, Connecticut, over a complete year, from July 1942 through June 1943. There were three objectives in the work. The first was to determine the nature of the population—the permanent and transient residents found in that particular habitat, with special emphasis on the relative abundance of the various components on a seasonal basis. The second objective was to reveal methods needed for more detailed analyses of the life histories of the different fishes encountered. The third, and in many respects the most important, was to gather as much data as possible on the smaller inshore species—this information to form the basis for further studies of those fishes that are commercially important, either directly or indirectly. Some of the species of the shore zone of Long Island Sound are the young of individuals that later become significant elements in different commercial fisheries. Others may be important as sources of food for more desirable forms, or as competitors, either in the early stages of development when they live in the shore zone or later when they occupy deeper water habitats. Therefore, studies of this nature contribute directly to the solution of problems involving rational utilization, the causes of

fluctuations in abundance, and other fundamental aspects of fishery biology.

In all probability it would be possible to summarize the seasonal occurrence of the various species of fish of the Connecticut shore-line from the previously published reports of such authors as Baird (1889), Gill (1873, 1905), Goode and Bean (1879), T. H. Bean (1888, 1901, 1903), Tracy (1906, 1910), Fowler (1918), Gigelow and Welsh (1925), and Nichols and Breder (1926). However, compiling this information for the purposes outlined above would be difficult, inasmuch as most of these papers were not written with these objectives in mind. Further information along these lines is found in the works of Greeley (1939), Perlmutter (1939), and Pearse, Humm, and Wharton (1942); but even these differ in their approach. To accomplish the aims indicated above, therefore, it seemed desirable to conduct an investigation designed especially for the purpose. It is with the listed objectives in mind that this report is presented, in the hope that other investigators will find in it material for reference and comparison with data from other areas.

*The Locality.* Morris Cove is a curving beach approximately a mile in length on the east side of New Haven harbor. It has direct exposure to the west, but is sheltered from the open part of Long Island Sound a mile to the south by harbor breakwaters. The shore is lined with houses, and the area is popular with summer bathers—factors which contribute to the large amount of extraneous material which often lines the beach.

The slope of this cove is such that at no place does the depth exceed 12 feet at mean high tide, and at extreme low tide not over 50 yards of the bottom is exposed at any place. The bottom is predominantly sand, with occasional small and partially buried boulders which do not impede seining operations or offer shelter for fishes. Except for the fact that there are considerable areas of rocks at the extreme ends of the beach, Morris Cove could be described as a sandy beach biotope after the classification of Hesse, Allee and Schmidt (1937). Strictly speaking, however, two other limitations would need to be placed on this designation, for the area is not directly exposed to the sea, nor is it large in size when compared with the great expanses of beach on other sections of the Atlantic shore. Also, it should be emphasized that this study covered only a portion of the biotope, in that collections were made at low tide and did not extend far from the shore.

*Methods.*[2] All the fish were taken in a standard minnow seine, four feet deep and 30 feet long. Collections were always made during the low tide period. In general, hauls were roughly parallel to the shore line, except when the catch was brought to the beach at the conclusion of each seining operation. The area fished never exceeded a distance of more than 100 feet from the low tide mark, and the maximum depth reached by this method was four feet. Seining was confined essentially to the southern half of Morris Cove, and this area was worked in as uniform a manner as conditions permitted on each collection date. However, several times during the winter Morris Cove was frozen; under these circumstances hauls were made in nearby regions of much the same character, but where the type of exposure had prevented freezing. Since no fish were taken for some time before, on, or after the dates of freezing, there is every reason to assume that the validity of the data is in no way impaired by the fact that Morris Cove itself could not be seined on these occasions. In seining Morris Cove, the number of hauls varied with the conditions—*i. e.*, in some instances three long hauls were made, while in others six short drags were needed to cover the area effectively. But with the exception of the dates on which the cove was frozen, approximately the same area was worked as thoroughly as possible. Therefore, the fishing effort on each occasion can be considered roughly equivalent, and variations in abundance, as reflected in the catch, are probably reasonably accurate indications of population conditions in the area under consideration.

Notes on the temperature, tide, condition of the water, weather, etc., were made in the field, although full information is lacking for some collection dates (Table I). The temperature of the water was recorded regularly, and air temperatures were available from the local weather station. Water samples were taken at the time of collection, and the total salinity was determined in the laboratory by means of a suitable hydrometer.

[2] The authors were fortunate in receiving the help of Drs. Samuel F. Hildebrand and Charles M. Breder, Jr., in checking certain difficult identifications. They are also indebted to Yngve H. Olsen for his generous assistance both in the field and laboratory work, as well as in the preparation of the manuscript. They further take pleasure in acknowledging the help of various people associated with the Bingham Oceanographic Laboratory in different capacities since 1942—especially Andrew H. Wolff, Yale 1946, who did the illustrations in this paper, and Dr. G. E. Hutchinson, whose frequent suggestions and friendly interest have been a constant source of pleasure and stimulus to both authors.

TABLE I. FIELD DATA, MORRIS COVE, NEW HAVEN, CONNECTICUT, 1942–43

| *Date* | *Temperature in °C.* | | *Weather* | *Tide* | *Water* |
|---|---|---|---|---|---|
| | *Air* | *Water* | | | |
| VII–10–42 | 27.0 | 21.5 | Hazy | Low | .... |
| VII–24–42 | 25.6 | 25.1 | Partly cloudy | Low | .... |
| VIII–7–42 | 24.6 | 23.6 | Partly cloudy | Low | .... |
| VIII–21–42 | 28.2 | 26.8 | Partly cloudy | Low | .... |
| IX–4–42 | 25.9 | 23.9 | Cloudy | Rising | .... |
| IX–18–42 | 23.5 | 22.3 | Overcast | Low | Calm |
| X–2–42 | 15.2 | 17.1 | Fair | Low | Rough |
| X–16–42 | 17.0 | 16.6 | Overcast | Low | Turbid |
| X–30–42 | 16.3 | 12.7 | Clear | Low | Clear |
| XI–13–42 | 9.8 | 9.1 | Overcast | Low | Very turbid |
| XI–26–42 | 9.8 | 8.1 | Cloudy | .... | Turbid |
| XII–11–42 | 2.9 | 4.2 | Cloudy | Low | Slightly turbid |
| XII–24–42 | 2.2 | −0.4 | Overcast | Rising | .... |
| I–8–43 | −7.8 | −0.3 | Fair | Rising | Clear |
| I–22–43 | 0.0 | 1.2 | Fair | Rising | Clear |
| II–5–43 | 4.4 | 0.5 | Fair | Rising | Clear |
| II–19–43 | 2.8 | 0.6 | Fair | Falling | .... |
| III–5–43 | 7.2 | −0.2 | Hazy | Low | Rough |
| III–19–43 | 4.4 | 1.9 | Rain | .... | Clear |
| IV–1–43 | 9.0 | 5.6 | Fog | Rising | Slightly turbid |
| IV–16–43 | 16.1 | 6.2 | Snow | Falling | .... |
| IV–30–43 | 23.5 | 7.3 | Rain | Falling | Turbid |
| V–14–43 | 14.0 | 12.5 | Clear | Low | .... |
| V–28–43 | 21.0 | 18.4 | Partly cloudy | Low | .... |
| VI–11–43 | 22.5 | 19.4 | Partly cloudy | Low | Turbid |
| VI–25–43 | 28.9 | 24.1 | Hazy | Low | Very turbid |

The fishes were preserved in 10% formalin in the field. Identification, sorting and measuring were done after preservation. Measurements were made to the nearest millimeter by means of dividers, the standard length being used throughout. The measurements were grouped by five-millimeter intervals, both in the presentation of length-frequency data and in the calculation of mean lengths wherever the number of specimens warranted such treatment. Exceptions were *Syngnathus fuscus* (Table IV, Fig. 6), where 10-millimeter intervals were used for both purposes, and *Clupea harengus* (Table XIV), where the data were grouped by two-millimeter intervals in calculating mean lengths. In Tables II–XXI the mean values for the standard lengths are listed for those collections and parts of collections that were relatively homogeneous, *i. e.*, where the range

was narrow and the numbers were large. Where the collection was small and the range wide-spread, no mean was calculated, but the values for the range in length are listed.

Identification of the fishes was checked with the aid of standard references for this region. Nichols and Breder (1926), Breder (1929), Hildebrand and Schroeder (1928), Bigelow and Welsh (1925), and Jordan and Evermann (1896–1900), were the principle sources, although more specialized material was used when necessary, *e. g.*, Hildebrand (1943), Norman (1934). The nomenclature used is largely that of Breder (*loc. cit.*), and the system of classification that of Jordan, Evermann, and Clark (1930); however, it should be mentioned in this connection that the system of Berg (1940) has many advantages.

## Analysis of the Fish Population by Species

The total collections from Morris Cove involved more than 16,000 individuals. There were 32 species distributed among 21 families from 12 orders as shown below.

Order ISOSPONDYLI
- Family Clupeidae
  - *Clupea harengus* Linnaeus
  - *Pomolobus pseudoharengus* (Wilson)
  - *Brevoortia tyrannus* (Latrobe)
- Family Engraulidae
  - *Anchoa mitchilli* (Cuvier and Valenciennes)
- Family Osmeridae
  - *Osmerus mordax* (Mitchill)

Order APODES
- Family Anguillidae
  - *Anguilla rostrata* (Le Sueur)

Order INIOMI
- Family Synodontidae
  - *Synodus foetens* (Linnaeus)

Order CYPRINODONTES
- Family Cyprinodontidae
  - *Fundulus heteroclitus* (Linnaeus)
  - *Fundulus majalis* (Walbaum)

Order ANACANTHINI
Family GADIDAE
*Pollachius virens* (Linnaeus)
*Microgadus tomcod* (Walbaum)
*Urophycis tenuis* (Mitchill)
*Urophycis regius* (Walbaum)
Order HETEROSOMATA
Family PLEURONECTIDAE
*Pseudopleuronectes americanus* (Walbaum)
Family BOTHIDAE
*Scophthalmus aquosus* (Mitchill)
Order THORACOSTEI
Family GASTEROSTEIDAE
*Pygosteus pungitius* (Linnaeus)
*Apeltes quadracus* (Mitchill)
Family SYNGNATHIDAE
*Syngnathus fuscus* (Storer)
Order PERCOMORPHI
Family ATHERINIDAE
*Menidia menidia notata* (Mitchill)
Family CARANGIDAE
*Caranx hippos* (Linnaeus)
Family POMATOMIDAE
*Pomatomus saltatrix* (Linnaeus)
Family SCIAENIDAE
*Bairdiella chrysura* (Lacépède)
*Leiostomus xanthurus* (Lacépède)
*Menticirrhus saxatilis* (Bloch and Schneider)
*Cynoscion regalis* (Bloch and Schneider)
Order CATAPHRACTI
Family COTTIDAE
*Myoxocephalus aeneus* (Mitchill)
Family TRIGLIDAE
*Prionotus evolans evolans* (Linnaeus)
*Prionotus carolinus* (Linnaeus)
Order PHARYNGOGNATHI
Family LABRIDAE
*Tautogolabrus adspersus* (Walbaum)
*Tautoga onitis* (Linnaeus)

Order JUGULARES
Family BATRACHOIDIDAE
*Opsanus tau* (Linnaeus)
Order PLECTOGNATHI
Family TETRAODONTIDAE
*Spheroides maculatus* (Bloch and Schneider)

Before attempting comprehension of the total population of fishes at different times of year, or before any conclusions can be drawn as to the general nature and characteristics of the whole fish fauna, it is essential to consider the individual components as distinct entities. Hence each species is discussed separately below. Most of the material presented constitutes a brief summarization of pertinent data which provides certain evidence regarding the nature of the whole population. Also, each species obviously offers interesting possibilities for further and more detailed study. The arrangement of the following list is in order of abundance as determined by a scoring method which is described later (p. 80).

*Menidia menidia notata* (Mitchill)

The most persistent and abundant fish in the Morris Cove area was *Menidia menidia notata.* This species was taken 17 times out of a possible 26 and consistently ranked first in abundance from July through mid-October, 1942. On October 30 it was superseded by a large school of *Brevoortia tyrannus,* and on November 13, it was apparently driven out by very turbid water. On November 26 and December 11, *M. menidia notata* was again the most prevalent form, but by that time the temperatures were low and the numbers of individuals and species encountered had fallen considerably (Fig. 17). No silversides were taken from mid-December until the spring of 1943. *M. menidia notata* first appeared in mid-April which was the first collection of that year that contained an appreciable number of fishes, but at no time until June did it appear in large quantities. On June 11, under fairly favorable circumstances, larger numbers of these fish were taken as shown in the curve of abundance (Fig. 1). The last collection was made under unfavorable conditions, the water being turbid, so that the total number went down again. However, during

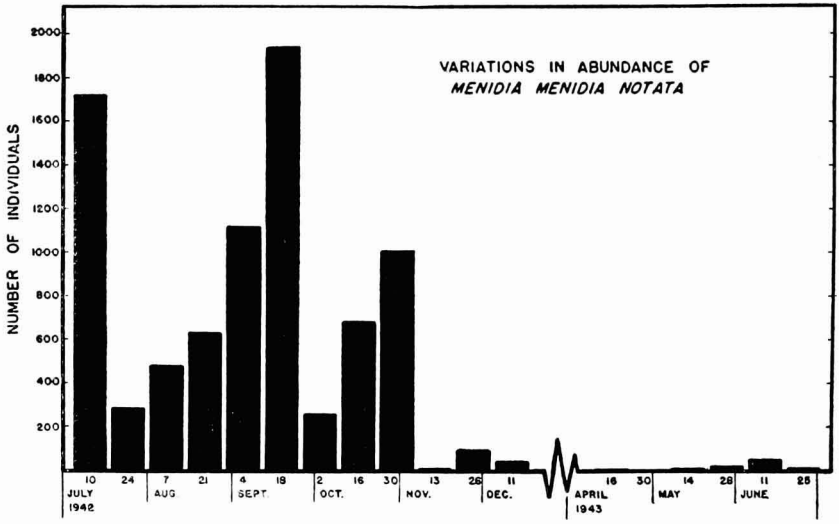


**Figure 1.** Variations in abundance of *Menidia menidia notata*. The break in the base line indicates the winter period when no fish were taken.

the last week in June, in the course of collections in the same area for other materials, general observations indicated that the population was tending to return to the original condition observed the previous year. On these trips gravid individuals of both sexes were encountered and a few scattered fish of-the-year (0+) were also taken for the first time in 1943.

Certain obvious trends in the numbers of *M. menidia notata* in the biweekly collections from July to November, 1942, are apparent in Fig. 1. It will be noted that following the peaks of abundance there was a sharp drop to a comparatively low level, and that on two occasions the numbers then gradually increased again. This suggests that *M. menidia notata* was a prominent part of a population of fishes which showed a tendency to build up to maximal levels until the area became overcrowded, with the result that sudden dispersal occurred, after which the numbers increased again until the quantities were sufficient to cause repetition of this cycle of events. This subject is more fully discussed in the section on the analysis of the fish population as a whole (pp. 83–85).

The first collection of *M. menidia notata* for this study was taken July 10, 1942, and consisted of 1722 individuals. With one exception,

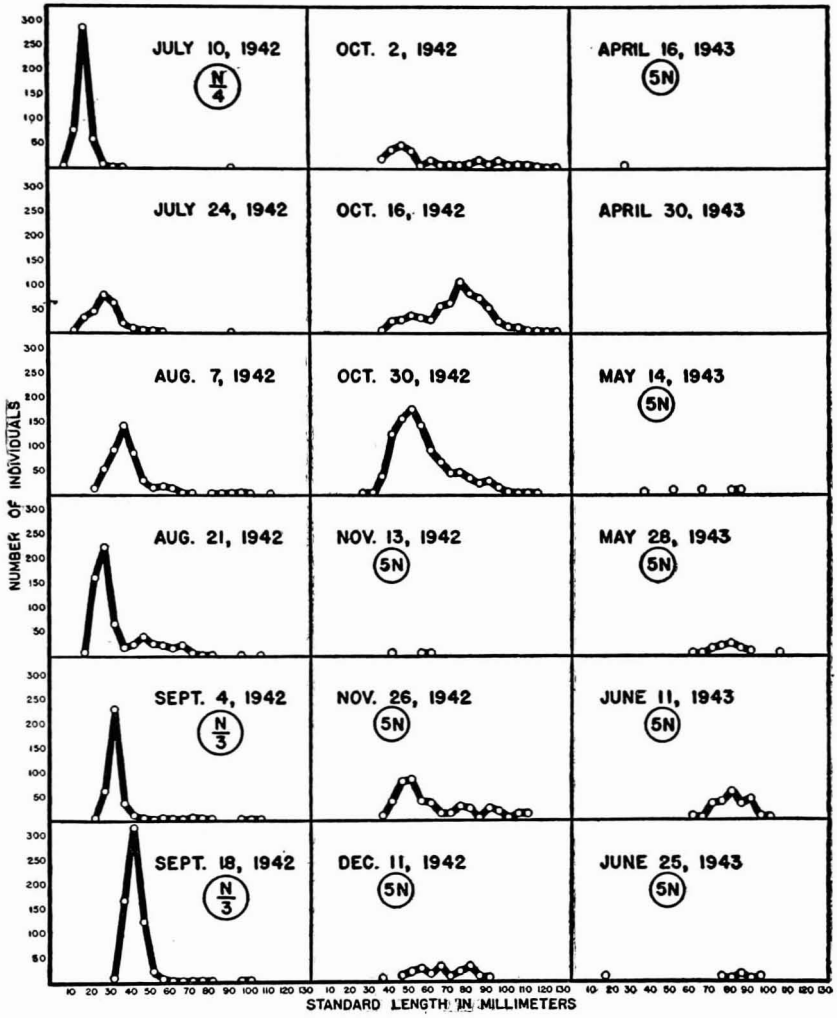


Figure 2. Length-frequency distribution of *Menidia menidia notata*. The encircled values represent adjustments of numbers of individuals to accommodate the data on one graph. N/4 indicates that the number of individuals has been divided by 4. 5N means the number of individuals has been multiplied by 5.

an individual 92 mm. long, it seems probable that all these were fish-of-the-year. It also seems probable that these fish developed in the neighborhood of Morris Cove since ripe individuals are encountered in that area in June, and also since the fish of the collection were so small as to make it unlikely that they had migrated any great distance. All but the single individual mentioned fell within the range from 7 to 39 mm., the mean being 16.99 mm. and the mode approaching the 15 mm. mark (Fig. 2).

The collection made on July 24 was considerably smaller, having only 282 individuals and was more heterogenous. The bulk of the collection fell within a range of 12 to 40 mm.; 23 fish were from 40 to 60 mm. long, and one was 95 mm. Exclusive of the latter specimen, the population had a mean standard length of 29.58 mm., and the mode was about 2 mm. less. It seems reasonable to assume that this collection represented the same population encountered two weeks earlier, and that the difference between the central tendencies is indicative of growth for that period, the increment being about 12.5 mm.

TABLE II. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF *Menidia menidia notata*

| *Date* | *Number* | *Size Range* (*S.L. in mm.*) | *Mean Size* (*S.L. in mm.*) | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–10–42 | 1722 | 7– 92 | 16.99 ± .79* | 3.30 ± .056 | 1 |
| VII–24–42 | 282 | 12– 95 | 29.58 ± .37* | 8.02 ± .341 | 1 |
| VIII–7–42 | 479 | 20–114 | 40.03 ± .59 | 12.96 ± .419 | 1 |
| VIII–21–42 | 629 | 19–106 | 33.25 ± .54* | 13.53 ± .382 | 1 |
| IX–4–42 | 1115 | 22–108 | 34.61 ± .31 | 10.47 ± .226 | 1 |
| IX–18–42 | 1938 | 30–101 | 42.23 ± .11* | 5.03 ± .081 | 1 |
| X–2–42 | 254 | 35–127 | 64.03 ± 1.47 | 23.40 ± 1.04 | 1 |
| X–16–42 | 661 | 35–129 | 74.98 ± .66 | 16.94 ± .47 | 1 |
| X–30–42 | 1003 | 27–118 | 58.32 ± .48 | 15.27 ± 3.41 | 2 |
| XI–13–42 | 3 | 42– 61 | ..... | ..... | 4 |
| XI–26–42 | 88 | 37–112 | 65.00 ± 2.20 | 20.62 ± 1.55 | 1 |
| XII–11–42 | 37 | 39–109 | 69.84 ± 2.44 | 14.63 ± 1.72 | 1 |
| IV–16–43 | 1 | .... | ..... | ..... | .. |
| V–14–43 | 9 | 37– 89 | ..... | ..... | 5 |
| V–28–43 | 20 | 62–105 | 81.50 ± 2.15 | 9.64 ± 1.52 | 5 |
| VI–11–43 | 49 | 62–101 | 82.20 ± 1.27 | 8.86 ± .895 | 3 |
| VI–25–43 | 11 | 15– 97 | ..... | ..... | 4 |

* One or two large individuals, obviously out of the range of the main body of the collected population, omitted from the calculation of the mean. See Fig. 2.

The third collection, taken August 7, was larger than the previous one but not as large as the first. It was not as homogeneous as either of the other two, and contained a considerable number of large individuals. Most of the fish within the lower limits of the length-frequency curve (Fig. 2) were probably fish of the year; further study should demonstrate that they were of essentially the same population as were the fish of the earlier collections. There were also 39 fish ranging in standard length from 55 to 75 mm., which might have belonged either to this same group, or on the other hand, might have been related more nearly to the 13 additional individuals that occurred within the 80 to 114 mm. range.

The fourth collection, taken August 21, was of particular interest in that it was larger than the two previous hauls, and that the range for the whole was practically the same as the population taken two weeks earlier, yet the mean for the entire group was 6 mm. less than the collection of August 7. Thus the collection of August 7 had a mean standard length of 40.03 mm., and the modal value for the bulk of the collection fell in the neighborhood of 37 mm. The collection of August 21, however, had a mean standard length of 33.25 mm., and the modal value for the population was 27 mm., 10 mm. less than the collection immediately preceding. There are a number of possible explanations for the presence of the smaller fish. It is possible, but highly improbable, that the males and females have differential growth rates in this species, and that the first collections consisted of fish mainly of one sex, while the population under consideration was dominantly of the opposite sex. It might also be true that the collection of August 21 represented a later brood of fish spawned in the vicinity of Morris Cove. And it is further possible that this was an entirely new population, of essentially the same age as the previous individuals, but which had migrated from other areas. Of the last two conjectures the first seems the more logical, especially in view of the apparently somewhat protracted spawning season of this species; however, this would perhaps indicate a more definite spawning rhythm than is generally attributed to marine fishes. Three modes appear in the length-frequency curve (Fig. 2): one, around 27 mm., another in the 45–49 mm. frequency, and another in the 65–69 mm. grouping. On the basis of the length-frequency data alone, it would appear that in all probability there were three major components of the population as follows: several individuals of previous year-classes

grouped around the higher mode, fish of the original population for the area of the 1942 year-class near the middle mode, and around the lowest mode, 0+ fish of a new population either from a subsequent spawning in the same area or from a spawning elsewhere.

The first collection made in September was almost twice as large in numbers of individuals as the collection immediately preceding. However, in terms of standard length, it was essentially the same, the range and mean standard length differing but little from the collection of August 21 (Table II). The modal value for the principal peak of the curve, on the other hand, was about 5 mm. greater (Fig. 2). A few individuals, 40 in number, were grouped around the 57 mm. point, and 37 fish ranging in length from 70 to 109 mm. were present. But the bulk of the specimens seemed to be fish-of-the-year from the same population as those of the preceding collection.

The largest single collection of *M. menidia notata* was taken September 18, there being 1938 individuals. The mean standard length for this population, except for two individuals 97 and 101 mm. long, was 42.23 mm., and the mode for the curve fell at the same point. Of this large number of individuals, 1899 were within the range of length between 30 and 52 mm., and 39 were larger, including the two fish excluded from the calculation of the mean. This collection seemed to stand in relationship to the two previous populations in the same manner as did the collection taken August 7, and a peak of abundance for the second new population of 0+ fish was reached at this time. The measurements on the collections of August 21, September 4 and 18 indicate the rate of growth of this new population to a certain extent only, for presumably this second group of fish did not all appear simultaneously and mixed with the first group of 0+ individuals over a period of time, so that neither mean values nor length-frequency curves indicate more than general growth trends. It also seems apparent that the population taken in mid-September, along with the two previous collections, represented the product of the peak of the spawning season, which probably occurred in July rather than in June as Nichols and Breder (1926) indicate.

The collection taken October 2 showed an abrupt drop in numbers from that of the preceding collection date. While the mean standard length was high, there was a considerable variation in size. The population appeared to be made up of the remnants of 0+ fish represented in previous collections, as well as a few stragglers of previous

year-classes which were still in the vicinity and moving with the younger fish. Also there is the distinct possibility that the mode at the 45 to 49 mm. frequency represented a new wave of 0+ individuals from another area.

On October 16, 661 individuals were taken. The fish of this collection, while varying widely in standard length, were much larger on the average than any population encountered previously. A study of the length distribution of this collection leads to the conjecture that fish of the earlier populations (July 10, 24, and August 7), or those from another area and of an average size comparable to the previously studied collections, dominated the population again on this date.

While *M. menidia notata* was taken in great numbers on October 30, it was superseded for the first time in relative abundance by the appearance of a large group of *Brevoortia tyrannus*. *M. menidia notata* was relegated to second place in rank of abundance, yet the collection contained 1003 individuals. The mean standard length was smaller than at any time since mid-September and the abundance of individuals leads to the conclusion that again a new population had moved into Morris Cove. It also seems reasonable to assume that the forerunners of this group accounted for the small mode on the 47 and 52 mm. marks on October 2 and 16, the growth rates being slow at this time owing to falling temperatures.

November 13 was an unfavorable day for collecting, for a strong west wind prevailed and the water was extremely turbid. This collection contained but six species represented by 285 individuals. Only three *M. menidia notata* were taken, all of them fish that could have come from the population of the year since they ranged in size from 42 to 61 mm. Even so, *M. menidia notata* ranked fourth in abundance, the more abundant species being demersal and probably not so much affected by the extreme turbidity.

*M. menidia notata* was present in the area again on November 26, when 88 silversides were taken in a collection of 118 individuals distributed among four species. This was a widely divergent population ranging from 37 to 112 mm. in length. The lowest mode, which had the greatest frequency, fell near 50 mm. (Fig. 2). New individuals had apparently continued to come into the area, and remnants of previous populations were still present in small numbers. It is interesting to speculate on the age of the smaller individuals. These fish must have been the product of the latest spawning of the year—pos-

sibly even later than July—and their growth rates may have been impeded due to descending temperatures.

The last collection for the 1942 season was taken on December 11. This was a small lot of 37 individuals, with a range in length which was much the same as the previous group; they probably represented the same population.

No *M. menidia notata* were taken after December 11, 1942, until April 16, 1943, when one individual was collected. On May 14, one month later, nine more were netted ranging in size from 37 to 89 mm.; probably these were mainly fish that were just becoming one year old. Two weeks later, May 28, 20 *M. menidia notata* were taken and on June 11, 49 fish of this species were collected from the area. The mean standard lengths of the last two collections were approximately the same (81 to 82 mm., see Table II), and it is probable that they were the forerunners of the spawning population for the season. The last collection, that of June 25, 1943, contained but 11 fish; two were fish of the year of 1943 and measured 15 and 17 mm., and the others were within the range from 75 to 97 mm., so that it would appear that *M. menidia notata* had spawned by early June, 1943, and some eggs had hatched.

### *Pseudopleuronectes americanus* (Walbaum)

*Pseudopleuronectes americanus*, the winter flounder, was the second most abundant fish found in Morris Cove. While it was taken 18 times out of a possible 26, which was once more than *Menidia menidia notata*, it was never as numerous in the single collections as the silverside. On three occasions more than 100 individuals were taken, as shown by the three pronounced peaks of abundance indicated in Figure 3. *P. americanus* achieved first rank twice (Table III), was second in abundance on six occasions, third once, fourth four times, fifth once, sixth twice, and seventh once. It was represented by a lone individual in the otherwise abundant collection of May 14, 1943.

*P. americanus* disappeared in mid-December, 1942, and appeared again in mid-April, 1943. It thus coincided with *Menidia*, and, on the basis of consistent presence, both species can be called residents, although as nearly as can be judged by the data at hand, breeding winter flounders rarely, if ever, come into the area from which these fish were collected. The presence of a few larger *P. americanus* would seem to indicate that a population of older individuals exists at certain

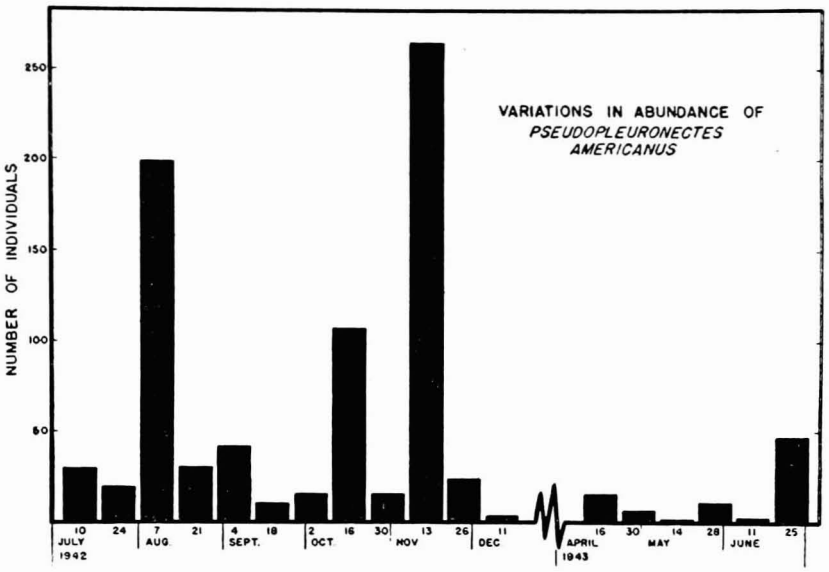


**Figure 3.** Variations in abundance of *Pseudopleuronectes americanus.*

TABLE III. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF *Pseudopleuronectes americanus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–10–42 | 30 | 31– 56 | 42.1 ± 1.03 | 5.66 ± .730 | 4 |
| VII–24–42 | 20 | 33–101 | ..... | ..... | 5 |
| VIII–7–42 | 199 | 27–117 | 46.4* ± .623 | 8.27 ± .441 | 2 |
| VIII–21–42 | 31 | 27–102 | 43.6* ± 1.79 | 9.66 ± 1.27 | 7 |
| IX–4–42 | 42 | 35–169 | 49.8* ± 1.35 | 8.32 ± .950 | 4 |
| IX–18–42 | 10 | 43– 66 | ..... | ..... | 6 |
| X–2–42 | 16 | 40–101 | ..... | ..... | 4 |
| X–16–42 | 107 | 35–127 | 57.9* ± .964 | 9.74 ± .682 | 2 |
| X–30–42 | 16 | 42–131 | ..... | ..... | 3 |
| XI–13–42 | 264 | 49–148 | 65.3* ± .669 | 10.32 ± .473 | 1 |
| XI–26–42 | 24 | 63–138 | ..... | ..... | 2 |
| XII–11–42 | 4 | 56– 83 | ..... | ..... | 2 |
| IV–16–43 | 16 | 48–142 | ..... | ..... | 1 |
| IV–30–43 | 11 | 38–141 | ..... | ..... | 2 |
| V–14–43 | 1 | 51 | ..... | ..... | .. |
| V–28–43 | 11 | 55– 78 | ..... | ..... | 6 |
| VI–11–43 | 2 | 61–132 | ..... | ..... | 4 |
| VI–25–43 | 47 | 19–112 | 32.1* ± .905 | 5.36 ± .640 | 2 |

* Only those fish in the lowest mode calculated in the mean standard length. Limits of the curves expressed in terms of the mean values are indicated in Fig. 4.

times just a little further off shore, and this is confirmed in part by small trawl collections made in the vicinity of New Haven Harbor in March and April, 1943. The specimens taken in the small trawl at this time ranged in size from 50 to 275 mm., with most of the individuals in the higher frequencies and the mode falling between 210 and 230 mm. None of the fish taken from Morris Cove were this large, and comparatively few were more than 100 mm. in length.

Several factors enter into any study of the winter flounder which make it extremely difficult, on the basis of length alone, to arrive at justifiable conclusions in respect to population analyses. For example, the length of the spawning period is a complicating factor. Considerable difference of opinion concerning the exact period of spawning in the waters of southern New England is manifest throughout the literature, although all authorities are in agreement that *P. americanus* is a winter-spawning fish. Bigelow and Welsh (1925) state that spawning takes place from January through March; Tracy (1910) and Smith (1898) give February to April; and Perlmutter (1939) thinks the dates from mid-December through May are more nearly correct. Other opinions on this subject agree in that they all fall in the same general period, but the limits of the spawning time are uncertain.

Another complicating factor is the matter of races, or more or less distinct subdivisions within the species. DeKay (1842) recognized two divisions of *P. americanus* which he designated as species, and recently Perlmutter (1939) described the differences between so-called "bay" and "sea" flounders and inferred that they conform to the earlier descriptions of DeKay. Size differences in the fish encountered in an area such as Morris Cove might be due to racial differences, but a careful analysis of the population from all viewpoints would be necessary to verify this.

Another factor that renders an analysis on the basis of length uncertain in *P. americanus* (and unquestionably other species) is the matter of compensating growth pointed out by Bigelow and Welsh (1925). These investigators state, "The rate of development of the larvae is governed by temperature, occupying from about 2½ to about 3½ months, according to the data available, and the larvae hatched later may catch up with the earlier ones before metamorphosis." If this be true in southern New England, the difficulty of a population analysis on the basis of length is obvious, for this phenom-

enon would tend to minimize the effect of a protracted spawning period.

In order to obtain information concerning the age of *P. americanus* of the sizes taken in this work (and so as to preserve the Morris Cove collections intact since they will be studied in greater detail later), the otoliths and scales of a small sample of fish collected at Bushnell Beach, Pine Orchard, Connecticut during the summer of 1943 were examined. This locality, a few miles east of New Haven, is in many respects similar to the Morris Cove area, except that it faces the open Sound. This study indicated that those individuals ranging up to about 60 mm. were in their first year of growth, while those above 100 mm. were in their second year, thus confirming the statements of Bigelow and Welsh (1925) concerning growth during early life of this species in southern New England.

The first collection from Morris Cove, that of July 10, 1942, contained 30 individuals, ranging from 31 to 56 mm. in length. The mean length of this collection was 42 mm., and it seems reasonable to assume that these were all fish-of-the-year.

The collection of July 24 contained 18 fish of approximately the same range of standard lengths as those of two weeks before, and in addition two larger fish, 94 and 101 mm.; these two individuals were of the same general size as the larger fish of this species taken through most of the collecting season at Morris Cove (Fig. 4). This population consisted of two groups—apparently fish-of-the-year and two individuals of the 1941 year-class, if the analysis of the Bushnell Beach sample is applicable to the Morris Cove area. On the other hand, it is possible that the two groups represent separate races produced in the same spawning season; however, it is improbable that the larger fish could have grown approximately 100 mm. during the period from spawning to July 24, when they were taken, especially since they would have had the benefit of only a relatively short period of good growth conditions.

The collection made on August 7 consisted of 199 individuals, which were divisible into two distinct groups, on the basis of length. The larger group, 176 fish, had a mean standard length of 46.4 mm. and were fish-of-the-year. The smaller group, in which the fish ranged from 83 to 117 mm., were either fish of the previous year-class, or fish of another race, as indicated above.

The collection made August 21 included 31 individuals, two of

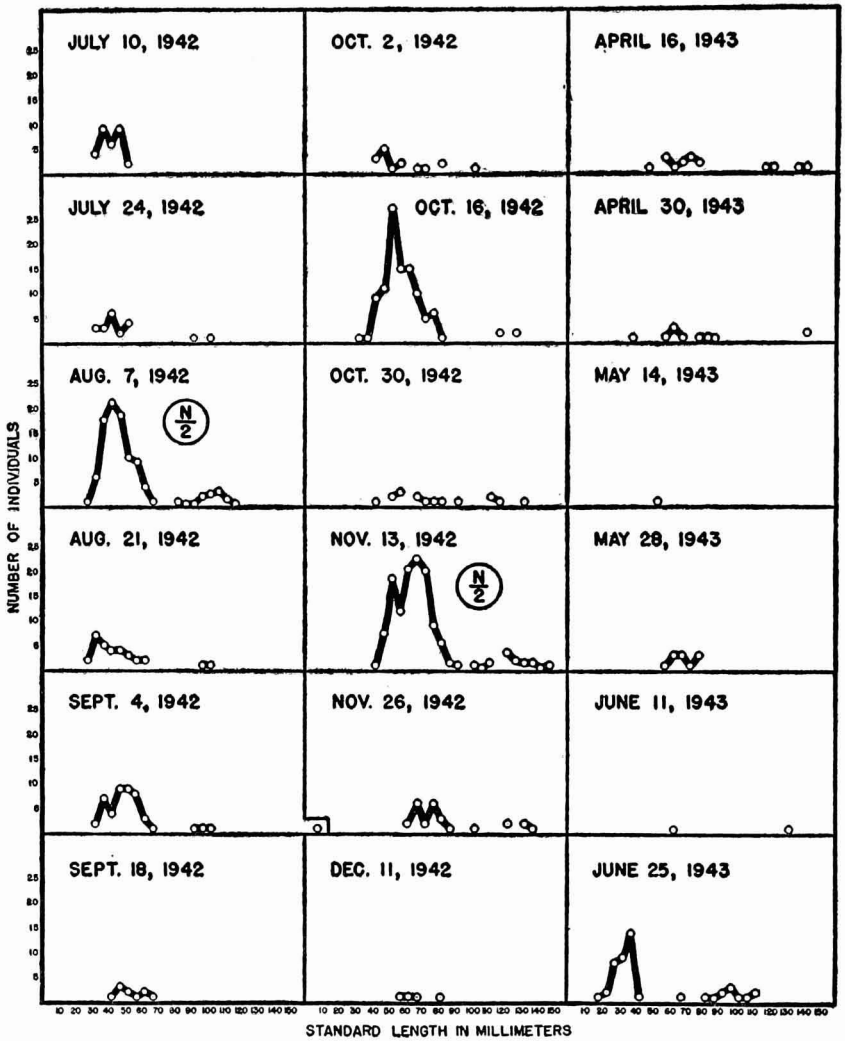


Figure 4. Length-frequency curves for *Pseudopleuronectes americanus*. The encircled figures indicate that the numbers of individuals have been divided by 2 to accommodate the data to the graph.

which approached 100 mm. in length, while the balance of the population ranged from 27 to 65 mm. and had a mean length of 43.4 mm. This mean length of the smaller individuals of the collection was less than that of the similar part of the collection made August 7 and is probably indicative of a new population of *P. americanus*. It should be mentioned, however, that since the sample of August 21 was small in numbers, direct comparison may not be justified. But if the phenomenon of compensatory growth is general in this species, added evidence that a different group of fish were taken in this collection can be derived from the lower mean and general spread of this mode (Fig. 4). On the basis of the available information, therefore, it seems most reasonable to assign the collection of August 21 to the status of a new population for the area.

The collection of September 4 contained 42 fish, which can be subdivided into two main size groups in a manner similar to the three previous hauls. The mean of the lower mode was 49.8 mm., which represents an increment of 6.2 mm. in the preceding two weeks. Apart from the two main size-groups of this population, one other specimen was taken, 169 mm. in standard length, the largest individual of this species taken during the course of the study.

On September 18 only 10 specimens of *P. americanus* were taken. This was one of the smallest collections made. All appeared to be fish-of-the-year, and reference to the length-frequency curve for this date indicates a growth of about the same order of magnitude as the previous biweekly collection showed over that of August 21. It seems probable that the fish taken in the second half of August and throughout September were all of the same population.

The first collection in October contained 16 individuals, 15 of which ranged from 40 to 82 mm. in length, the other being 101 mm. long. On October 16, 107 individuals were netted, 102 of which were within the range from 35 to 81 mm. The mean standard length of those individuals was 57.9 mm. The five additional individuals ranged from 116 to 127 mm. The collection of October 30 was low in numbers again, containing but 16 specimens, 12 of which ranged from 42 to 92 mm. and five from 111 to 131 mm. It is difficult and probably not profitable to speculate on the homogeneity of the October collections, but there is some evidence from the spread of the length-frequency curves that members of both the previously mentioned populations might have been present.

On November 13 the largest number of *P. americanus* taken in the course of this study was collected—264 specimens. In this group 238 individuals fell in the range from 43 to 94 mm., with a mean of 65.3 mm. Two modes are apparent in this curve, one near the 50 mm. mark and one at approximately 65 mm.; these are suggestive of the two different populations. The other 26 individuals were widely distributed between 103 and 148 mm. This was the only date on which *P. americanus* achieved the first rank of abundance in 1942.

The collection of November 26 showed considerable recession in numbers present in the Morris Cove area, only 24 specimens being taken. Of this small number, 18 were in the 63 to 87 mm. range and showed a bimodal tendency, while six were distributed between 101 and 138 mm.

The last collection taken in 1942 was that of December 11, when four fish, ranging in standard length from 56 to 83 mm., were seined.

The steady upward progression of the mean values for the standard length during the months of September, October, and November (Table III) are probably not accurate indications of the growth of individual groups or populations of the winter flounder, but unless different races are represented in the collections these values may be said to represent the general increment for that period for *P. americanus* in the region under consideration.

In the spring of 1943 the collections contained small numbers of individuals, but the range in size was much the same as those for the preceding fall season, except for the last collection in June (Table III). *P. americanus* returned to Morris Cove on April 16, when 16 individuals were collected and this species ranked first in abundance. Two weeks later, on April 30, 11 individuals were taken, and on May 14, only one was collected. On the next date, May 28, 11 fish were netted, and on June 11, only two were taken. Most of the fish contained in those small collections ranged from 50 to 75 mm. The lower limits of the range for each collection, as well as the higher, were much the same as those for the fall, as indicated above. Thus it would seem that little if any growth took place during the winter months in this species. However, this may not be a completely accurate picture, since there is evidence for a size stratification, particularly as regards flounders—that is, there seems to be a definite size limit to the fish encountered in the shallow water of the shore zone. Furthermore, the spring collections as a whole indicate that

regardless of the age of the individuals concerned (in this case fish probably entering the second year), they seek an environment that is compatible with their size (pp. 75–76).

On June 25, 47 individuals were collected. These were the smallest fish of the species taken during the entire study. Thirty-five of them ranged from 19 to 43 mm. and were, no doubt, fish of the year 1943. The mean standard length of that part of the collection was 32.1 mm. Of the balance of the collection it seems logical to believe that they were fish of the year 1942, which, for the most part, had returned to the area and would not leave until they had grown to approximately 100 mm. in length.

*Syngnathus fuscus* (Storer)

Third in rank of abundance in the collections, though not in that rank by virtue of the total numbers taken, was *Syngnathus fuscus*, the pipefish. This fish was consistently present in Morris Cove during the spring, summer, and fall months (Fig. 5). During this time it

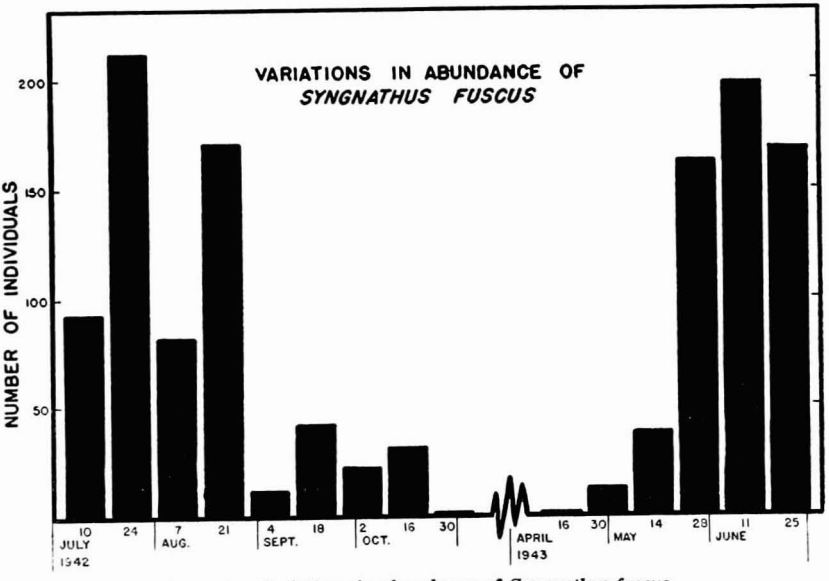


Figure 5. Variations in abundance of *Syngnathus fuscus*.

ranked first in abundance twice, second five times, and third four (Table IV). The month of September marked a period of compara-

TABLE IV. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Syngnathus fuscus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–10–42[1] | 93 | 32–213 | ..... | ..... | 3 |
| | 19 | 32– 84 | 58.7 ± 0.25 | 10.9 ± 1.77 | .. |
| | 74 | 131–213 | 169.0 ± 2.21 | 19.0 ± 1.56 | .. |
| VII–24–42[1] | 212 | 39–220 | ..... | ..... | 2 |
| | 170 | 39–113 | 74.0 ± 1.34 | 17.5 ± 0.95 | .. |
| | 42 | 136–220 | 174.5 ± 3.27 | 21.2 ± 2.30 | .. |
| VIII–7–42 | 82 | 44–193 | 94.6* ± 1.87 | 16.8 ± 1.21 | 3 |
| VIII–21–42 | 171 | 42–137 | 86.9 ± 1.35 | 17.7 ± 0.96 | 3 |
| IX–4–42 | 14 | 90–121 | ..... | ..... | 5 |
| IX–18–42 | 42 | 49–154 | 96.6 ± 3.16 | 20.4 ± 2.22 | 4 |
| X–2–42 | 22 | 59–144 | 93.1 ± 4.90 | 23.0 ± 3.47 | 3 |
| X–16–42 | 31 | 65–165 | 100.9 ± 4.09 | 22.8 ± 2.89 | 4 |
| X–30–42 | 1 | 123 | ..... | ..... | .. |
| IV–16–43 | 1 | 153 | ..... | ..... | .. |
| IV–30–43 | 12 | 114–227 | ..... | ..... | 1 |
| V–14–43 | 39 | 114–219 | 160.9 ± 3.79 | 23.6 ± 2.67 | 2 |
| V–28–43 | 161 | 92–234 | 160.5 ± 2.48 | 31.5 ± 1.76 | 2 |
| VI–11–43 | 199 | 104–221 | 160.6 ± 1.93 | 27.3 ± 1.37 | 2 |
| VI–25–43 | 169 | 124–238 | 163.3 ± 1.77 | 23.0 ± 1.25 | 1 |

[1] Means for the two obvious subdivisions of the population computed separately.
* Isolated, large individuals not included in the mean value.

tive scarcity, which coincided with the appearance of *Fundulus* spp. and *Brevoortia tyrannus* in considerable numbers. *Syngnathus fuscus* disappeared six weeks earlier than most of the permanent residents of the immediate shore zone, but was one of the first species to reappear in the spring. The water temperatures on the dates of departure and arrival were 12.7° C. (October 30, 1942) and 6.2° C. (April 16, 1943).

The life history of this species, as indicated in the literature, is not at all clear, and there is considerable diversity of opinion concerning the fundamental aspects of development and growth. The breeding date is given by Bigelow and Welsh (1925) as March to August for southern New England; Nichols and Breder (1926) list May 13 as the earliest breeding date, and June throughout July for spawning; and Hildebrand and Schroeder (1928) say that "spawning takes place from April to October" for the Chesapeake Bay region. Bigelow and Welsh (*loc. cit.*) further quote Gudger (1906) as saying that the period from fertilization to parturition is ten days, and Tracy (1910) has

observed growth from 10 to 70 mm. in two months. Bigelow and Welsh believe that maturity is reached in about a year. Much of the published data concerns the phenomena associated with the method of breeding, and many of the conclusions reached by American investigators are based largely upon observations by European workers.

The first collection of this species was taken July 10, 1942, and contained 93 individuals. *S. fuscus* was the second most abundant form on that date, ranking next to *M. menidia notata*. The members of this collection fell into two readily recognizable length categories, 19 individuals ranging in length from 32 to 84 mm. and 74 from 131 to 213 mm. These differences in length were pronounced (Fig. 6) and seem to indicate age distinctions, although the larger fish were predominantly males, the majority of which were carrying larvae in their pseudo-marsupia. The smaller fish may have been either individuals in or entering their second year, or fish-of-the-year that had been spawned early, as indicated by Bigelow and Welsh, and had grown at the rate indicated by Tracy (1910).

The collection of July 24 contained 212 individuals, which also were divisible into two size-classes. The smaller, as judged by a comparison of the length-frequency curves, seemed to belong to the same population as those of the similar group from the previous collection; the larger fish, while slightly longer than the large individuals taken two weeks earlier, also matched its corresponding population. Two modes appeared in the length-frequency curve for the smaller fish in this collection, and this suggests the possibility of subdivisions within that portion of the population. A comparison of the means of the two collections of smaller fish on July 10 and July 24 gives an indication of the growth of individuals in that size category during the two weeks, if it be assumed that the same population was present over this period. The difference of 15.3 mm. is remarkably close to the growth rate indicated by Tracy (*loc. cit.*).

The collection of *S. fuscus* taken on August 7 contained 82 individuals, all except one of which corresponded to the smaller size-groups taken on the two previous dates. The single individual measured 193 mm., and was probably representative of the larger, mature individuals of the former collections. If the smaller fish can be considered members of the corresponding population which appeared in previous collections, the average growth rate was fast, for the difference between the mean standard lengths for July 24 and August 7 was 20.6 mm.

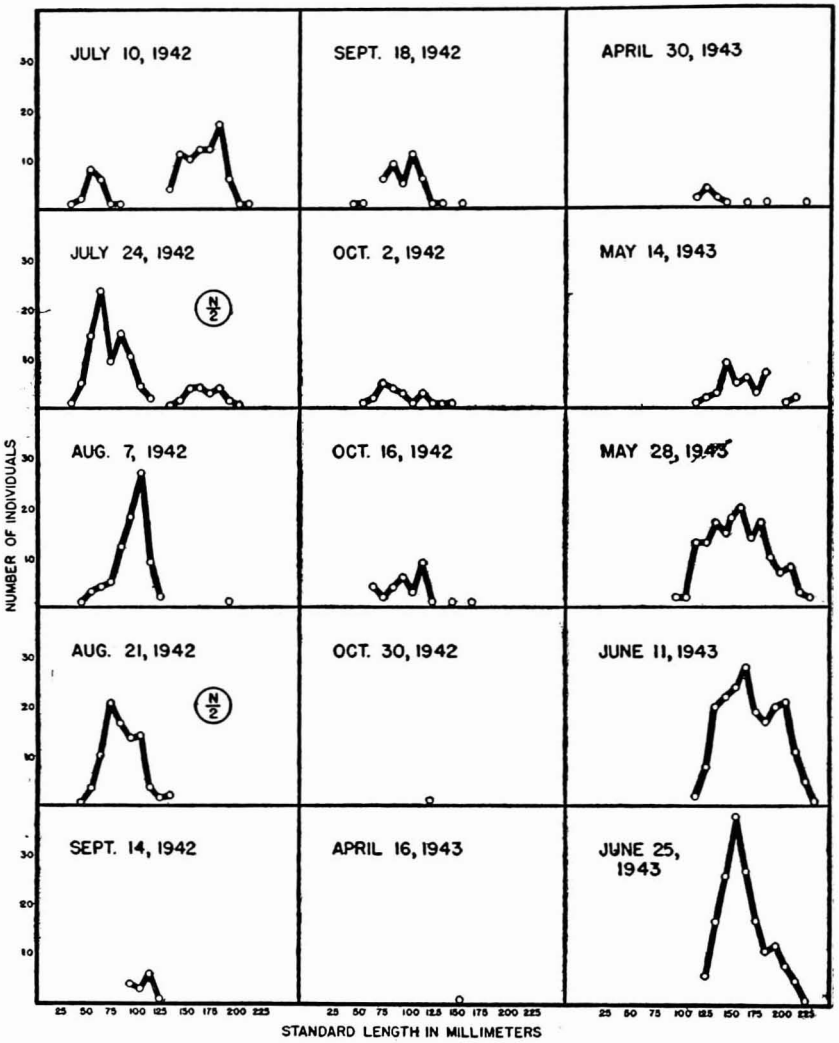


Figure 6. Length-frequency curves of *Syngnathus fuscus*.

On August 21 a collection of 171 individuals was obtained in which no large, mature fish occurred. That this was made up mainly of a new population seems to be indicated by the fact that the mean length was 7.7 mm. below that of the smaller fish of August 7.

Only 14 specimens of *S. fuscus* were taken on September 4, and the range of lengths indicated that they were a remnant of the collection taken two weeks previously. The next three collections were small and of about the same mean length (Table IV). It is perhaps significant that, except for the mature fish apparently in the area for spawning purposes, relatively few individuals larger than 100 mm. were encountered.

Collections made in the spring of 1943 consisted almost entirely of mature individuals, the males of which were carrying young after early June. The collection taken April 30 contained a few *S. fuscus* comparable in size to the larger individuals collected the previous autumn. The subsequent spring samples were similar to one another in that they showed much the same size range and mean length values throughout (Fig. 6 and Table IV).

From the foregoing description of the collections of *S. fuscus* it becomes apparent that several past assumptions regarding the life history are at variance with findings in the present study, and it is difficult to relate the statements of other observers to the condition of the fish examined in collections from Morris Cove. All "spawning" fish in this area—that is, females with ripe eggs or males carrying developing young—were collected in June and July; there was no indication of "spawning" after late July, or possibly early in August. This accords with Nichols and Breder (1926), but offers no confirmation for the statement of Bigelow and Welsh (1925) concerning March spawning. On the other hand, it is possible that the smaller fish encountered in the Morris Cove collections of July and early August conceivably might have been the result of early (spring) spawning in other areas. If such were the case, breeding activity and brood pouch development would have taken place at least as early as May if Tracy's (1910) estimate of growth is valid for early spring in southern New England, and if the brood period is ten days as indicated by Gudger (1906). It seems reasonable to suppose, however, that Tracy's estimates (which were made in the summer months) would not hold for the spring, that development would be much slower at that time, and therefore spawning would have occurred before May. Nichols and Breder (1926) found a post-larval individual somewhat off shore which may be taken as an indication that young *S. fuscus* are pelagic for the first few weeks of life. This might account for the fact that individuals below 30 mm. were not taken

during the course of the Morris Cove study, and it might also serve to explain the presence of the comparatively well developed individuals of the smaller size classes in on-shore waters where presumably no spawning individuals were available to produce them.

Be this as it may, the breeding activity of *S. fuscus* in Morris Cove was confined to the months of June and July. The eggs in the brood pouches taken in early June were in an early stage of development. Males examined two weeks later had eggs that were eyed, although little pigment had developed; by the end of the month (June 25, 1943) many of the individuals examined had embryos with definitely pigmented eyes. Mature fish, many with full brood pouches, were taken in July, 1942, but by August only one definitely mature individual was found, a female that had all the appearances of having missed the breeding period in that she carried a number of large eggs in her ovaries. On the basis of the Morris Cove observations, therefore, it would seem that breeding did not take place until late May. By middle to late June breeding was complete and the males were carrying embryos, most of which were still in relatively early stages of development. Parturition took place mainly in July, and by August all reproductive activity was complete. Therefore, the small-sized individuals (averaging 59 to 95 mm. in length—Table IV) so prominent in the collections of July and August were either fish-of-the-year which had been produced much earlier in another breeding area and had moved into the shore zone following a brief pelagic existence, or they were fish of the previous year. The latter possibility receives support from several incidental collections made in Morris Cove and other localities on the coast during July and August of 1943. These samples contained a group of *S. fuscus*, averaging approximately 35 mm. in length—fish which were without question a product of the 1943 spawning season. If these were fish of the current year, the small fish of the July–August (1942) collections may have been members of the 1941 year-class which were immature. This would mean that the large, obviously mature individuals in the collection were two years old or more, which is at variance with Bigelow and Welsh's (1925) estimate of one year for the age at maturity. And it would also mean that Tracy's (1910) observations of the growth rate of the young are not characteristic of fish in their normal habitat. It is readily apparent that there is much room for study on the spawning period, rate of development and growth, etc., in *S. fuscus*.

*Fundulus heteroclitus* (Linnaeus) and *Fundulus majalis* Walbaum[3]

Two members of the genus *Fundulus* were collected during the course of this study, *F. heteroclitus* and *F. majalis*. Since they were both present at essentially the same times during the course of this study, although in varying relative numbers, and inasmuch as their general habitat preferences are somewhat similar, they are dealt with as a unit in the present discussion.

In July and early August, 1942, the collections of *Fundulus* species were inadvertently discarded; consequently the data on the relative abundance of all species for that period, as well as the entire data for

[3] Due to general lack of uniformity in the literature regarding the distinguishing features of *F. heteroclitus* and *F. majalis*, a critical study of the more common characters used in the recognition of these forms was attempted. Coloration, while often referred to, is difficult to use because of differences resulting from increasing age, pronounced sexual variations, and preservation. Therefore morphological features were evaluated for 50 fish of each species of all sizes and ages, and the most useful are set forth below. Depth measurements were taken across the *base of the pectoral* rather than across the deepest part of the abdomen in order to eliminate seasonal variations between "ripe" and non-gravid individuals. The standard length was used in all cases.

*F. heteroclitus:* Head short, 3.5 in length; depth 4.4; caudal peduncle 6.8. Eye 3.5 in head; snout 3.6; interorbital space 2.4. Branchiostegals 5, rarely 6. D. 11–12.

*F. majalis:* Head long, 3.0 in length; depth 4.6; caudal peduncle 7.7. Eye 4.7 in head; snout 2.3; interorbital space 3.0. Branchiostegals 6. D. 13–14.

These proportions were tested to determine whether or not the ratios change with age, and in *F. heteroclitus* the interorbital space was found to be relatively larger in the older fish, while in the larger *F. majalis* the orbit was relatively smaller.

Several authorities have cited the external oviduct as a characteristic of *F. heteroclitus* females, but Jordan and Evermann (1896) described the same structure in *F. majalis*. They estimated the oviduct to be ½ to ⅔ the length of the first anal finray in *F. heteroclitus* and stated that it extended far out on the margin of the fin in *F. majalis*. Measurements of 105 *F. heteroclitus* females showed that the oviduct constituted about 45% of the anterior margin of the anal except during the spawning season, whereas in gravid females taken in June it covered roughly 65% of the fin edge. It appears from this evidence that this structure varies in *F. heteroclitus* with the degree of seasonal maturity, becoming larger during spawning and receding afterwards. Insufficient specimens of *F. majalis* were collected during the spawning season to allow an evaluation of this relationship. However, an interesting trend was revealed between the length of the fish and the oviduct/anal ratio. Measurements of 17 females collected in September and October showed that the larger fish had the higher ratio and the smaller the lower, indicating that the oviduct becomes proportionately longer with age.

The authors are indebted to Pfc. Arthur J. Driscoll, Jr., for making the measurements and calculations.

the rank of abundance of these two species, is subject to that error. However, as memory serves, the collections made at that time were of insufficient size to affect the relative positions of the more abundant species, and could have caused only minor alterations in the species of lower rank, *i. e.*, changes which would be comparatively insignificant.

The first collection of *Fundulus* available for study was that taken August 21, 1942. This was a collection of 67 individuals, 61 of which were *F. heteroclitus*, and 6 were *F. majalis*. The *F. heteroclitus* were divisible, by inspection, into two length groups (Fig. 7). One group of smaller size, had a mean length of 27.2 mm. and contained 27 individuals; the other lot was made up of 34 individuals with a 64.6 mm. mean length (Table V). That these fish represented at least

TABLE V. NUMBER AND LENGTH OF *Fundulus heteroclitus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* |
|---|---|---|---|---|
| VIII–21–42[1] | 61 | 19– 82 | ..... | ..... |
| | 27 | 19– 47 | 27.2 ± 1.40 | 7.27 ± .989 |
| | 34 | 59– 82 | 64.6 ± .91 | 5.33 ± .645 |
| IX–4–42[1] | 168 | 20–100 | ..... | ..... |
| | 57 | 20– 58 | 36.3 ± 1.24 | 9.35 ± .875 |
| | 111 | 60–100 | 72.9 ± .86 | 9.05 ± .607 |
| IX–18–42 | 19 | 25– 51 | ..... | ..... |
| X–2–42 | 1 | 32 | ..... | ..... |
| X–16–42 | 19 | 23– 83 | ..... | ..... |
| X–30–42 | 1 | 44 | ..... | ..... |
| XI–13–42 | 4 | 30– 84 | ..... | ..... |
| V–14–43 | 31 | 29– 74 | 44.8 ± 2.31 | 12.85 ± 1.63 |
| VI–11–43 | 1 | 37 | ..... | ..... |
| VI–25–43 | 1 | 52 | ..... | ..... |

[1] Means for the two obvious subdivisions of the population computed separately.

two age groups is obvious. The larger fish may or may not have been of one age group, but apparently they were mature individuals which had spawned in the spring, while the smaller individuals were unquestionably fish-of-the-year. The *F. majalis* collected on the above date, averaged 36.6 mm., exhibited juvenile features, and were probably 0+ individuals.

The largest collection of *Fundulus* was taken on September 4 when 377 individuals were netted. Roughly 45% of those were *F. heteroclitus* and the rest *F. majalis*. The *F. heteroclitus* were again divisible

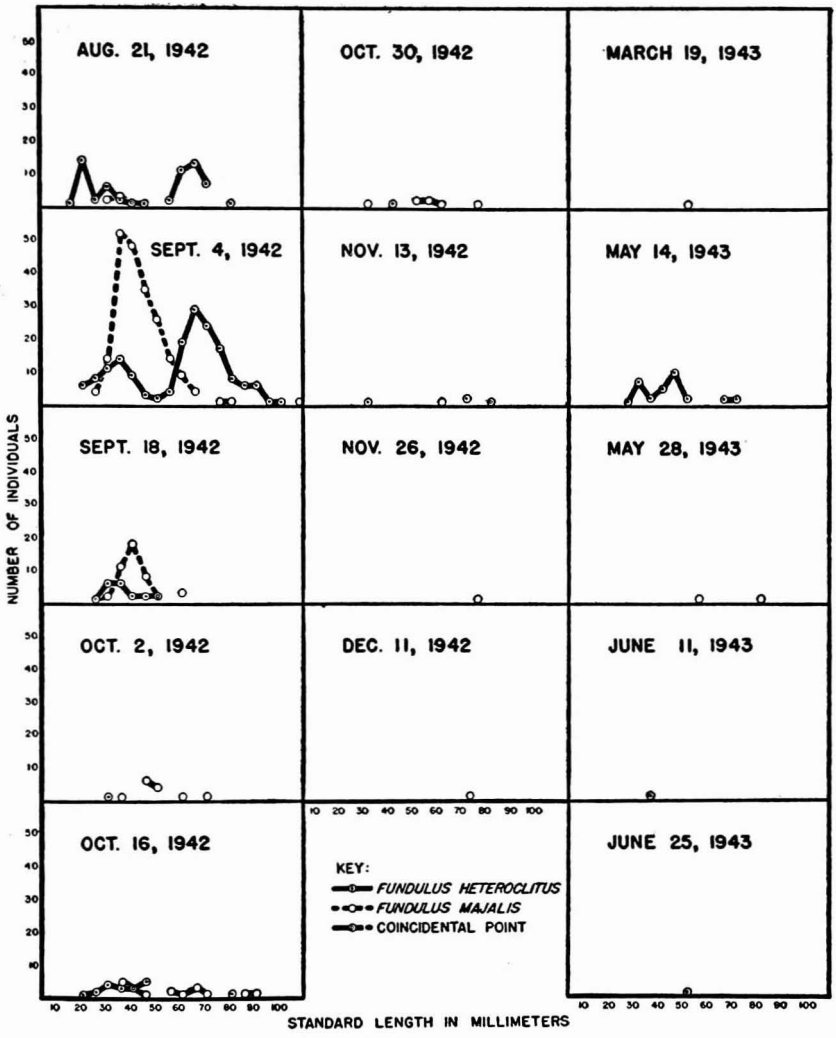


Figure 7. Length-frequency curves of *Fundulus heteroclitus* and *Fundulus majalis*.

into two groups, the smaller fish having a mean length of 36.3 mm., and the larger a mean length of 72.9 mm., thus indicating the general order of growth of the 0+ and mature fish. *F. majalis*, on the other hand, while having a fairly wide range in length, was apparently a homogenous population, except for a lone individual 112 mm. long.

The mean standard length of this collection, exclusive of the single large individual, was 44.6 mm. (Table VI), and there is good reason to conclude that the vast majority of these smaller specimens were immature fish-of-the-year. The single large fish was a female, whose ovary was compact and contained small eggs. Examination of its scales indicated that it was in its second year of growth.

On September 18, 64 specimens were collected that belonged to this genus, 19 of which were *F. heteroclitus* and 45 *F. majalis*. The *F. heteroclitus* were small, averaging 38.1 mm. and corresponding roughly to the smaller groups of the two previous collections. The 45 indi-

TABLE VI. NUMBER AND LENGTH OF *Fundulus majalis*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* |
|---|---|---|---|---|
| VIII–21–42 | 6 | 31– 44 | ..... | ..... |
| IX–4–42 | 209 | 25–112 | 44.6* ± .640 | 9.24 ± .453 |
| IX–18–42 | 45 | 29– 63 | 42.7 ± 1.06 | 7.13 ± .751 |
| X–2–42 | 13 | 37– 70 | ..... | ..... |
| X–16–42 | 18 | 36– 93 | ..... | ..... |
| X–30–42 | 7 | 31– 79 | ..... | ..... |
| XI–13–42 | 2 | 61– 83 | ..... | ..... |
| XI–26–42 | 1 | 75 | ..... | ..... |
| XII–11–42 | 1 | 74 | ..... | ..... |
| III–19–43 | 1 | 50 | ..... | ..... |
| V–28–43 | 2 | 59– 83 | ..... | ..... |

* One individual, 112 mm., not included in calculation of the mean.

viduals of *F. majalis* corresponded to the collection of that species taken before, except that the mean length of the population (42.7 mm.) was slightly less than that of the preceding sample owing to the absence of larger individuals approaching 80 mm. Some indication of the growth of the 0+ fish in this period is given by the progression of the modes of the length-frequency curves.

The collection taken two weeks later on October 2 contained but 14 individuals of this genus, all but one of which were *F. majalis*. The single *F. heteroclitus* was 32 mm. long, and the average length of the 13 *F. majalis* was 50.3 mm. Apparently these fish were immature, although the largest of them was beginning to show the marking of the female adult.

The collection of October 16 consisted of 37 individuals. The specimens of *F. heteroclitus* had a mean length of 37.6 mm., excluding

one individual 83 mm. long. The smaller fish ranged from 23 mm. to 49 mm. and were definitely fish-of-the-year, while the larger individual was an adult. *F. majalis* was represented by 18 fish with a mean length of 54.8 mm. The range in length of *F. majalis* from 36 to 93 mm. was a fairly evenly distributed variate, and most of these individuals were clearly immature fish-of-the-year; indeed, superficial examination of scales from the three larger fish, females which were assuming the adult color pattern, indicated that they were members of the 1942 year-class.

Only eight fish of this genus were collected on October 30, one *F. heteroclitus* and seven *F. majalis*. The *F. heteroclitus* was 44 mm. long and the *F. majalis* ranged from 31 to 79 mm. and appeared to be fish-of-the-year.

On November 13 four *F. heteroclitus* and two *F. majalis* were taken. The *F. heteroclitus* ranged from 30 to 84 mm., and the *F. majalis* from 61 to 83 mm. The small *F. heteroclitus* was a fish-of-the-year and the other three, measuring 73, 74, and 84 mm., were apparently adults, probably of the 1941 year-class. The *F. majalis* still possessed many juvenile characteristics. One *F. majalis* and no *F. heteroclitus* were taken on November 26, a collection in which only four species were represented. On December 11, one specimen of *F. majalis*, 74 mm. long, was collected; it was one of three species taken on that date.

No specimens of the genus *Fundulus* were taken again until March 19, 1943, when one specimen of *F. majalis* was netted, the only fish collected on that date. This specimen measured 50 mm. On May 14, 31 specimens of *F. heteroclitus* were taken, and the species ranked third in relative abundance. Many of these individuals were small (Table V) and had features generally ascribed to juvenile fish of the species. Cursory examination of the scales of some of these specimens revealed annuli, thus indicating that they were members of the 1942 year-class. They were probably the product of an unusually late spawning. Two weeks later two specimens of *F. majalis* were netted which measured 59 and 83 mm. Other collections made at biweekly intervals in June resulted in the capture of one *F. heteroclitus* on June 11, and another of the same species on June 24.

The genus *Fundulus* was not very abundant along the shore line of the sandy beach in Morris Cove. It occupied a rank of abundance near the middle of the more common species, but never achieved the rank of first unless the single fish collected on March 19 is considered

(Table VII). On August 21 both species combined ranked fifth, and in the next collection, that of September 4, they ranked second—the date on which the greatest number of these fish were taken. The third largest collection, 64 individuals, was made on September 18 and the genus ranked third in relative abundance. Two weeks later the two species were in fifth place, and on October 16 they were third. During the next eight weeks they varied from third to fourth and after December 11 they were not taken again until mid-March, when the

TABLE VII. COMPARATIVE NUMBERS OF *Fundulus heteroclitus* AND *Fundulus majalis*.

| *Date* | *Numbers of F. heteroclitus* | *Numbers of F. majalis* | *Rank** |
|---|---|---|---|
| VIII-21-42 | 61 | 6 | 5 |
| IX-4-42 | 168 | 209 | 2 |
| IX-18-42 | 19 | 45 | 3 |
| X-2-42 | 1 | 13 | 5 |
| X-16-42 | 19 | 18 | 3 |
| X-30-42 | 1 | 7 | 4 |
| XI-13-42 | 4 | 2 | 3 |
| XI-26-42 | .. | 1 | 4 |
| XII-11-42 | .. | 1 | 3 |
| III-19-43 | .. | 1 | 1 |
| V-14-43 | 31 | .. | 3 |
| V-28-43 | .. | 2 | .. |
| VI-11-43 | 1 | .. | .. |
| VI-25-43 | 1 | .. | .. |

* Rank of abundance is for the genus.

single specimen of *F. majalis* was netted. During the rest of the spring comparatively few specimens of either species were collected, and the genus only achieved a rank in relative abundance on May 14, when *F. heteroclitus* alone was represented. Among the possible explanations for the scarcity of these fish in the Morris Cove shore zone in the spring is the fact that these species were on spawning beds at some other type of biotope than that of the rather barren sandy beach at Morris Cove.

It is apparent from Table VII and Fig. 8 that approximately the same number of *F. heteroclitus* and *F. majalis* were collected during the season. Six of the collections contained more *F. heteroclitus* and eight held more *F. majalis*.

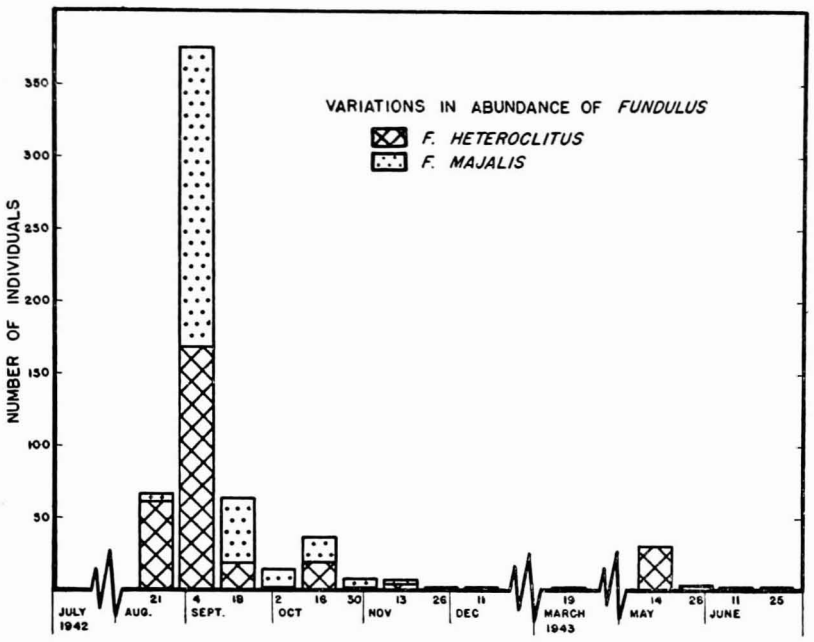


**Figure 8.** Variations in abundance of *Fundulus heteroclitus* and *Fundulus majalis*.

*Brevoortia tyrannus* (Latrobe)

The menhaden was among the more abundant fishes in Morris Cove during early July and again in early fall. This species first appeared in the collections on July 10, 1942, when 774 specimens were collected and it ranked second in relative abundance. One individual was obtained on August 7, and five fish were seined on September 4. Beginning in September and continuing through the month of October *Brevoortia tyrannus* was present consistently. During this period it was very abundant twice (Table VIII and Fig. 9)—on September 18, when 550 individuals were taken, and six weeks later on October 30, when 1565 fish were netted. The last collection November 26, contained but five individuals.

When *Brevoortia tyrannus* was present it was a comparatively important member of the population in terms of relative abundance. Of course it is impossible to say how long the separate schools of this species stayed in the area, but the wide variation in standard length for the different collections, as well as the irregular capture of extremely

TABLE VIII. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Brevoortia tyrannus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–10–42 | 774 | 9–45 | 24.79 ± .152 | 4.23 ± .110 | 2 |
| VIII–7–42 | 1 | 27 | ..... | ..... | .. |
| IX–4–42 | 5 | 23–66 | ..... | ..... | .. |
| IX–18–42 | 550 | 31–79 | 57.25 ± .530 | 12.42 ± .374 | 2 |
| X–2–42 | 30 | 34–56 | 43.50 ± 1.010 | 5.50 ± .710 | 2 |
| X–16–42 | 22 | 30–73 | 54.28 ± 2.220 | 10.40 ± 1.570 | 5 |
| X–30–42 | 1565 | 30–71 | 48.73 ± .555 | 6.95 ± .394 | 1 |
| XI–26–42 | 5 | 38–55 | ..... | ..... | 3 |

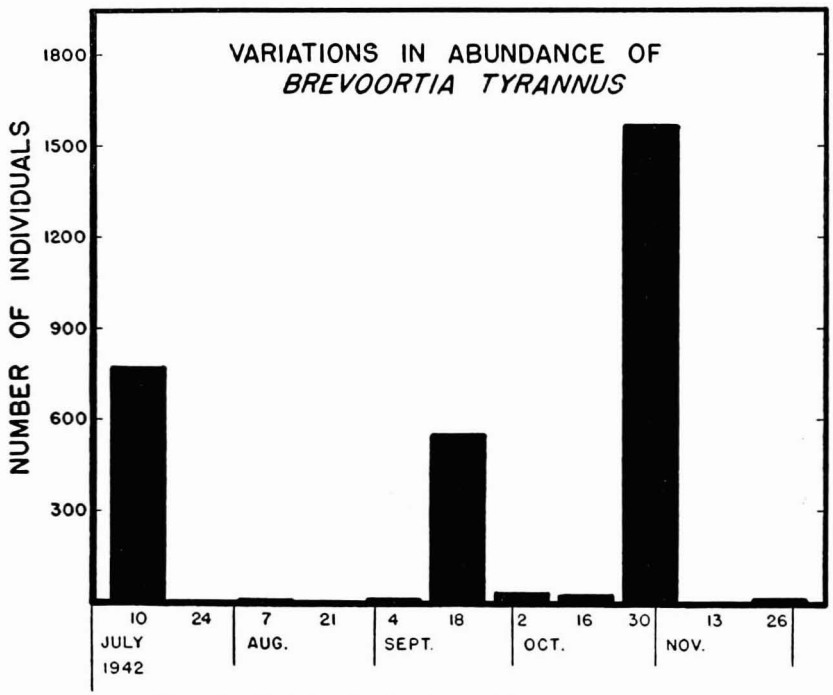


Figure 9. Variations in abundance of *Brevoortia tyrannus*.

large numbers, would seem to indicate that individual schools were moving along the shoreline during this season. It ranked first in abundance on October 30, was second on three occasions, third on November 26, fifth on October 16, and on two collection dates the numbers were so low that the fish was not ranked (Table VIII). It is

of interest that two peaks of abundance for this species, July 10 and September 18, coincided with the two highest peaks for all species (Fig. 20). But it should be noted that while the menhaden contributed to the height of the peaks for all species on these dates it was not the major element in either case. On the other hand, the peak at October 30 (Fig. 21) was caused mainly by the tremendous influx of

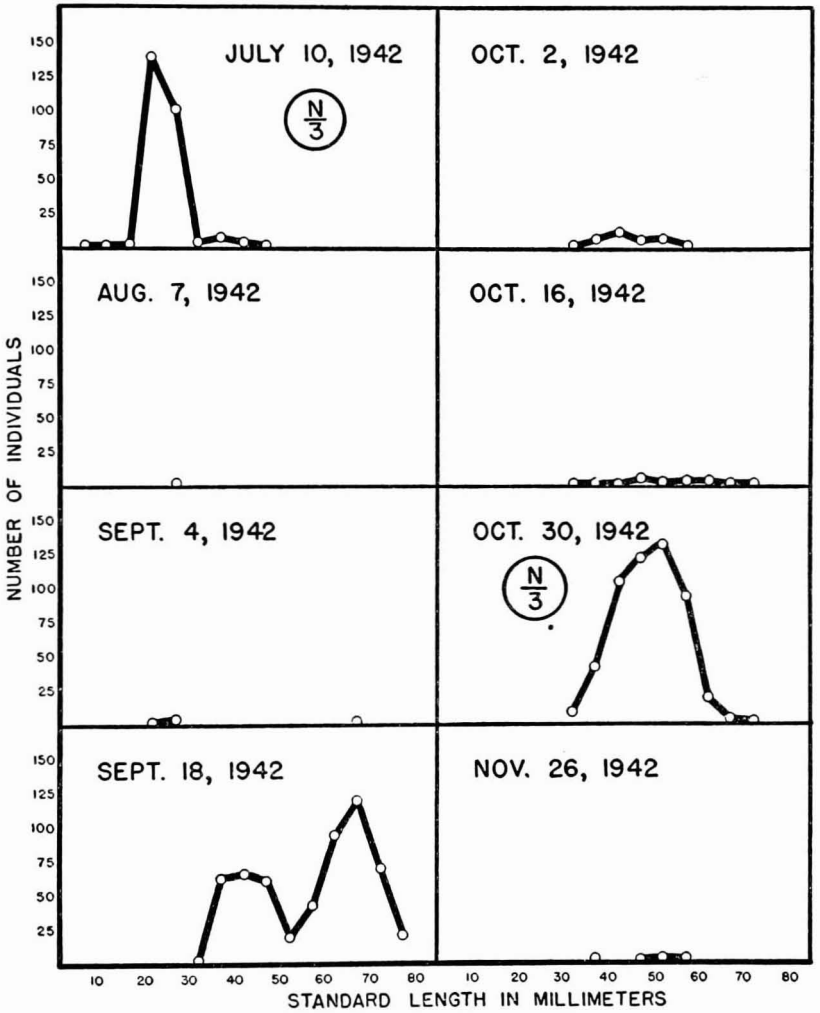


**Figure 10.** Length-frequency curves of *Brevoortia tyrannus*.

*B. tyrannus*. The wide range in numbers of menhaden during the season when they were taken was striking; they were either abundant, relatively few in numbers, or totally absent (Fig. 9). This fluctuation in numbers has been noted by Nichols and Breder (1926) who also cite large peaks of abundance in the early summer and fall.

The size of the individuals taken at Morris Cove indicates that they were all fish-of-the-year, but fluctuations in the mean length from one collecting period to another provides evidence of different populations (Table VIII). The collection of September 18 contained the largest fish taken, and that of July 10 the smallest. No individuals less than 9 mm. long were encountered. The rather consistent presence of menhaden around the 30 mm. length interval, which is at the lower limits of each collection, is also suggestive of the presence of successive new populations (Fig. 10).

The fact that the smallest fish collected were taken in early July seems to substantiate Nichols and Breder (1926) in their assumption that the peak of spawning in this region is in June. The wide variation in size and the fluctuation of the mean size points to agreement with Greeley (1939) who says, "A wide variation in the size of young was noted, indicating a long breeding season or possibly immigration of more advanced young from southern waters." In this connection, migration from the eastward should not be overlooked as a possibility, especially in regard to those fish taken in October which had mean standard lengths smaller than that for the fish taken two weeks previously in September.

*Spheroides maculatus* (Bloch and Schneider)

This species was taken in Morris Cove from early July until mid-October and was most abundant in late August and early September (Fig. 11). Almost all the individuals encountered in this study were small and were apparently fish-of-the-year, although large specimens are sometimes found in areas as near the tide line as the locality of this study.

*Spheroides maculatus* was fairly abundant in the collections from early July until mid-September and ranked sixth for the entire year. It ranked fifth in early July, third in late July, fourth in August, third in early September, and fifth later in that month. While it composed an important part of the shore zone fish population in the late summer, it did not exhibit the abrupt, erratic fluctuations in

number that characterized some of the more abundant forms. It gradually increased in numbers until it reached a peak on August 21, 1942; thereafter it decreased in abundance so that it was negligible after mid-September. The date of maximal quantities of *S. maculatus* did not coincide with the peak of the other species.

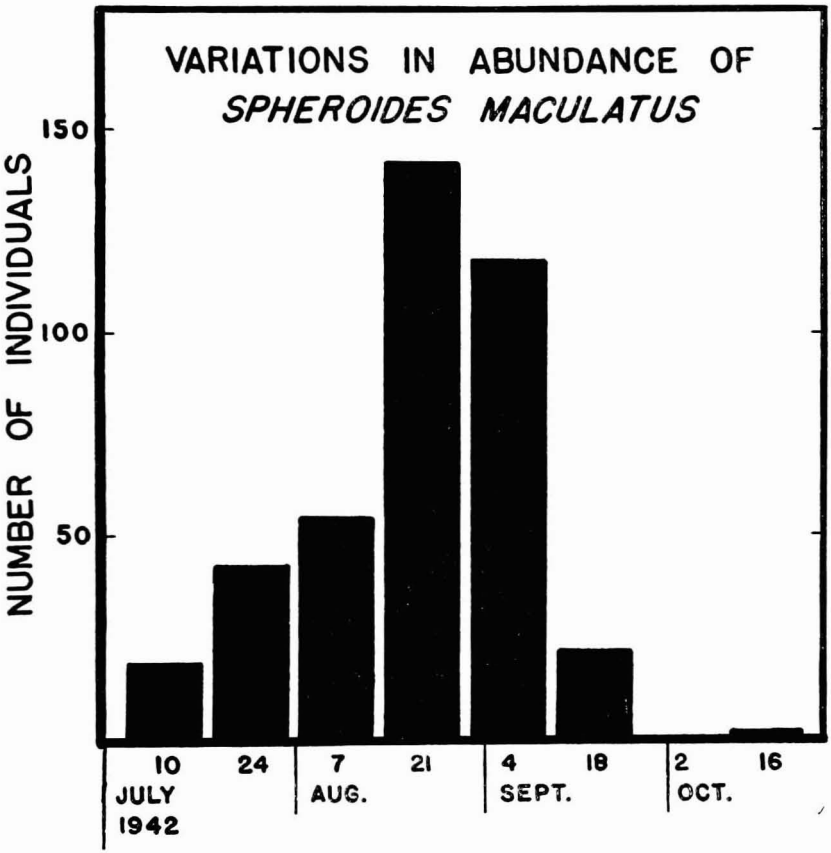


Figure 11. Variations in abundance of *Spheroides maculatus*.

This fish, which is quite common along the Atlantic coast, probably reaches a peak of spawning during the early summer. Bigelow and Welsh (1925) say they spawn from June on, in shallow water close to shore. Smith (1898) gives the date as June 1 to 10 at Woods Hole; Perlmutter (1939) indicates "May through August in Long Island;"

and Nichols and Breder (1926) agree with Smith for Woods Hole but state that ripe females have been taken as early as June 7 and as late as early September in the vicinity of New York, although in Sandy Hook Bay these authors found no ripe females after July 27. The evidence listed below points to a somewhat protracted spawning period.

The first collection, taken July 10, 1942, contained 19 fish having a mean length of 14.9 mm. This small collection was fairly homogeneous and without doubt consisted of fish-of-the-year. The next collection two weeks later also consisted of fish-of-the-year; they had a mean length slightly larger than that for the first collection, although some of the specimens were as small as those taken previously. The

TABLE IX. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Spheroides maculatus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–10–42 | 19 | 12–17 | 14.95 ± .25 | 1.07 ± .17 | 5 |
| VII–24–42 | 43 | 11–25 | 16.90 ± .50 | 3.28 ± .35 | 3 |
| VIII–7–42 | 55 | 16–28 | 20.10 ± .33 | 2.44 ± .23 | 4 |
| VIII–21–42 | 142 | 14–35 | 26.00 ± .40 | 4.73 ± .28 | 4 |
| IX–4–42 | 118 | 12–64 | 41.10 ± .69 | 7.50 ± .49 | 3 |
| IX–18–42 | 22 | 14–74 | ..... | ..... | 5 |
| X–16–42 | 2 | 27–32 | ..... | ..... | .. |

third collection contained more *S. maculatus* and these also showed an increase in size over the previous lot. Likewise, the two following collections (the largest hauls of the season for this species) not only continued the trend of increased length, but also exhibited successively greater growth increments as judged by the mean lengths and the length-frequency curves (Table IX and Fig. 12).

On September 18 a much smaller collection was made than on any former date except July 10, but the size range was the widest encountered up to that time. In this group six individuals ranged from 14 to 18 mm. in length, five from 28 to 32 mm., six from 35 to 41 mm.; two were in the 50 to 60 mm. interval, two more in the 60 to 70 mm. interval, and one was 74 mm. No fish of this species were taken on October 2, and only two individuals, one 27 and another 32 mm. in length, were secured on October 16, which was the last time they were taken.

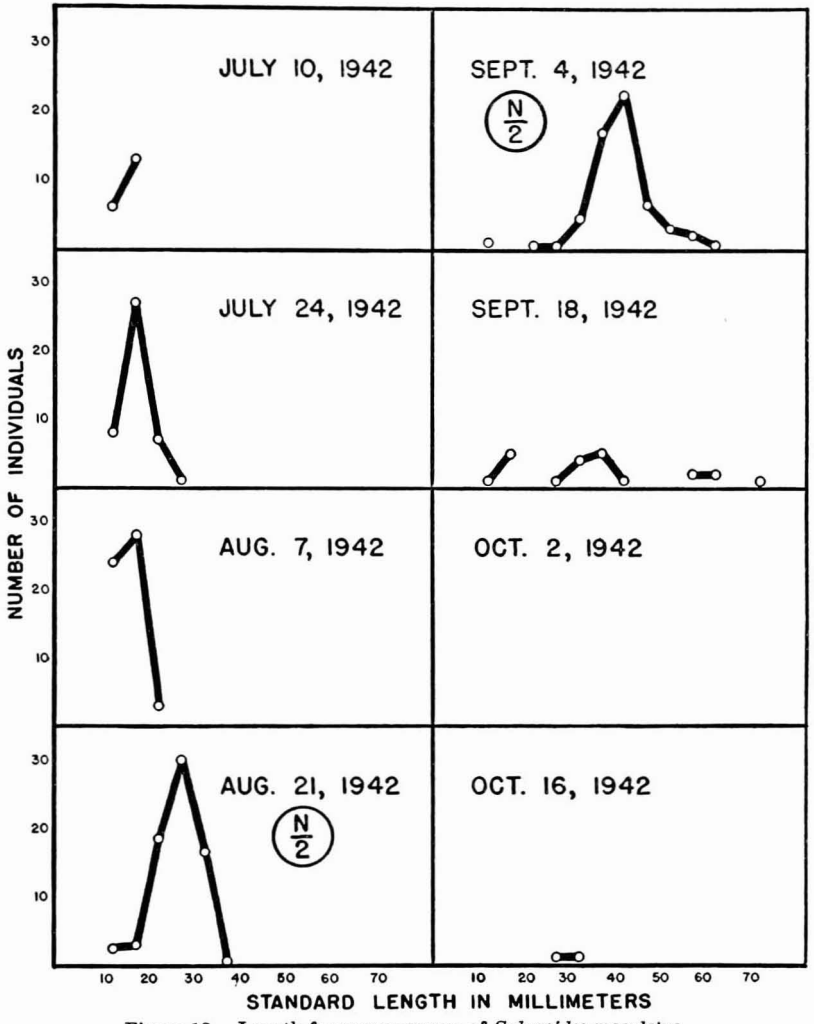


Figure 12. Length-frequency curves of *Spheroides maculatus*.

It is apparent from the length data that no individuals less than 11 mm. in length were taken in the Morris Cove collections during the summer and fall of 1942. Yet these small fish were consistently present until the middle of September—a fact which supports the published accounts of the considerably protracted spawning period cited above, since small individuals, which were apparently the

product of later and later spawnings, kept appearing in the shore zone all the time from July until early fall. On the other hand, the mean standard length, as well as the upper size limits were increasing in value steadily; in fact the growth increments at biweekly intervals, as judged by the mean lengths, appeared to be geometric in their progression. In any event two facts stand out—the number of individuals collected was successively greater from early June through August, and a rapid increase of the mean standard length was exhibited until mid-September.

Welsh and Breder (1922) studied certain aspects of the early life history of this species in New Jersey, and in their data they recorded approximately five days for incubation at a temperature of 67° F., and a larval period of 10 days, presumably at the same temperature. This temperature was reached in the vicinity of New Haven in early June, 1942. Inasmuch as the fish collected on July 10 were 15 mm. long, which is more than five times the length of the fish described by these authors at the emergence from the larval stage, it can be assumed that spawning took place either late in May, considering a longer incubation period at the temperature for that period, or early in June. Further, since the largest number of individuals was taken in the last of August, and since that collection still contained small fish of approximately the same size as those of the earlier collections, it seems to follow that the height of the protracted spawning period for the vicinity of New Haven harbor was early July, or possibly late June, in the season of 1942. In this connection it is important to note that no *Spheroides maculatus* were encountered in the May or June collections in 1943, although 0+ fish of this species were taken in July at Pine Orchard, Connecticut, in the course of another study; these agreed in size with the collections from Morris Cove of July 1942.

### *Microgadus tomcod* (Walbaum)

*Microgadus tomcod* was one of the few species that exhibited distinct seasonal abundance in Morris Cove. Several individuals were taken in the fall of 1942, and it was present again only during May and June, 1943. On several occasions in the spring it was present in comparatively large numbers, and it ranked first in abundance once.

The first *M. tomcod* were taken on November 13, 1942, when two individuals 172 and 292 mm. in length were collected. Both were females with prominent ova, which, so far as could be determined

from an examination of the preserved specimens, were not yet fully developed. In mid-spring young *M. tomcod* appeared in the catch, 12 individuals being collected on May 14; these ranged from 16 to 31 mm. On May 28, 91 fish of this species were taken, and these ranged from 24 to 55 mm., the mean length for the collection being 36.1 mm. On June 11, 198 tomcod, ranging from 31 to 76 mm. were seined; this population had a mean length of 51.3 mm. Two weeks later only 20 *M. tomcod* were taken. Subsequent collections, made after the end of this study, failed to reveal *M. tomcod* in the region in early and mid-July, 1943.

*M. tomcod* ranked seventh in relative abundance of the species represented in the Morris Cove collections. On November 13 the two individuals taken ranked fifth in abundance, the collection containing only 285 fish divided among six species. On May 14, the tomcod ranked fourth, and on May 28, third. *M. tomcod* dominated the list on June 11, and was third again on June 25.

The appearance of relatively large individuals of this species in the Morris Cove area in the fall of 1942 corresponded with the movements associated with spawning, and it seems reasonable to suppose that the

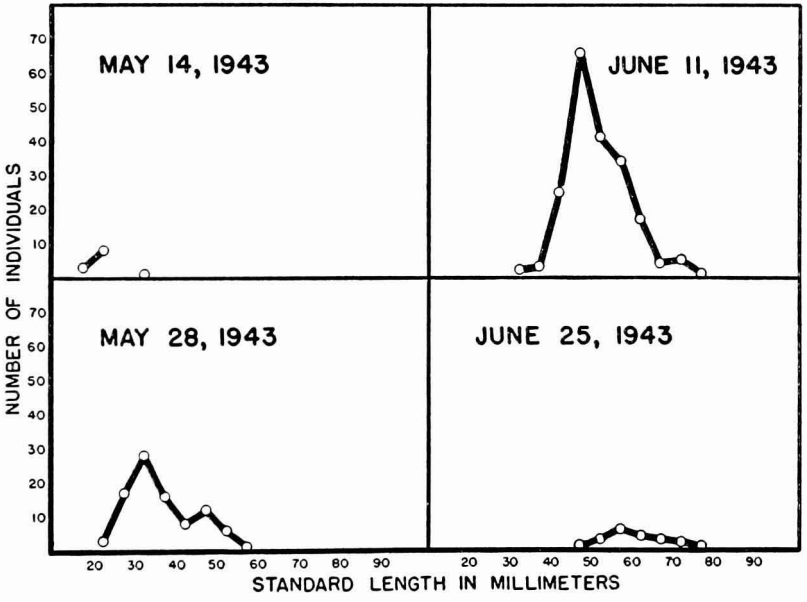


Figure 13. Length-frequency curves of *Microgadus tomcod*.

young that were present in the spring of 1943 were the result of a spawning in nearby waters. The rate of growth of these 0+ fish is indicated by the progression of the modes in Fig. 13 and the mean standard lengths in Table X. However, there is no positive assurance

TABLE X. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Microgadus tomcod*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| XI–13–42 | 2 | 172–292 | ..... | ..... | 5 |
| V–14–43 | 12 | 16– 31 | ..... | ..... | 4 |
| V–28–43 | 91 | 24– 55 | 36.1 ± .714 | 6.82 ± .505 | 3 |
| VI–11–43 | 198 | 31– 76 | 51.3 ± .540 | 7.65 ± .384 | 1 |
| VI–25–43 | 20 | 47– 75 | ..... | ..... | 3 |

that the young individuals represented in the spring collections were necessarily the product of the spawning of adult fish on or near the same date. The spawning period probably extends over several months, and the young fish taken in the spring could therefore differ considerably in age. That this situation obtained in the May 28 and June 11 collections is supported by the shape and extent of the length-frequency curves on those dates (Fig. 13).

### *Cynoscion regalis* (Bloch and Schneider)

*Cynoscion regalis* was among the species which were consistently present, although not particularly abundant, during the summer of 1942. This fish first appeared in the collections from Morris Cove on July 24. It reached a peak of abundance on August 21, when 222 individuals were taken, and following this date the numbers declined sharply. Mid-October marked the last appearance of this species for the year in the Morris Cove collections, and it was not represented at all in 1943. Obviously, *C. regalis* did not rank high in terms of relative abundance. When first collected it was fourth, two weeks later it was sixth, and on August 21, it was second. On September 4 it was in the sixth place of abundance, and that date marked the last time that it was taken in sufficient numbers to be ranked.

It is probably true for *C. regalis*, as for many of the other species in this study, that the collection dates did not coincide precisely with the actual peaks of abundance. But on the other hand, general trends in abundance seem to be indicated clearly in many of the fishes

TABLE XI. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Cynoscion regalis*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–24–42 | 25 | 25–70 | 36.8* ± .84 | 4.15 ± .46 | 4 |
| VIII–7–42 | 31 | 14–89 | 46.6† ± 1.24 | 9.06 ± 1.36 | 6 |
| VIII–21–42 | 222 | 30–73 | 46.2 ± .16 | 2.38 ± .11 | 2 |
| IX–4–42 | 8 | 43–65 | ..... | ..... | 6 |
| X–2–42 | 1 | 55 | ..... | ..... | .. |
| X–16–42 | 2 | 72–98 | ..... | ..... | .. |

* One specimen, 70 mm., omitted from calculation of the mean.
† Three specimens, 14 mm., 71 mm., 89 mm., omitted from calculation of the mean.

encountered. Needless to say, *C. regalis* may have been in Morris Cove a week or so before July 24, when it was first taken. Of the 25 individuals encountered on this date, 24 were well within the size range of fish-of-the-year, but one was considerably larger than any of the other fish in that collection. Omitting this large individual (70 mm.), the remaining 24 had a spread from 25 to 44 mm., and the mean length for the collection was 36.8 mm. The next sample contained six more fish than the previous collection, but three of them were well separated in length from the rest. Two of these fish were large (71 and 89 mm.) and one was very small (14 mm.). The mean length of the 28 individuals constituting the bulk of the August 7 collection was 46.6 mm. The largest collection of *C. regalis* (August 21) ranged from 30 to 73 mm. in size and was distributed mainly between 30 and 60 mm., with a few additional fish at the upper limits of the spread (Fig. 14). That this population was reasonably homogeneous is evidenced by the fact that the variation coefficient (expressed as percentage of the standard deviation in the mean) was 5.16, compared with 11.27 on July 24, and 19.44 on August 7. The mean length of this collection was 46.2 mm. The next collection was taken on September 4, and contained but eight fish ranging from 43 to 65 mm. No more *C. regalis* were encountered until a month later, when one fish was collected; the two individuals taken on October 16 marked the last appearance of the species for the season.

The numbers of immature *C. regalis* in Morris Cove were considerably less than might have been expected from reports in the literature. Many investigators have encountered these fish in just such localities. Higgins and Pearson (1927) say they remain in the

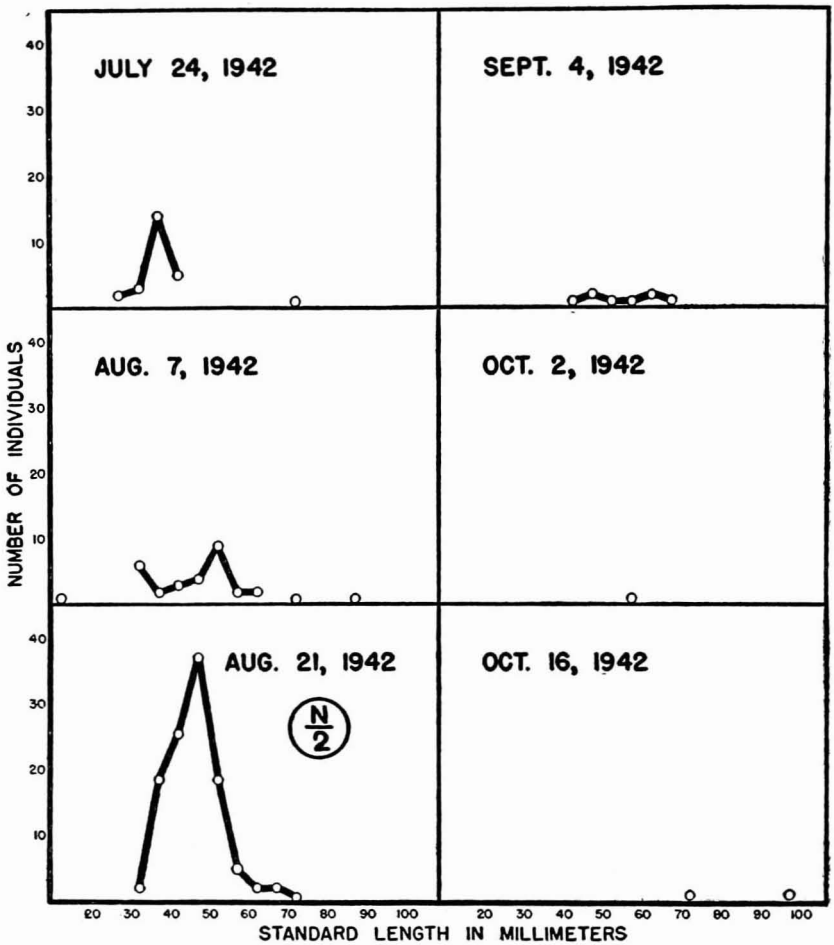


Figure 14. Length-frequency curves of *Cynoscion regalis*.

sounds and bays as immature individuals, and Welsh and Breder (1923), Hildebrand and Cable (1934), Nesbit (1939), Greeley (1939), and Bigelow and Welsh (1925), all substantiate this view. Thus the impression is gained that they were more abundant in the localities referred to by these authors than in the area under consideration in this study. Apart from the fact that the collection dates may not have corresponded with the dates of actual abundance, as mentioned above, there are several possible explanations for the relatively few

weakfish collected in Morris Cove. For example, 1942 may not have been a good spawning year for this species. That great fluctuations in abundance of the young occur is well known; Sherwood and Edwards (1901) pointed to this and suggested a possible inverse relationship between the numbers of *C. regalis* and *Pomatomus saltatrix*. However, this relationship is now generally discounted (Bigelow and Welsh, 1925). Sherwood and Edwards (*loc. cit.*) also indicated local variations in abundance between Buzzards Bay and Narragansett Bay, and this points to the fact that New Haven Harbor may be sufficiently out of the range of this species to limit the number that would ever be taken from Morris Cove at one time.

The small numbers taken in 1942 do not shed much light on the population analysis of this species, and any inferences are questionable. On the basis of the limited evidence available, it appears that new populations of *C. regalis* came into the area throughout the season, as in previously discussed species. Almost all the collections contained fish-of-the-year, and the sizes agree generally with the observations of other authors. Sherwood and Edwards (1901) cite measurements that are in essential agreement with the present observations; Perlmutter (1939) lists 40 to 44 mm. as the size of the fish taken in July and August; on the other hand, Tracy (1910) encountered larger specimens in August. If Hildebrand and Cable (1934) are correct in their assumption that weakfish less than 10 mm. in length are the product of nearby spawnings, then some of the individuals encountered in Morris Cove probably were produced in regions close at hand. However, Welsh and Breder (1923) think that the eggs and larvae are carried by currents and sink only during later stages of development. Thus many of these fish may well have been spawned at more distant places. But it is difficult to believe that a specimen as small as 14 mm. taken in August could have been spawned far from the scene of the study.

The few larger individuals encountered in the earlier collections allow room for various speculations as to their origin. These fish may have been representatives of the upper size limits of this species which were in the area on that date, and the seine may have failed to sample the population adequately. They may also have been the result of an early spawning either in nearby waters or in more southerly waters. That they were fish-of-the-year seems reasonable in view of the generally-accepted fact that second-year weakfish remain in more southern regions.

*Scophthalmus aquosus* (Mitchill)

*Scophthalmus aquosus*, the windowpane or daylight flounder, one of the common residents of Long Island Sound, was encountered occasionally in the course of the Morris Cove study. It never was plentiful, and occupied ninth place in rank of abundance for the year in conjunction with *Menticirrhus saxatilis*. It is given preference over *M. saxatilis* because *S. aquosus*, when it was present, more nearly dominated the population in numbers. Comparison of the respective ranks of abundance indicated in Tables XII and XIII shows that *S. aquosus* ranked second, third, and fourth on those dates when it could be ranked, while *M. saxatilis* never achieved better than sixth place.

*S. aquosus* only ranked high in the scale of relative abundance in April and early May, when very few fish of any species were present in the area. It ranked second on April 16, and third on April 30, but in late May, when the largest collection of this species was made, it ranked fourth, *Clupea harengus*, *Syngnathus fuscus*, and *Microgadus tomcod* exceeding it in numbers.

Nichols and Breder (1926), Tracy (1910), and other authors place the spawning period of this species in May and June. But if reproduction is confined to these months in Long Island Sound, then the smaller fish taken at Morris Cove in the course of the present study are extremely difficult to explain on the basis of length alone. The individuals taken in August and October (85 and 80 mm. respectively) would either have to be fish-of-the-year which grew remarkably fast, or 1+ fish which grew rather slowly. The 49 mm. specimen taken in late April, as well as the majority of the 45 *S. aquosus* in the collection of late May, would have to be fish which were approximately a year old; this would indicate an almost inconceivably slow growth rate and would be difficult to reconcile with statements by Tracy (1910) and Bigelow and Welsh (1925) to the effect that growth in the early stages of development is rapid. Similarly the 88 mm. specimen of June 25 would have to be an incredibly fast-growing 0+ fish, or a surprisingly small one-year-old.

The present authors, from observations on the commercial trawlers operating out of Connecticut ports in 1943, incline to the belief that spawning in this region may possibly begin as early as May, reaches a peak in June and July, and continues at least into August. Although it is obviously impossible to draw well-substantiated conclusions from

TABLE XII. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF *Scophthalmus aquosus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VIII–21–42 | 1 | 85 | ..... | ..... | .. |
| X–2–42 | 1 | 80 | ..... | ..... | .. |
| XI–13–42 | 1 | 211 | ..... | ..... | .. |
| IV–16–43 | 2 | 204–231 | ..... | ..... | 2 |
| IV–30–43 | 3 | 49–212 | ..... | ..... | 3 |
| V–28–43 | 45 | 35– 73 | 51.1 ± 1.23 | 8.25 ± .87 | 4 |
| VI–25–43 | 1 | 88 | ..... | ..... | .. |

the exceedingly limited data at hand, the sizes of the small *S. aquosus* in the Morris Cove collections fit the conception of summer spawning far better than that of reproduction in the spring. Under these conditions the August and October fish, 85 and 80 mm. long, would quite certainly be in the 1+ group; the 49 mm. individual taken in April as well as the majority, if not all of the collection of May 28 (mean length 51.1 mm.), would definitely be fish approaching the completion of their first year of life; and the 88 mm. specimen of June 25 would either be a rather large fish approximately one year old, or a slow-growing *S. aquosus* nearing or at the completion of its second year. If the above assumptions concerning age are correct, an adjustment of previously conceived ideas regarding the time and length of the spawning period is clearly in order. It should be mentioned that not only may the spawning period extend over a much greater period and occur later in the summer than has heretofore been recognized, but there may well be distinct races of this species, as suggested for *Pseudopleuronectes americanus*, which spawn at different times.

The larger fish taken in this study are not easy to account for in water as shallow as that of the Morris Cove area, although it is recorded by Nichols and Breder (1926) that this species is sometimes found stranded on beaches by falling tides. But the concensus of opinion seems to be that they inhabit deeper water as a rule. It seems possible that they approach the shore in the pre-spawning period. The large fish, encountered late in the winter and spring, may indicate an on-shore movement of adults in the colder months.

*Menticirrhus saxatilis* (Bloch and Schneider)

The northern kingfish was among the species taken consistently although never in large numbers through the summer of 1942 at Morris Cove. It was collected from July 10 through October 2, 1942, with a single interruption in late September. This species tied with *Scophthalmus aquosus* for the ninth place of abundance, but never achieved a rank higher than sixth place on any collecting date.

The *M. saxatilis* taken on the Morris Cove beach were, without exception, small and it seems entirely probable that these were all fish-of-the-year if Nichols and Breder (1926) are correct in their statements regarding growth. Most authorities agree that spawning takes place mainly in June and early July, although Welsh and Breder

TABLE XIII. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF *Menticirrhus saxatilis*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Rank* |
|---|---|---|---|
| VII–10–42 | 14 | 13–26 | 6 |
| VII–24–42 | 13 | 17–49 | 6 |
| VIII–7–42 | 10 | 42–78 | 8 |
| VIII–21–42 | 17 | 27–90 | 8 |
| IX–4–42 | 7 | 21–87 | 7 |
| X–2–42 | 7 | 59–90 | 7 |

(1923) state that it continues until August. The collection of the smaller individuals in early September seems to point to a spawning date later than mid-July in 1942, although the material available for study is not sufficient to justify general conclusions.

The first collection, taken July 10, 1942, contained 14 fish that ranged in size from 12 to 26 mm., and the species ranked sixth in abundance on that date. Two weeks later 13 individuals were taken, and the size range was different in that the upper limit was considerably higher than that of the previous collection, and the lower limit only slightly so. However, most of the individuals of the collection fell around the 20 mm. mode, and only three were in the 40 to 49 mm. length interval. *M. saxatilis* ranked sixth on that date. The third collection (August 7) contained 10 fish that were comparatively large, ranging from 42 to 78 mm., with five of them falling in the 50 to 59 mm. length interval. The rank of abundance fell to eighth place.

The collections taken in late August and early September contained

individuals which were smaller than those taken in early August and which apparently represented new populations that had come into the area. The large collection taken August 21 had two individuals in the 27 to 29 mm. length interval, two in the 30 to 39 mm. interval, and four in the 40 to 49 mm. interval. Others, presumably the product of earlier spawnings, were present in the 50 to 59 mm., 60 to 69 mm., and 80 to 89 mm. intervals. With the exception of the fish in the 50 to 59 mm. category, the larger individuals probably represented fish of the populations taken previously. But the smaller fish were apparently younger, probably resulting from an early August spawning. The same assumption seems reasonable for most of the collection taken September 4 although the lone 21 mm. fish might have been stunted. For if a mean length of 19 mm. (computed for the population of July 10, 1942) was attained in the period from early June to July 10, similar or slightly larger fish taken in early September in all probability would have been born in August, especially since the higher temperatures of summer should make for faster development.

The last collection was taken on October 2 and contained seven individuals that were comparatively large, ranging from 59 to 90 mm. Most authorities agree that this species leaves the vicinity of southern New England in October, and it is probable that the smaller fish which inhabit the shore zone would leave that area a little earlier, and after a period of life spent further from shore, move southward.

### *Clupea harengus* Linnaeus

The common herring was encountered three times in the course of this study. All of these collections were in the spring of 1943, and twice this species dominated the fish population in the area. All specimens were small, many of them being but little advanced from the larval stage.

The first collection that contained *C. harengus* was on April 30, when one postlarval individual 34 mm. long was taken. The next collection, May 14, contained 464 *C. harengus* ranging from 33 to 54 mm. in length, with a mean at 42.4 mm. Of this collection 100 individuals were so different in external appearance from the other specimens taken at the same time that they were designated as "postlarval" stages. The rest of the collection, 364 fish, were older and were designated as "juveniles." It seems probable that two broods were

taken at this time, although this is not indicated in Fig. 15, where examination of the curve suggests an apparently false homogeneity owing to the overlap in lengths of the postlarval and small juvenile fish. Two weeks later 431 specimens were collected, all having the characteristics of juvenile fish and ranging in length from 34 to 63 mm., with a mean for the collection of 41.2 mm.

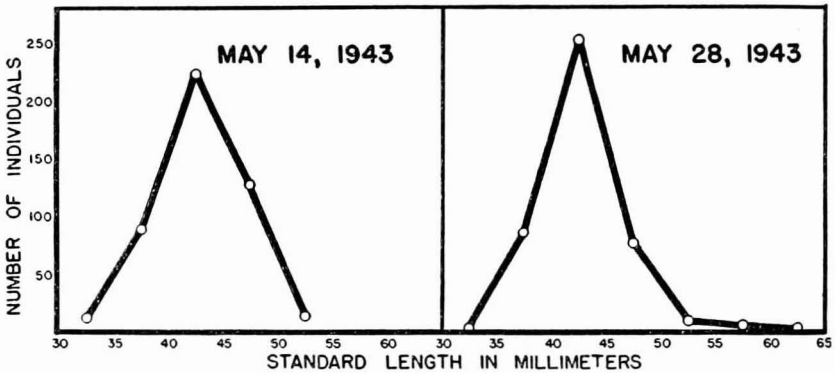


Figure 15. Length-frequency curves of *Clupea harengus*.

TABLE XIV. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Clupea harengus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| IV-30-43 | 1 | 34 | ..... | ..... | .. |
| V-14-43 | 464 | 33-54 | 42.4 ± .174 | 3.74 ± .123 | 1 |
| V-28-43 | 431 | 34-63 | 41.2 ± .170 | 3.49 ± .119 | 1 |

The entire collections of May 14 and May 28 were dominated by *C. harengus* and this species ranked first in abundance on these dates. *C. harengus* ranked eleventh in relative abundance for the entire year.

The presence of these small individuals corroborates the statements of Bigelow and Welsh (1925), who say that "—west of Cape Cod the herring do not begin to spawn until mid- or late October, with the major production of eggs about the 1st of November." The winter growth rates observed by others in southern New England, when applied to the small herring encountered in this study, would indicate a late fall or early winter spawning. It is also probable that the highly limited seasonal appearance of herring in this biotope as shown in this study is characteristic.

*Myoxocephalus aeneus* (Mitchill)

Of the various species in the genus *Myoxocephalus* listed for the Long Island Sound region, there are two which, when they have been given separate specific rank, have not been easily distinguishable. According to Nichols and Breder (1926) one, *M. aeneus*, is supposed to be common; the other, *M. mitchilli*, is supposed to be rare, but is occasionally mentioned in the literature. The exact distribution of these two species and their identity has been the subject of considerable confusion—*e. g.*, Greeley (1939) considered that all of the sculpins in his collection were *M. mitchilli*, while Perlmutter, in the same report (1939) identified all his specimens as *M. aeneus*.

The fish in the present collection were examined and measured by Mr. Willard D. Hartman, a student at Yale University, who in the course of his work discovered that all the specimens identified as *M. aeneus* were females, and the *M. mitchilli* males. This obviously indicated that these fish were identical as to species. Mr. Hartman, who has pursued this study further and has examined other collections (Hartman, MS.) has supplied the following brief discussion of the situation in regard to the Morris Cove specimens:

> "Examination of 34 specimens of the *Myoxocephalus* which were taken during the course of the study of the fishes of Morris Cove, suggests the synonymy of the two species, *M. aeneus* and *M. mitchilli*. Of the total number caught, 31 were females, as was revealed by examination of their gonads. These specimens corresponded fully to the usual descriptions of *M. aeneus*, *i. e.*, they had a "brassy" color and generally had three indistinct bars across their ventral fins. These bars were entirely absent in young specimens (*circa* 50 mm.), and one or two of the bars were sometimes either absent or represented only by small spots on the fin rays in the adult females. The remaining three specimens caught on the regular biweekly Morris Cove trips were males. Two of these specimens were young, measuring 53 and 60 mm. standard length and being only slightly darker in color than the average female. The ventral-fin bars were not conspicuous, but were more clearly defined than in females of corresponding sizes. The third specimen measured 73 mm. Its color was darker than that of the average female, and it had three distinct ventral-fin bars which were more clearly defined than on any female in the collection. Two adult

male specimens, 85 and 82 mm. standard length, were caught in New Haven harbor on occasions other than the regular Morris Cove trips. These clearly answered the description usually given for *M. mitchilli*, *i. e.*, they were darker, nearly black, in general body color, and they possessed four clearly outlined bars on the ventral fins. On the basis of the limited amount of material in this collection, the most logical conclusion is that the two supposed species are males and females of the same form."

TABLE XV. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Myoxocephalus aeneus*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Rank* |
|---|---|---|---|
| VII–10–42 | 1 | 68 | .. |
| VII–24–42 | 2 | 67–124 | .. |
| VIII–21–42 | 2 | 65– 83 | .. |
| IX–18–42 | 1 | 178 | .. |
| X–16–42 | 15 | 53–116 | 6 |
| X–30–42 | 1 | 53 | .. |
| XI–13–42 | 9 | 64–111 | 2 |
| V–14–43 | 1 | 65 | .. |
| V–28–43 | 1 | 82 | .. |
| VI–25–43 | 1 | 112 | .. |

The first *Myoxocephalus aeneus* was taken on July 10, 1942, and was a female. On July 24 two more females were taken, two were collected on August 21, and another was taken September 18. On October 16 the largest collection of this genus was made; all were females except one. This collection ranged from 53 to 116 mm. in length and ranked sixth in abundance. A single female was also taken on October 30, and 9 individuals were netted on November 13, two of which were males. This last collection ranked second in abundance. This fish did not appear again until May 14, 1943, when a female 65 mm. long was collected. On May 28 and June 25 single females, 82 and 112 mm. long respectively, were secured.

That these fish are permanent residents of the region seems to be indicated by the fact that they were taken pretty generally throughout the entire course of the study, except in the extremely cold months of the winter. They appeared to be more abundant near the tide line of the sandy beach during the fall, but the numbers taken were so small that it is doubtful that they are ever plentiful on a sandy

bottom. The heavy preponderance of females in this species seems unusual and is worthy of further investigation.

*Pomatomus saltatrix* (Linnaeus)

The bluefish, *Pomatomus saltatrix*, was taken in Morris Cove in October 1942 on two occasions. This species, the young of which are very common on the southern New England coast during the fall in most years, was not encountered in the area at any other time in the course of this study, although of course it may have been present at intervals between the regular collections.

TABLE XVI. NUMBER, LENGTH, AND RANK OF ABUNDANCE OF *Pomatomus saltatrix*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Rank* |
|---|---|---|---|
| X-2-42 | 9 | 80- 97 | 6 |
| X-16-42 | 6 | 86-118 | 7 |

It ranked sixth and seventh on the dates when it was captured, but collections made in 1943 for other purposes indicated that during that year it was probably more abundant than in 1942. In general, collections made outside New Haven Harbor seem to contain more small bluefish than those taken inside; this would point to the assumption that a more open environment is preferred, but Perlmutter (1939) and others have found many young bluefish in bays. The fact that the bluefish is such an active animal may also account for the few captures in this work.

The absence of smaller bluefish, 50 to 70 mm. in length, is possibly an indication that the Morris Cove area is not a favorable environment for this species, but it might also be argued from this inadequate evidence either that 1942 was a poor spawning year, or that the areas where reproduction takes place are sufficiently far removed so that the smaller fish do not often stray as far west on the north side of Long Island Sound.

*Prionotus evolans evolans* (Linnaeus)

Two species of the genus *Prionotus* were collected in the summer of 1942, *Prionotus evolans evolans* and *Prionotus carolinus*. Of these *P. evolans* was the more common, *P. carolinus* being taken only once.

*P. evolans evolans* was one of the minor species in the collections from Morris Cove, and was taken only in the months of August and September. The first lot was secured on August 7 and contained 28 fish, ranging in size from 23 to 51 mm. The mean length of this population was 36.1 mm. The next collection, taken on August 21, consisted of 59 individuals which ranged in standard length from 34 to 66 mm. and had a mean length of 46.2 mm. On the next two collecting dates a total of five fish were obtained; the lone individual taken September 4 was 89 mm. long and the four taken two weeks later ranged from 54 to 88 mm.

TABLE XVII. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Prionotus evolans*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VIII–7–42 | 28 | 23–51 | 36.1 ± 1.26 | 6.65 ± .889 | 7 |
| VIII–21–42 | 59 | 34–66 | 46.2 ± 1.11 | 8.55 ± .809 | 7 |
| IX–4–42 | 1 | 89 | ..... | ..... | .. |
| IX–18–42 | 4 | 54–88 | ..... | ..... | .. |

All of the individuals comprising the collections were small, and it seems reasonable to suppose that they were fish-of-the-year which were the product of a June or early July spawning. The means of the collections in August are probably a rough measure of the general order of growth at that season.

*Anchoa mitchilli* (Cuvier and Valenciennes)

The common anchovy was present in Morris Cove during the summer of 1942, and a single individual was collected in May of the succeeding year, but it was not common enough to have a designated rank of abundance in any of the biweekly collections except that of August 7.

The first collection of *A. mitchilli* was taken July 24, when a single individual was collected. The next was taken August 7 and consisted of 39 individuals, ranging from 25 to 36 mm., having a mean of 28.8 mm., and being fifth in abundance among the species collected on that date. The collections of August 21 had three anchovies with standard lengths of 25, 27, and 34 mm. The last collection for the summer season was taken on September 4, when a single individual 22 mm. long was secured. Another anchovy was collected on May

14, 1943; it was smaller than any caught previously, but was so damaged that measurements could not be taken.

Spawning in this species is supposed to take place in July and August, and it seems reasonable, judging by the size of the fish, to assume that the specimens in the first two collections (Table XVIII)

TABLE XVIII. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Anchoa mitchilli*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Mean Size (S.L. in mm.)* | *Deviation* | *Rank* |
|---|---|---|---|---|---|
| VII–24–42 | 1 | 26 | ..... | ..... | .. |
| VIII–7–42 | 39 | 25–36 | 28.8 ± .413 | 2.58 ± .292 | 5 |
| VIII–21–42 | 3 | 25–34 | ..... | ..... | .. |
| IX–4–42 | 1 | 22 | ..... | ..... | .. |
| V–14–43 | 1 | .... | ..... | ..... | .. |

were the result of July reproduction. The individuals taken in late August and early September were apparently the product of later breeding activity, while the small fish caught in May 1943 was in all probability an individual which had been born at the conclusion of the 1942 spawning season.

In many parts of Long Island Sound and adjacent waters this species is generally regarded as abundant. Greeley (1939), Perlmutter (1939), Tracy (1910), and Smith (1898), considered it common in parts of the region they studied, but Nichols and Breder (1926) point out that it is less numerous "to the westward," presumably meaning the approaches to New York.

### *Bairdiella chrysura* (Lacépède)

In the late summer and early fall a few specimens of the silver perch, *Bairdiella chrysura*, came into Morris Cove. On August 21 this species ranked ninth in abundance and in mid-September it ranked seventh. The individuals in the collections were small, and if the assumptions of numerous other workers are correct they were all fish-of-the-year. They did not exceed the sizes indicated by Welsh and Breder (1923), Hildebrand and Schroeder (1928), and Perlmutter (1939), for fish in their first season.

It would be interesting to discover where these specimens were born, *i. e.*, whether they were the product of local or more southern spawning. The northernmost record of spawning is furnished by the

TABLE XIX. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Bairdiella chrysura*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Rank* |
|---|---|---|---|
| VIII-21-42 | 11 | 19–31 | 9 |
| IX-18-42 | 8 | 18–48 | 7 |
| X-2-42 | 2 | 33–47 | .. |
| X-16-42 | 1 | 39 | .. |

egg collection made by Perlmutter (1939) on the south shore of Long Island. Tracy (1910) first reported juveniles of this species from near Wickford, Rhode Island, but his collection was in the same category as the one from Morris Cove since a few individuals were taken in a shore seine and no further data is available.

*Tautoga onitis* Linnaeus

The tautog or blackfish, *Tautoga onitis*, was one of the minor species taken in the late summer and early autumn months of 1942. It was never abundant, not over five specimens being taken at one time, the highest rank achieved being eighth on two occasions.

TABLE XX. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Tautoga onitis*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Rank* |
|---|---|---|---|
| VIII-21-42 | 2 | 18–48 | .. |
| IX-4-42 | 2 | 50–61 | .. |
| IX-18-42 | 5 | 32–51 | 8 |
| X-2-42 | 4 | 31–60 | 8 |
| X-16-42 | 1 | 42 | .. |

Apparently these collections were composed of fish-of-the-year, and the small numbers are probably best explained by the fact that the sandy beach is not a preferred habitat. Baird (1855) reported taking large numbers of small individuals in rivers and inlets of the New Jersey and Long Island coasts when hauling nets; T. H. Bean (1888) concurred with observations made at the same locality in New Jersey. Smith (1898) cited the species as being abundant everywhere on rocky bottom, and in this Bigelow and Welsh (1925), Nichols and Breder (1926), Tracy (1910), and others agree. Therefore it would seem that the fish taken in Morris Cove were either stragglers from more desirable habitats nearby or possibly young-of-the-year that had

not become acclimated to the more common rocky bottom environment.

*Synodus foetens* (Linnaeus)

In August and September the lizard fish, *Synodus foetens*, appeared three times in the collections, and in early September the species ranked eighth in abundance. Various authorities, Smith (1898), Bean (1888), and Tracy (1910) report it as being consistently taken but never in great numbers. The specimens collected in this study were small. Although little or nothing is known of the spawning habits, age at maturity, etc., of this species, the evidence from Breder (1944) points to an extended reproductive period. In view of this fact, as well as the voracious feeding habits and presumably fast growth rate, it seems probable that all the specimens in this collection were fish-of-the-year, with the possible exception of the largest individual—that taken on September 18.

TABLE XXI. NUMBER, LENGTH AND RANK OF ABUNDANCE OF *Synodus foetens*

| *Date* | *Number* | *Size Range (S.L. in mm.)* | *Rank* |
|---|---|---|---|
| VIII–7–42 | 1 | 55 | .. |
| IX–4–42 | 6 | 63– 78 | 8 |
| IX–18–42 | 1 | 107 | .. |

## The Less Abundant Species

In addition to the species discussed previously, there were 13 other kinds of fishes taken at Morris Cove which were much less abundant. Some of these were sporadic strays which are relatively uncommon in this region because it lies near the periphery of their known geographical distribution. Others were forms which are normal inhabitants of shallow-water sandy-beach areas but are never particularly abundant. And some were types which are more commonly found in other environments of the shore zone, but occasionally move onto different grounds. A further reason for the scarcity of some of the species probably lies in low productivity in one breeding season as opposed to another and in the vagaries of the distribution of pelagic eggs and larvae by different currents in succeeding years—*i. e.*, factors which cause fluctuations in abundance over the whole or any part of the range of the species under consideration. Finally, it should be mentioned that some fish which normally occur in habitats such as the

Morris Cove area were not taken in the course of this study; the reasons for their absence in the collections are not readily apparent.

TABLE XXII. NUMBER AND RANGE OF STANDARD LENGTHS OF THE LESS ABUNDANT SPECIES

| *Species* | *Date* | *Number* | *Size Range (S.L. in mm.)* |
|---|---|---|---|
| *Apeltes quadracus* | IX–18–42 | 4 | 32–41 |
| *Pungitius pungitius* | VII–10–42 | 1 | 24 |
| *Caranx hippos* | VIII–7–42 | 4 | 34–39 |
| | VIII–21–42 | 1 | 42 |
| *Leiostomus xanthurus* | VII–10–42 | 1 | 31 |
| *Tautogolabrus adspersus* | VIII–21–42 | 1 | 21 |
| *Opsanus tau* | VIII–21–42 | 1 | 58 |
| *Urophycis tenuis* | IV–30–43 | 1 | 57 |
| *Urophycis regius* | VI–11–43 | 1 | 45 |
| *Pomolobus pseudoharengus* | VIII–7–42 | 1 | 27 |
| *Osmerus mordax* | V–14–43 | 4 | 60–79 |
| *Pollachius virens* | IV–16–43 | 2 | 24–27 |
| | V–14–43 | 1 | 23 |
| *Prionotus carolinus* | VII–10–42 | 1 | 134 |
| *Anguilla rostrata* | (Taken fairly regularly throughout the collecting season.) | | |

The sticklebacks, *Pungitius pungitius* and *Apeltes quadracus*, and possibly the jack, *Caranx hippos*, were in all probability strays from habitats with more abundant vegetation; this can also be said of the spot, *Leiostomus xanthurus*, if the data of Hildebrand and Cable (1930) are applicable to Long Island Sound. Both *C. hippos* and *L. xanthurus* approach the northern limits of their ranges in southern New England and therefore would not be expected to be as plentiful as further to the south. *Tautogolabrus adspersus* and *Opsanus tau* were apparently wanderers from rocky habitats where they are well known, although they have been reported from sandy or muddy bottoms occasionally. The hakes, *Urophycis tenuis* and *regius*, were also presumably strays from other environments and it is not easy to account for their presence in the shallow water of the sandy beach. Some difference of opinion is expressed in the literature concerning the habits of the young *U. tenuis*, but that they have been found frequently associated with floating vegetation seems agreed upon by Bigelow and Welsh (1925) and Nichols and Breder (1926). Young *U. regius*, according to Nichols and Breder (*loc. cit.*), are to be found

"on the bottoms of rather deep, muddy bays." The single alewife, *Pomolobus pseudoharengus*, and the four smelt, *Osmerus mordax*, were almost unquestionably the product of spawning in nearby fresh or brackish water. Since they are both well known from the region, it is difficult to explain their near absence in the biweekly samples from Morris Cove. The two collections of pollack, *Pollachias virens*, both taken in the spring, form examples of a species nearing the southern limits of its geographical range. These fish, the product of spawning in late 1942, probably were carried toward the vicinity by currents, since it is doubtful if spawning takes place "west of Cape Cod," according to Bigelow and Welsh (1925). *Prionotus carolinus* apparently prefers the sandy habitat as an adult, and it is possible that the young may be present there also. The single specimen collected in mid-summer indicates that they are to be found in Morris Cove, but their apparent rarity is peculiar in view of statements by Nichols and Breder (1926) regarding their abundance, as well as the relatively large numbers of *P. evolans evolans* which were taken in this study. Finally, the common eel, *Anguilla rostrata*, was encountered in a number of the spring, summer, and fall collections, although seldom more than a single individual or two were taken on one date. Unfortunately they were discarded in the early part of the study, and inasmuch as the record was incomplete they were merely noted subsequently. Although they were fairly consistently present they were among the less abundant species.

## PHYSICAL ASPECTS OF THE ENVIRONMENT

Reference to the field data, with respect to such physical factors as were noted in connection with the Morris Cove biweekly collections, indicates some interesting trends that are important in the analysis of the fish population of the area under consideration. Although the data and general observations were for the most part rough and not entirely consistent, the information shows relationships that seem significant.

### Temperature

Water temperatures ranged from 26.8° C. in late August to subzero in late December. No consistent and measurable stratification existed in the shallow water of the shore zone at Morris Cove, so that near-surface readings were indicative of conditions throughout the area. Ice

was formed in late December and continued through February, except for a thaw which was produced by rain on February 5, 1943. The general ascending and descending seasonal trends of heat acquisition and loss were fairly regular, and only comparatively minor variations appeared in the summer and winter periods of relatively constant temperature (Fig. 16).

From the standpoint of this study, there were definite relationships not only between the temperature and the population of fishes as a whole, but also between temperature and the various component species. These are presented below, but it should be borne in mind also that the individual fish within each species were probably affected by temperature in a manner so subtle that clear-cut correlations could not be detected from rough data of the type collected in this study. Therefore the relationships here presented concern only the total population and the component species, both of which were affected profoundly by temperatures and reacted in a fairly definite manner. These reactions obviously concern definite sizes and age categories in some species—notably the young and immature, while in others they involve a wide range of size and age-groups.

The most obvious relationship between temperature and the population at the Morris Cove shore zone is the fact that during the winter months, beginning in December and continuing through to mid-April, no fish were taken except for a lone *Fundulus majalis* on March 19, 1943. During this period the temperatures ranged from 4.2° C. on December 11, 1942, downward to −0.4° C. on December 24, and up to 6.2° C. on April 16, 1943, when the first collection that contained more than a single fish was made. As the temperatures rose in the spring a greater variety of fishes appeared in the area, six species being taken on April 16, 1943, as compared with 17 taken on August 21, 1942 (Fig. 17). As the temperatures descended in the late summer and fall the variety of species decreased until December 11, 1942, when only three species were present. After that no fish were taken in the area until spring, despite the fact that full normal effort to secure them was made. This tendency to increase in variety as the summer season progressed has been noted before. Thus Greeley (1939) mentioned it as a "well known" fact, but his data covered only the summer months and he qualified his statement by saying that if collections could be continued into the fall a downward trend might be proven. The close parallelism between the two factors shown in Fig. 17 substantiates this view.

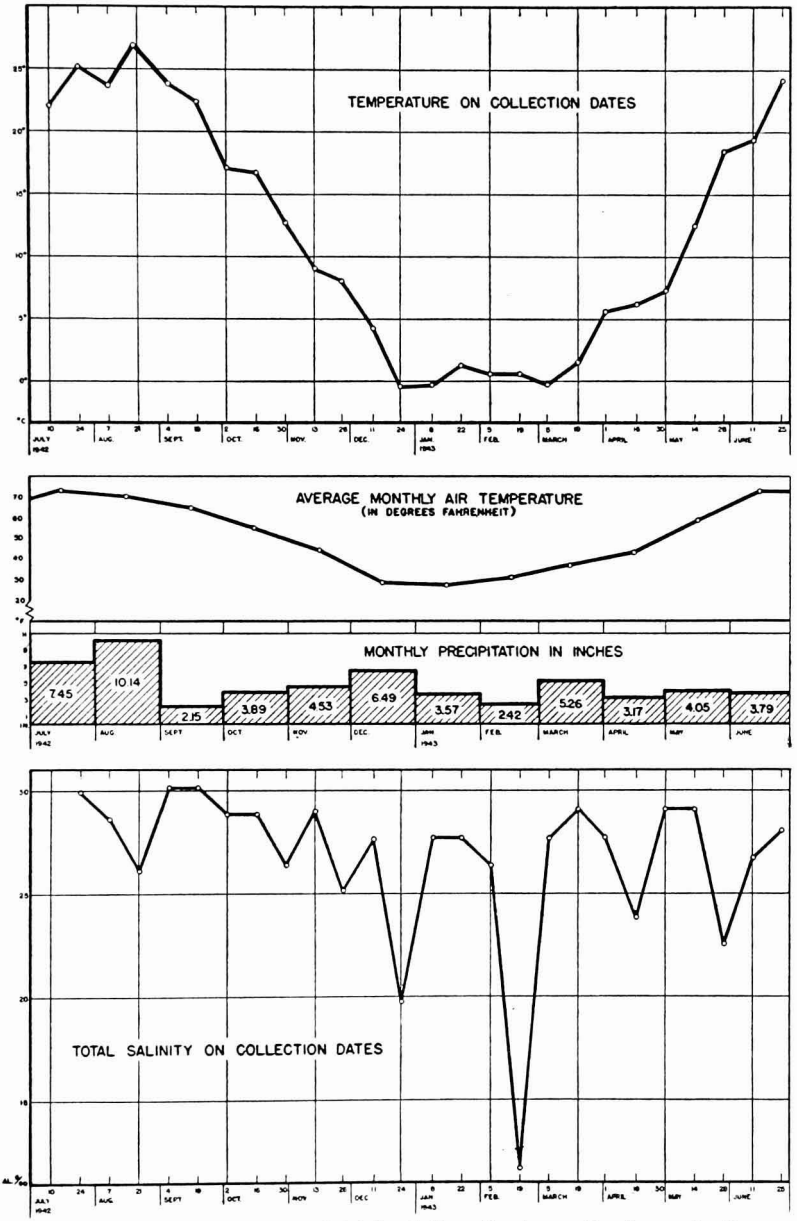


**Figure 16.** Water temperature and total salinity estimates on the days collections were made, compared with air temperatures and precipitation data from records of the United States Weather Bureau.

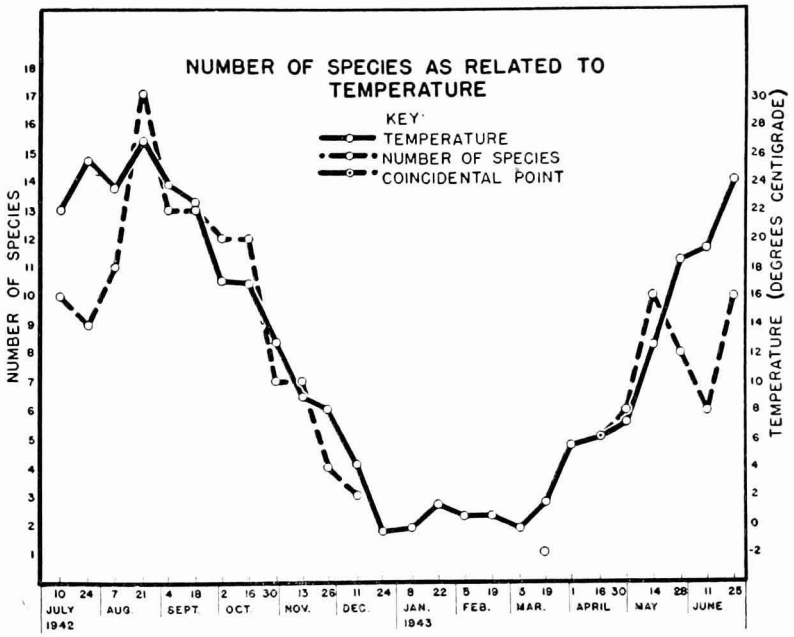


Figure 17. The variety of species as related to the temperature of the water on the collection dates.

Turning to the relationship of temperature and the individual species, the limits are indicated in a general way by the data in Table XXIII. However, the maximum temperatures are in no way accurate indicators of the upper limits, since 26.8° C. was the highest level reached, and there is no reason to suppose that some of the species concerned would not have remained in the area if the water had become warmer. On the other hand, the minimum temperatures probably give a fairly good indication of the lower limits for the different sizes of the species of this biotope, since the water temperature went considerably below the level at which all the fish disappeared from the area. It should be emphasized, then, that the maximum and minimum temperatures as listed in Table XXIII are nothing more than broad estimates of the limits within which the individuals of the size here encountered will remain in this biotope. That certain species exhibited variations from the trend of increasing variety with increasing temperature is apparent from consideration of the data in Table XXIII. Thus *Microgadus tomcod* and *Clupea harengus* were

TABLE XXIII. MAXIMUM AND MINIMUM TEMPERATURES ENCOUNTERED BY THE MORE ABUNDANT SPECIES

| *Species* | *Date* | *Maximum Water Temp. in °C.* | *Date* | *Minimum Water Temp. in °C.* |
|---|---|---|---|---|
| *M. m. notata* | VIII–21–42 | 26.8 | XII–11–42 | 4.2 |
| *P. americanus* | VIII–21–42 | 26.8 | XII–11–42 | 4.2 |
| *S. fuscus* | VIII–21–42 | 26.8 | IV–16–43 | 6.2 |
| *Fundulus* spp. | VIII–21–42 | 26.8 | XII–11–42 | 4.2 |
| *B. tyrannus* | IX–4–42 | 23.9 | XI–26–42 | 8.1 |
| *S. maculatus* | VIII–21–42 | 26.8 | X–16–42 | 16.6 |
| *M. tomcod* | VI–25–43 | 24.1 | XI–13–42 | 9.1 |
| *C. regalis* | VIII–21–42 | 26.8 | X–16–42 | 16.6 |
| *S. aquosus* | VIII–21–42 | 26.8 | IV–16–43 | 6.2 |
| *M. saxatilis* | VIII–21–42 | 26.8 | X–2–42 | 17.1 |
| *C. harengus* | V–28–43 | 18.4 | IV–30–43 | 7.3 |
| *M. aeneus* | VIII–21–42 | 26.8 | XI–13–42 | 9.1 |
| *P. saltatrix* | X–2–42 | 17.1 | X–16–42 | 16.6 |
| *P. evolans evolans* | VIII–21–42 | 26.8 | IX–18–42 | 22.3 |
| *A. mitchilli* | VIII–21–42 | 26.8 | V–14–43 | 12.5 |
| *B. chrysura* | VIII–21–42 | 26.8 | X–16–42 | 16.6 |
| *T. onitis* | VIII–21–42 | 26.8 | X–16–42 | 16.6 |
| *S. foetens* | IX–4–42 | 23.9 | IX–18–42 | 22.3 |

important components of the spring population when the temperatures were ascending, but were gone from the area before the peak of variety was reached. Similarly, the adults of *Syngnathus fuscus* left the area before the highest temperature was recorded, although the immature forms were collected regularly thereafter. Certain minor species also appeared at times other than at the height of the summer season, but these were apparently stragglers from other habitats.

The reactions of individual fish of the different species to temperature were not apparent from this study, although some evidence regarding the relation of numbers and season is forthcoming. Since the temperatures recorded for Morris Cove also applied in a general way to a large expanse of adjacent water, it follows that the fish were not limited to the area which was seined by the heat factor alone. As might be expected, therefore, the number of individuals did not show a regular increase with temperature, either in the aggregate for all species or for any particular species. Obviously there were more fish in this area in the warmer months as mentioned above, but beyond this broad generalization there appears to be no direct correlation with temperature. The peaks of total abundance and the

fluctuations in numbers of individuals by collection dates (Fig. 20) show no clear trend, although it is true that near the lower limits of the temperature curve the number of individuals of the species that were present was less, and the collections were small.

## Salinity

The salinity varied from 30.2°/₀₀ in September to 11.6°/₀₀ in February. Reference to Fig. 16 indicates that generally the total salt concentration was conditioned by the precipitation, that the trend in late summer and early fall was downward, and that after the extreme low encountered in late winter the spring samples showed relatively rapid fluctuations between 22.5 and 29.1°/₀₀.

No direct evidence is apparent from this data as to the effect of total salinity on the populations of fishes taken in Morris Cove, although the downward trend in the fall more or less followed the decline in temperature and variety of species discussed above. But the fluctuations in salinity from one date to another over the line of general trend were so marked that it is doubtful if total salinity was a limiting factor, either for species or numbers of individuals.

The range of total salinity during the period when the fishes were present in the area was from 22.5°/₀₀ to 30.18°/₀₀, a difference of 7.7°/₀₀, and the mean of the salinity readings for the same period was 27.7°/₀₀. Most of the species collected from the shore zone were unquestionably euryhaline forms. However, the limits of salinity were rather narrow during the time when some species were present. This was especially true for the immature forms of some of the migrants from the south, although the data collected from Morris Cove do not permit definite conclusions. Table XXIV shows the extremes of total salinity encountered by each of the more abundant species as well as the differences between the maxima and minima.

## Light

Light conditions within the area were manifest both in the condition of the sky and the water. The condition of the sky was recorded but showed no direct relationship with the numbers of fish taken. Considering the three most abundant collections, one (September 18) was taken on a cloudy day, one (July 10) on a hazy day, and one (October 30) on a clear day. And one of the less abundant collections (October 2) was taken on a clear day.

TABLE XXIV. THE MINIMUM AND MAXIMUM TOTAL SALT CONCENTRATIONS (°/₀₀) ENCOUNTERED BY THE MORE ABUNDANT SPECIES

| *Species* | *Date* | *Highest Salinity* | *Date* | *Lowest Salinity* | *Difference between extreme salinities* |
|---|---|---|---|---|---|
| *M. m. notata* | IX–4–42 | 30.2 | V–28–43 | 22.5 | 7.7 |
| | IX–18–42 | .... | .... | .... | .. |
| *P. americanus* | IX–4–42 | 30.2 | V–28–43 | 22.5 | 7.7 |
| | IX–18–42 | .... | .... | .... | .. |
| *S. fuscus* | IX–4–42 | 30.2 | V–28–43 | 22.5 | 7.7 |
| | IX–18–42 | .... | .... | .... | .. |
| *Fundulus* spp. | IX–4–42 | 30.2 | XI–26–42 | 25.1 | 5.1 |
| | IX-18-42 | .... | .... | .... | .. |
| *B. tyrannus* | IX–4–42 | 30.2 | XI–26–42 | 25.1 | 5.1 |
| | IX–18–42 | .... | .... | .... | .. |
| *S. maculatus* | IX–4–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| | IX–18–42 | .... | .... | .... | .. |
| *M. tomcod* | V–14–43 | 29.1 | V–28–43 | 22.5 | 6.6 |
| *C. regalis* | IX–4–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| *S. aquosus* | IV–30–43 | 29.1 | V–28–43 | 22.5 | 6.6 |
| *M. saxatilis* | IX–4–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| *C. harengus* | IV–30–43 | 29.1 | V–28–43 | 22.5 | 6.6 |
| | V–14–43 | .... | .... | .... | .. |
| *M. aeneus* | IX–18–42 | 30.2 | V–28–43 | 22.5 | 7.7 |
| *P. saltatrix* | X–2–42 | 28.8 | X–2–42 | 28.8 | 0.0 |
| | X–16–42 | .... | X–16–42 | .... | .. |
| *P. evolans evolans* | IX–4–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| | IX–18–42 | .... | .... | .... | .. |
| *A. mitchilli* | IX–4–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| *B. chrysura* | IX–18–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| *T. onitis* | IX–4–42 | 30.2 | VIII–21–42 | 26.1 | 4.1 |
| | IX–18–42 | .... | .... | .... | ... |
| *S. foetens* | IX–4–42 | 30.2 | VIII–7–42 | 28.6 | 1.6 |
| | IX–18–42 | .... | .... | .... | .. |

The condition of the water, recorded as turbidity, apparently had more effect upon the numbers of fishes present on the sandy bottom than the condition of the sky. Unfortunately less data is available concerning this factor than for those previously discussed; it is also true that the conditions which gave rise to the turbidity may have been the primary agents affecting the fish. However, on six different occasions when small collections were taken the water was recorded as turbid (Table I). Moreover since it is likely that turbidity reduces visibility of the fish so that it would be less apt to see the collector and net, it is reasonable to assume that there would be a better chance of

sampling the population. But since the degree of turbidity was not noted with complete regularity, it cannot be assumed with certainty that abundance was conditioned by this factor. It also seems probable that there was some relationship between turbidity and the number of species. For example, the number of species, as well as individuals, was low on June 11 and June 25, 1943, turbid water being recorded on both these days. The data further suggests that the demersal species were less affected by turbidity than were the pelagic forms, for on days when water conditions were recorded as "very turbid," *Pseudopleuronectes americanus* and *Syngnathus fuscus* were comparatively abundant. Indeed, it seems wholly logical that demersal species would feel the effects of suspended material to a lesser degree than forms that habitually remain at higher levels.

## ANALYSIS OF THE FISH POPULATION AS A WHOLE

### Major Categories

Above and beyond a consideration by species, the fish collected from Morris Cove at biweekly intervals from July 10, 1942 through June 25, 1943 can be subjected to analysis on other grounds. Two additional classifications, each of which have various subdivisions, suggest themselves in this connection. First, on the basis of geographical distribution, four categories can be distinguished. Second, on the basis of size, and concurrently age, three divisions are readily apparent.

### Geographical Distribution

Turning first to the division of the fish population on the basis of the geographical distribution of the various species involved, Greeley (1939) recognized three groups in his work along the Long Island shoreline. He designated these as permanent residents, immature summer residents, and breeding migrants. While this classification may be adequate for an area such as the whole shoreline of Long Island Sound, it is possible to make various refinements for a particular region such as Morris Cove and probably for any other definite shore biotope. Four divisions are recognized in the present study: 1) resident at all stages of the life history, 2) resident only during the immature stages, 3) immature offspring of breeding migrants, and 4) immature migrants. The term "resident" as used in the first division obviously refers not only to the sandy-bottom shore zone under consideration but also to

the broad geographical area of Long Island Sound or southern New England. As used in the second division, it refers only to the particular biotope here studied, although the adults live sufficiently near at hand so that the species may be said to be residents of the general region. These first two categories, then, include fish which spend the great majority or a part of their life history in a shore zone of the Morris Cove type, and which do not undertake extensive coastwise migrations with the seasons, although some of them may move on and off shore at different times of year. The last two categories include forms which are not permanent residents of this general region, since they only appear in the area seasonally either through the migration of adults which breed nearby and produce young which occupy the biotope, or the migration of immature fish which are the product of a more distant spawning. It should be noted that in these divisions there is no place for mature migrants from regions considerably to the south or north. A fifth category of this sort could be added, but its members are so limited and rare in this biotope that they do not warrant such treatment.

Arbitrary classification in the four categories listed above is extremely difficult for many of the species in the Morris Cove collections. Therefore it is necessary to qualify a number of the forms which are included under the different headings. This is so because of the lack of definite knowledge of spawning and migratory habits, together with variations in behavior from season to season in certain species. Such qualifications regarding given species are discussed below, and it should be understood that these forms have been placed in the different categories on the basis of existing information which in many cases is so inadequate as to make their classification little better than surmise.

1.) *Resident at all stages of the life history.* These are species which are found in the sandy-bottom shore-zone biotope for the greatest part of the life cycle, and which were so represented in the Morris Cove collections. They are normal inhabitants of this area, both in young and old stages, except during the extremely cold parts of the winter, when the shallow part of the shore zone is apparently completely devoid of fishes. These include:

*Menidia menidia notata*
*Syngnathus fuscus*
*Fundulus majalis*
*Fundulus heteroclitus*

Certain qualifications are clearly necessary for the species in this classification. *M. menidia notata* was collected in all its stages from the sandy-beach shore zone, with the exception of spawning individuals; even these latter were not necessarily precluded, since definitely ripe fish were taken in the area. But Hildebrand (1922) and Fowler (1918) indicate that a weedy situation is preferred. Therefore this species may be considered as a shore-zone resident, which regularly occupies this biotope, although it is not confined to the sandy beach habitat. *S. fuscus* is also a permanent resident; but in late July most of the adults which were present in the spring and early summer left, and the collections were composed of immature individuals. The two species of *Fundulus* were taken both as adults and juveniles; these fish are rather catholic in their habitat preference, but they are definitely shore-zone residents although not necessarily confined to the sandy beach.

2) *Resident only during the immature stages.* These are species which are generally considered to be year-around residents of the region, but which are present in the biotope of the type under consideration only as juveniles. The species so classified are:

*Pseudopleuronectes americanus*
*Scophthalmus aquosus*
*Microgadus tomcod*
*Myoxocephalus aeneus*
*Tautoga onitis*
*Prionotus evolans*
*Spheroides maculatus*
*Anchoa mitchilli*

With the exception of the last three species, the inclusion of the various fish in this list needs but little qualification. It is true, however, that almost all of these forms probably come into the area as mature individuals on rare occasions, and that with equipment better suited to the capture of larger fish than the gear which was used (30-foot minnow seine), they would have been taken from time to time. Evidence from trawl hauls in connection with tagging experiments indicates that at least the adults of the two flounders concerned often come close to the area which was worked in sufficient numbers so that it would be almost inconceivable that a few of them should not stray even closer toward shore. And several apparently mature *M. tomcod* were taken in the course of this study during the fall of 1942. Furthermore, adult *M. aeneus* were seined at Morris Cove and adjoin-

ing areas in 1942 and 1943. But in all such instances the mature individuals were so rare and so heavily outnumbered that these species fit more logically in the second than in the first category. It will be noted also that all the forms listed as being resident only during the immature stages grow to much larger sizes as adults than the members of the first category—*i. e.*, those that are resident at all stages of the life history. Since size is apparently a limiting factor in the Morris Cove biotope (pp. 75–76), and since the above-mentioned adults only come into the area as occasional strays or possibly pass through part of it without becoming in any sense of the word resident, it seems reasonable to list these species as members of the sandy-bottom shore zone only during the immature stages. The adults are clearly not members of the population under consideration.

More serious qualification of the last three species in this list, and possibly *M. tomcod,* is necessary. Because of insufficient knowledge of the fish concerned, it is difficult to state with any degree of certainty whether or not these forms are year-round residents of southern New England. Subsequent investigation may show that they are migrants from more distant areas which breed in this region, thus producing young which then come to occupy biotopes of the Morris Cove sort during the early stages of their life histories. Nichols and Breder (1926) state that *M. tomcod* move off shore in the summer; the present authors wonder if there is not a migration northward in the late winter or spring, with a corresponding return to southern New England waters in the fall. Certainly this species is rarely seen in the Connecticut trawl fishery in the summer; if it undertook nothing more than seasonal off- and on-shore movements, it might reasonably be expected to be a regular, if small, component of the catch of these boats from May to October. Also it is suggested by various authors (*e. g.*, Nichols and Breder, *loc. cit.*; Bigelow and Welsh, 1925), that *P. evolans* and *S. maculatus* apparently go into deeper water during the winter. Again it seems quite possible from the highly seasonal appearance of these species and from their total absence in the winter trawl catch from deeper water, that they undertake marked coastwise migrations—north in the spring and south in the fall. It may also be that a few individuals of the three above-mentioned species remain in these waters in all seasons, as is true with the striped bass (Merriman, 1941), thus leading to the false supposition that these are not coastwise migratory forms. Finally *A. mitchilli* may not be a year-round

resident of this region, but may spend its winters farther to the south; that it is a migratory form is suggested by the comments of Bigelow and Welsh (1925) who state that "it appears from May to October in Southern New England waters." But as with the other species considered above, it seems best to include this fish in this category until fuller knowledge of its life history and habits provides information to the contrary.

3) *Immature offspring of breeding migrants.* These are the immature individuals of species that migrate to the region and spawn. They include:

*Brevoortia tyrannus* *Menticirrhus saxatilis*
*Cynoscion regalis* *Clupea harengus*
*Pomatomus saltatrix*

Here again, the assumption that all of these forms behave in identical patterns is misleading and some qualification is necessary. Adult *C. harengus*, although "present at all seasons in irregular numbers," is "abundant to the eastward in fall" (Nichols and Breder, 1926), the time of spawning in this region. It would seem, therefore, that mature herring in all probability migrate south at this time of year to spawn in southern New England waters—at least close enough to New Haven so that the young are distributed throughout the region. On the other hand, the remaining species in this category migrate *from* the south, and spawn in southern New England waters as well as elsewhere. Many, if not all of the fish here listed, have prolonged spawning seasons; reproduction also occurs over a wide coastal range. Unquestionably some, and perhaps the majority of the young encountered in an area such as the Morris Cove biotope are the product of reasonably local spawning. It is equally certain that some of the immature individuals are the result of more distant spawnings with a subsequent migration of the young. It is the mixture of individuals from nearby and further removed spawnings over rather long periods of time that makes analysis by length-frequency curves alone extremely hazardous as indicated in the preceding sections of this paper. The spatial and temporal nature of the spawning of these species, as well as the apparent intermixture of the young produced at different periods and in different areas, is a consistent source of difficulty.

4) *Immature migrants.* These are the young individuals which are produced elsewhere and then migrate to southern New England waters. In general the adults of these species are not found in the region, or if they do occur, they are so rare as to warrant consideration only as stragglers or strays, while the young are sufficiently abundant to be included as true members of the population. Greeley (1939), in his survey of Long Island, indicated that the pompano (*Trachinotus* spp.) fell into this general category. In the Morris Cove collections only two of the more abundant species fit here:

*Bairdiella chrysura* *Synodus foetens*

Adult *B. chrysura* occur north of New York in extremely limited numbers, although Welsh and Breder (1923) state that it is common in New Jersey in the summer and early fall, spawning occurring from June to August. Perlmutter (1939) found the adults uncommon on the south shore of Long Island, although the young were relatively abundant throughout the summer in this area and even further north. He suggested that this species may spawn in New York waters, since eggs and larvae were taken in the vicinity of Moriches Inlet. That considerable numbers of young apparently migrate to the north and east is clearly indicated by Perlmutter's (*loc. cit.*) observations which are substantiated fully by the present study. These authors have not encountered spawning silver perch in Connecticut waters. In the same way, immature *S. foetens* were taken with some regularity in the Morris Cove collections, but these authors have seen only one mature lizard fish in this region, and that was taken in November in outer Long Island Sound. Therefore it seems logical to believe that immature individuals migrate from spawning areas further to the south.

Finally, in regard to the division of the fish population on the basis of geographical distribution, the less abundant species (Table XXII) cannot be classified in separate categories because their numbers are so small. Although none of them can be considered residents of the Morris Cove biotope, most of them are probably residents of southern New England. Clear exceptions are *Caranx hippos* and *Leiostomus xanthurus*, both of which are immature migrants from the south. *Prionotus carolinus* may fall into this group also, and the young of *Pollachius virens* apparently migrate from the east and north. Of

all these less abundant species, *Anguilla rostrata* is probably the one which comes closest to qualifying as a resident of the area under consideration, in that it is found just outside the zone reached by the seine and strays into shallower water with some degree of regularity.

## Size

Turning to the division of the fish population on the basis of size, the following categories, listed in order of abundance, seem to describe the components of the Morris Cove collections best.

1) *Fish-of-the-year.* All of the more abundant species were apparently represented by fish-of-the-year, with the possible exception of *Syngnathus fuscus*, where the age of the smaller individuals is in doubt (pp. 27–28).

2) *Mature adults.* A number of species were represented by mature adults, the most obvious being *Menidia menidia notata*, *Syngnathus fuscus*, and *Fundulus heteroclitus*. *S. fuscus* adults, as indicated above, were seasonal in their appearance. A single adult *Fundulus majalis* and several *Microgadus tomcod* were seined, the latter probably being a chance capture of individuals in the spawning movement. The collections also contained specimens of *Scophthalmus aquosus* and *Myoxocephalus aeneus* which were large enough to be mature adults, as judged by comparison with fish of these species taken in other studies in these waters.

3) *Fish of other year-classes.* Because of the lack of adequate data concerning the life history of so many of the species included in this study, this category is somewhat problematical. The modes of the length-frequency curves and the size ranges of many of the species taken in Morris Cove that are residents of the region indicate that fishes of intermediate ages were present on occasions—*e. g.*, *Menidia menidia notata*, *Syngnathus fuscus*, *Fundulus* spp., *Myoxocephalus aeneus*, and *Tautoga onitis*. But in the absence of more detailed knowledge none of these species can be included with any degree of certainty, especially since their respective ages at maturity are unknown. However, it does seem reasonable to assume on the basis of the available information and the general observations of these authors that intermediate stages of *Pseudopleuronectes americanus*

and *Scophthalmus aquosus* were present in the collections on various occasions. That the edge of a larger-sized population of both species of flounders was reached by the seine possibly explains the presence of these fish. There is little to indicate that either species spawns in any quantity at a length of 200 mm. or less.

## Size Stratification

In connection with the classification of the fish population on the basis of size it is significant that a definite relationship existed between the size of the fishes and the nature of the area studied. The fishes encountered were limited as to length, and in general this seemed to be true regardless of age. Reference to the length-frequency distributions of the various species shows that the range in sizes averaged well below the 100 mm. mark. This was true for fish that were resident and adult, as well as for fish-of-the-year. Most of the shore-zone residents of the area here studied are fish that do not grow to lengths much greater than 100 mm., except for the oldest individuals which are generally few in number. The largest *Menidia menidia notata* collected measured 129 mm. in standard length, but more significant is the fact that the greatest mean length computed for any of the larger collections of this species was 82.2 mm., the lengths for that particular sample ranging from 62 to 100 mm. In general the two species of *Fundulus* were less than 100 mm. in length. For example, on September 4 the *Fundulus heteroclitus* collection consisted of two fairly well marked modes, the larger apparently composed of adults with a mean length of 72.9 mm. On the other hand, *Syngnathus fuscus* formed an exception to the general rule as regards size stratification. In May and June only adults were present, and these were much longer than representatives of other species collected from the area (Fig. 6). In July and August the population of *Syngnathus fuscus* was represented by two size-classes which were recognizable as adults and juveniles, the adults being slightly larger than those taken during the earlier months. Thereafter the area was occupied by juveniles exclusively, and the mean length of these animals ranged near the 100 mm. length mark. In regard to the resident immature species, *Pseudopleuronectes americanus* and *Scophthalmus aquosus* were interesting in that there is definite indication that some of the fish in the older age groups, juveniles in or approaching the second year, continue to inhabit the shore zone investigated in this study (or

rather, return to it after the winter) if they are less than approximately 100 mm. All of the immature offspring of breeding migrants and the few immature migrants were within the range of size necessary to fit this generalization.

Thus it would seem that the shore-zone fishes are definitely limited as to the size at which they occupy the Morris Cove biotope. Under most circumstances the different species are not found in the area after they reach 100 mm., although there are occasional strays and other exceptions to the general rule. The most notable and regular exception is *Syngnathus fuscus*, but it should be mentioned that if size were judged by volume rather than length this fish would fall far below other species of the area which are less than 100 mm. long. This size stratification holds regardless of age, as illustrated in the case of the flounders. Furthermore, this shore zone area acts as a "nursery ground" for fish-of-the-year of many species and for older individuals of some of the species—an area in which the young may and frequently do stay until they approach the 100 mm. mark. Such "nursery grounds" are unquestionably of considerable significance in the maintenance of stocks that are of commercial significance.

## Abundance

Before discussing the abundance of fishes occurring in the Morris Cove biotope, it seems logical to evaluate the area under consideration and to show that it is a definite ecological entity, for otherwise the relative number of fishes contained in it has little or no significance.

The sandy-bottom shore zone is a marginal area, lying between the open sea and the land, which is difficult to define because of the changes to which it is subjected as the tides ebb and flow, and because its outer edge is not sharply delimited from the deeper water region. That the deeper-water zone is fundamentally distinct was apparent from observations on the composition of the catch in a small-meshed trawl operated not far off the Morris Cove sandy-beach biotope in 1943. This zone contained some small individuals and larger fish of a number of the types encountered in-shore, as well as additional species. Subsequent investigation may show that the fish from the shallow- and deeper-water zones intergrade to varying extents under different conditions. Since large fish were occasionally taken in the Morris Cove collections, *e. g.*, flounders, it would appear that the edge of what seems to be an overlap region between the two zones was ap-

proached in the present work. Furthermore, the fact that the vast majority of the individuals encountered in the present study were small, many of them fish-of-the-year, lends emphasis to the conception that this is an area that must be considered as a separate and distinct entity with its own highly characteristic fauna. The composition of the catch also points to the idea that here may be found factors which are important in promoting the growth of the contained fishes in their early stages.

No definite evaluation of the factors associated with the nature of the substrate can be made since it is essentially the same both seaward and shore-ward. It seems extremely doubtful also if the chemistry of the area is sufficiently different from the conditions found somewhat further from shore to provide any clear-cut limitations, although it is reasonable to suppose that the variation in salinity is greater due to the direct influence of drainage from the shore, and that the oxygen content is perhaps higher at times than in the deeper-water zone. On the other hand, physical conditions, especially depth and temperature, may establish recognizable limits to the area—limits which may work to the advantage of the contained fish population in some instances and to its disadvantage in others. Thus depth is probably a factor which limits the volume of the organism relative to the volume of the surrounding medium, both in terms of the size of the individuals concerned and the total mass of the entire population. At the same time the shallow water of the area may offer refuge from larger predators which more normally occur somewhat further off shore. Temperature may also be a differentiating factor, for its range is unquestionably greater than in deeper waters. The extremely high and low levels in the summer and winter may be disadvantageous, as may be the more rapid fluctuations which would characterize an area so near the inter-tidal zone. On the other hand definite advantages may accrue from the periodic flooding and exposure at the extremes of the tides and concurrent effects—*e. g.*, the rapid warming in the spring months to provide adequate conditions for the spawners and young which are able to make use of the area. Finally, the biological conditions may offer means of delimiting the area, for the bottom fauna of the shallow-water zone may possibly differ from that further off shore in quite as definite a manner as does the fish population, if not more so.

That this biotope is an ecological entity, then, is clearly indicated

by the nature of the fish population here studied. Unquestionably it can be delimited further, as suggested above, by comparative physical and biological data; and possibly additional refinements could be provided on chemical bases, but the demonstrated fact that a characteristic population of fishes exists in this area provides undeniable evidence that this is a definite ecological facies.

It should be mentioned also that there are two well defined subdivisions within this shore-zone facies. In terms of the fishes encountered, these can be designated as pelagic and the demersal. These subfacies are recognizable in part on the basis of the morphology of the fish concerned. But the size of the fishes taken in the Morris Cove collections indicates that the whole area is a unit, the fish population of which, although divisible into sub-facies, is competitive throughout. There appears to be much evidence that the volume of fish is related to the volume of water, irrespective of the particular mode of life involved. Nevertheless, distinctions in the behavior of pelagic and demersal forms, as during the periods of turbid water, were apparent.

It does not seem out of place to suggest that the shallow-water shore zone is an area where energy values are readily acquired and most efficiently utilized. Incoming tides conceivably bring with them planktonic elements which, because they move in and out again within a limited amount of space, are more concentrated, and thus more available. Efficient utilization is perhaps enhanced in that the limited volume of the surrounding water offers a better opportunity for heat acquisition, both from the sun and the underlying bottom. The fact that the greater part of the fish population is composed of fish-of-the-year that grow rapidly lends credence to the idea. Regarding some of the older fishes which are classed as shore-zone residents and which generally do not exceed the limits of size associated with fish-of-the-year of other species, their energy requirements perhaps differ from those of younger individuals, but this does not exclude them from the area. Instead, the limiting factors seem to be the size of the individuals (pp. 75–76) and the total volume of the fish population in the biotope (pp. 83–85).

When the numbers of individuals of the various species of fish in the 1942–1943 biweekly Morris Cove collections were examined, it was immediately obvious that some kinds were more abundant than others. This suggests that some of the more plentiful forms domin-

ated the subfacies in which they were found, and hence (p. 78), the entire facies—for if a species of fish is consistently present and able to withstand the pressure exerted by invading forms, it may be considered dominant in the sense that it is the organism at the apex of an Eltonian pyramid. This does not mean that there are not other dominants at the various levels of the pyramid. In any ecosystem organized in trophic levels there are apical, intermediate, and basal dominants. The apical dominant includes the species of the highest level controlling the biocoenosis. The basal dominant includes the controlling organisms at the lowest level. Normally the apical dominant will be the largest common predator, the basal dominant the major photosynthetic species. In the Morris Cove ecosystem the fundamental energy-converting organisms are at the base of the Eltonian pyramid, and on this base are the zooplankters, bottom-dwelling invertebrates, and certain nekton; at the peak are the fish, the apical dominant. All the fish in the area would be included in the pinnacle of the pyramid, but superimposed upon the whole structure, and at the same time deeply imbedded in the substance of the pinnacle, would be the most abundant species of fish encountered. The main feature in the consideration of the fishes of the shore zone is the analysis of a constantly shifting population. The composition of the aggregation of fishes is never twice the same and the precise make-up of the peak of the Eltonian pyramid varies correspondingly. Hence there are degrees of apical dominance—that is, not only will the volume of fish at the peak vary, but also the predominant *species* of fish within the peak will vary both in number and kind. Thus one fish may dominate the shore zone for a time and then be supplanted by another. The length of time during which such an organism is present in a dominant position is indicative of its degree of dominance. The problem is to evaluate this factor.

As already indicated in the discussion by species, two classes of fishes are recognized, the more abundant and the less abundant. The more abundant are those that were present in sufficient quantities to be placed in the ranks of the first ten species, these ranks being based on the relative numbers of individuals (p. 80). The less abundant species (Table XXII) were stragglers from other environments, and were so few in number that they do not merit consideration in this connection.

Two approaches have been used to evaluate the abundance of the

more numerous species in the Morris Cove collections. These can be termed "relative abundance" and "total abundance."

*Relative Abundance.* This involves an approach which indicates the relative position of the various species on any given date, and which, when summarized, gives a true expression of positional values regardless of the influence of extraordinary numbers of individuals present on any one day. For estimating relative abundance a system of scoring was devised which facilitated the summarization of the positional rank for each species at different times during its presence in the area. All species in the first ten ranks were assigned a score, the first rank being given 10, the second 9, the third 8, and so on until the form in tenth place was assigned a score of 1. The advantages resulting from this system are merely simplicity and direct comparison in that the score allows an animal high in the ranks of abundance a high score. No attention need be given significant figures relating to the numbers of individuals of a particular species. The values derived refer to position only. The disadvantages are that the system is arbitrary and has no real value in terms of the collection except for position. However, when position in rank is assigned to a

TABLE XXV. RELATIVE AND TOTAL ABUNDANCE SUMMARY

| *Species* | *Relative Abundance* | | *Total Abundance* | | |
|---|---|---|---|---|---|
| | *Rank* | *Score* | *Rank* | *%* | *Number* |
| *Menidia menidia notata* | 1 | 134 | 1 | 50.21 | 8297 |
| *Pseudopleuronectes americanus* | 2 | 132 | 5 | 5.15 | 851 |
| *Syngnathus fuscus* | 3 | 109 | 3 | 9.40 | 1554 |
| *Fundulus* spp. | 4 | 85 | 6 | 3.70 | 611 |
| *Brevoortia tyrannus* | 5 | 51 | 2 | 17.86 | 2952 |
| *Spheroides maculatus* | 6 | 42 | 7 | 2.43 | 401 |
| *Microgadus tomcod* | 7 | 39 | 8 | 1.95 | 323 |
| *Cynoscion regalis* | 8 | 26 | 9 | 1.75 | 289 |
| *Scophthalmus aquosus* | 9 | 24 | 12 | 0.33 | 54 |
| *Menticirrhus saxatilis* | 10 | 24 | 11 | 0.41 | 68 |
| *Clupea harengus* | 11 | 20 | 4 | 5.42 | 895 |
| *Myoxocephalus aeneus* | 12 | 15 | 14 | 0.21 | 34 |
| *Pomatomus saltatrix* | 13 | 9 | 16 | 0.09 | 15 |
| *Prionotus evolans evolans* | 14 | 9 | 10 | 0.56 | 92 |
| *Anchoa mitchilli* | 15 | 6 | 13 | 0.27 | 45 |
| *Bairdiella chrysura* | 16 | 6 | 15 | 0.13 | 22 |
| *Tautoga onitis* | 17 | 6 | 17 | 0.08 | 14 |
| *Synodus foetens* | 18 | 3 | 18 | 0.05 | 8 |

species, a figure denoting the rank has to be used in any case, and by eliminating the intermediate percentage calculation, proportionate numbers of individuals need be considered only on the basis of the rank which a particular species occupies on the day of the collection. In this way true values can be assigned to species that were consistently present, such as *Pseudopleuronectes americanus*, as opposed to species present in large numbers but sporadic in their occupancy of the area, such as *Brevoortia tyrannus* (Table XXV).

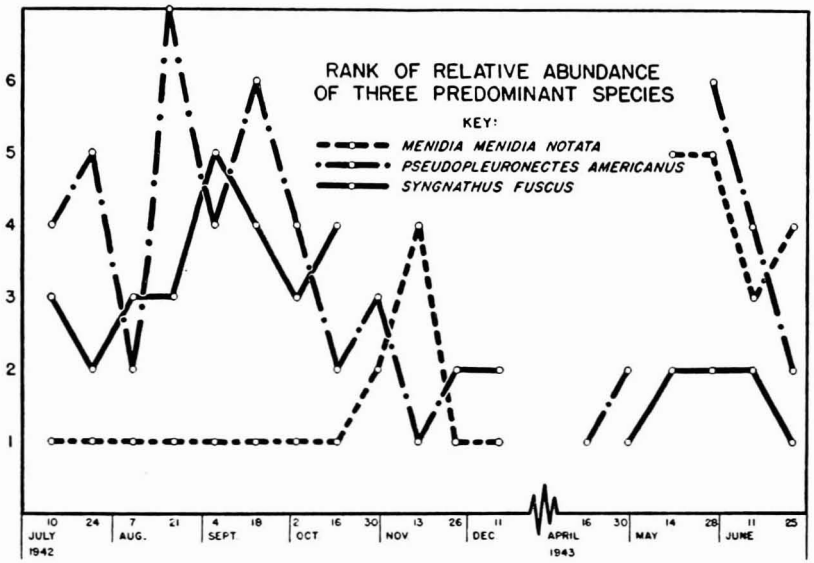


**Figure 18.** The ranks of abundance occupied by the three most common species, *Menidia menidia notata*, *Pseudopleuronectes americanus* and *Syngnathus fuscus*.

The ranks of relative abundance of the more common species are illustrated in Figs. 18 and 19. The higher ranks of abundance were largely dominated by the same species throughout the year. Three of the genera were shore-zone residents, *Menidia menidia notata*, *Syngnathus fuscus*, and the two species of *Fundulus*. Two species were resident immature fish, namely *Pseudopleuronectes americanus* and *Spheroides maculatus*, and one, *Brevoortia tyrannus* was the immature offspring of a breeding migrant. In the summer and fall the dominant species was *M. menidia notata*. From July 10 to October 16, 1942, this species occupied the first rank of relative abundance.

It was supplanted by *B. tyrannus* on October 30, and by *P. americanus* on November 13, but it regained the first rank on November 26, and December 11. In the spring *M. menidia notata* did not enter prominently into the ranks of abundance. On March 19, 1943 the only fish taken was a single *Fundulus majalis*. On April 16 *P. americanus* was the first species, on April 30 *S. fuscus* occupied first rank, and in May the first position was held by *Clupea harengus*. In early June

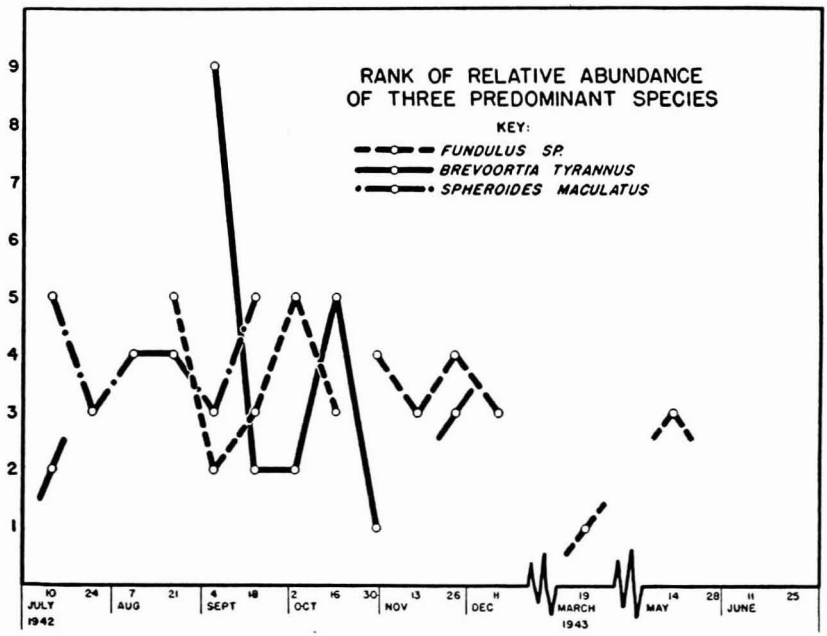


**Figure 19. The ranks of abundance occupied by the three species in the fourth, fifth, and sixth ranks in the summary of the relative abundance indicated in Table XXV.**

*Microgadus tomcod* was first, and in late June this rank was occupied by *S. fuscus* for the second time that spring. The second rank of abundance was divided between a variety of species. *B. tyrannus* was second on July 10, September 18, and October 2, *S. fuscus* on July 24, May 14, May 28 and June 11, *P. americanus* on August 7, October 16, November 26, December 11, April 30, and June 25, *Cynoscion regalis* on August 21, *F. heteroclitus* and *F. majalis*, considered together, on September 4, *Myoxocephalus aeneus* on November 13, and *Scophthalmus aquosus* on April 16. The third rank of abun-

dance was divided between the above-listed species, with the addition *Spheroides maculatus* and *Pollachius virens*, the latter being placed in this rank rather than second on April 16 when it was tied with *Scophthalmus aquosus*, since it appeared in the first ten places of abundance only once. The same list of species occupied the fourth rank of abundance. To the fifth *Anchoa mitchilli* was added, to the sixth *Menticirrhus saxatilis*, *Pomatomus saltatrix* and *Osmerus mordax*, to the seventh *Prionotus evolans* and *Bairdiella chrysura*, and in the eighth *Tautoga onitis* appeared.

Obviously the above considerations have to do with the entire facies, and the subfacies are disregarded. Paucity of information at the different stages of the life history of many of the species encountered in Morris Cove precludes the classification of the entire list of the more abundant species on the basis of ranks of abundance of free-swimming and bottom-living forms. However, the dominant species for the entire area, *M. menidia notata*, is free-swimming. Second and third positions of relative abundance were occupied by the demersal *P. americanus* and *S. fuscus*. The fourth and fifth places were filled by the genus *Fundulus* and *B. tyrannus*, the former being predominantly free-swimming, the latter clearly so. The sixth and seventh places fell to *S. maculatus* and *M. tomcod*, both of which are essentially demersal. It is at least clear from the above that there is no overwhelming predominance of the fishes of one mode of life over the other —the one does not exist to the exclusion of the other.

*Total Abundance.* Here the approach indicates the fluctuations in total numbers collected on one day as compared with the total numbers taken on any other dates; when summarized, the total abundance of a single species in terms of the percentage of the whole of the collections in the entire study is shown (Table XXV).

Interesting trends are revealed in the analysis of the total abundance of the species by dates of collection (Fig. 20). Three peaks were reached during the summer and fall of 1942—July 10, September 18, and October 30. These were followed by marked regression in numbers of individuals, and then slow, gradual recovery, except in November when the numbers declined as winter approached. This suggests a possible effect of population pressure on the number of individuals—*i. e.*, in an area inhabited by highly mobile and gregarious species of fish under optimal living conditions the tendency is to build up the

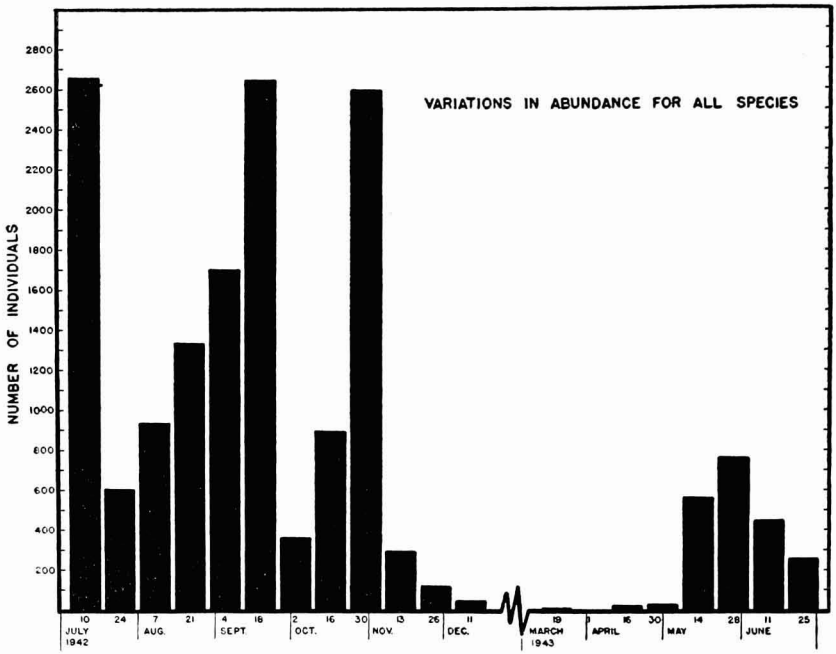


Figure 20. Variations in total abundance on the days collections were made.

population gradually to a point where the density reaches a definite level or supersaturation point, following which the fish disperse and then repeat the building-up process. That the recurrent peaks and subsequent drop in numbers followed by a regular increase as indicated in Fig. 20 is a true reflection of actual conditions, cannot be stated with absolute certainty. More frequent samplings might have altered the picture. Furthermore, it should be noted that the two predominant species in each of three peaks of maximal abundance (Fig. 21) are types which school heavily, and it could be argued therefore, that they were both present in great numbers throughout the summer and fall, but that the seine only happened by chance to pass through the schools on three occasions thus giving a false picture of great numbers. That such is not the case is indicated not only by the method of seining, which covered the area under consideration with such thoroughness as to almost preclude this possibility, but also by the regularity of the cycle of abundance. The similar heights of the three peaks, subsequent decrease, and eventual rebuilding of the

population in regular cyclical fashion provides good evidence that the picture presented here is not false and is not the result of inadequate sampling.

It is interesting to note that the peaks of abundance do not correspond with the peaks of variety (Fig. 21). For example, a wider

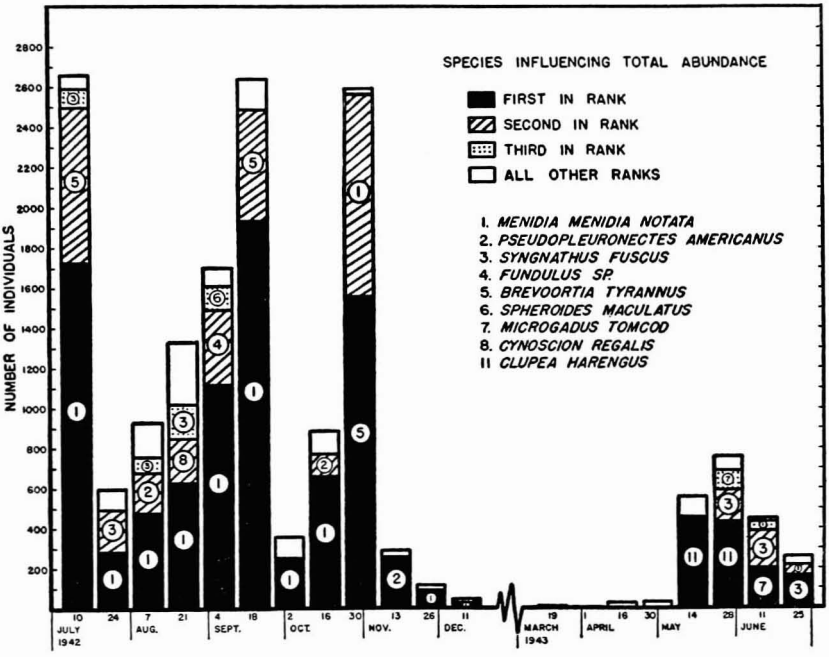


**Figure 21. The species influencing the total abundance of the collections.**

variety of species was present in Morris Cove on August 21 than at any other time, yet there were only a little more than half as many individuals on that day as compared with the catch one month later. This would indicate that the extremes of abundance are not necessarily dependent upon a wide variety of species; instead the extremes seem to result from the presence of an extraordinary number of individuals of a few species.

Further reference to Fig. 21 shows that during summer and fall the fluctuations in total abundance were largely conditioned by *M. menidia notata.* The next most prominent species in this connection was *B. tyrannus.* In the spring *C. harengus, M. tomcod* and *S. fuscus*

were dominant influences. On the basis of total number of individuals encountered during the year, *M. menidia notata* was first in that, of the 16,525 fishes studied, 8,297 were of that species. The next species, *B. tyrannus*, was represented by 2,952 individuals, *S. fuscus* was third with 1,554, *C. harengus* was fourth with 895, *P. americanus* was fifth with 851, and the two species of *Fundulus* considered together were sixth with 611 individuals.

In concluding the discussion on abundance a consideration of the fish occupying the upper six ranks of relative abundance (Table XXV) seems significant. On the basis of *relative* abundance, if these species had been present in the first six ranks consistently they would have attained an aggregate score of 810 by the system outlined above. Actually they scored 554, or 68.3% of the possible maximum. On the basis of total abundance, *i. e.*, the sum of all the fish taken throughout the year, they constituted 92.0% of the total. Thus the first six species made up 92.0% of the volume of all the collections, but they dominated the individual collections, and hence the fish population of the biotope, only 68.3% of the time.

TABLE XXVI. THE FISHES COLLECTED FROM MORRIS COVE ARRANGED IN THE ORDER OF RELATIVE ABUNDANCE FOR EACH DATE

| *Date* | *Number of species collected* | *1st Species* | *No.* | *2nd Species* | *No.* | *3rd Species* | *No.* | *4th Species* | *No.* |
|---|---|---|---|---|---|---|---|---|---|
| VII–10–42 | 10 | *M. m. notata* | 1722 | *B. tyrannus* | 744 | *S. fuscus* | 93 | *P. americanus* | 30 |
| VII–24–42 | 9 | *M. m. notata* | 282 | *S. fuscus* | 212 | *S. maculatus* | 43 | *C. regalis* | 25 |
| VIII–7–42 | 11 | *M. m. notata* | 479 | *P. americanus* | 199 | *S. fuscus* | 82 | *S. maculatus* | 55 |
| VIII–21–42 | 16 | *M. m. notata* | 629 | *C. regalis* | 222 | *S. fuscus* | 171 | *S. maculatus* | 142 |
| IX–4–42 | 12 | *M. m. notata* | 1115 | *Fundulus* Spp. | 377 | *S. maculatus* | 118 | *P. americanus* | 42 |
| IX–18–42 | 12 | *M. m. notata* | 1938 | *B. tyrannus* | 550 | *Fundulus* Spp. | 64 | *S. fuscus* | 42 |
| X–2–42 | 11 | *M. m. notata* | 254 | *B. tyrannus* | 30 | *S. fuscus* | 22 | *P. americanus* | 16 |
| X–16–42 | 11 | *M. m. notata* | 661 | *P. americanus* | 107 | *Fundulus* Spp. | 37 | *S. fuscus* | 31 |
| X–30–42 | 6 | *B. tyrannus* | 1565 | *M. m. notata* | 1003 | *P. americanus* | 16 | *Fundulus* Spp. | 8 |
| XI–13–42 | 6 | *P. americanus* | 264 | *M. aeneus* | 9 | *Fundulus* Spp. | 6 | *M. m. notata* | 3 |
| XI–26–42 | 4 | *M. m. notata* | 88 | *P. americanus* | 24 | *B. tyrannus* | 5 | *Fundulus* Sp. | 1 |
| XII–11–42 | 3 | *M. m. notata* | 37 | *P. americanus* | 4 | *Fundulus* Sp. | 1 | .... | .. |
| III–19–43 | 1 | *Fundulus* Sp. | 1 | .... | ... | .... | .. | .... | .. |
| IV–16–43 | 6 | *P. americanus* | 16 | *S. aquosus* | 2 | *P. virens* | 2 | .... | .. |
| IV–30–43 | 6 | *S. fuscus* | 12 | *P. americanus* | 11 | *S. aquosus* | 3 | *C. harengus* | 1 |
| V–14–43 | 10 | *C. harengus* | 464 | *S. fuscus* | 39 | *Fundulus* Spp. | 31 | *M. tomcod* | 12 |
| V–28–43 | 8 | *C. harengus* | 431 | *S. fuscus* | 161 | *M. tomcod* | 91 | *S. aquosus* | 45 |
| VI–11–43 | 6 | *M. tomcod* | 198 | *S. fuscus* | 199 | *M. m. notata* | 49 | *P. americanus* | 2 |
| VI–25–43 | 10 | *S. fuscus* | 169 | *P. americanus* | 47 | *M. tomcod* | 20 | *M. m. notata* | 11 |

TABLE XXVI. THE FISHES COLLECTED FROM MORRIS COVE ARRANGED IN THE ORDER OF RELATIVE ABUNDANCE FOR EACH DATE (*cont.*)

| *Date* | *Number of species collected* | *5th Species* | *No.* | *6th Species* | *No.* | *7th Species* | *No.* | *8th Species* | *No.* | *9th Species* | *No.* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VII–10–42 | 10 | *S. maculatus* | 19 | *M. saxatilis* | 14 | .... | .. | .... | .. | .... | .. |
| VII–24–42 | 9 | *P. americanus* | 20 | *M. saxatilis* | 13 | .... | .. | .... | .. | .... | .. |
| VIII–7–42 | 11 | *A. mitchilli* | 39 | *C. regalis* | 31 | *P. evolans* | 28 | *M. saxatilis* | 10 | .... | .. |
| VIII–21–42 | 16 | *Fundulus* Spp. | 67 | *P. evolans* | 59 | *P. americanus* | 31 | *M. saxatilis* | 17 | *B. chrysura* | 11 |
| IX–4–42 | 12 | *S. fuscus* | 14 | *C. regalis* | 8 | *M. saxatilis* | 7 | *S. foetens* | 6 | *B. tyrannus* | 5 |
| IX–18–42 | 12 | *S. maculatus* | 22 | *P. americanus* | 10 | *B. chrysura* | 8 | *T. onitis* | 5 | .... | .. |
| X–2–42 | 11 | *Fundulus* Spp. | 14 | *P. saltatrix* | 9 | *M. saxatilis* | 7 | *T. onitis* | 4 | .... | .. |
| X–16–42 | 11 | *B. tyrannus* | 22 | *M. aeneus* | 15 | *P. saltatrix* | 6 | .... | .. | .... | .. |
| X–30–42 | 6 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| XI–13–42 | 6 | *M. tomcod* | 2 | .... | .. | .... | .. | .... | .. | .... | .. |
| XI–26–42 | 4 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| XII–11–42 | 3 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| III–19–43 | 1 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| IV–16–43 | 6 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| IV–30–43 | 6 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| V–14–43 | 10 | *M. m. notata* | 9 | *O. mordax* | 4 | .... | .. | .... | .. | .... | .. |
| V–28–43 | 8 | *M. m. notata* | 20 | *P. americanus* | 11 | .... | .. | .... | .. | .... | .. |
| VI–11–43 | 6 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |
| VI–25–43 | 10 | .... | .. | .... | .. | .... | .. | .... | .. | .... | .. |

## REFERENCES


BAIRD, S. F.

1855. Report on the fishes observed on the coasts of New Jersey and Long Island during the summer of 1854. 9th Ann. Rept. Smithsonian Inst., 1854: 317–337.

1889. The sea fisheries of eastern North America. Report U. S. Comm. Fish and Fisheries, 1886, Pt. XIV, App. A: 3–224.

BEAN, T. H.

1888. Report on the fishes observed in Great Egg Harbor bay, N. J., during the summer of 1887. Bull. U. S. Fish Comm., 1887. *7:* 129–154.

1901. Catalogue of the fishes of Long Island, with notes upon their distribution, common names, habits, and rate of growth. 6th Ann. Rept. Forest, Fish, and Game Comm. New York, 1900: 373–478.

1903. Catalogue of the fishes of New York. New York State Mus. Bull. 60, Zool. 9. 784 pp.

BERG, L. S.

1940. Classification of fishes, both recent and fossil. Work of Zool. Inst. Acad. Sci. U. S. S. R. *5* (2): 346–517 in English. Moscow and Leningrad.

BIGELOW, H. B. AND W. W. WELSH

1925. Fishes of the Gulf of Maine. Bull. U. S. Bur. Fish., 1924. *40* (1): 1–567.

BREDER, C. M., JR.

1929. Field book of marine fishes of the Atlantic coast from Labrador to Texas. Pp. 1–332. G. P. Putnam's Sons, New York and London.

1944. The metamorphosis of *Synodus foetens* (Linnaeus). Zoologica. *29,* 1 (3): 13–16.

DEKAY, J. E.

1842. Natural history of New York. Zoology of New York. Fishes. Pt. IV: 415 pp. W. and A. White and J. Visscher. Albany.

FOWLER, H. W.

1918. Fishes from the middle Atlantic States and Virginia. Occ. Papers Univ. Mich. Zool. No. 56: 1–19.

GILL, THEODORE

1873. Catalogue of the fishes of the east coast of North America. Report, U. S. Comm. Fish and Fisheries, 1871–1872. Pt. I: 779–822.

1905. State ichthyology of Massachusetts. Rept. U. S. Bur. Fish. 1904: 163–188.

GOODE, G. B., AND T. H. BEAN

1879. A list of the fishes of Essex County, including those of Massachusetts Bay, according to the latest results of the work of the U. S. Fish Commission. Bull. Essex Inst. *11:* 1–38.

GREELEY, J. R.

1939. Fishes and habitat conditions of the shore zone 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.: 72–91.

GUDGER, E. W.
1906. The breeding habits and the segmentation of the egg of the Pipefish, *Siphostoma floridae*. Proc. U. S. Nat. Mus. *29:* 447–500.

HESSE, RICHARD, W. C. ALLEE AND K. P. SCHMIDT
1937. Ecological animal geography. John Wiley and Sons, Inc. New York. 597 pp.

HIGGINS, ELMER, AND J. C. PEARSON
1927. Examination of the summer fisheries of Pamlico and Core Sounds, N. C., with special reference to the destruction of undersized fish and the protection of the gray trout *Cynoscion regalis* (Bloch and Schneider). Rept. U. S. Comm. Fish. for 1927. Doc. No. 1019, App. II: 29–65.

HILDEBRAND, S. F.
1922. Notes on habits and development of eggs and larvae of the silversides *Menidia menidia* and *Menidia beryllina*. Bull. U. S. Bur. Fish. 1921–1922. *38:* 113–120.
1943. A review of the American Anchovies (Family *Engraulidae*). Bull. Bingham Ocean. Coll. *8* (2): 1–165.

HILDEBRAND, S. F., AND L. E. CABLE
1930. Development and life history of fourteen teleostean fishes at Beaufort, North Carolina. Bull. U. S. Bur. of Fish. *46:* 416–430.
1934. Reproduction and development of whitings or kingfishes drums, spot, croaker, and weakfishes or sea trouts, Family Sciaenidae, of the Atlantic coast of the United States. Bull. U. S. Bur. of Fish. *48:* 41–117.

HILDEBRAND, S. F., AND W. C. SCHROEDER
1928. Fishes of Chesapeake Bay. Bull. U. S. Bur. Fish., 1927. 43 (I): 1–366.

JORDAN, D. S., AND B. W. EVERMANN
1896–1900. The fishes of North and Middle America. Bull. U. S. Nat. Mus. *47*. 4 vols.

JORDAN, D. S., B. W. EVERMANN AND H. W. CLARK
1930. Check list of the fishes and fishlike vertebrates of North and Middle America north of the northern boundary of Venezuela and Colombia. Rept. U. S. Comm. of Fish. for 1928. Pt. II: 1–670.

MERRIMAN, DANIEL
1941. Studies on the Striped Bass (*Roccus saxatilis*) of the Atlantic Coast. Fish. Bull. 35, U. S. Fish and Wildlife Service. *50:* 1–77.

NESBIT, R. A.
1939. Weakfish (*Cynoscion regalis*). A Biological Survey of the Salt Waters of Long Island, 1938, Pt. I, No. XIV. Suppl. 28th Ann. Rept., New York Conserv. Dept. 97–106.

NICHOLS, J. T., AND C. M. BREDER, JR.
1926. The marine fishes of New York and southern New England. Zoologica, *9* (1): 1–192.

NORMAN, J. R.
1934. A systematic monograph of the flatfishes (Heterosomata). Vol. I: Psettodidae, Bothidae, Pleuronectidae. Adlord and Son, Ltd. (by order of the Trustees of the British Museum). 459 pp.

PEARSE, A. S., H. J. HUMM AND G. W. WHARTON
1942. Ecology of sand beaches at Beaufort, North Carolina. Ecological Monographs. *12:* 135–190.

PERLMUTTER, ALFRED
1939. An ecological survey of young fish and 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.: 11–71.

SHERWOOD, S. H., AND V. M. EDWARDS
1901. Notes on the migration, spawning, abundance, etc., of certain fishes in 1900. Bull. U. S. Fish Comm. for 1901. Biological Notes, No. 2. *21:* 27–31.

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

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.

WELSH, W. W., AND C. M. BREDER, JR.
1922. A contribution to the life history of the puffer, *Spheroides maculatus* (Schneider). Zoologica. *2* (12): 261–276.
1923. Contributions to life histories of Sciaenidae of the eastern United States coast. Bull. U. S. Bur. Fish. 39: 141–201.