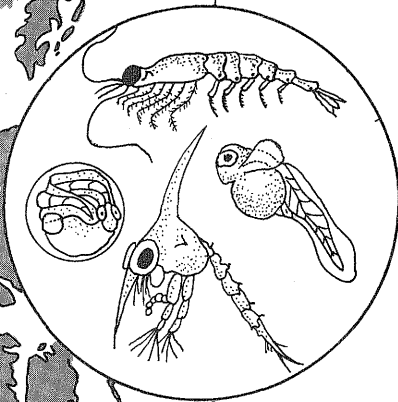
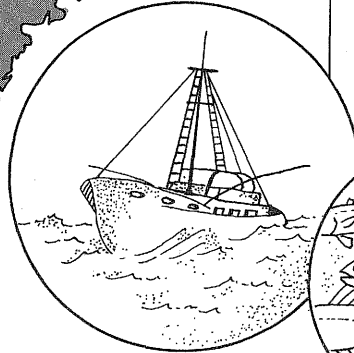
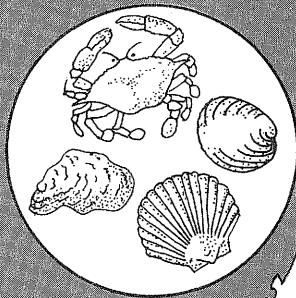
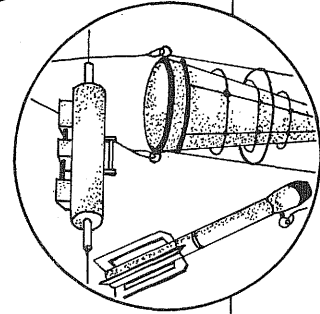
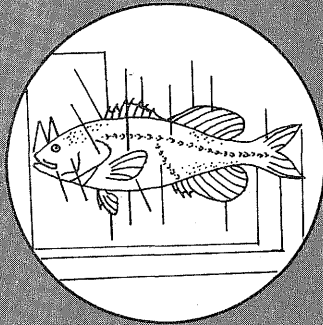


Proceedings Of A Workshop On Egg, Larval And Juvenile Stages Of Fish In Atlantic Coast Estuaries



UNITED STATES DEPARTMENT OF COMMERCE
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PROCEEDINGS OF A WORKSHOP ON EGG, LARVAL,
AND JUVENILE STAGES OF FISH IN ATLANTIC COAST ESTUARIES

Held at Bears Bluff Laboratories
Wadmalaw Island, South Carolina

JUNE 1968

Edited by Anthony L. Pacheco

Sponsored jointly by the Atlantic States Marine Fisheries Commission
and the U. S. Fish and Wildlife Service

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DR. G. ROBERT LUNZ, JR.

(Photo courtesy of Post Courier,
Charleston, S. C.)

DEDICATION

Dedicated to the memory of G. ROBERT LUNZ, JR. (1909-69), General Chairman of the Workshop on Egg, Larval, and Juvenile Stages of Fish in Atlantic Coast Estuaries.

Dr. Lunz was educated in the schools of Charleston, South Carolina. He received the B.S. degree and M.S. degree from the College of Charleston, and the D.Sc. degree from Clemson University, 1958.

He was Director, Bears Bluff Laboratories, Wadmalaw Island, South Carolina, from 1946 until his untimely death in 1969. The planning, construction, and development of the Laboratories, as well as the responsibility for securing private funds for the Laboratories, were successful largely through his individual efforts. From 1952, funds for the Laboratories were appropriated through the South Carolina Resources Department. Dr. Lunz served as Director of the Division of Commercial Fisheries of the South Carolina Wildlife Resources Department from 1959-69.

Dr. Lunz was a Life Member, American Association for the Advancement of Science, 1947-69; Fellow, 1952; he was Past President, Atlantic Estuarine Research Society; Past Chairman of the Atlantic States Marine Fisheries Commission; Past President of the South Carolina Academy of Science; and was the first President of the World Mariculture Society. Other professional associations included the American Fisheries Society, American Society of Ichthyologists and Herpetologists, the Association of Southeastern Biologists, and the National Shellfisheries Association, to which he was elected an Honorary Member in 1969.

The results of his research are represented by more than 50 papers published in various scientific journals. Dr. Lunz received the Jefferson Award for Outstanding Research from the South Carolina Academy of Science in 1941, and was made a Fellow of the Guggenheim Foundation in 1949. For his accomplishments in the field of science, he was listed in "American Men of Science," "Leaders in American Science," "Who's Who in the South and Southwest," "Who's Who in Science," and "Who's Who in the World of Science."

It was largely through his interest and initiative that marine biologists of the Atlantic seaboard states convened for the first time at Sandy Hook to discuss research of mutual interest, and it is entirely fitting that this record of the Proceedings be dedicated to the memory of G. ROBERT LUNZ, JR.

PREFACE

The purpose of the Charleston workshop was to assess the role of Atlantic estuaries as nursery grounds for economically important fishes and to encourage further work on estuaries. This was to be accomplished through a joint review and discussion of data by participants from each of the coastal states. It was evident to many that, although the momentum of interest in the role of estuaries to fish is increasing, some researchers were unaware or only casually aware of the work done, in progress, or anticipated at various coastal facilities. The time was right for exchange of ideas, seeding of new insights, and the development of camaraderie to encourage an improved and continued exchange of observations on the early life history of fishes. Only by studying the information from many states and agencies is one able to learn the estuarine requirements of migratory species.

The call for papers went out to biologists who might have contributions on: (1) the occurrence of egg and preadult stages; (2) environmental requirements which govern occurrence of estuarine-dependent juvenile stages; or (3) comments on needs and procedures for a manifold and integrated approach to describing the role of Atlantic coast waters in the life history of estuarine-related fishes.

The ground rules for the program were simple: the only manuscripts accepted were those pertaining to seaboard states on the east coast of the United States, with titles to be submitted by January 30, 1968, by participants actively working in the field. The workshop presentations were to be brief. Thirty-one presentations were given; of these, 13 appear in the Proceedings only as abstracts because some authors planned to publish their work in other sources or did not choose to develop their ideas into formal papers. The open discussions following each presentation were taped and these are included in the Proceedings.

A special session on the range and distribution of estuarine species, chaired by John Clark, was intended to review information from available literature, to point out existing gaps, and to generate from the group individual insights and information on any errors of omission. The workshop registrants were principally researchers from state, federal, and university laboratories. Included in the group were others concerned with administration, conservation foundations, and graduate studies -- drawn in because of their interest and involvement in estuarine problems. All the Atlantic coastal states except Rhode Island, Connecticut, and Delaware were represented. This unusually broad representation for such a meeting -- the first of its kind, both in theme and sponsorship (joint ASMFC and USEWS) -- was one of the elements that contributed to its success. The tone of the sessions was informal, retorts spontaneous, and interest level high.

There was a concensus that the workshop succeeded in providing a forum for fishery workers from along the seaboard to meet and exchange views. It gave many a broader perspective of the range of research and their individual roles in the coastal framework of activity. Information gaps became much more apparent to many individuals. The ASMFC members present were delighted that such a workshop developed under their aegis in cooperation with the U. S. Fish and Wildlife Service.

Even in view of problems summarized in the last session, the Proceedings reflect the level of involvement, diversity of interest, and degree of sophistication which various laboratories are approaching and have attained in understanding the young fish biota of Atlantic estuarine waters.

My special thanks go to Mabel Bennett, who prepared many of the abstracts and thoroughly checked referenced material, and to Cynthia Joyner, who did much of the proofing. Both also attended to a variety of other editorial chores. Thanks are also due to Catherine Walstrom, who with Mary R. Branan of the ASMFC, prepared a transcript of the discussions from the recorded tapes. Virginia Yarnell prepared base maps used in the range and distribution session.

A. L. Pacheco
Proceedings Editor

GENERAL CHAIRMAN'S REMARKS

G. Robert Lunz, Jr.

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Wadmalaw Island, South Carolina 29487

This workshop is being held to provide an opportunity for joint review and discussion of information on the occurrence of fish eggs, larvae, and juveniles in Atlantic estuaries. Specific objectives are to present appropriate scientific papers, with publication of a volume of collected contributions; to provide a forum for informal discussions among biologists active in estuarine fish research; to encourage and assist in dissemination of unpublished data on estuarine fish nurseries; and to assess the present state of knowledge and recommend future lines of research.

The Atlantic States Marine Fisheries Commission and the U. S. Fish and Wildlife Service (Bureaus of Sport Fisheries and Wildlife and Commercial Fisheries) jointly sponsored this workshop program. The workshop was planned by the following Steering Committee: William Anderson, Bureau of Commercial Fisheries; John Clark, Bureau of Sport Fisheries and Wildlife; L. Eugene Cronin, University of Maryland; Harold Lyman, Boston, Massachusetts; and Ernest Mitts, Atlantic States Marine Fisheries Commission.

The Belle W. Baruch Foundation kindly offered funds to defray travel expenses of some of the attendants. As responses from attendees were received, the Steering Committee decided this aid was not needed, but thanks are extended for the offer of aid.

The Bureau of Sport Fisheries and Wildlife agreed to publish the Proceedings of the meeting, with Anthony Pacheco of the Bureau's Sandy Hook Marine Laboratory appointed to serve as editor. Thanks are due to staff people who have put in much effort in preparing for the workshop arrangements and still are on hand to see the meeting through. These include Mrs. Mary Branan, ASMFC; Ruth Yoacum and Lois Richter, Bears Bluff Laboratories; and Catherine Walstrom, Sandy Hook Marine Laboratory.

The Steering Committee feels the response is excellent. Even though the meeting is primarily geared to those actually engaged in estuarine research along the Atlantic seaboard, we received applications from Germany, Honolulu, the west coast, and some inland states. In all, 82 have registered. It is safe to say that none of us realized until the meeting just how many people were actively working on egg, larval, and juvenile stages of fish in the Atlantic coast estuaries.

The Steering Committee strongly urges that this type of program be continued. I, personally, recommend that the same sponsors plan a similar workshop for crustaceans, dealing with lobsters, crabs, and shrimp along the Atlantic coast.

The workshop agenda is in five sessions:

RESEARCH TECHNIQUES
ESTUARINE HABITATS AND LIFE HISTORIES OF FISHES
DISTRIBUTION STUDIES
ESTIMATION OF MORTALITY RATES
ENVIRONMENTAL ADAPTATIONS

An additional session on RANGE AND DISTRIBUTION OF SOME ESTUARINE FISHES will be presented by Sandy Hook Marine Laboratory staff members and colleagues at the BCF Laboratory, Beaufort, North Carolina.

Dr. Cronin from the Chesapeake Biological Laboratory will summarize the workshop at a concluding session.

RESEARCH TECHNIQUES

Chairman

William W. Anderson

AN ASSESSMENT OF EGG, LARVAL, AND JUVENILE FISH RESEARCH NEEDS
AND PROBLEMS, WITH COMMENTS ON RESEARCH AT THE UNIVERSITY OF
NORTH CAROLINA INSTITUTE OF MARINE SCIENCES

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ABSTRACT

Sampling problems experienced by all researchers who deal with eggs, larvae, and juveniles of marine fishes are reviewed. Technical problems involving sampling gear, field facilities, and personnel, as well as standardization of sampling methods and literature retrieval, are of primary importance.

One purpose of this meeting on eggs, larval, and juvenile stages of fishes is to assess our present position regarding this aspect of fishery research. I plan to call to your attention some of the many needs necessary to refine our study approach.

Each of us has literally gone his own way and each has encountered the same problems and frustrations. Let us use the meeting as a way to recognize these needs and problems and decide how we can best alleviate them and achieve future research success.

Among our greatest needs are solutions relating to the following problems:

1. Gear

- a) Refinements. Opening and closing nets would allow the volume sampled to be determined accurately. This feature would also remove the uncertainty of the depth at which the sample was obtained.
- b) Comparisons of gear types. Researchers have used Gulf I-IV nets, jet nets, Hardy samplers, etc., but few data comparisons have been made among these samplers for efficiency, species composition, and other variable characteristics.

- c) Durability. Today the makeshift gear designed for estuarine sampling does not withstand the rigors of the ocean, while oceanic designed gear is often too bulky to be employed in estuaries from smaller operating vehicles.
- d) Mobility -- in the sense of getting gear from one level to another quickly. Animals move by themselves or with external aid. Inability to move with them will negate effectiveness of any sampling technique.

2. Standardization

- a) Mesh size and its variability. Different-sized mesh materials offer varied straining capabilities. Lack of manufacturing controls often results in mesh size variations of the "same" material when reordered.
- b) Area of sample. One person tows 5 minutes, another some other time interval. These cannot be compared to give an index of abundance.
- c) Volume sampled. We lack adequate equipment to resolve the amount of water sampled. Also, each researcher samples different volumes, making comparisons inadequate.
- d) Vessel tow speed. Often, one researcher tows at 1 knot, another at 3 knots, etc., yielding results which are not directly comparable.
- e) Tow interval. Varying the time of sample intervals complicates research sampling comparisons.
- f) Horizontal or oblique tows. Each researcher has a personal preference for type of tow. Though tactics may be controlled by topography, standardization would help.
- g) Stationary or moving sampling. Each method has its advantages. Most researchers use a moving method but too much variation remains.
- h) With, against, or cross-current tows. Most workers modify their sampling technique to meet the local conditions and/or their gear. Enough is now known to attempt standardization of direction of tow.
- i) Size of specimen to be sampled. Researchers vary in their sampling, from retaining and analyzing everything collected to working with only materials of a specific size.

- j) Size of aliquot and what constitutes an aliquot. Biases easily enter this aspect of research, especially if the sample is permitted to settle out.
- k) How to obtain an unbiased aliquot. Unique subsampling devices have been used and devised to circumvent this problem, but many inconsistencies persist.
- l) Seasonality of sampling. Few researchers sample only when known or expected catches are present. Seasonal sampling is needed to resolve when and where a form may occur.
- m) Priority of catch analyses. Storage space is always a problem; therefore, serious thought should be given before rooms or buildings are filled with samples which decay or await the trained researcher.
- n) Units of measurement. Metric units should be used consistently instead of the mixed English and metric combinations prevalent in the United States.

3. Biology

- a) Embryology studies on individual species. Much effort is expended on indiscriminate sampling, whereas working with a particular species to determine the various developmental stages would have more value.
- b) Knowledge of effects of external forces on the biology of various stages. Factors such as light, temperature, and currents have effects on the growth and development of larval fishes. These could be resolved by aquarium studies.
- c) Effects of nuisance forms (ctenophores, jellyfishes, and debris).

4. Work platforms

Ships or stationary platforms are sorely needed. Too often, research is conducted from a flimsy boat with makeshift gear-handling techniques.

5. Support personnel

Training of people in techniques such as handling young stages and identification of important structures, as well as artists to draw the findings, is needed. More essential is the ability to place these people where needed. Often, a need exists but funds are lacking or denied for support.

6. Funding

Like systematics, this field is hard to sell since results are not always as newsworthy or immediately visible as, for example, pollution, ecology, or applied biology in terms of position advancement or return-for-effort.

7. Literature service

The burgeoning biological literature is too scattered to permit even the most conscientious researcher to scan it all. Atlases and bibliographies are needed to pull the scattered literature together for ready use.

8. Rapid retrieval methods

Data and literature must be retrieved quickly or they are soon lost to the biological community. Research has little value if no one knows it has been done.

From our discussions in the next few days, these questions will arise: Where are we going in the long run? Are we seeking answers to local, continental, or political problems by our sampling? Are we working on the "right" species? Are we looking at the whole picture or at some restricted niche?

How do we attain our goals -- singly, jointly, or by coordinated action? We need more meetings like this one to aid in solving problems of rearing, ecological factors, physiology, species systematics, zoogeography, and others. Only then will the whole picture come into clear focus and perhaps a unified approach can be attempted. I suggest that we turn to the Atlantic States Marine Fisheries Commission, cosponsors of this workshop, as the medium through which we call attention to our problems and with whose cooperation we may be able to make strong forward progress in our studies of eggs, larvae, and juvenile stages of fishes. The ASMFC can:

1. Call meetings to discuss the findings and needs of the 14 Atlantic coastal states.
2. Direct attention to work that is going on or that is needed in a particular area.
3. Provide a conjoined voice in obtaining research funds and/or legislation.
4. Pass on to the National Marine Fisheries Service (which has ocean-going ships for offshore operations) the knowledge of the inshore state biologists and academic researchers so inshore data can be correlated with offshore findings.

5. Be an exchange medium between other organizations (ICNAF, ICES, GSMFC, etc.) and countries (Japan, Russia, and Canada) working along our coasts to lessen duplication of effort and funds, and allow better utilization of information by all researchers.

Advancement in these directions will strengthen the state of the art and knowledge on fish eggs, larvae, and juveniles.

SUMMARY OF INSTITUTE OF MARINE SCIENCES
STUDIES OF FISH EGGS, LARVAE, AND JUVENILES

Six research efforts have been undertaken during the past 10 years by the IMS on early life history of fish. These are:

1. Plankton sampling of Pamlico Sound. Principal investigator: A. B. Williams.
2. Tagging of juvenile flounders for the Biological Committee of ASMFC. Principal investigator: E. E. Deubler.
3. Metamorphosis of three species of flounders sampled at selected inlets along the North Carolina coast. Principal investigator: E. E. Deubler.
4. A ten-year study of meroplankton in North Carolina estuaries. Results authored by A. B. Williams and E. E. Deubler and published in Chesapeake Science 9: 27-41, 1968.
5. Effects of temperatures on the morphology of the striped killifish, Fundulus majalis. Principal investigator: W. Fahy.
6. Larval menhaden abundance, distribution, etc., in the Neuse River of North Carolina. Principal investigator: F. Holland.

PRESERVING AND PREPARING LARVAL FISHES FOR STUDY¹

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ABSTRACT

Current methods for fixing, preserving, sorting, and treating larval fishes are described. Recommendations are made and emphasis is placed on the need for further research.

INTRODUCTION

Studies of larval fishes depend on methods that first fix and preserve, sort, and specially treat the specimens. The studies under discussion are primarily for identification, but continue on into specialized taxonomical, embryological, and anatomical research. This paper describes and discusses the methodology of preserving and preparing larvae for such study. We regard the methods in current use as inexact and in need of improvement. The following comments are based on personal experience and information from interested colleagues. We submit them as recommendations for preferred methods of treatment and hope better methods will be developed, standardized, and adopted.

PRESERVATION OF SAMPLES

Preservation of fish eggs and larvae begins when the plankton sample in which they were caught is removed from the sampling device. There is an immediate need for speed in preservation of a sample on completion of a tow. Too often, procrastination on the part of technicians causes delays in the addition of preservatives, a factor that can have disastrous effects on the quality of

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the sample (cannibalism is common, and many organisms decompose rapidly). Plankton samples are often made up of organisms other than fish eggs and larvae, and the calcareous nature of many of the other organisms (which must also be preserved) necessitates the use of a neutral preservative solution of pH 7 (or slightly basic) for satisfactory permanent preservation. Two different preservative solutions are in common use -- formalin and ethyl alcohol. We strongly recommend the use of formalin for the first and subsequent preservations. We discommend the use of ethyl alcohol for the following reasons: (1) Its high concentration (70%) leads to rapid evaporation, whether the specimen is exposed for study or remains inside a jar that may be loosely sealed. (2) Shrinkage, desiccation, and distortion of the specimens are likely. (3) During study, it is difficult to handle larvae that have been preserved in ethyl alcohol -- when a specimen is placed in a dish of water, the mixing of the water and the alcohol causes the larvae to gyrate. (4) Ethyl alcohol is much more expensive than formalin.

We recommend the use of 5 to 10% formalin. The saturated aqueous solution known as "concentrated formalin" contains 37 to 40% formaldehyde. One part of this solution should be added to 9 to 19 parts of ambient water (including the plankton sample) to obtain a 5% solution with low settled volume or a 10% solution with higher settled volume (about 50% or more). Fresh or distilled water should not be used to preserve marine samples.

Because formalin solutions are originally acidic, a buffer should be added to produce a neutral or slightly basic solution. We find that borax (sodium tetraborate) is a good standard buffer. In time (usually 1 to 10 years), borax loses its effectiveness, but the addition of 2.5 grams to 1 liter of 5% formalin (5 grams per liter of 10% formalin) should provide immediate buffering, with enough reserve to extend the effective period to 4 or 5 years. Since excess borax may macerate and bleach tissues, a pH greater than 8.0 to 8.3 should be avoided. We strongly disapprove of hexamine (hexamethylamine) as a buffer. Hexamine is expensive; it crystallizes easily around organisms when the sample is subjected to slight evaporation; and it may macerate, bleach, or clear larvae eventually to the extent that they become essentially worthless. The claimed self-perpetuation of the product does not compensate for these disadvantages.

A color preservative sometimes may be added to the sample. We routinely add 1 ml of IONOL CP-40 to an 8-oz sample jar of plankton. When specimens are protected from light, this fluid has retained the red pigments in fish larvae and crustaceans for almost 3 years. If too much IONOL is added, the specimens stain bright yellow, but diagnostic black pigment is not affected. Other color retaining reagents are currently under study at our laboratory and elsewhere.

For protracted, permanent storage of eggs and larvae in the plankton sample, the formalin solution should be changed within 5 to 10 days (at most, within 2 or 3 months) after original preservation, to guarantee that the specimens are fixed and that the solution is neutral. At this time, a 5% buffered

formalin solution is sufficient. One word of caution -- if a preserved plankton sample is acidic, the buffer should not be added and stirred into the sample. Instead, a fresh buffered solution should be exchanged for the old one.

Another solution for storing fish larvae has sugar as its basic ingredient. Joseph J. Graham (Bureau of Commercial Fisheries, Boothbay Harbor, Maine) has used the sugar method and reports (personal communication) that, although the solution does not preserve color, the larvae appear in good condition in all other respects. Graham's formula (the subject of further research) is: 9,210 cc tap water, 232 grams NaCl, 35 grams KCl, 29 grams H_3BO_3 (dry boric acid), 16 grams NaOH, 100 cc formalin, and 1,000 grams sugar.

In samples collected and retained aboard a vessel for more than 1 month, agitation of the material inside the container often obliterates writing on a label placed inside the container. We find it best to place the label on top of the liquid within the container rather than pushing it down into the sample. In addition to the inside label, pertinent information written on an external tag or label is advisable. The container should be completely filled to reduce sloshing of the contents. At all times, but particularly aboard ships, plankton should be stored away from heat, which can be harmful to collections, especially in the tropics. The threat is so serious that temperature-controlled rooms should be considered for shipboard storage if plankton is to be put ashore in prime condition.

Samples of whole plankton -- or fish eggs and larvae that have been removed from the sample -- are kept in a buffered solution of 5% formalin for long-term storage. It is wise to check the samples at least once a year to ensure neutral pH and to guard against loss by evaporation. Checking for acidity in multitudinous small vials entails high labor costs, but no satisfactory shortcut has been found. Perhaps a compromise solution would be to retain a small collection of an ontogenetic size series of each species, check it each year, and trust to luck for the remainder of the material.

These remarks underscore the urgent need we see for long-range, intensive research to determine the best methods and materials for permanent preservation.

INITIAL SORTING

We find it best to remove all fish eggs and larvae from the plankton sample before any other procedures, such as splitting or subsampling the sample, are undertaken. If splitting begins before the fish larvae are removed, the succeeding subsamples may be misplaced and may never be sorted for fishes. Because fish eggs and larvae generally make up such a small proportion of

a plankton sample (particularly in some tropical waters), enumeration of them is nearly meaningless when only split portions are examined. Also, because of different densities (some organisms float, some sink) and different features (some adhere, some slither through separating devices), thorough mixing of whole plankton before splitting is often difficult or impossible. When too much plankton is collected for complete sorting for fish larvae, thorough care should be given to ensure adequate splitting.

Determinations of plankton volume are usually made before fish sorting; most such procedures call for the removal of organisms larger than 5 or 10 mm. Again, valuable fishes are sometimes lost unless they are returned to the sample or unless careful note is made of their disposition. We recommend that these large fishes be retained with the larvae, because they often aid in larval identifications (through comparison).

To ensure accuracy, the fish larvae must be removed under magnification. Because the organisms are fragile, careful handling is also important. We recommend the use of eyedroppers, wire loops, or microdissection forceps. Ordinary small forceps (with nonflexible tips) may be used, but only by well-trained people. We have seen many collections in which the print of the forceps was plainly visible on specimens -- occasionally so visible that the specimen was nearly broken in half. Eyedroppers or wire loops may be best for the removal of eggs.

When sorting, we find it best to survey small instead of large amounts of plankton at one time. The larger the quantity of plankton examined, the greater the likelihood that larvae or eggs will be overlooked. We instruct our sorters to remove not only all fish, but any organisms that might possibly be fish. The presence of chaetognaths in our samples of fish larvae serves to reassure us that all larvae were carefully picked out. The character of material other than fish collected has a bearing on the sorting -- high concentrations of filamentous algae make sorting difficult and lead to errors by even the best of sorters. Eggs and larvae can be overlooked easily, particularly when they are minuscule. Larvae can be overlooked when the eyes are missing (because of damage) or are unpigmented. Well-trained sorters usually overlook less than 1% of the fish larvae in a sample. We have known sorters who missed as many as 50% of the fish larvae, but either they did not continue to miss that many, or we came to miss the sorters.

The larvae we collect and sort are stored in small vials containing a 5% solution of buffered formalin. We consider our vials -- 5-dram, clear glass capsules with nylon cap liners -- the most convenient size for the larvae from most plankton samples. When the samples are placed in specially made boxes with lids, bleaching effects of light are reduced. Nylon cap liners in the vials retard evaporation.

SORTING COSTS

The physical separation of eggs and larvae from other organisms in a plankton sample can be most expensive. The labor required accounts for this high cost, and the time it takes a sorter to complete his procedures depends not only on his experience and ability, but on the nature of the sample. The time needed for sorting is determined by the numbers of eggs and larvae present, their size and visibility, and the presence of filamentous algae and other extraneous organisms. For instance, sorting of samples that contain many small larvae with unpigmented eyes is extremely time-consuming. In one brief survey, we discovered that costs ranged from \$20 to \$56 per sample (sample size equals 100 cc of plankton). According to David Kramer (personal communication) of the Fishery Oceanography Center, Bureau of Commercial Fisheries, La Jolla, California, where this type of work has been done for many years, costs are low compared with the amount of work accomplished. For example, the representative cost is about \$20 to \$21 per sample for an average sorting job. This sum covers the removal and counting of all fish eggs and larvae, as well as the identification and measurement of eggs and larvae of three fish species found in great abundance in the area. The La Jolla group experiences a high rate of turnover among its employees (as do most agencies) but enough experienced sorters are always on hand to help train new employees. A constant high volume of work also promotes a relatively stable operation, a factor that probably accounts for the low cost per sample. Costs of \$30 to \$56 per sample were reported by two other large research groups, and their procedures entailed only removing and counting the larvae.

SUBSEQUENT SORTING

It is important to record what has been removed from the larval fish sample and its disposition after eggs and larvae have been either identified or removed from the final sorting. We urge that the total larval sample from a single collection not be separated on the basis of gross similarities (unless an unusual circumstance arises) until the major components and most of the species are known, and most of the intraspecific ontogenetic stages are identified (or at least recognized as distinct entities). Premature separation leads to numerous smaller samples that must receive the same amount of curating as the original. Another obvious disadvantage inherent in handling such small samples is that the specimens may be lost through the complete physical loss of the specimens and container, through errors in labeling, or through insufficient curatorial care. The greatest risk, though, is that very small specimens of a species may be separated from larger specimens of that species because their conspecificity is not recognized.

Some of the larvae may be removed and separated from the main sample for various reasons. If so, labels denoting the kind, number, and disposition of the specimens removed should be placed with the original sample.

We find that one of the safest ways of storing larvae that have been identified and removed from the samples is to place them in shell vials of appropriate sizes (usually 17 × 60 mm, 1.5 dram), plugged with cotton and placed (plug down) in a larger jar filled with preservative. The shell vial takes up little space, and the specimens can be retrieved quickly. A word of caution: upon reexamination, larvae adhering to the cotton plug can be easily overlooked. A small vial (50 × 10 mm, of West German manufacture), which may represent an improvement over the ones we use, has recently come to our attention. The space-saving vial has a grooved nylon plug that prevents evaporation; cost of the vial is low (\$10 per thousand). We have had fair success with screw-topped vials, but unless the caps have liners, evaporation is almost inevitable.

ADDITIONAL PREPARATIONS FOR STUDY

Several methods in use for specialized study of larval fishes also provide permanent storage for the specimens. One such procedure is the clearing and later staining (usually of calcified parts) of the larvae. Taylor (1967) outlined an excellent method for staining bone which we have used with success. Under his system, specimens that have been cleared and stained may be maintained indefinitely in pure glycerine with a few crystals of thymol added to prevent fungal growth. Other similar staining methods, based on the less desirable potassium hydroxide as a clearing agent, have been summarized by Evans (1948). A number of procedures have been described for cartilage staining; one used in our laboratory with variable success was described by Moran (1956). More specialized techniques such as the staining of nerves described by Freihofner (1966) are sometimes useful.

Another method that combines study and permanent storage is used when larvae are prepared for histological study (sectioning, staining, and mounting). Materials under study are treated the same as any other animal tissue, but detailed work requires that the larvae be fixed in a histological solution more suitable than formalin (e.g., Bouin's solution).

In a sense, photographs, radiographs, and illustrations of larvae also provide permanent storage although larvae do not generally photograph well because they are small and often misshapen. Radiographs are widely used for adult fishes and lately our laboratory and others have used radiography on larvae. Bartlett and Haedrich (1966) outlined a method

we use to radiograph small fishes but the application of similar techniques to larvae results in higher costs for equipment -- it is necessary to X-ray in vacuums and use photographic emulsions that resolve 1,000 lines per millimeter.

Illustrations of larvae should be made with great care and with close attention to correct proportions, meristics, and other salient characters. Specimens often must be slightly distorted or drawn from unusual perspectives to illustrate specific features. It may be desirable, especially among damaged or distorted specimens, to use several specimens in preparing the illustration of a particular larval stage. When such circumstances exist, careful note of the facts should be made in the figure heading.

CONCLUSION

Clearly, a real need exists for sound research covering the preservation, care, and handling of larval fishes. Without doubt, most of our recommended procedures can be improved. International concern over this problem has resulted in the formation of the SCOR-UNESCO Working Group No. 23 (Vagn Hansen, Chairman). The group held its first meeting in Washington, D. C., 25 to 30 March 1968. Similar concern has been mentioned in the report by the FAO Panel for the Facilitation of Tuna Research (Matsumoto et al., 1966).

ACKNOWLEDGMENT

We thank Dr. Elbert H. Ahlstrom, Senior Scientist, Bureau of Commercial Fisheries, La Jolla, California, who has been so cognizant of these problems through the years, whose ideas have been behind much of the thought presented here, and who has critically reviewed this manuscript.

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DISCUSSION

Wollam asked if any of the attendees used No. 7 sugar preservation solution and might wish to comment on its advantages and disadvantages. Graham said sugar solution is sticky to work with, but keeps larvae in good condition. This preservative, however, circumvents the problem of noxious fumes encountered with other solutions.

Cronin mentioned the Smithsonian Institution has a study on invertebrate preservation and asked if there were any similar programs on fish eggs and larvae. Knapp replied that Daryl Cronin, Director of the Smithsonian Sorting Center, is making plankton collections in the Caribbean, from the R/V Pillsbury. An English biochemist, Dr. Steedman, will supervise this experimentation in which various techniques will be tested in order to gain general information on the preservation of plankton collections.

In response to Richards' inquiry on the use of 40% isopropyl alcohol for storing larvae and eggs, Williams said this preservative is useful for larvae. However, it collapses eggs as does any kind of alcohol. Berry asked if the transfer from formalin to isopropanol is done directly or is run up in stages. Williams replied that running up in stages is unnecessary for larvae, but even progressive changes in small stages will collapse fish eggs.

Marak asked if anyone used the enzyme LDH for the identification of larvae. Massmann answered that Battelle Institute in Ohio under a contract with the Ohio Fish and Game Department uses LDH for identification to distinguish strains of walleye using larvae and eggs as well as the larger fish. Richards added that research on adult tuna at the Tropical Atlantic Biological Laboratory revealed the enzyme to be unstable unless the material is frozen. There is difficulty in removing larvae from a frozen mass of plankton and keeping them frozen.

COMMENTS ON THE IDENTIFICATION OF LARVAL SCOMBRID FISHES¹

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ABSTRACT

Positive identification of larval Atlantic scombrids is necessary in determining mortality rate and estimating population fluctuations. The characters that facilitate identification of 21 Atlantic species in 11 genera include numbers of myomeres, morphometric, and morphological features, particularly the distribution of chromatophores on the larvae. Larvae are initially separated into three groups according to numbers of myomeres. Genera and species are listed and their distinctive characters described.

INTRODUCTION

Because the family Scombridae includes some of the world's most important food fishes, worldwide research is devoted to many of its species. One important aspect of this work is an understanding of the early life histories of the fishes, since most fishery biologists agree that the population fluctuations of commercial fish stocks can be attributed largely to variable early mortality (National Academy of Sciences/National Research Council, 1967). To understand this mortality, the fish larvae must be identified. In this paper, I review briefly our knowledge of identification of larval Atlantic scombrids. Much of the information I present is published; some is unpublished, but is based on my own research and that of my colleagues, Walter M. Matsumoto, Shoji Ueyanagi, Witold L. Klawe, and S. Jones. As a group, we were charged recently, by the FAO Expert Panel for the Facilitation of Tuna Research, with the responsibility of preparing a report on the identification of tuna eggs and larvae. This report will not be ready for several years.

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I will treat by genera the 21 Atlantic species in 11 genera, with comments about species where pertinent. I do not include references to all published accounts of the species; I have selected only those accounts that give thorough descriptions and figures of the larvae, and only those characters that contributed to identification. These characters are: the number of myomeres; the shape of various body parts (jaw length, body length, position of the eye, length of the first dorsal fin, etc.); and absence or presence and amount of pigment (chromatophores) on various parts of the larvae such as tips of jaws, pectoral symphysis, over the forebrain and midbrain, and on various parts of the dorsal, ventral, and lateral aspects of the body and caudal peduncle. Recent work has shown that the distribution of red pigment also may be a useful character (Ueyanagi, 1966).

DIAGNOSES

On the basis of their myomere counts, which reflect the number of vertebrae, the larvae can be separated into three fairly distinct groups. The first has the lowest number of myomeres (30 or 31) and includes the two species of Scomber; the second has between 38 and 43 myomeres and includes Auxis, Katsuwonus, Euthynnus, Thunnus, and Allothunnus; the third group has between 43 and 65 myomeres and includes Sarda, Scomberomorus, and Acanthocybium. Gasterochisma melampus Richardson and Oreynopsis unicolor (St. Hilaire) are poorly known; the former is probably not a scombrid and the latter probably has larvae similar to those of species in the second or third group.

The first group consists of two species, Scomber scombrus Linnaeus and S. japonicus Houttuyn, easily separable from the other Atlantic scombrids by their low number of myomeres (30 or 31). Kramer (1960) gave an excellent account of S. japonicus; Sette (1943) described S. scombrus. To my knowledge, no one has compared carefully the larvae of the two, a comparison that is needed before detailed biological studies can be made in areas where they are sympatric. I have never examined the larvae of these species so I will withhold further comment about them. In general, S. japonicus and S. scombrus have much more pigment distributed over the body than other species of Atlantic scombrids; they lack preopercular spines; and the first dorsal fin develops before the second dorsal fin.

The second group, composed of the species of Auxis, Katsuwonus, Euthynnus, Thunnus, and Allothunnus, is becoming well understood mainly because of the efforts of Matsumoto and Ueyanagi. Distinctive features of this group are the 38 to 42 myomeres, large head, few chromatophores, and similar body proportions.

Auxis: Although Richards and Randall (1967) indicated the presence of two species in the Atlantic, I believe -- on the basis of my further study -- that they may have been wrong. I will, therefore, treat the larvae only in the generic sense and not allocate a larval type to any particular species (Matsumoto, 1959). Auxis larvae are characterized by a chromatophore on the pectoral symphysis (like Euthynnus); chromatophores over the midbrain but absent from the forebrain (like Thunnus); chromatophores over the gut; chromatophores on the ventral, dorsal, and lateral midline in Matsumoto's (1959) Type I, and present on the ventral and dorsal midline but absent from the lateral midline in his Type II larvae. This separation of Type I and Type II stops at about the 8-mm size; all larger specimens are referable to Type I. Chromatophores are usually present on the tips of the jaws and absent from the poorly developed first dorsal fin at lengths less than 10 m. Red pigmented spots are distributed as in Katsuwonus (Ueyanagi, 1966).

Katsuwonus pelamis (Linnaeus): This species, described at length by Matsumoto (1958), is characterized by chromatophores over the forebrain and midbrain (like Euthynnus); no chromatophores on the pectoral symphysis (like Thunnus); one to three chromatophores on the ventral edge of the caudal peduncle; chromatophores usually present on the tips of the jaws; chromatophores over the gut and a few on the first dorsal fin. One chromatophore infrequently appears on the dorsal edge of the caudal peduncle. A row of red pigmented spots begins above the anus and curves down and back, along the ventral midline, onto the caudal peduncle (Ueyanagi, 1966).

Euthynnus alletteratus (Rafinesque): This species, thoroughly described by Matsumoto (1959), has chromatophores on the pectoral symphysis (like Auxis); chromatophores over the forebrain and midbrain (like Katsuwonus); and chromatophores on the ventral edge of the body above the anal fin. Chromatophores are present also over the gut, behind the brain, at the tips of both jaws, and along the lateral ramus of the lower jaw. The dorsal fin is high and distinctly marked with chromatophores. I have observed a row of red pigmented spots beginning above the anus, then curving down and back along the ventral midline onto the caudal peduncle identical with the pattern shown for Katsuwonus by Ueyanagi (1966).

Thunnus: The six species of Thunnus are very similar. All are characterized by an absence of chromatophores on the forebrain and pectoral symphysis, and the presence of chromatophores on the midbrain, gut, and first dorsal fin. Chromatophores on the upper and lower jaw tips and body are variable and their presence or absence is used to separate the species. The following is a discussion of the current disagreement concerning the identification of the species. Matsumoto (1958) described T. albacares as lacking body chromatophores (except on the first dorsal fin) and stated that chromatophores were variably present or absent on the tips of the jaws. Matsumoto (1962) described T. obesus as like T. albacares except for the addition of one to eight chromatophores along the ventral edge of the trunk; T. thynnus as

similar to the previous species except for one to six chromatophores on the ventral edge of the trunk and two or three on the dorsal edge of the body between the origins of the second dorsal and caudal fins; T. tonggol (though not an Atlantic species) as similar to T. thynnus but with the first dorsal chromatophore in advance of the second dorsal fin origin; and T. alalunga as similar to T. obesus but with one chromatophore on the dorsal edge of the trunk. Ueyanagi (1964) also described these six species but his account differed from Matsumoto's (1962) in several respects. Ueyanagi's descriptions agreed with Matsumoto's (1962) for T. albacares, T. tonggol, and T. obesus. Ueyanagi, however, considered Matsumoto's T. alalunga a variant of T. thynnus and offered an entirely different concept for T. alalunga, which he characterized as nearly identical to T. albacares but separable as follows: chromatophores do not appear at the tip of the lower jaw until the fish reaches a length of about 9 mm (they appear at 3 mm in T. albacares); the center of the eye is bisected by an imaginary line drawn from the tip of the snout to the center of the hypural plate (the center of the eye lies above this line in T. albacares). Ueyanagi (1966) upheld his view by citing evidence based on difference in red pigmentation. In his 1966 paper, he noted the occurrence of several red spots along the ventral, lateral, and dorsal edges of the body in T. alalunga and T. thynnus; the red spots on the dorsal edge are reduced to 0 to 3 in T. obesus and 0 to 2 in T. albacares. I tend to agree with Ueyanagi because the few specimens of T. alalunga from the Mediterranean Sea that I studied matched his descriptions, and because T. albacares is not known to be indigenous to the Mediterranean. However, further research is needed to definitely clarify this problem. From my studies, I believe that further research must be done before T. tonggol can be identified. Figures 1 to 4 show four larvae collected in the eastern Atlantic off Cape Verde, Senegal. The largest specimen (Fig. 1) is a typical T. thynnus following Matsumoto (1962) and Ueyanagi (1964); the specimens in Figures 2 and 3 should be T. tonggol, because of the presence of an anterior dorsal chromatophore, but this species is not found in the Atlantic according to current knowledge. I presume that all specimens in Figures 2 to 3 are probably T. thynnus. The smallest one (Fig. 4) is similar to T. tonggol in arrangement of trunk chromatophores but the head pigmentation is excessive for a Thunnus -- perhaps it is Euthynnus.

I am currently working on the determination of T. atlanticus, the identity of which is not yet known. I suspect the species is very similar to T. obesus because larvae of the T. obesus type abound in areas inhabited by T. atlanticus.

Ueyanagi recently noted (personal communication) that larvae of the southern bluefin tuna (Thunnus maccoyii) closely resemble those of Pacific bluefin tuna (T. thynnus orientalis), but the chromatophores on the dorsal body area are smaller than those of T. thynnus orientalis.

Allothunnus fallai Serventy: The larvae of this species have been well described in figures by Watanabe, Yukinawa, Nakazawa, and Ueyanagi (1966), and their presence in the south Atlantic has been confirmed by Mori (1967). According to Watanabe et al. (1966), A. fallai larvae have the general appearance of the others in this group, but are unique in having pigment on the ventral midline of the lower jaw in specimens larger than 5 mm total length (TL); specimens longer than 6 mm have pigment below the second dorsal fin. Otherwise, as in Thunnus, pigmentation is absent over the forebrain until 10 mm TL, absent from the pectoral symphysis, and present on the tips of the jaws and over the gut and midbrain. The pattern of red pigmentation is also similar to Thunnus (Ueyanagi, 1966). Another feature unique to A. fallai is a distinct dorsal protuberance at the end of the snout, which is believed by these workers to be analogous to the shape of the premaxillary bone of an adult described by Nakamura and Mori (1966). However, it may be an artifact caused by dehydration of the specimens.

Least known is the third group, made up of the species of Sarda, Scomberomorus, and Acanthocybium. Attention has been minimal because of low economic interest in the species. Further, because of nearshore habits of the group, their larvae (except Acanthocybium) do not often appear in high seas collections of tuna larvae. Distinctive features of this group are the high number of myomeres (43 to 65), presence of a spiny supraorbital crest, and the progressive increase in snout length -- from short in Sarda to long in Acanthocybium.

Sarda sarda (Bloch): Demir (1963) reviewed the literature on the identification of this species and showed figures of eggs and larvae. Because I have seen no larvae from the Atlantic that I could positively identify as Sarda, I will only say I believe that identification of the species may be difficult and that a careful descriptive study is called for -- particularly since Orcynopsis may be confused with Sarda. Preliminarily, S. sarda can be tentatively characterized as having about 50 myomeres; chromatophores over the midbrain and perhaps over the forebrain; chromatophores over the gut and along the ventral edge of the trunk; and chromatophores on the pectoral symphysis (in most specimens). In addition, one should consider the presence of chromatophores along the base of the first dorsal fin (even before spines are visible) and the possibility of chromatophores midway between the pectoral symphysis and the anus.

Scomberomorus: Four species of this genus are found in the Atlantic: Scomberomorus tritor (Cuvier and Valenciennes) off the west coast of tropical Africa, and S. maculatus (Mitchill), S. cavalla (Cuvier), and S. regalis (Bloch) in the western Atlantic. Donald P. de Sylva and I are working on the problem of identifying the young of Scomberomorus but the work has been hampered by the loss of most of our material in the recent fire at the Institute of Marine Sciences. My own tentative conclusions would be to characterize these larvae as follows: 43 to 53 myomeres; jaws long but not as long as in

Acanthocybium; chromatophores distributed on the tips of both jaws, over the midbrain, forebrain, and gut, on the pectoral symphysis, usually midway between pectoral symphysis and anus, and (3 to 8) along the ventral midline; occasional chromatophores on the dorsal midline and on the midline beneath the lower jaw (similar to Allothunnus). The first dorsal fin spines are short and no chromatophores appear on them until the fish has grown to 8 mm. Hildebrand and Cable (1938) described the larvae of S. maculatus. Their figures 7 through 10 are undoubtedly Scomberomorus, but identities of larvae in their figures 2 through 5 (smaller larvae, measuring 2.75 to 4 mm) are questionable and their figure 6 is probably a Thunnus larva.

Acanthocybium solanderi (Cuvier): Larvae of this species have been excellently described by Matsumoto (1967). The few specimens I have examined from the Atlantic are closely similar to his Pacific specimens. The species is easily characterized by the high number of myomeres (64 or 65); the long snout; the distribution of chromatophores on the tips of both jaws, along the snout, over the midbrain, and over the gut; the absence of chromatophores over the anal fin at about 4 mm and chromatophores below the second dorsal fin origin at about 6 mm; and the absence of chromatophores on the first dorsal fin at lengths shorter than 10 mm.

CONCLUSIONS

Except for a few problems, the larvae of the family Scombridae are probably the best known of any principally pelagic fishes. Separation to species is now possible for most and probably will soon be possible for all larvae between 3 and 12 mm long. Below this length, the larvae are not yet distinguishable; above this length, juvenile rather than larval characters must be used.

A feature evident from this review is the marked similarity of some of these larval characters between closely related species. The myomeres divide them into three groups; then the pigment patterns diverge and converge to separate and relate the species from and to one another. This is evident in the presence or absence of pigment on the pectoral symphysis and forebrain in Auxis, Euthynnus, Katsuwonus, and Thunnus. In Thunnus, the progressive loss of body pigment from thynnus to albacares and alalunga is notable, and the same reduction is apparent in Auxis through Euthynnus to Katsuwonus. Workers studying the evolution of this family could draw on some of these characters to denote relationships.

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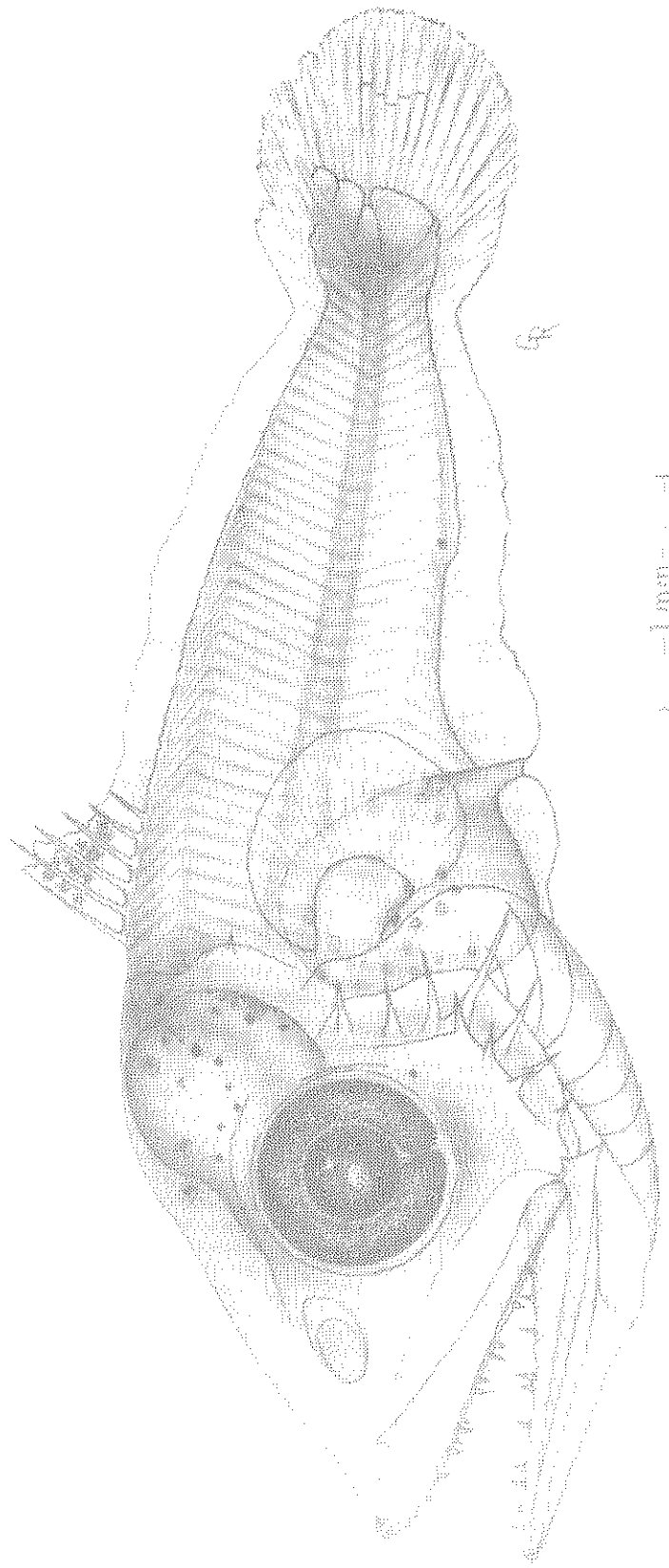
DISCUSSION

Joseph asked about the status of Scomber colias and Pneumatophorus. Richards said Matsui* recognizes three species of Scomber: scombrus, japonicus, and australasicus. Matsui synonymizes colias with japonicus. The lack of a swim bladder in Scomber scombrus is not considered to be a generic difference, so Matsui places Pneumatophorus in the genus Scomber.

In reply to McCormick's inquiry for recommending expert help, Richards said Elbert Ahlstrom of La Jolla, California, can identify larval fishes.

*Matsui, T. 1967. Review of the mackerel genera Scomber and Rastelliger with description of a new species of Rastelliger. Copeia, 1967: 71-83.

Figure 1. Thunnus thynnus. 6.0 mm. R/V Explorer, Cruise 439, Sta. 96.
06°10.7' N, 13°25.9' W, 29 March 1963.



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Figure 2. Thunnus thynnus? 4.0 mm. R/V Explorer, Cruise 439, Sta. 68.
05°00' S, 15°28.5' W, 22 March 1962.

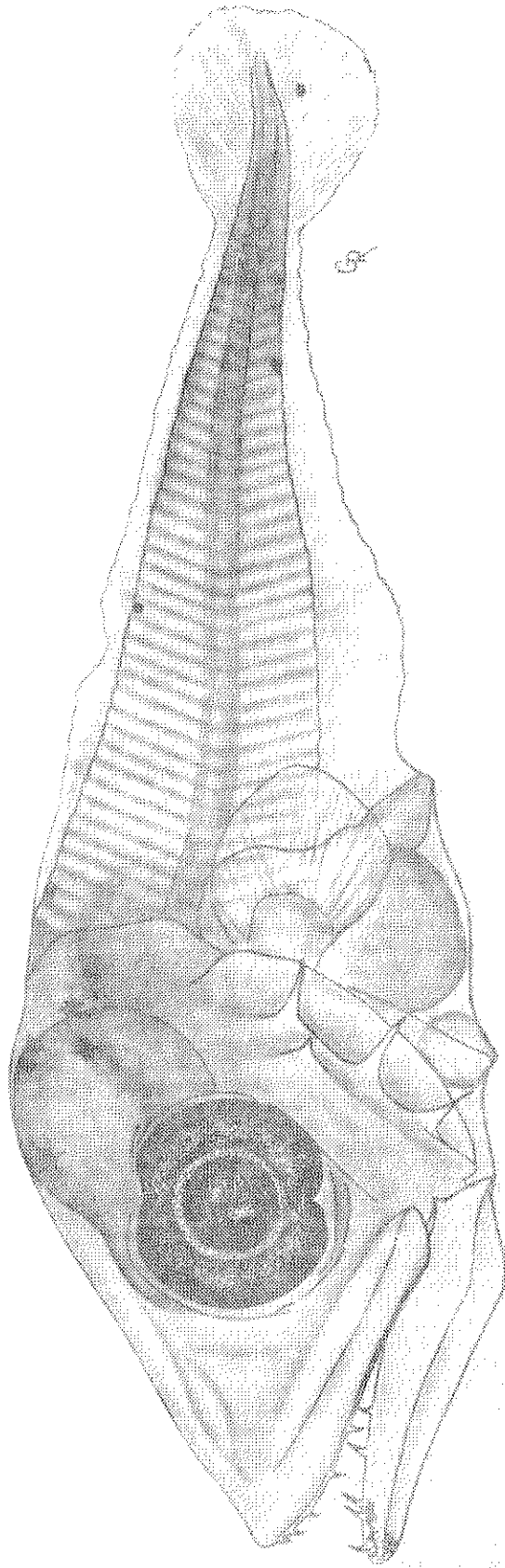


Figure 3. Thunnus thynnus? 3.1 mm. R/V Explorer, Cruise 439, Sta. 65.
07°56.2' S, 15°27.4' W, 26 March 1963.

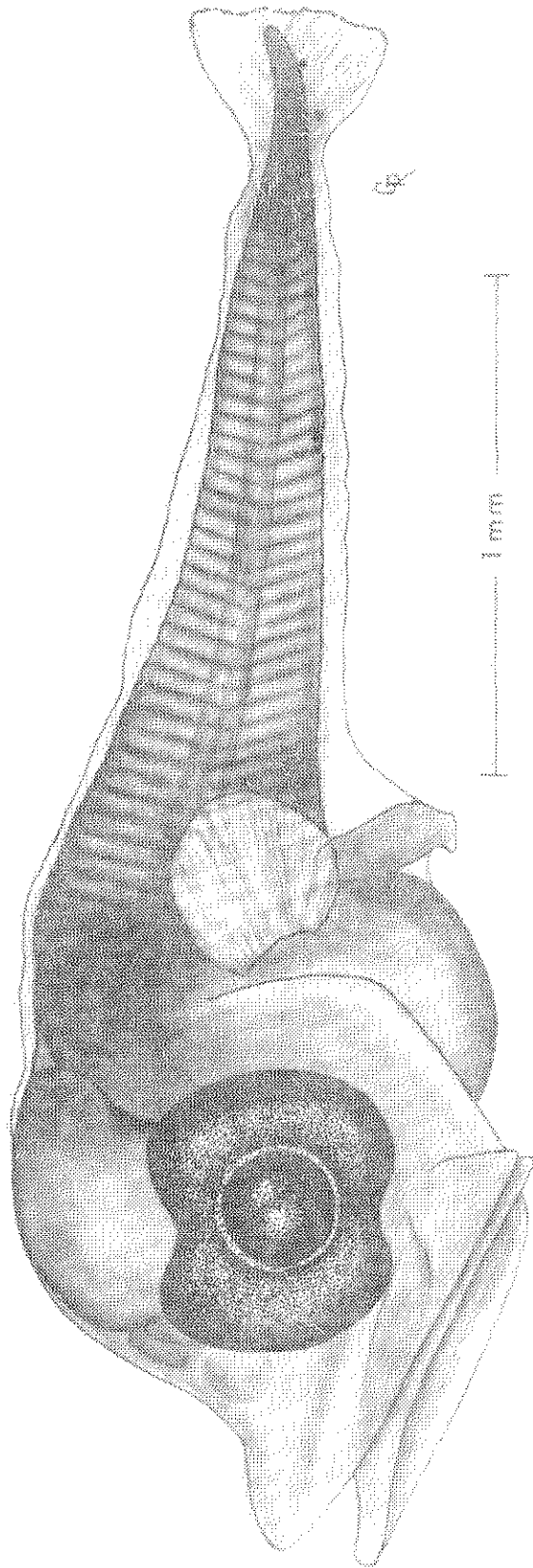
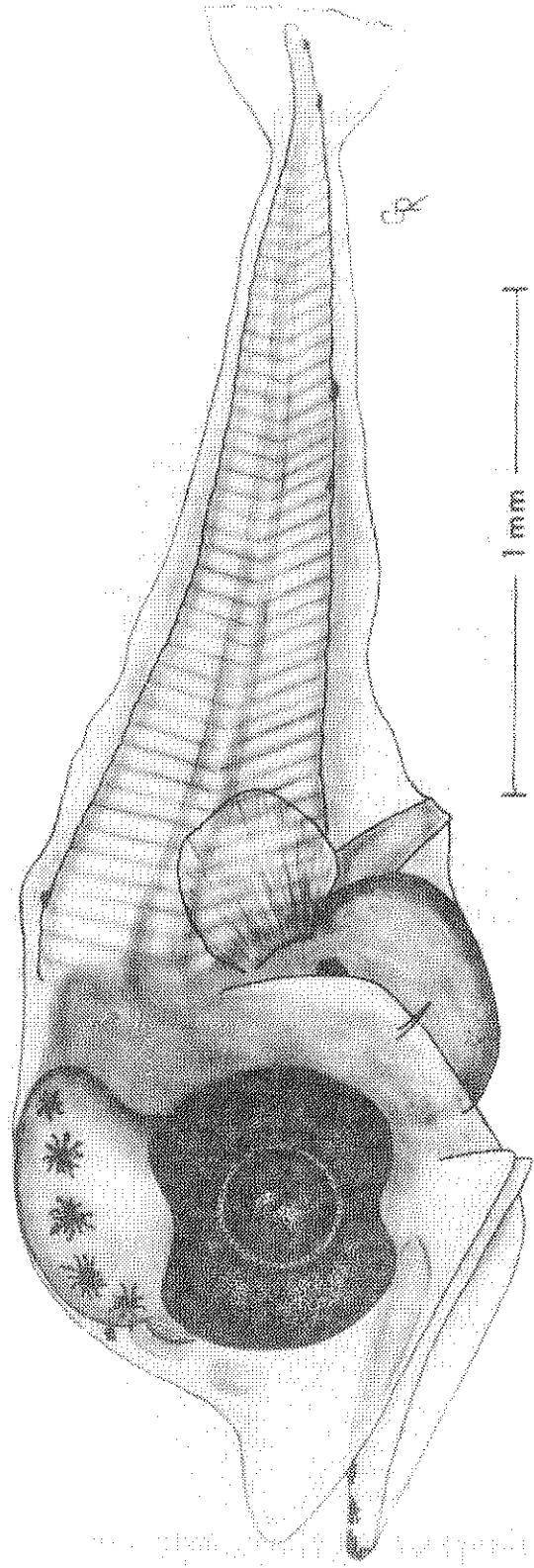


Figure 4. Thunnus? or Euthynnus? 3.0 mm. R/V Explorer, Cruise 439, Sta. 68.
05°00' S, 15°28.5' W, 22 March 1963.



Microgaster (Microgaster) ...

TECHNIQUES FOR MEASURING OSMOTIC AND IONIC
CONCENTRATIONS IN FISH EGGS AND LARVAE

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ABSTRACT

Techniques for measuring ionic and osmotic concentrations in small samples of biological fluids taken from fish eggs and larvae were reviewed. The Kalber biological cryoscope is the only available way for measuring osmoconcentrations in nanoliter volumes of fluid taken from these small systems. Sodium, potassium, calcium, and magnesium ion determinations are possible through helium glow plasma flow absorption spectrophotometry. A device is available to determine such elements in nanomolar concentrations and nanoliter volumes. Procedures for withdrawal of fluid from fish eggs and larvae were also discussed.

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ESTIMATING YEAR-CLASS STRENGTH OF JUVENILE MENHADEN

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ABSTRACT

Three methods of sampling for juvenile Atlantic menhaden, Brevoortia tyrannus, were developed from 1961-66. These were mark-recapturing, beach seining, and surface trawling. All three methods were used to measure year-class strength along the Atlantic coast and all gave similar results. Surface trawling was more versatile, expedient, and efficient for coastwide use. The surface trawl method was standardized for systematic sampling. Sampling problems are discussed.

Sampling for the abundance of juvenile menhaden (genus Brevoortia) as an index of year-class strength has been an integral part of the Bureau of Commercial Fisheries Menhaden Investigations since 1957. Most of the early work, centered in White Creek, Delaware, was concerned with the development of suitable techniques for sampling juveniles in estuarine nursery areas. By 1962, surveys for estimating the abundance of juvenile menhaden were conducted annually in 10 streams along the Atlantic coast, and in 1964 seven sampling sites were added in the Gulf of Mexico.

Estimates of year-class size provide indices of abundance and serve as a guide to the menhaden industry in planning fishing operations. The seasonal appearance of young menhaden in estuaries provides an excellent opportunity to assess year-class size before recruitment into the commercial fishery. Sampling for juveniles is considerably more economical than sampling for the earlier life stages that occur in the ocean, and the estimates derived are more accurate because they are made nearer the time that menhaden enter the fishery.

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The feasibility of estimating year-class strength of Atlantic menhaden (B. tyrannus) in estuarine nursery areas was explored in four coastal streams from 1961 to 1966: Broad Creek, North Carolina; Felgate Creek, Virginia; White Creek, Delaware; and Childs River, Massachusetts. After the influx of larvae in late spring, the relative abundance of juveniles inhabiting each stream was estimated by the mark-recapture method and by catch per unit-of-effort in beach seines and surface trawls. Trends in abundance measured by the three methods were in agreement (Fig. 1); however, the surface trawl method, because of its greater expediency and efficiency, proved superior to the mark-recapture and beach seine methods for coast-wide application.

Adoption of the surface trawl method led to a refinement and standardization of survey techniques and to the development of a systematic procedure for sampling juveniles throughout the range of the fishery. Survey sites were distributed in proportion to the amount of estuarine surface water in each of a number of adjoining areas extending from Cape Cod, Massachusetts, to Fernandina Beach, Florida, on the Atlantic coast, and from Apalachicola Bay, Florida, to Galveston Bay, Texas, on the Gulf coast. These geographical limits correspond roughly to the present range of the commercial fishery. The total number of survey streams was increased to 36 along the Gulf coast in 1967 and to 60 along the Atlantic coast in 1968; each sampling site represented 60,700 hectares (150,000 surface acres) of water.

Once the designated number of survey sites was selected, they were fished during the same time period and at the same stations each year thereafter. The surface trawl used, a modification of the net described by Massmann, Ladd, and McCutcheon (1952), is 6.1 m long with a mouth opening 6.7×0.9 m, and is constructed of 6-mm mesh (bar measure) knotted nylon netting (Fig. 2). The trawl is towed between two outboard motorboats in the midchannel of the stream. The tows are evenly spaced in each stream and extend from a point well into freshwater to the mouth of the stream; in streams that are brackish throughout, the tows are spaced from the headwaters to the mouth. Each tow is timed for 5 minutes at a speed of 9 km per hour and covers a distance of about 740 m. At the end of each tow, the net is hauled between the two boats (Fig. 3), and the catch is removed, subsampled, and returned to the water. Numbers of fish in the total catch are estimated from counts in the subsamples. The number of menhaden per tow is used as a basis for measuring relative fluctuations in abundance between streams, areas, and years.

As in other surveys, the precision of estimates of juveniles depends on the adequacy of the sample size and on the cross-section of the population represented by the sampling. Estimates of menhaden abundance are based on the assumption that the numbers taken by sampling are proportional to the density of the populations in the streams. Although the surveys presently attempt to measure only population trends rather than numbers of fish, some sampling problems are evident. Shifts in the distribution of juveniles within streams

undoubtedly affect the accuracy of the estimates and constitute a real problem that cannot be resolved without the accumulation of ecological information. Another problem in clear streams is that of net avoidance. Light penetration apparently plays an important role in trawling success; catches of menhaden decrease as water clarity increases. The problem of net avoidance can be resolved by sampling at night, but the work is more hazardous and considerably slower than during the day.

Fortunately, the trawling surveys can be supplemented with aerial surveys in areas where the water is clear. The size and number of fish schools can be recorded during flights over coastal waters in the fall, when juvenile menhaden emigrate from estuarine nursery areas. Use of the two-boat surface trawl in regions where the water is turbid, and aerial surveys and night sampling in regions where the water is clear, make it possible to obtain estimates of juvenile abundance along the entire coastline.

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1952. A surface trawl for sampling young fishes in tidal rivers.
Trans. 17th N. Am. Wildl. Conf., p. 386-392.

DISCUSSION

Carlson asked if there is a difference in numbers of menhaden taken when the tow is with or against the current. Turner said his tows are usually with the downstream tide. He tries to standardize to avoid problems of tide variability.

Koo inquired as to other variables such as time of day, weather, wind, and water temperature. Turner replied that water clarity is the most important variable. Clear water increases the escapement of larger fish. He suggested night sampling or sampling in muddy water as solutions to net avoidance in clear water. This situation is obviously reversed during aerial surveys in which clear water is helpful for counting fish.

Kalber asked if all Atlantic coast estuaries, per unit of area, are of equal value for producing menhaden. Turner answered negatively but said this assumption is followed in his study. Menhaden sampling is conducted in proportion to the amount of surface area along the coast. Some areas have more estuarine water than others and these regions are sampled more extensively.

Massmann commented on sampling for juvenile shad and herring with a surface trawl. He said schools disperse at night, so night sampling shows more random distribution than day tows. Turner interjected that there is a similar occurrence of dispersion with menhaden schools. Pacheco added that night seining yields a good abundance index with less effort than day seining.

Cronin suggested observations of visible schools of 100-mm menhaden as a feasible year-class index. Turner replied that fish of 30 mm in size are vulnerable to his surface trawls, but larger menhaden are less available, either because of increase in escapement or because they move out of sampling areas.

Carlson asked if there were opportunities to make comparisons between sub-surface and surface tows. The validity of the method was questioned since vertical distribution sampling is incomplete in the deeper estuaries. Turner answered that he used only surface tows even in depths over 27 m. Based on general knowledge of the species, he expected the fish to be close to the surface. However, in some areas there were fish caught at night but not in the daytime, suggesting a change in availability or even in distribution.

Massmann added that he used a double-necked surface trawl -- one net directly beneath the other and each about 2.3 m deep -- and found little difference in the catches.

Bearden remarked that during the colder winter weather, menhaden stay more to the bottom; however, that would have no effect on Turner's summer sampling.

Figure 1. Population trends of juvenile menhaden in four Atlantic coastal streams as indicated by three different survey methods, 1961-66.

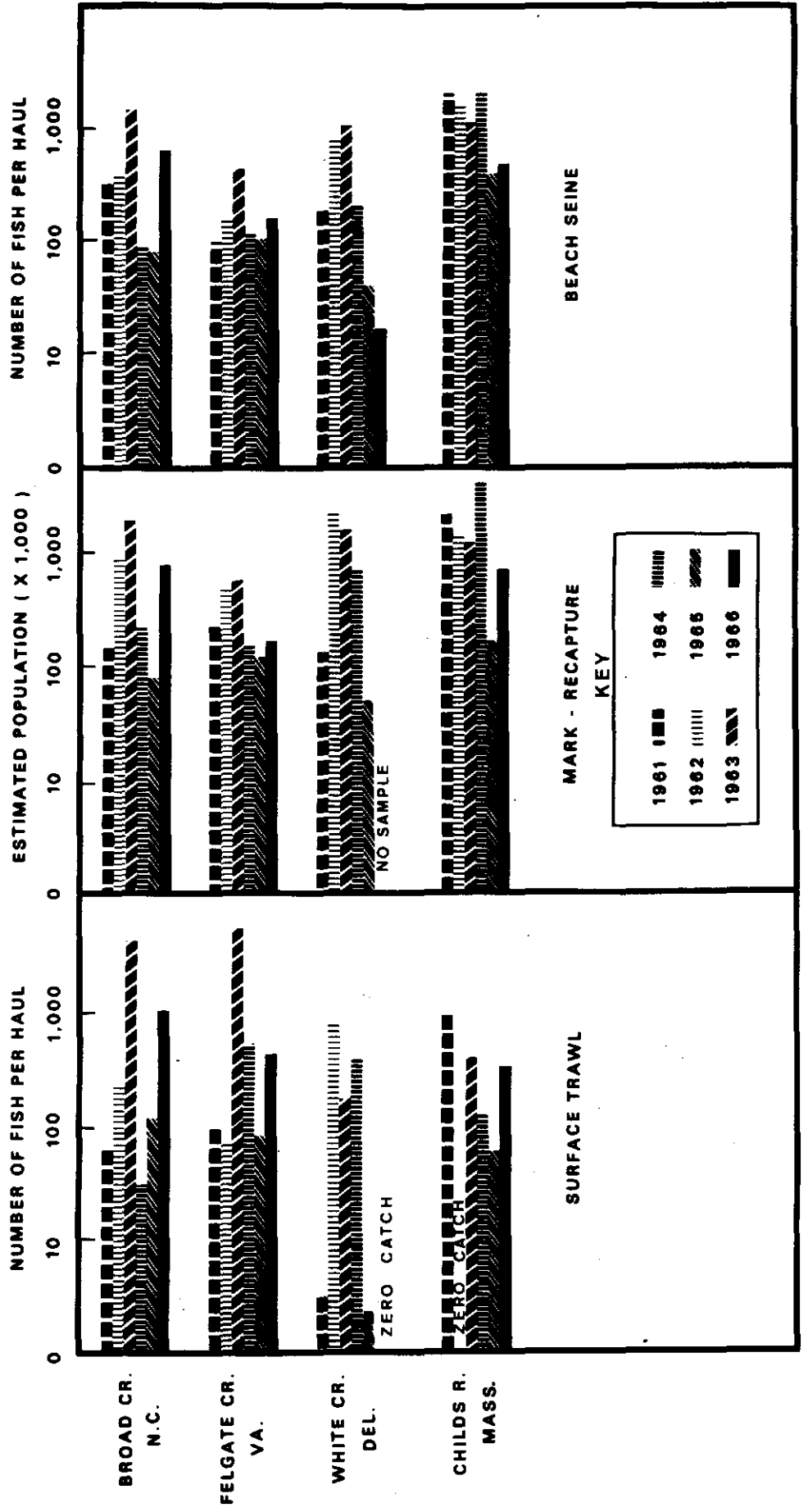


Figure 2. Two-boat surface trawl used in juvenile menhaden surveys.

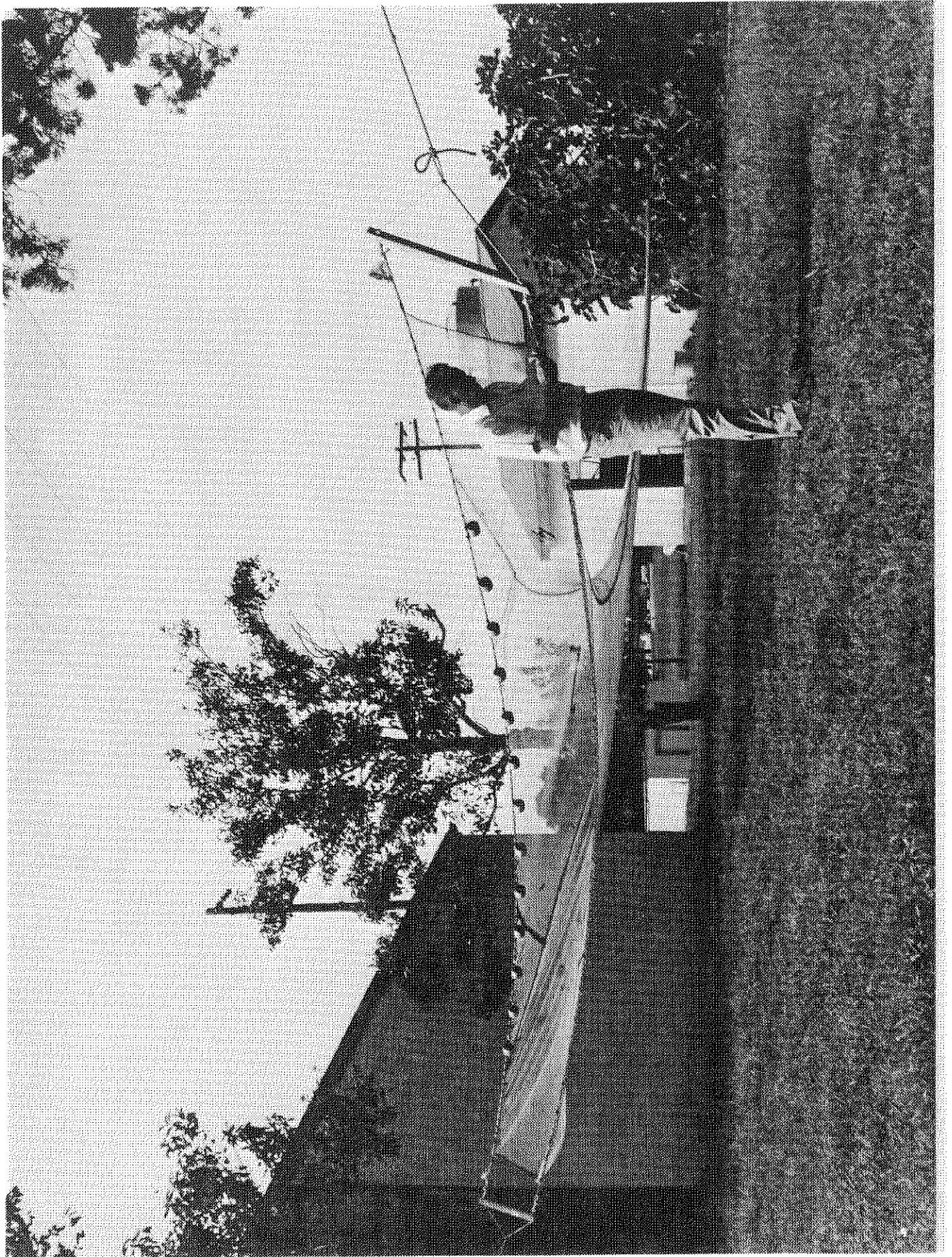
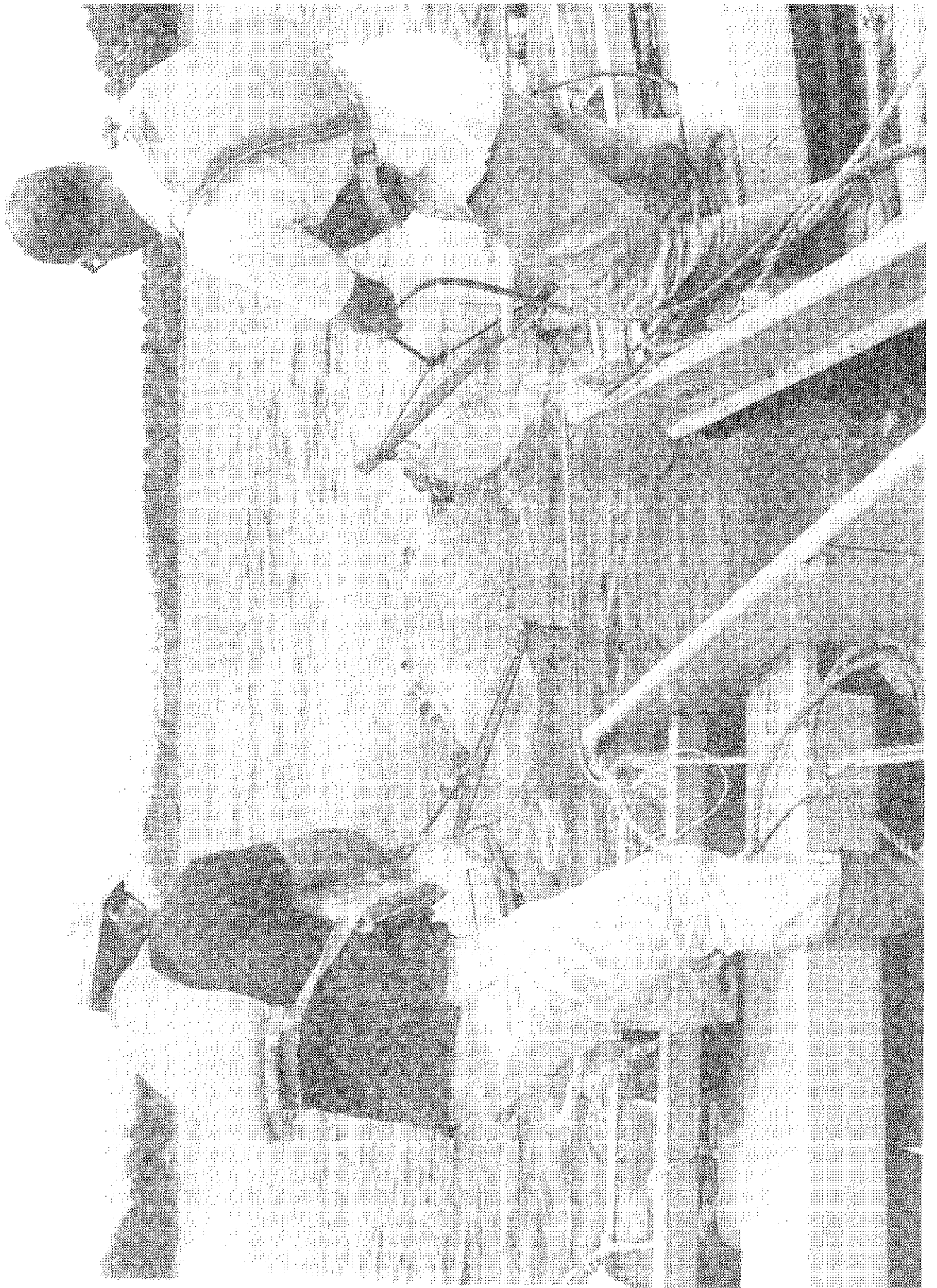


Figure 3. Landing the two-boat surface trawl.



CHARACTERS USEFUL TO THE STUDY OF LARVAL FISHES¹

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ABSTRACT

Guidelines useful in the identification of fish larvae are summarized. A "dynamic" approach, wherein the smallest larva is described in detail followed by description of developmental sequences of individual characters and structures, is most desirable. Myomere-vertebrae meristics are somewhat more valuable than caudal fin meristics and morphology in making positive identification because, in most species, myomere complement is completed early in the larval stage. Description of fins must include not only fin meristics, but also their morphology and morphometry. The caudal fin is valuable in identification because caudal fin rays are generally the first to develop and harden and because, in many cases, the number and arrangement of the principal rays are uniform within orders and families. Recommendations are given for terminology and routine measurements.

"There are only two basic approaches or entries into the study of fish eggs and larvae. One approach is to work backwards from the adult, utilizing characters common to both adult and larva. The other approach is to work forward from fertilized eggs obtained from known parents.

"Recent advances in rearing marine fishes give new emphasis to the second approach. If eggs can be reared through embryonic and larval stages to the juveniles -- a complete series of specimens becomes available, all in prime condition. This can be considered the experimental approach to life history studies -- and I, for one, heartily encourage it.

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"However, it may be many years before we can culture the range of pelagic fishes; mesopelagic and bathypelagic fishes, especially, may be difficult to obtain and culture. Hence, the 'taxonomic' approach is likely to remain the technique for identifying fish eggs and larvae."

Elbert H. Ahlstrom
(personal communication, 28 June 1968)

INTRODUCTION

This paper discusses some of the more important characters and methods useful or necessary to researchers concerned with fish larvae (fish eggs are not considered here). We have assembled this information because: (1) similar guidelines and suggestions are not summarized and available to a beginning student of the identification, morphology, taxonomy, and ontogeny of larval fishes; (2) mistakes and wasted time are often the products of untrained and uninformed students; (3) additional study and revision of methods are still needed -- this paper may serve to delineate some of the needs.

Comments on morphological characters and kinds of development considered and exemplified in this paper are generalized. A few exceptions are noted because the exceptions themselves may serve as useful tools in identifying specimens. Our treatment here is in part generalized, and some of our statements and suggestions are oversimplified. The beginning student must spend many hours of effort and application to gain a basic knowledge of larval fishes. Competence in the field is probably better achieved by those who have been trained previously in ichthyology and taxonomy.

In the subsequent comments, we deal mainly with larvae collected by plankton nets. This presupposes, for many forms or species, that the complete size series of specimens (from embryo to the recognizable juvenile or adult) is not available, specimens may be damaged or distorted, or the total species complement of the ichthyofauna of the sampled environment is not present.

Some larval forms can be identified by comparison with published illustrations. The beginning worker should familiarize himself early with pertinent literature, remembering that in some of this literature the species have been misidentified and generic and specific names later voided (Roule and Angel, 1930). Although species of a genus may vary from one geographical area to another, generally the larval forms of closely related species (and sometimes of genera and even families) look alike. At the same time, the larvae of distantly related forms may be closely similar in gross appearance.

It is most important that a student knows the species (juvenile and adult forms) that occur in the area from which he obtained his samples of larvae, and also realizes that larvae of a species may occur in an area in which the adults are unknown. He should be familiar with the morphological characters of the juveniles and adults; some adult characters may be used for identification of larvae but others may not. Among the meristic characters of value in larval fish identification, the most important are myomere-vertebrae meristics, with caudal fin meristics and morphology next. Other meristic and morphometric characters are of lesser importance. Two aspects of meristic and morphometric characters must be kept in mind: (1) Meristic complements that could be useful are not available in the literature for many species of marine fishes. The larval fish worker, therefore, might have to analyze the meristic complements of adult specimens and prepare frequency distributions of the important characters. In such analyses, intraspecific variation must be considered and comprehended, and abnormalities recognized. (2) Morphometric characters are valuable in some groups, but growth is usually allometric, frequently with appreciable inflections near the end of the larval stage, so that morphometrics of larvae are not consonant with those of juveniles. In the past, time has been wasted in making and recording relatively useless measurements of larval specimens.

DESCRIPTION OF LARVAL DEVELOPMENT

In describing larval development, the "dynamic" approach is strongly recommended, rather than the "static" one, especially in preparation for publication. This approach is particularly desirable when nearly complete size series of specimens are available. In a dynamic description, the smallest larva is described in detail, and the significant characters and structures are described individually throughout their developmental sequences. The archaic static treatment describes all the characters of the smallest specimen, then repeats the process for larger specimens. In the following sections, we identify pertinent characters useful in descriptive studies of larval fish.

VERTEBRAE AND MYOMERES

The number of myomeres is nearly, if not exactly, equivalent to the number of vertebrae. Because myomeres begin forming in the embryonic stage and formation of the adult complement usually is complete early in the larval stage, knowledge of the myomere complement in a given species is of primary importance in identification of larval fish.

The myomere complement of a species is best determined (or closely estimated) by the adult complement of vertebral centra. By majority definition, the vertebral count includes the terminal ural element or elements considered as a single unit.

In rare instances (as in the symbranchid eels), myomeres continue to form late into the larval stage. In some species, the terminal one or two myomeres on the caudal peduncle may be difficult to define, because they are late in forming or incomplete. The anterior one or more myomeres may be crowded and present only on the dorsolateral part of the body. In early larval stages, the myomere alignment is vertical but as development progresses, the outer surfaces of the myomeres generally are shaped into a three-angled form (as a splayed M turned 90 degrees to the right). When the anterior or posterior myomeres are difficult to interpret or discern, they should be carefully studied and the method and reference points used should be thoroughly defined. Use of polarized light or immersion in glycerin adds greatly to the accuracy of these counts and other determinations of the larvae.

Partial counts of myomeres can be used as reference points to locate other structures, such as the position of the vent or the origins of the fins. The possibility of fin or vent migration should be considered in this procedure -- partial counts can be used to trace such migration.

Division of vertebral counts into precaudal and caudal components can be useful. The first caudal centrum is defined as the anterior-most centrum which lacks pleural ribs and has a median hemal spine; in many of the percomorph fishes and in some others, the posterior surface of the first interhemal (anal pterygiophore) spine approximates, or touches, the anterior surface of the first hemal spine.

Superficial resemblances that exist (frequently at earliest stages) between the larvae of some phylogenetically diverse groups of fishes can readily be resolved by comparing the myomere numbers (as between myctophids and scombrids, and between carangids and stromateids). Often, myomere or vertebral counts will separate, or assist in separating, closely related species when the adult complements and the intraspecific variations and their modes are known. These counts are useful in the separation of species of larval clupeids.

FINS

The finfolds are the earliest structures related to fins to appear. The median finfolds begin to develop in the embryonic stage, but are more pronounced after hatching. The dorsal, caudal, and anal portions of the finfold are continuous in early stage larvae and become individually distinct after formation of the dorsal and anal fins. A preanal finfold is present in many larvae and is more prominent in fishes with more posterior vents. The period of retention of the finfolds and their relative size are variable in various species, but all finfolds are usually reabsorbed or reconstituted by the early juvenile stage.

Considerations necessary to the study of the fins themselves are: the number and kinds of rays and their relative lengths in each fin, the sequence of formation of the various fins and the ray elements in each fin, the position of the fins on the body, and the migration of some fins.

The number of rays in a fin must be determined from study and analysis of intraspecific variation of juveniles and adults. Fin rays rarely form in the embryonic stage, and the formation of the complete complement of rays in a fin is highly variable, both intraspecifically and with respect to the various fins of a species. Before the rays are formed (in the dorsal and anal fins particularly), their number may be determined or closely estimated if the adult complement of ray buds has completed formation in the finfold.

In species with both spines and soft rays, it is important to discriminate between these two kinds of elements, but separation based on definition in the adult stage does not necessarily apply to the larval structures. Spines and soft rays may have fimbriated ends in their early developmental stages, but these ends are soon replaced in the spines by pointed or blunt tips. The segment marks that primarily distinguish the soft rays do not develop in a soft ray until after the ray has formed. In certain groups, one or more soft rays may develop into spines during or after the larval stage (Mansueti, 1958).

Relative length of fin rays in a species varies ontogenetically, but may differ between closely related species. Larvae of serranids and gempylids have a very long spine in the dorsal and pelvic fins; an elongated first dorsal spine is characteristic of balistids and monacanthids; some flatfishes have an elongated ray or rays at the origin of the dorsal fin and often in pelvic fins as well; larval carapids and some trichiurids have an elongated ray in the dorsal fin.

The sequence of development of rays within a fin is variable in different groups, but is probably consistent within a species. In most if not all species with homocercal caudal fins, the rays of the caudal fin begin to develop at the median part of the caudal bases, and development proceeds almost equally dorsad and ventrad. Fin ray development in the dorsal and anal fins may begin at both ends of the fin base and converge, it may start near the middle, or it may begin at or near the origin (Kramer, 1960). In species with spines in the dorsal and anal fins, the first rays to develop are usually those at or near the fin origin. Rays in the pectoral fins usually begin to develop at or near the dorsal (or lateral) margin. The pectoral fin buds are the first to develop on most fishes, but the completion of the development of their rays may lag behind that of the other fins.

In most fish species, the caudal fin is the first on which ossified rays are formed, and the principal caudal fin rays are the first to form completely; a notable exception is the plectognaths, in which the caudal fin is the last to develop. The median caudal fin rays and the pectoral fin buds may develop (and apparently be functional) in the embryo. In many fishes, the beginning and completion of dorsal and anal fin development are nearly simultaneous;

in others, the development of either fin may be more prolonged. The pelvic fins are often the last to form as buds, but their ray formation may be completed before that of the pectorals. In some groups (as melamphoids and gempylids), the pelvic fins are a prominent and distinctive larval structure.

Dorsal, anal, and pelvic fins migrate anteriorly or posteriorly during the larval development of some forms (e.g., clupeoids).

Caudal Fin

In fishes with a homocercal caudal fin, the caudal fin is almost always the second component (after the myomeres) to be completely formed -- at least the internal supporting bones and the principal caudal fin rays -- and, therefore, is of considerable importance in identification of fish larvae. The caudal fin is most useful as a means of distinguishing orders and families, because the number and arrangement of principal caudal fin rays are, in most groups, conservative and consistent within broad phylogenetic groups. For example, 10 (dorsal) + 9 (ventral) principal caudal rays occur in almost all species of isospondylids and iniomids, and in nearly all berycoids. The typical percoid number is 9 + 8; exceptions tend to be consistent within a family. For example, the count for chaetodontids is 9 + 9; acanthurids, 8 + 8; labrids, embiotocids, mugilids, 7 + 7; scarids, 7 + 7 or 7 + 6. Synentognaths (with rare exceptions) have 7 + 8 principal caudal rays; plectognaths usually have 6 + 6. The highly variable heterosomatids have between 10 and 23 principal caudal rays.

In fish groups with rounded caudal fins, the number of principal caudal rays differs considerably and is usually reduced -- blennoids range from about 4 to 15 and cyprinodonts from about 11 to 20. The gadoids (with an "isocercal" caudal) and the osteoglossoids are unique and cannot be defined in the same terms (branched caudal rays of gadoids range about 12 to 35 and osteoglossoids about 10 to 20).

Secondary caudal fin rays are absent in some groups but numerous in others and may be intraspecifically variable. Although the principal caudal fin rays are usually the first fin elements to become completely formed, the more anterior secondary caudal fin rays may be the last.

The principal caudal fin rays articulate with the hypural bones of the caudal skeleton, although the most ventral principal ray is inserted ventrad to the ventral hypural in some species. The rays are formed ventrad of the position of the upturned notochord and become divided into superior (dorsal) and inferior (ventral) groups along the horizontal body axis. The most dorsal principal ray and the most ventral principal ray remain unbranched, and the intervening principal rays all become branched, generally during the larval stage (Ahlstrom and Counts, 1958).

The number and arrangement of the bones of the caudal complex can be most useful in larval fish identification and fish taxonomy, but interpretation of structures can be encumbered by ontogenetic changes (usually through fusion of some parts and excessive bony proliferation of others). Currently there is disagreement about terminology and homology of certain elements.

Dorsal and Anal Fins

The number of rays in the dorsal and anal fins and the relative numbers of spines and soft rays (where they exist together) form fairly early in larvae of many species and are useful identifying characters. The number of spines in the dorsal and anal fins is generally constant in many family and generic groups; rarely is the number of soft rays similarly constant. In many species, the terminal soft ray of the dorsal and anal fins consists of an anterior and a posterior element, closely approximated, but actually divided at the base, a condition considered and counted as a single element, because it is segmentally associated with a single interneural or interhemal spine.

The relative position of the dorsal and anal fins on the body, with respect to each other and to other body structures, can be used in discrimination.

Pectoral and Pelvic Fins

Because the rays of the pectoral and pelvic fins usually form later in the larval stage than those of the other fins, they are generally given less consideration. In some fishes, however, the numbers are useful, especially in the pelvic fin with its nearly constant complement of one spine and five rays in most percomorph families. Rarely do some species lack pectoral fins. One stomiatooid has a well-developed pair of pectoral buds in the larval stage that degenerates in metamorphosis and is lacking in the juveniles. The pelvic fins are lacking or extremely modified in some species, and in a few the pelvics degenerate and disappear.

OTHER MERISTIC CHARACTERS

Several additional characters that may be treated meristically are discussed in the following paragraphs.

Gillrakers

Gillraker complements are usually of little value in larval fish identification, because gillrakers in most species continue to form over the anterior ends of the epibranchial and hypobranchial bones, and the adult complement is not attained until well into the juvenile stage. In some species, the number of gillrakers over the ceratobranchial portion of the lower limb may form fairly early and remain stable with growth. If this pattern is determined, it can serve as a useful character.

Branchiostegal Rays

The number and relative position of branchiostegal rays are useful in the separation of some groups, especially of genera and higher groups (McAllister, 1968). The value of branchiostegal characters depends upon the phyletic group -- in some groups they vary intraspecifically, in others they are constant within genera and families.

The adult branchiostegal ray complement usually forms early in larval development, although special techniques (like clearing and staining) may be necessary for accurate counts.

Photophores

In those fishes with photophores, the development, distribution, and migration of these structures can serve as a diagnostic character. Because some photophores develop late in the juvenile stage, total counts must be carefully determined (Ahlstrom and Counts, 1958).

MORPHOMETRIC AND OTHER MORPHOLOGICAL CHARACTERS

Morphometric characters can be of appreciable value in larval fish studies, depending on how and for what purpose the measurements are taken and used.

We feel that measurements of body parts of larval fishes generally should be taken in the saggital (transverse) plane of the specimen, or in a plane parallel to it. This method facilitates comparison with two-dimensional illustrations in the literature. Obvious exceptions to this procedure are body width and lateral extensions of body parts at distinct angles. Also, nonsaggital plane measurements of late stage larvae may be useful for comparison with juveniles. All methods used to make the various measurements should be described thoroughly in any report.

Care should be exercised in the conditions under which measurements are made. Specimens from routine plankton tows are frequently bent or distorted; if the specimens cannot be straightened or reconstructed, they should be rejected for measurement. A "relaxing" agent that would facilitate straightening or reconstruction would be valuable. Most fish larvae may shrink with preservation (Farris, 1963), and they may swell when changed from formalin solution to water or glycerin. Conditions for measuring should be standardized and stated in publication.

Purposes for which measurements of larval fishes are selected, recorded, and analyzed should be determined before the work begins. Routine measurements (specimen length, head length, eye diameter, and body depth) are customary and acceptable. Other measurements should be taken only to satisfy one or more basic purposes for such measurements: (1) To compare shape and proportion of the larval stage with those of juveniles and adults. Such comparisons can be useful in relating an unknown larval form to recognizable juveniles and adults. For example, most larval and adult clupeiform fishes tend to be slender and elongated. In many other groups, the shape and proportion of larvae does not have a useful relation to that of adults. (2) To study the ontogeny of shape and proportion during larval development. Changes can be considerable. The carangid Trachurus symmetricus, for example, is a thin larva when hatched, but soon develops into a relatively deep-bodied form with a large head. For comprehension and description of these changes -- important in the dynamic approach -- the characters should be measured on a series of larvae from the smallest to the largest. Additional measurements should be made on larvae in the size range at which critical changes in form or dimension occur. These morphometric data should then be plotted and treated statistically. (3) To distinguish between related species, and between genera and even families. Morphometric characters have been found to be more important than meristic characters in separating certain species of myctophid larvae (E. H. Ahlstrom, personal communication).

Size and Shape

The relative length of specimens, considered at a particular stage of development, can be a useful character (Appendix 2). Many species hatch at lengths less than 2 mm, a few hatch at 5 mm long or more, but most hatch between 2 mm and 5 mm. Transition from larval to juvenile stages can occur at different sizes in closely related species (one tropical iniomid transforms at about 25 mm, although its more temperate cognate attains about 45 mm as a larva). See Appendix 1.

Body shape may vary greatly in larvae. Some are extremely compressed (leptocephali, many isospondylids), others are almost cylindrical in cross-section (many iniomids), some are round or globular (ceratoids, molids), and some may be depressed, long or thin, short or stubby.

Head

A number of head characters should be considered: size of the head compared with the body, and size of the eye and length of the snout compared to the head; shape and inclination of the gape of the mouth; presence, number, shape, and location of teeth; shape of the eye and possible presence of eyestalks; presence of barbels on the chin; and location and size of the otocyst.

Spines, ridges, and crests on the head are often diagnostically important. Some of these larval characters persist into the juvenile and even the adult stages (especially opercular spines). The persistence of these features should be considered (they may disappear or be reabsorbed at a smaller size in one species than in another closely related one). The number of spines in a series may be diagnostic, but intraspecific variation may be significant; this variability also applies to relative lengths of spines or heights of crests and ridges. The nature, number, and extent of serrations on these features should be determined. Spines and ridges may variously occur on the opercle and preopercle, on the mandible and snout, and in the nuchal, pterotic, supraoccipital, and supraocular regions. The location of these spines, ridges, and crests is frequently useful in familial or generic identification.

Measurement of head length may be expressed best as the distance between the snout tip and the anterior margin of the cleithrum. The cleithrum, one of the first bones to ossify in larval fishes, is a useful reference area, especially in stained specimens. The posterior margin of the operculum is frequently damaged or distorted.

Body

Spines are present on the cleithral or humeral region in some forms. Some larvae have spines on the body that are usually either lost or greatly reduced with growth of the fish.

The nature of the gut or alimentary canal is a fundamental body character. The gut may be foreshortened and end close behind the isthmus, or it may extend to near the posterior end of the body. It extends to near the tail on many isospondylids, and the relatively greater posterior gut extension distinguishes most clupeid larvae from the similar engraulid larvae. The gut may be straight, undulating, or looped, and may protrude from the ventral profile.

The size and position of the yolk-sac can distinguish some forms.

PIGMENTATION

Black or brown melanophores on preserved larval specimens are often important in defining larvae of closely related species. Pigment or melanophore pattern usually changes, sometimes appreciably, during larval growth. To study the pigmentation changes in a species, a series of larvae of all sizes must be examined and documentation made of the appearance, disappearance, and migration of pigment spots or areas during larval development. This procedure illustrates the dynamic approach and gives an insight into pigment variation among larvae of similar sizes. As a caution, one should realize that the individual pigment spots (melanophores) preserve in expanded or contracted condition, and that preserved specimens may fade partially or entirely.

If possible, pigment should be examined on living or recently preserved specimens, or on specimens fixed with a color preservative, because yellow, red, and blue chromatophores fade rapidly after death. Little has been written about this (Orton, 1955; Uchida et al., 1958; D'Ancona et al., 1931-56). In several groups of fishes, particularly scombrids, red pigment spots are useful diagnostic characters (Ueyanagi, 1966). We have observed red spots in other groups (particularly flatfish and callionymids).

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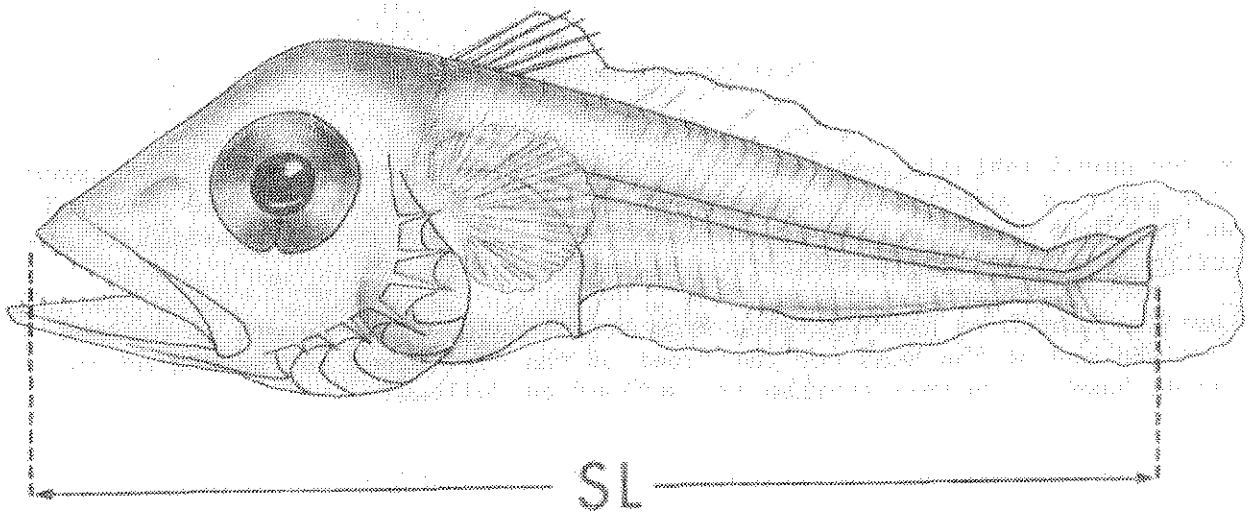
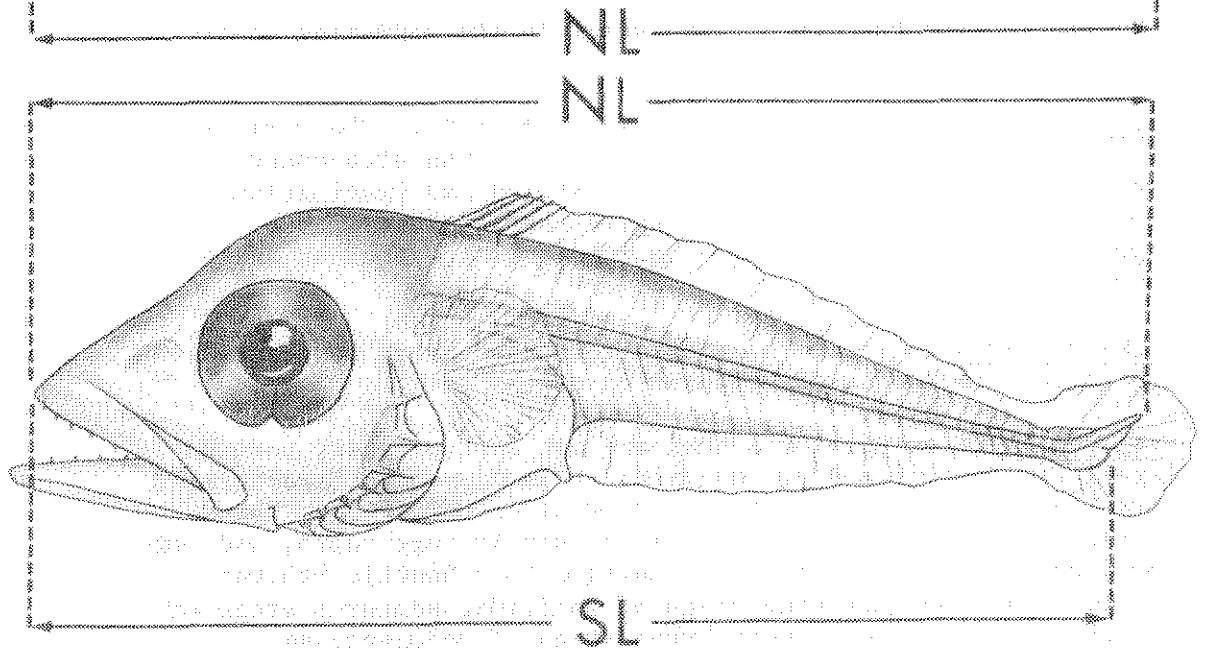
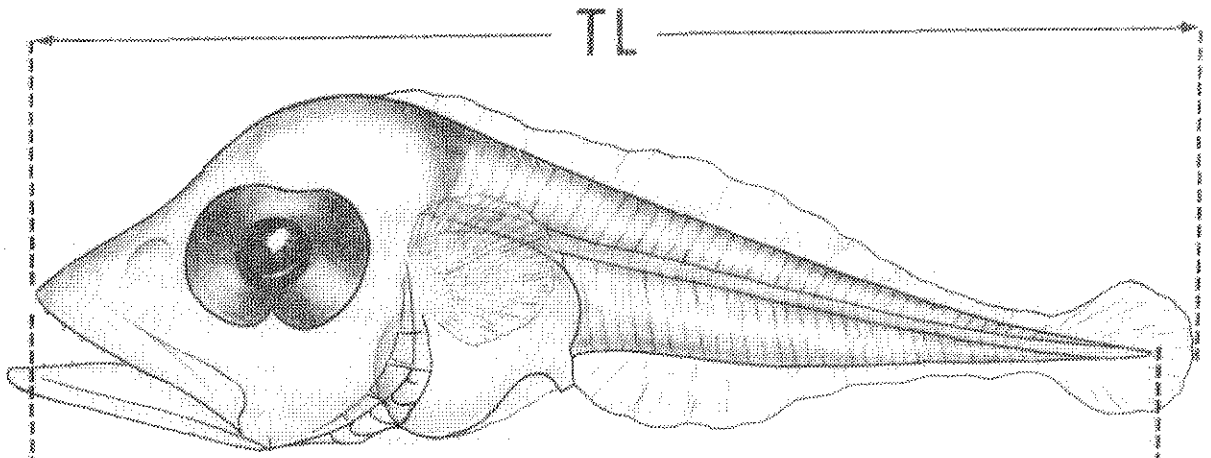
DISCUSSION

Graham asked if environmental problems biased systematic sampling results. Berry cited one example of net bias in CALCOFI collections of bathypelagic forms. Very few of these specimens were taken in routine 1-m, 14-minute plankton tows because of escapement ability. Later a liner trawl with a 27- × 30-m (80- × 90-ft) mouth opening was dropped down to the region of bathypelagic forms, resulting in a collection of 80 or 90 specimens.

Marak made the point that many of the fish eggs and larvae being dealt with at this meeting are normally thought of as those of purely estuarine species. However, because of current patterns (small gyres) or strong offshore wind conditions, these fish eggs and larvae find their way into offshore situations. His work at Woods Hole is for the most part concerned with species that are from offshore deep (to 150 fathoms) water. Generally, there is little trouble identifying the more common fish eggs and larvae but problems begin when there is an intrusion of Gulf Stream water onto the shelf, sometimes as far as the southern part of Georges Bank. Woods Hole Oceanographic Institution cooperative work with the Soviets in the fall of 1967 pointed this problem up quite vividly. Most of the 15, or so, unknown species of larvae in their samples consisted of southern inshore or estuarine species. Normally, a few larvae would not be of importance but these unknown sometimes composed a large proportion of the catch. More should be known of these inshore and offshore relationships not only for identification, but also because of their importance to those working with survival rates. The question of whether these larvae are lost to the inshore stock remains to be resolved.

Marak added that the relatively new methods of separating genetic characters by electrophoretic techniques on enzymes appear promising in identifying fish eggs and larvae. At present, they are engaged in a cooperative experiment with Yale University to determine whether eggs and prolarvae of cod and haddock can be separated. Until just prior to hatching, these species are visually identical. There is also the possibility, by use of a good densitometer, of extracting the proportionate contribution of many species in a combined sample. Marak felt that this or similar techniques will be the answer to the positive identification of eggs and larvae from large volumes and numbers of samples.

Figure 1. Diagrammatic larva (Thunnus albacares) indicating reference features for measurements of specimen lengths. (A) Early larval stage with notochord straight and caudal bones not formed. (B) Midlarval stage with caudal elements forming and notochord flexing. (C) Late larval stage with caudal elements formed and notochord completely flexed.



APPENDIX 1

Definition of Developmental Stages

A single set of definitions of developmental stages is unavoidably encumbered by a large number of exceptions because of the great variety of fish forms and degrees of development. This situation holds for the most widely used (and often misinterpreted or misused) set of descriptive terms (Hubbs, 1943). The following definitions are recommended:

Larva -- from hatching to completion of formation of the adult complement of rays in all fins (usually determined by red staining of the rays in alizarin).

Juvenile -- from the end of the larval to the beginning of the adult stage.

Adult -- from the attainment of sexual maturity. The term is mostly a subjective one of convenience, because attainment of maturity may be determined only by histological examination. The distinction made between juveniles and adults may be imprecise, and may depend more on relative size than on state of development.

Yolk-sac larva is recommended if a term is desired to describe the larva before complete absorption of the yolk.

Prejuvenile refers to forms that are not appropriately termed larval (or postlarval) or juvenile; it is commonly characterized by strong spines, bony plates, and peculiar body form. Transformation into the juvenile stage is usually very rapid, and often associated with movement from a pelagic to a benthic habitat. Examples are the querimana stage of mugilids, aconurus stage of acanthurids, and the rhynchichthys stage of holocentrids.

APPENDIX 2

Definitions of Measurements

We recommend that all measurements of larval fishes (except widths) be taken from point to point in the saggital (transverse) plane, or a plane parallel to it. This system allows direct comparison with the two-dimensional illustrations usually used to characterize a larval form.

Specimen length is distinguished from body length. Body length is defined from the end of the head (or the front of the cleithrum) to the end of the caudal base. Specimen lengths are defined as follows:

Total Length (TL) -- from the snout tip, through the horizontal body axis, to the end of the caudal finfold or a perpendicular to the end of the longest caudal fin ray (Fig. 1).

Fork Length (FL) -- from the snout tip to the end of the shortest median caudal fin ray.

Standard Length (SL) -- from the snout tip, through the horizontal body axis, to the end of median bones at the caudal base (the hypural bones). (Fig. 1).

Notochord Length (NL) -- from the snout tip to the tip of the notochord before its dorsal flexion, and afterwards perpendicular to the horizontal body axis through the tip of the upturned notochord. (Fig. 1).

SL and NL are recommended instead of TL and FL because of frequent damage to the caudal fin and pronounced allometric growth of the caudal fin in many species.

SL measurement is imprecise until horizontal alignment of the median hypural bones is completed, but it can be approximated when the hypural elements begin to form. While the hypurals are in the process of formation and alignment, both NL and an approximated SL should be recorded.

In many early stage larvae, the snout and jaws may not have developed or may be greatly subtended by the anterior protrusion of cranial bones. In this condition, the anterior reference point of snout tip for specimen lengths may be impractical, and the anterior margin of the larva may be used as the anterior reference point. When such a measurement is used, it should be clearly stated.

APPENDIX 3

Literature

Literature on larval fishes is widespread and numerous. We list here some of the important general works that may serve as an introduction to the beginning student. The references cited in this paper are also included. We call attention to an unpublished bibliography compiled by the late Romeo Mansueti, which was distributed in mimeograph form on a limited basis in August 1954 by the Chesapeake Biological Laboratory, Solomons, Maryland, and entitled "A partial bibliography of fish eggs, larvae and juveniles, with particular references to migratory and estuarine species of the Atlantic coast and supplemented by a check list and references to the early development of the fishes and fish-like chordates of Maryland waters." This bibliography contains 1,158 citations and is annotated.

A NOMOGRAPH FOR AGE DETERMINATION OF
STRIPED BASS (MORONE SAXATILIS) EGGS

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ABSTRACT

A nomograph technique can be used to derive the time interval from 13 selected stages to hatching of striped bass eggs. Values are drawn from material subjected to a temperature range of 15.0° to 22.0°C (59° to 72°F). After egg development, stages are determined from plankton net samples. Use of this technique permits a determination of river area and time of spawning when stream flow is known.

DISCUSSION

Cronin asked if there are other early stage nomographs in use. Brown said he attempted unsuccessfully to construct a nomograph using drawings of several stages of hatching time for comparison, including striped bass eggs of known stages. Williams mentioned a similar nomograph was produced by A. T. Simpson for plaice eggs.

LARVAE OF CITHARICHTHYS AND ETROPUS IN THE CHESAPEAKE BIGHT

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ABSTRACT

Larvae of many important flatfishes are found nearshore and in estuaries, but specific identification of these larvae is complicated by several factors: (1) early symmetrical stages cannot be distinguished as right-eyed or left-eyed types, and (2) a great number of lesser known forms are taken in the same collections.

Previously undescribed larvae of two of these lesser-known species, Etropus microstomus (Gill) and Citharichthys arctifrons Goode, were the most numerous of all flatfishes collected in the Chesapeake Bight (water between Cape Henlopen, Delaware, and Cape Hatteras, North Carolina) from 1959 to 1963 by the Virginia Institute of Marine Science (VIMS).

Adults range approximately from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina. They are the only representatives of these two genera common in the Chesapeake Bight. Etropus microstomus is generally found inside the 20-fathom line, while C. arctifrons is taken deeper than 20 fathoms. The larval distribution was not as clearly defined. Some E. microstomus were found out as far as the 100-fathom line, while some C. arctifrons were taken nearshore.

Larval identifications are based on knowledge of adult bothids occurring in that area (VIMS trawl data), their relative abundance, their spawning times (the larvae were taken primarily July through October), and their meristic counts. Anal fin ray counts (usually 50-60 for E. microstomus and 60-70 for C. arctifrons) and caudal vertebrae counts (24-25 for E. microstomus and 26-28 for C. arctifrons) were the most useful characters.

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Larval stages are described and compared from 3 mm SL to metamorphosis at 10 to 12 mm SL in E. microstomus and 13 to 15 mm SL in C. arctifrons. Etropus microstomus larvae have preopercular spines evident until 8 mm SL. Citharichthys arctifrons larvae possess characteristic attenuated dorsal rays from 4 to 12 mm SL. Pigmentation is more pronounced and body depth is relatively greater in E. microstomus. Dorsal and anal fin ray counts are possible by 8 mm SL and vertebral counts by 9 mm SL in E. microstomus. All three counts are possible by 10 mm SL in C. arctifrons.

DISCUSSION

Schwartz suggested that Miss Leonard keep in touch with Gordon Gunter's Laboratory, in connection with their work on the genus Citharichthys in the Gulf of Mexico.

ESTUARINE HABITATS AND LIFE HISTORIES OF FISHES

Chairman

G. Robert Lunz, Jr.

SOME FAUNAL AND OTHER CHARACTERISTICS OF MAINE ESTUARIES

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ABSTRACT

Maine estuaries have historically variable faunal records. About half the fossil species appear in midden piles. Species absent from the recent middens are those less tolerant of low seawater temperature.

There is evidence of some major changes in marine and estuarine species abundance associated with cyclic change in water temperature. Absence of fossil oysters and hard clams in the Damariscotta estuary suggests post-glacial conditions were unfavorable for these species.

Within the last 30 years, the east and northward spread of some crustaceans has been attributed to increases in water temperatures. Distinct differences in species abundance have been found between estuaries and temperature subcycles; however, use of annual mean temperatures may mask changes which are season-dependent. Other estuarine features are discussed which may relate to faunal differences in finfish and shellfish population abundance.

Although the Gulf of Maine may be considered to be a single estuary, as indeed it was during recent prehistoric times, for more accurate differentiation of its component parts, selected tributary rivers and streams and their estuaries will be given primary consideration.

Maine estuaries exhibit variable faunal records both in time and in space. Carbon¹⁴ age determinations by the U. S. Geological Survey indicate that Maine was glaciated from some time prior to 38,000 years B.P.¹ until approximately 12,000 years ago². Besides fossil shells in ancient Maine estuarine systems, many modern shorelines are overlaid by assemblages of shell-dominant kitchen middens. Approximately one-half the species commonly found in middens are also found in fossil assemblages; the remaining species not generally occurring are those which are less tolerant of relatively low seawater temperature ranges.

¹Lab report #WR-910 (1960) USGS

²Lab report #IWR-737 (1958) USGS

Recent studies demonstrated that major fluctuations in abundance among several intensively exploited marine and estuarine species are associated with fluctuations in seawater temperature. If fluctuations in the relative abundance of these resident decapods, annelids, or mollusks can be associated in time or in space with fluctuations in larval or juvenile finfish abundance in northern estuaries, then a valuable, naturally occurring, biological monitor will be readily available.

Water temperature differences and possibly other conditions appear to be major limiting factors in faunal growth rates and distribution in adjacent and nearby estuaries -- the Sheepscot and Damariscotta, which in places are separated by less than 15 km, and the Damariscotta and St. George, which are less than 25 km apart.

Some middens with alternating layers of soft (*Mya arenaria*) and hard (*Mercenaria mercenaria*) clam shells suggest that fluctuations in seawater temperature may have abruptly reversed the abundance cycles of the two species, as occurred between 1949 and 1958 when soft clam populations were replaced by hard clams and between 1959 and the present when hard clams have been in turn replaced by soft clams. When mean annual temperature is 9.0°C or higher (measured at Boothbay Harbor by the Bureau of Commercial Fisheries), soft clam abundance declines more than 50%. Associated with these high temperature levels is a marked increase in predator populations, especially that of the green crab (*Carcinides maenas*), and also an increase in the number of months during the year when predation activity is intensive. Survival of soft clam populations during their first year is directly related to post-setting predation.

In the decade 1939-48, annual average production of hard clams was 50 metric tons. During the next decade, 1949-58, annual average production was 175 metric tons; since 1958, annual yield has averaged 9 metric tons. Production fluctuations appear to be directly the result of changes in seawater temperature. The mean temperature for the 1939-48 period was 7.9°C; for the 1949-58 decade it was 9.9°C, and for the years since, 8.2°C, as measured at Boothbay Harbor.

Recent short-term fluctuations in seawater temperatures and hard and soft clam abundance and midden stratigraphic composition by species indicate that similar cyclic fluctuations probably occurred in prehistoric times when the middens were forming. Several strata of hard clam shells separated by accumulations of overlaying sediments suggest that optimum conditions for the species in the New Meadows estuary of Casco Bay have varied over inferred widely spaced periods of time.

Remnant oyster populations of the Sheepscot have supported a small commercial fishery since 1954, with annual harvest averaging 1.5 metric tons.

Carbon¹⁴ aging of the largest extant midden (consisting of shells of Crassostrea virginica) in the Damariscotta estuary, where no surviving stocks have been found, indicates a range from approximately 1,400 to 2,200 years B.P.³ (Broecker et al., 1956). Estimates of prehistoric average annual yield of this geographically isolated growing area do not exceed 25 metric tons of shucked meats.

Since oysters and hard clams are shallow water species and many of the post-glacial species are shallow water forms, the absence of fossil oysters and hard clams suggests that post-glacial conditions were unfavorable for these species.

Sea level has ranged widely in Maine during the past 10,000 years, from approximately 120 m above to 5 m or more below the present level. It is probable that tidal range during the immediate post-glacial period was greater than the present 3- to 7-m range because conformation of the bottom and shoreline was different at that time.

To the geomorphological types of estuaries defined by Pritchard (1967) -- drowned river, fjord-type, bar-built, and those produced by tectonic processes -- should be added, in terms of dynamic transition, the emergent-type. In this type, the estuary is moved seaward from its former horizontal limits by nontectonic isostatic adjustment of the earth's crust, as during the post-glacial climatic optimum some 8,000 to 4,000 years ago. Later subsidence is a transitional stage of the drowned river type of estuary. Locally, these processes of emergence and subsidence appear to be still in operation.

Although many geologists consider Somes Sound to be the only fjord-type estuary in Maine, there are many other estuaries of proportional dimensions and comparable characteristics (Table 1).

³Damariscotta, Maine, oyster shell heaps; sample from 30 cm from the bottom of the largest heap. L-160: 1800 ± 250 B.P. (200 years added, correction for Suess effect).

Damariscotta, Maine. Sample 30 cm above bottom of largest oyster shell heap. L-160B: 2100 ± 250 B.P. (200 years added, correction for Suess effect).

Table 1. Partial list of Maine estuaries with fjord-type characteristics.

Name of Estuary	Basin Depth (meters)	Sill Depth (meters)	Shore Elevations (meters)
Somes Sound	51	10	198 to 256
Damariscotta River	37	14	30 to 98
Taunton River	24	6	49 to 67
Skillings River	22	8	37 to 55
Dyer Bay	20	6	43 to 72
Salt Pond (Blue Hill)	16	2	40 to 55
Benjamin River	15	6	46 to 72

Invertebrate fossils occur in marine clays throughout the Kennebec River valley of Maine from north of Norridgewock, south more than 112 km to the Atlantic Ocean and from mean sea level to about 100 m above. Strata of fossiliferous clays generally are underlaid by glacial sand and gravel and overlaid by marine or glacial sand and gravel. Thickness of clay strata ranges from a few centimeters to several meters. All fossil species occur as living animals in the Gulf of Maine. Radiocarbon age determinations and biological evidence support the assumption that all species occupied the same post-glacial site as living animals at or about the same time.

Fossilized remains of walrus (Dow, 1954), the pre-Wisconsin flora, and the post-glacial marine invertebrates strongly suggest that for many thousands of years only marine animals occupied much of what is now Maine. Evidence of trees growing below present mean sea level found by Bradley, Hussey, and Dow indicates that coastal flora was well established some 3,000 to 5,000 years B.P. (Hussey, 1959).

Scattergood (1952) reported the eastward spread of green crab (Carcinides maenas) populations between 1939 and 1951 from Winter Harbor, Maine, to Passamaquoddy Bay, New Brunswick. Blue crabs (Callinectes sapidus) were captured in lobster traps by Maine fishermen and turned over to Sea and Shore Fisheries biologists with increasing frequency from the late 1940's into the middle 1950's, but apparently they did not occur east of Deer Isle in eastern Penobscot Bay. The eastward and northward spread of both species was attributed to increases in seawater temperature. The annual mean (measured by the Bureau of Commercial Fisheries at Boothbay Harbor) increased from 6.4°C in 1939 to 11.1°C in 1953.

During the early years of this period, an isolated population of hard clams (Mercenaria mercenaria) in the Union River estuary increased in magnitude, but in 1950 and thereafter it declined rapidly because of increased predation by green crabs.

Populations of the horseshoe crab (Limulus polyphemus) occur intermittently and at widely scattered intervals from western Casco Bay eastward, but do not regularly occur between Cape Elizabeth and Kittery in western Maine.

In a small Casco Bay estuary and in a branch of the Sheepscot estuary, the sea scallop (Placopecten magellanicus) occurs as an intertidal resident; elsewhere in Maine coastal waters the species is generally found at depths exceeding 10 m.

Baird and Flagg (personal communication) found that alewives (Alosa pseudoharengus) from cold water estuaries are generally smaller than those from relatively warm water areas (Table 2).

Table 2. Size of alewives sampled from selected estuaries.

<u>Estuary</u>	<u>Mean Length (cm)</u>
Bagaduce	26
Damariscotta	29
Sheepscot	29
St. George	30

Baird (personal communication) found the incidence of microsporidian parasitism of the Atlantic smelt (Osmerus mordax) varies between the adjacent Sheepscot and Damariscotta estuaries. Incidence in the Sheepscot has not exceeded 20%, while in the Damariscotta it has exceeded 70%.

Mature salmon (Salmo salar), as well as juveniles, appear consistently in most of the smaller estuaries along the Maine coast. Mature menhaden (Brevoortia tyrannus) appeared with alewives in one of the tributary estuaries of the Penobscot in 1968. In 1950, when the mean annual temperature was 9.6°C, juvenile menhaden occurred in considerable numbers as late as December in Robin Hood Cove, a tributary of the Kennebec estuary.

Since 1874, the U. S. Weather Bureau's annual records of three stations (Portland, Bar Harbor, and Eastport) indicate a wide range in precipitation for the Maine coast. The annual average of the three stations for the period is 1.10 m; with 1.22 m at Bar Harbor, 1.08 m at Portland, and 0.99 m at Eastport. The lowest annual mean for the period was 0.58 m at Eastport in 1894; the highest, 1.59 m at Bar Harbor in 1953. The lowest three-station mean was 0.74 m in 1941, and the highest, 1.44 m in 1954.

The available supply of freshwater in estuaries is an important factor, possibly the major factor, in the egg survival of Atlantic smelt. Temperature and the amount of freshwater flow are critical factors in the migration of Atlantic salmon from the estuaries to the spawning areas. Survival of alewife larvae and juveniles is also dependent upon adequate precipitation and runoff.

Populations of blue mussels (Mytilus edulis) in the Royal River estuary of Casco Bay have been observed to vary in growth characteristics within and outside the influence of thermal discharge from a power generating plant (Table 3).

Table 3. Variation in growth of blue mussels in two temperature regimes, Royal River.

<u>Sample</u>	<u>Width as Percent of Length</u>	<u>Depth as Percent of Length</u>	<u>Mean February-August Temperature (°C)</u>
Control	45	41	7
Thermal	51	48	12

Distinct differences in species abundance have been found between estuaries and between temperature subcycles. Preliminary estimates of the available abundance of the more important commercial species in relation to mean annual temperature levels indicate optimum temperature ranges for the several species overlap, but optimum temperatures themselves probably do not (Table 4).

Table 4. Estimated abundance of selected species and associated temperatures.

<u>Species</u>	<u>Optimum Temperature Range °C</u>	<u>Optimum Temperature °C</u>	<u>Maximum Available Temperature (metric tons)</u>
Lobster (<u>Homarus americanus</u>)	9.0 - 10.0	9.25	10,400
Bloodworm (<u>Glycera dibranchiata</u>)	8.3 - 9.5	8.8	350
Sea Scallop (<u>Placopecten magellanicus</u>)	6.8 - 8.6	8.1	225
Soft Clam (<u>Mya arenaria</u>)	7.5 - 9.0	7.8	4,000
Northern Shrimp (<u>Pandalus borealis</u>)	7.2 - 8.9	7.5	4,100

Since most abundance-temperature optima are dependent upon seasonal temperature relations, which vary among the several species, the use of annual means for purposes of comparison does not provide the same precision that selected seasonal relations do.

Maine coastal bedrock ranges from Lower Ordovician to Upper Devonian and is composed of a wide variety of granites, schists, conglomerates, sandstones, slates, shales, quartzites, breccias, syenites, phyllites, gabbros, and undifferentiated volcanic and metamorphic rocks⁴. Glacial sands, gravels, boulders, tills, and clays overlay much of this bedrock, including that underlying estuaries. Except for cover provided for those species requiring it, e.g., gravels for Atlantic salmon spawning and boulders for lobster burrows, it has not been possible to demonstrate a consistent correlation between sediment types and species abundance.

Maine estuaries vary seasonally in some hydrographic characteristics. With spring melt-water runoff, turbulence and mixing in the estuary are greatly increased. Pesticide residues and coliform bacteria also increase during this season. Greater penetration of saline water into the estuary is associated with summer drought conditions. Heavy ice reduces river flow and, with removal of fresh surface water by freezing, also increases the salinity of the underlying water. Occurrence of ice frequently determines the type of fishery that can be operated in an estuary.

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DISCUSSION

Kinnear asked Dow if he had data other than that from the Kennebec estuary concerning the distribution of juvenile menhaden in Maine. Dow's answer was negative: after 1904, there were no commercial landings along the coast of Maine until the drastic rise in temperature of the early 1950's. Virginia boats made several landings of menhaden, and juveniles were observed in herring weirs in the Robin Hood Cove area. In reply to Kinnear, Dow said that he could not substantiate the reports of juvenile menhaden along the Atlantic coast of Canada as far as the Bay of Fundy.

IMMATURE FISHES ASSOCIATED WITH LARVAL ATLANTIC
MENHADEN AT INDIAN RIVER INLET, DELAWARE, 1958-61

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ABSTRACT

Plankton sets at Indian River Inlet, Delaware, made from October to May in the years 1958-61, resulted in the collection of 59 species of marine fishes. We compared catches from sets made with 1-m and $\frac{1}{2}$ -m nets, paired sets with 1-m nets, and a special series of sets made during ebb and flood tidal currents. Night-flood current sets with a 1-m net collected more species and individuals than did day-ebb current sets. Within the 9-month sampling period, six species -- Atlantic menhaden, bay anchovy, American eel, Atlantic silverside, summer and winter flounder -- made up nearly 70% of the catch. A marked annual variation in the catch-per-set occurred for summer flounder, American sand lance, bay anchovy, Atlantic croaker, Atlantic silversides, and striped cusk-eels. A decline in the catch of Atlantic menhaden, bay anchovy, Atlantic croaker, and summer flounder related to inlet water temperatures below 3.0°C. Various advantages and shortcomings of the techniques and objectives of reported studies are discussed.

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INTRODUCTION

In spite of increasing economic and scientific interest during the past hundred years in the Atlantic fishery resources of the United States, we know little about prejuvenile and juvenile inshore fishes in many areas. However, a basic need exists for documentation of relative abundance, seasonal occurrence, movements, and size distributions, particularly to evaluate the effects of environmental changes, both natural and man-made. Until a general, regular, and extensive resource inventory program is undertaken, we must add to our store of such information from special, short-term, and local studies.

This report summarizes the occurrence of immature fishes collected in association with larval menhaden and includes size range and relative numbers in samples taken between October and June, from 1958 to 1961 at Indian River Inlet, Delaware. We have also included comments on the water temperature and tidal and light conditions which may have influenced sampling success. We made some special effort to determine possible sources responsible for variations in catch. Conclusions may be useful in planning similar sampling activities, and since collections were made from fall to spring, a period during which sampling activity is often reduced, our results should be of special interest to some workers who have mostly summer data on hand for some species of inshore and estuarine fishes.

Only one general study of young fish in the Indian River Inlet area is reported (de Sylva, Kalber, and Shuster, 1962), based on material from zooplankton collections taken from July 1956 to July 1958. Their samples were taken biweekly with a 30.5-cm plankton net.

STUDY AREA

Indian River Inlet connects Indian River Bay with the Atlantic Ocean (Fig. 1). The inlet is 83 m wide and approximately 4 m deep, bulkheaded and protected by large jetties extending through the surf zone into the ocean, and by smaller jetties reaching into the bay. Alongshore, nontidal ocean drift near the inlet is southerly, varying in speed from 0.4 to 0.6 knot in winter, and slowing to 0.4 knot in summer (Bumpus, personal communication, 22 June 1960). The coastal water in this area is made up from such currents mixed somewhat with the Delaware Bay effluent (Miller, 1952). Through the inlet, maximum velocities in tidal currents varied from 3 to 8 knots. Observations on the distribution of water temperature and salinity indicate complete mixture of the water column through the inlet. Flood tide salinities averaged about 30‰ (Fig. 2).

SAMPLING PROCEDURE

We made sets with conical plankton nets suspended from the inlet bridge. The nets were of nylon netting with a mesh size of 0.9 mm. A 0.5-m net was fished at weekly intervals in 1958 and early 1959, and a 1-m net was operated twice weekly in late 1959, 1960, and 1961. Nets were set and retrieved with a small hand winch. The hoop forming the net mouth was buoyed, and remained perpendicular to and just under the water surface while fishing. We made sets for 1 hour during the period of maximum tidal current. Each net was equipped with a current meter centered in the mouth. On the basis of meter counts, we adjusted catches to a standard volume of 1,000 m³.

Because the inlet sampling was a part of a large estuarine study, we limited the sampling to periods when Atlantic menhaden were expected. From previous year-round spot sampling, we knew that occurrence of menhaden larvae normally peaked in cold months and larvae were absent from the inlet during the period from June to October. In each year, we made a series of sets from October to June, except for 1958-59, when sampling was initiated in December.

We made some special sets to measure the differences between day and night catches as well as those during ebb and flood currents. Day-night variation in collections of larvae has been reported by several authors and avoidance of a net fishing in a low velocity current is a recognized sampling problem in the capture of clupeid and other pelagic fish larvae. Ryland (1963) stated that both design of nets and increased ability of larger larvae to avoid nets generally explain diel differences in plankton net catches. Most of our collections were made at night, since the results of earlier year-round sampling favored night sets for collecting greater numbers of larval menhaden.

EXAMINATION OF COLLECTIONS

We preserved collections in a buffered 5% formalin solution in seawater immediately after a set. Fish larvae were identified, counted, and measured within 2 days after each set. Species identification was aided by reports cited in Wheatland (1956), and by those of Anderson (1957), Deubler (1958), Miller (1958), Gehringer (1959), and Gibbs (1959). Fork lengths of fishes were measured to the nearest millimeter. Fish with nonforked tails were measured to the tip of the longest median caudal rays. Seahorses, Hippocampus sp., were measured from coronet to the caudal extremity. The smaller gadids were cleared and stained (Clothier, 1950) for vertebral counts.

VARIABILITY IN CATCH DUE TO NET SIZE AND TIDE

In a paired net experiment, we made four sets with two 1-m nets tethered 2 m apart with a metal bar. Catches of the more abundant species did not differ between nets (Table 1). In another series of six sets during night flood tides, we tethered a 0.5-m and a 1-m net to determine if catches with different-sized nets were a simple function of net-mouth area. Bridger (1956) reported that catches of herring larvae were not proportional to the size of net openings of Helgoland and Hensen nets. In our catches, however, Atlantic menhaden, striped cusk-eel, windowpane, and winter flounder were taken in the expected 1:4 ratio, whereas American sand lance and elvers of the American eel deviated from the expected (Table 2). More species and more individuals of each species were collected in the larger net. Although a total of 32 species were collected during these trials, most were represented by only a few individuals. Twenty-six species were taken in 1-m net collections and 19 in the 0.5-m net collections. A total of 3,315 specimens were taken in 1-m nets and 646 in 0.5-m nets.

Catches of the three most abundant species present in samples at ebb and flood tides occurring during the same night are summarized in Table 3. We found no difference between flood tide catches before midnight and flood tide catches after midnight. However, catches during flood tide were greater, on the average, than those made in ebb tide sets. Occasionally, catches made during ebb tide were equal to those made during flood tide. This latter condition appeared to be related to periods of low water temperature occurring in winter (Fig. 2) and, in the case of eels collected as elvers, may have been related to their state of physiological preparedness to enter the estuary (Deelder, 1958).

In 1960-61, we conducted a special series of sets at weekly intervals from October to May, obtaining at each sampling date a daytime ebb, a daytime flood, a nighttime ebb, and a nighttime flood collection. From this series, we noted the differences in occurrence of fishes during each sampling period to determine what sampling regime was most effective. Some interesting variations occurred in catches of the series (Table 4) -- those considered noteworthy follow:

Atlantic menhaden. Collected as larvae mostly from sets at night on flood tides. Larvae first appeared in a late October set; low numbers and erratic occurrence continued until early December when catches increased. Although larval menhaden occurred in the winter collections, their appearance in sets made on ebb tides in December and January suggests they did not remain in the estuary. The abrupt decrease in numbers of fish caught in late January coincided with a rapid lowering of water temperature (Fig. 2). The reduction in catch of menhaden larvae associated with water temperatures below 3.0°C was first reported by June and Chamberlin (1959), and subsequently described from a 6-year collection series by Reintjes and Pacheco (1966). Lewis (1966) demonstrated lethal effects of temperatures below 3.5°C in laboratory studies on young stages. After February, we took no larvae on ebb tide, but only on flood tide, suggesting passage into the Indian River estuary, a known nursery area (Pacheco and Grant, 1965). In May, a few differentiating larvae (over 34 mm in fork length) were collected.

Atlantic herring. Collected as larvae from late February until late March. Sets at night during flood tide were most productive.

Bay anchovy. Captured mostly at night, common as both young and older fish during the sampling period. An abrupt drop in their numbers, similar to that described for the Atlantic menhaden, occurred in late January. Bay anchovies occurred again in early April, but in reduced numbers. Like Atlantic menhaden, bay anchovies were either present in small numbers or absent from catches made on ebb tides during April or May.

American eels. Collected as unpigmented elvers, except for two larger specimens taken in March. Elvers were first taken in late November and a peak in their numbers occurred in late February and March. Before this time, there was a noticeable day-night difference in catches, which were always greater at night. During and after the peak, daytime catches were comparable to those made at night. There was also a change in catches in sets made at different tide stages. After the February peak, the number of elvers collected during ebb tide diminished. This catch pattern suggests that the elvers behave similarly to those described by Deelder (1958) in Netherlands estuaries. He concluded that, while in the mouth of the estuary, elvers swim at random during the dark. The night-swimming elvers are carried upstream by a running flood tide and downstream again on the ebb. Because they avoid flowing freshwater, they probably do not remain upriver. A seasonal change in behavior is indicated by a preference for the locations where the flood tide has carried them and the elvers continue upstream.

Northern pipefish. Taken on all tides, but more abundant in samples collected at night during flood tide. Since the larval stage of this species is spent in a parental pouch, 37-mm to 38-mm specimens taken in November were probably young-of-the-year from summer spawning.

Seaboard goby. Collected as larvae during October in day and night sets on flood tide, but were generally absent from November to late March. Although collected in April, specimens larger than 26 mm were not taken in daytime sets. This species is a summer spawner and the catch of larvae peaks sometime between July and September (de Sylva et al., 1962).

Northern searobin. Appeared as young in April, but only in night sets. Since the northern searobin is a summer spawner in the Delaware area, we missed the peak of abundance which probably occurred during our lapse of sampling from June to September.

American sand lance. Taken as larvae from February to May. Except for a few small catches in mid-April, when they occurred in both ebb and flood current sets, most fish were taken in sets during ebb tides. This catch pattern strongly suggests a chance occurrence in estuarine waters and may be related to offshore movements suggested by Norcross, Massmann, and Joseph (1961). The sand lance was the only species in our collections that was taken consistently in greater numbers during daylight sets.

Striped cusk-eels. Taken mostly from March to early April. In contrast to the smaller specimens collected the previous year (Table 5), the 1960-61 catch was composed chiefly of young fish over 40 mm in length. Diurnal behavior (Hildebrand and Schroeder, 1928) was apparent -- we collected no specimens in day sets.

Rough silverside. Taken in two size groups (the smaller probably young-of-the-year) in October. The species did not occur in samples again until early May. Only one silverside smaller than 32 mm (a 5-mm specimen taken in April) occurred in the collections reported by de Sylva et al. (1962).

Atlantic silverside. Collected as larvae in May and as juveniles and adults the other months. Review of the catches reported by de Sylva et al. (1962) indicates that the abundance peak occurred during the summer lapse in our sampling schedule. Large numbers collected on ebb tide in winter suggest that these fish may move to deeper water in response to seasonal chilling. Although this species is fairly resistant to low temperatures (Bigelow and Schroeder, 1953), there was a sharp drop in numbers during late January coincident with water temperatures below 3.0°C (Fig. 2).

Windowpane flounder. Collected as larvae and young from October through March with a peak number in early April. We found 5-mm larvae in exploratory seine collections, inside the inlet mouth during June. Report of a few 3- to 9-mm specimens occurring in ichthyoplankton samples during June and July (de Sylva et al., 1962) suggests spawning probably continues through midsummer in southern Delaware, as Perlmutter (1939) described for the Long Island area.

Winter flounder. Taken as larvae in early March with greatest catches made late in the same month. The large collections in daytime sets during ebb and flood tides contrasted with the increased catches in night sets for most other larvae. These results differ from those of Croker (1965), who found a diel variation, favoring night sets, in numbers of winter flounder larvae collected in Sandy Hook Bay.

SPECIES OCCURRENCE

As a result of night sets made during flood tides, we collected 58 species representing 32 families (Table 5). The mean monthly catch per set and the length range of species that occurred in the three sampling periods between 1958-61 are summarized in Appendix Table 1. When bimodal groups appeared in the length distribution, limits of each size group are indicated. The 1958-59 series from 0.5-m nets is unadjusted. (Counts may be multiplied by four for an approximate comparison with the 1-m series.)

Although it was not our purpose to evaluate general abundance, we noted some species demonstrated marked yearly differences in catch. For example, catch of summer flounder was up in 1958-59; Atlantic menhaden, American sand lance, bay anchovy, and Atlantic croaker were up in 1959-60; and Atlantic herring, rough and Atlantic silversides, conger eel (as *leptocephali*), and striped cusk-eel were up in 1960-61.

GENERAL REMARKS

Although the technique of setting plankton nets in tidal currents for monitoring seasonal composition of young fish fauna is direct and inexpensive, relatively few studies have used this as a routine method of sampling. Graham and Venno (1968) described a set-net technique for sampling Atlantic herring in estuaries of Maine. They were able to measure seasonal changes in larval size and catch rate and pointed out certain advantages of buoyed nets as compared to towed gear. Williams (1960), studying fish dispersal, described collections (pipefishes and silversides) from mid-July to early September in bay spawning areas confluent to Nantucket Sound. Croker (1965) reported on 75 surface sets from which 20 species were identified as a result of 1 year's sampling in the Sandy Hook area. American eel, Atlantic herring, sand lance, winter flounder, northern pipefish, and Atlantic silversides made up 98% of the larvae collected. Reintjes and Pacheco (1966) described the collections of larval menhaden at Indian River, Delaware, and were able to show the relation of cold water temperature to occurrence of larvae at the inlet and subsequent appearance in the tributary nursery area. Williams and Deubler (1968) reported on a 10-year study, principally from pier sets, in Bogue Sound near Beaufort Inlet, North Carolina, and discussed variations in catches of flounder and shrimp larvae in relation to salinity, temperature, current strength, wind direction, lunar phase, and clogging. In South Carolina, Bearden (1961) used inlet sets to estimate abundance of shrimp postlarvae. In conjunction with supplemental tows in coastal waters, these have provided a series of relative abundance estimates of brown shrimp 4 to 5 months ahead of the commercial seasons (Lunz, 1965, 1966, 1967, 1968).

Net size has varied in the different studies and the choice apparently rested on the time and personnel available for sorting. Net sizes ranged from 30-cm nets used by Hopkins in the Indian River (summarized in de Sylva et al., 1962) to the 152-cm net by Williams and Deubler (1968); however, an intermediate net size of 1 m diameter was used in most studies.

If data on occurrence of species are desirable, the advantage of a relatively large net is obvious. In our study, for example, from the 1-m net catches we added 22 species and 10 families to the checklist of larvae and juveniles previously reported from 30-cm net collections at the same location. In our comparative sets, it is noteworthy that the 0.5-m net captured only from 33 to 83% of the number of species taken in simultaneous 1-m nets.

With regard to assessing environmental effects, the winter temperatures to which some larvae are subjected during their movement inshore can influence survival and thereby affect their subsequent abundance as juveniles in nurseries. In the Delaware area, seasonally low water temperatures did appear to preclude the occurrence of some larvae. The low temperature effect as a factor modifying survival was described for the Atlantic croaker by Massmann and Pacheco (1960) and for Atlantic menhaden by June and Chamberlin (1959). Water temperatures below 3.0°C occurred annually: in 1958-59 from late December to early February; in 1959-60 during March; and in 1960-61 from late January to late February. Species that were reduced in number or completely absent from catches during these periods of low temperature include Atlantic menhaden, bay anchovy, Atlantic croaker, and summer flounder.

A coastal network of inlet stations sampled on a regular basis could provide a valuable information source for (1) producing relative abundance forecasts of economically important species, (2) relating short-term environmental effects to changes in behavior or survival, and (3) determining long-term variations in the species complex associated with estuaries.

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DISCUSSION

Graham commented on a European study of elvers, in which Cruetzberg⁴ demonstrated how elvers migrate up the estuary. When he introduced seawater into an experimental tank and started a flow, the elvers dug into the bottom sand. When he added land-derived or estuarine water and reversed the circulation, the elvers came out of the sand and floated up the simulated estuary, carried by the current. Pacheco remarked that he has data supporting this theory, but has not observed this behavior.

Murawski described inlet sampling in New Jersey, specifically in the Manasquan River and Corson Inlet. This is part of a 2-year study, 14 months of which has been completed. He has data from 1961, primarily on the summer flounder larvae, but sampling is mainly confined to fall and winter collections. He uses the inlet set-net technique which is neither as expensive nor as vulnerable to poor weather as other collection methods.

Massmann asked if the larval menhaden moved out of the inlet at 3.0°C or if they continued to move indiscriminately. Pacheco replied that there was seemingly passive in-and-out movement until 3.5°C at which point only small numbers of the menhaden, if any, could be collected. Massmann commented that Joseph sampled with the Pathfinder offshore at the same time. Mortality occurred among the larval menhaden offshore when the temperature reached 3.0°C. Joseph substantiated this comment with his observation of recently dead larvae, during March 1960, when the water inside the 10-fathom line was nearly homogeneous, with a low temperature of 2.0°C.

The turbulent situation in the Indian River Inlet insured collections that were representative of the entire water column, substantiated by catch components in the net such as invertebrates, gravel, etc. Carlson asked if the apparatus used in Florida -- suspended nets at different elevations -- could be adapted to the situation in which the water of an inlet or river section is 3 to 8 knots velocity.

Sweat described the Florida rig apparatus: an A-frame, mounted on the pilings of a bridge, is lowered from the bridge catwalk. An L-shape is formed along the bottom and the nets are hung in a vertical array, always in the same location regardless of current flow -- one right under the surface, one in midchannel and one on the bottom -- the guideline extending right to the bottom. The apparatus weighs 150 to 200 pounds, so it cannot float back up.

⁴Cruetzberg, F. 1961. On the orientation of migrating elvers (Anguilla vulgaris Turt.) in a tidal area. Neth. J. Sea Res. 1: 257-338.

Williams then described techniques for which no bridge is needed for sampling in an inlet: one can either hold the tow line against the current or hold the net in the water with a pole. A 30.5-cm net is used in both instances for water not exceeding 5 knots velocity.

In response to a question by Graham, Brown discussed an efficiency measure on nets. Both meter nets and 25.4-cm plankton nets became clogged during collections of striped bass eggs, although 5-minute samples were more efficient than 10-minute ones.

Graham asked about the effect of water flow through small meshes: for example, whether or not water with a velocity of 8 knots could pass through a No. 2 mesh meter net. Brown replied that water of such speed would sweep away everything. Even 2 or 3 knots is too strong for plankton nets.

Lunz commented that the 4-plus knots measured by the Bears Bluff Laboratories in the North Edisto River is considered to be one of the highest rates in estuaries with an inlet along the east coast, according to the North American Current Atlas.

Brown agreed, adding that he never measured a current flow as great as 4 knots in the Roanoke River, although the currents are difficult to handle.

Nichols commented that a gill net could not be tied to the ladders of the lock chambers in the Cape Fear River.

Joseph noted that a mesh with holes small enough to be useful in sampling would be impractical for operation in water moving more than 3 knots. The turbulence would shunt most of the material off to the sides.

Marak suggested that a depressor for set-nets might alleviate the problem. Lunz replied that he successfully used a boat stabilizer to hold down plankton nets. However, he explained that it doesn't solve the problem with fine meshed nets.

Williams asked if sand lance larvae of all sizes are more abundant in the ebb than in the flood, or if this is true only of those above a particular size. Pacheco dealt only with total catch data and had no information on various sizes. In catches from some inlets off Long Island, Williams found that Ammodytes are the only larvae obviously more abundant in the ebb. For this species, he noticed no variation in behavior with difference in size for larvae up to 20 mm. However, he was unable to relate their abundance to any other physical factor. The sand lance is the only fish which, in the larval stage, can be collected in large numbers on the surface during daylight in the Long Island area.

Figure 1. Portion of the Atlantic coast showing the Indian River Inlet
of southern Delaware.

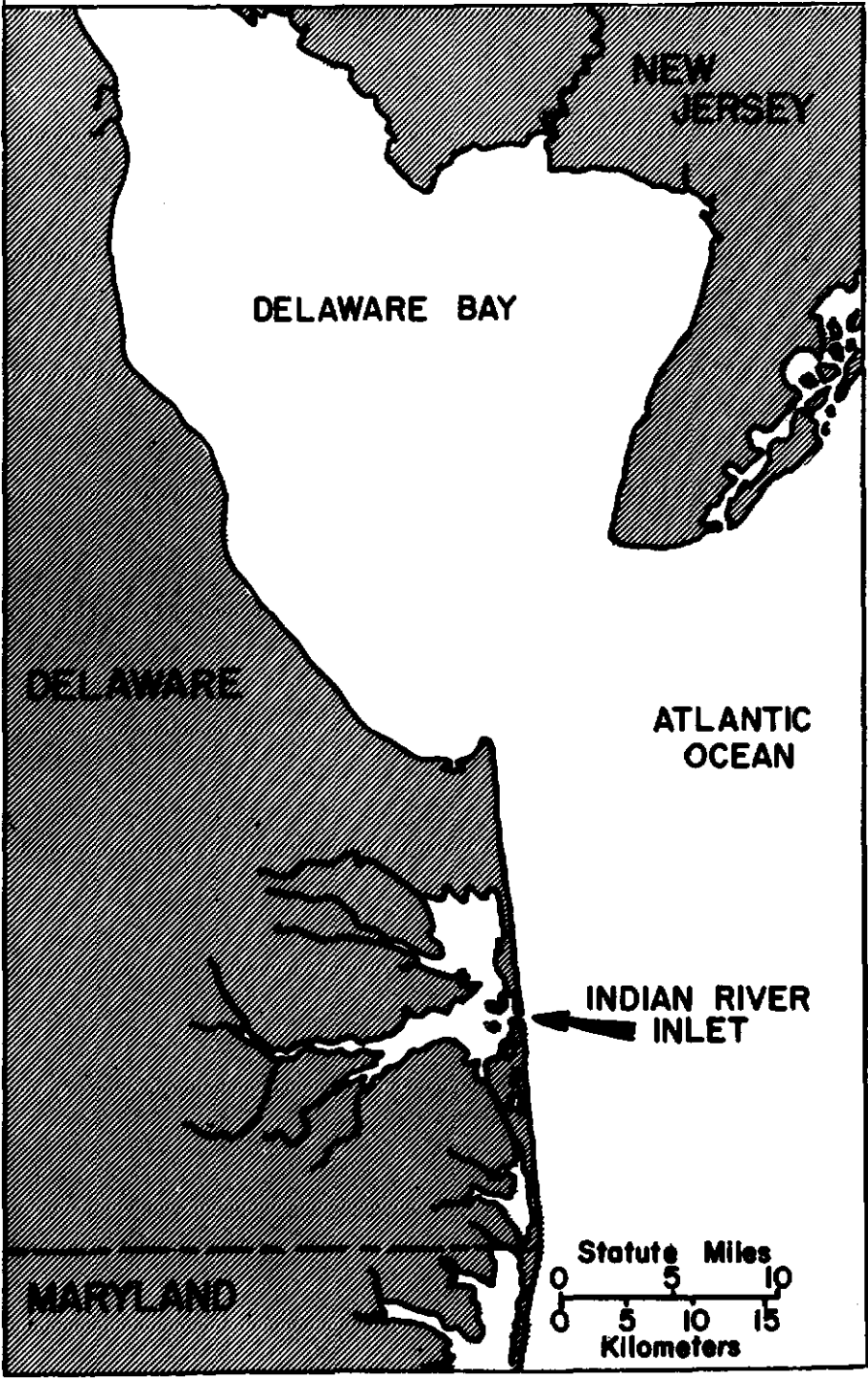


Figure 2. Surface water temperature (solid line) and salinity (dots) of flood current at Indian River Inlet, Delaware, during three sampling series.

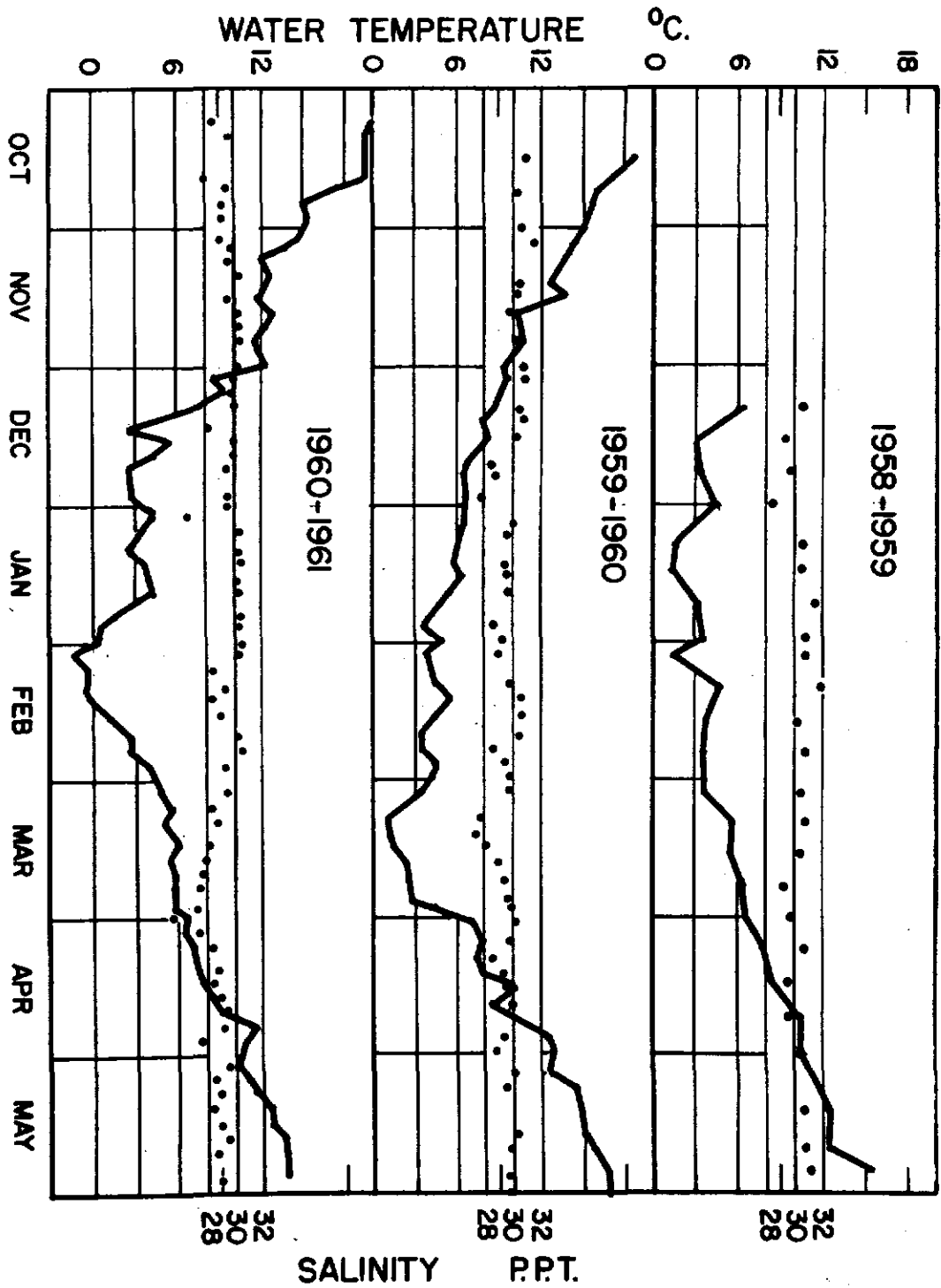


Table 1. Catch of five fish species in paired l-m nets. Nets fished simultaneously for 1 hour in surface water at night during flood tide, Indian River Inlet, Delaware, 1960.

Collection date	19 Jan.		29 Jan.		2 Feb.		5 Feb.	
<u>Brevoortia tyrannus</u>	8	13	250	255	127	133	43	43
<u>Anguilla rostrata</u>	10	18	197	173	551	450	1440	1650
<u>Micropogon undulatus</u>	15	19	7	15	1	1	1	2
<u>Menidia menidia</u>	2	50	7	2	18	14	15	16
<u>Paralichthys dentatus</u>	2	1	10	10	13	15	34	41
Total of above	37	101	471	455	710	613	1533	1752
Total of all fish	40	105	393	464	734	644	1535	1760
Total of species	8	7	8	10	11	11	8	8
No. of species taken in both nets	6		7		8		6	

Table 2. Catch of the fish species in 1- and $\frac{1}{2}$ -m plankton nets. Nets fished simultaneously for 1 hour in surface water at night, Indian River, Delaware, 1960.

Collection date	1 Apr.		12 Apr.		15 Apr.		29 Apr.		2 May		26 May	
	1 m	$\frac{1}{2}$ m	1 m	$\frac{1}{2}$ m	1 m	$\frac{1}{2}$ m	1 m	$\frac{1}{2}$ m	1 m	$\frac{1}{2}$ m	1 m	$\frac{1}{2}$ m
<u>Brevoortia tyrannus</u>	139	31	18	3	20	5	1	0	9	0	0	0
<u>Anguilla rostrata</u>	114	15	55	23	202	21	8	14	344	19	3	0
<u>Ammodytes americanus</u>	30	7	4	0	765	44	15	1	3	0	0	0
<u>Rissola marginata</u>	2	2	26	9	46	11	1	0	1	0	0	0
<u>Scophthalmus aquosus</u>	7	2	4	2	36	10	0	1	1	0	0	0
<u>Pseudopleuronectes americanus</u>	0	0	0	0	0	0	17	7	1265	344	4	0
Total	292	57	107	37	1069	91	42	23	1623	363	7	0
Total of all fish	324	64	130	53	1116	108	45	26	1638	369	58	24
Total no. of species	11	10	14	8	16	11	6	6	15	6	6	2
No. of species taken in both nets	9		7		10		4		5		2	

Table 3. Catch of three species of fish per 1,000 m³ of water filtered through 1-m plankton nets, Indian River Inlet, Delaware. Collections were made from ebb (E) and flood (F) tidal currents occurring in the same night. Sampling dates range from mid-January to mid-April, 1960.

Date	Tide	15 J	23 J	25 J	29 J	2 F	6 F	8 F	12 F	16 F	20 F	22 F	29 F	21 M	4 A	8 A	12 A	15 A
<u>Brevoortia tyrannus</u>	F	89			69	39			328	86		129	54				4	3
	E	39			38	24			42	54		44	20				0	Tr
	E		46	26			32	31			25			3	1	0		
	F		389	128			12	494			26			13	38	1		
<u>Anguilla rostrata</u>	F	10			28	171			121	19		22	76				12	33
	E	9			17	58			126	32		33	55				Tr	2
	E		21	11			22	49			44			17	81	5		
	F		22	10			396	83			223			14	620	0		
<u>Paralichthys dentatus</u>	F	1			3	4			17	4		6	2					
	E	1			Tr	4			1	3		7	Tr					
	E		2	2			2	Tr			6			0	0	0		
	F		3	3			9	8			12			5	2	0		

Table 4. Semimonthly catch of preadult fishes in plankton nets set at the surface in Indian River Inlet, Delaware, 1960-61. Catches of 0.5 or less, per 1,000 m³ of water, are designated as Tr.

Species	Tide*	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Brevoortia tyrannus</u>	DF	0	2	15	4	12	1	0	0
	DE	0	Tr	0	2	Tr	0	0	0
	NF	0	Tr	Tr	42	43	1	Tr	0
	NE	-	0	2	43	24	1	0	15
<u>Clupea harengus</u>	DF	0	0	0	0	0	0	0	0
	DE	0	0	0	0	0	0	0	0
	NF	0	0	0	0	0	7	Tr	0
	NE	-	0	0	0	0	Tr	0	0
<u>Anchoa mitchilli</u>	DF	1	1	13	1	7	6	0	0
	DE	0	93	58	0	24	1	0	0
	NF	1	14	28	93	121	13	0	2
	NE	-	5	274	46	287	7	0	8
<u>Anguilla rostrata</u>	DF	0	0	Tr	2	6	27	212	0
	DE	0	0	0	0	3	4	Tr	58
	NF	0	0	3	11	57	49	230	0
	NE	-	0	1	11	48	8	91	10
<u>Syngnathus fuscus</u>	DF	Tr	0	0	0	0	0	Tr	0
	DE	0	0	0	0	0	0	0	0
	NF	0	1	0	0	Tr	0	Tr	4
	NE	-	0	0	0	0	0	0	0
<u>Gobiosoma ginsburgi</u>	DF	13	0	0	0	0	0	0	0
	DE	Tr	0	0	0	0	0	0	0
	NF	54	Tr	0	0	0	0	13	0
	NE	-	Tr	0	0	0	0	1	0

Table 4 - continued

Species	Tide*	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Prionotus carolinus</u>	DF	0	0	0	0	0	0	0	0
	DE	0	0	0	0	0	0	0	0
	NF	0	Tr	0	0	0	0	2	1
	NE	-	0	0	0	0	0	0	0
<u>Ammodytes americanus</u>	DF	0	0	0	0	0	1	3	5
	DE	0	0	0	0	1	149	4	4
	NF	0	0	0	0	0	2	0	4
	NE	-	Tr	0	0	0	33	0	0
<u>Rissola marginata</u>	DF	0	0	0	0	0	0	0	0
	DE	0	0	0	0	0	0	0	0
	NF	0	0	0	0	0	3	165	0
	NE	-	0	Tr	0	0	0	1	12
<u>Membras martinica</u>	DF	0	0	0	0	0	0	0	0
	DE	0	0	0	0	0	0	0	0
	NF	1	0	0	0	0	0	0	0
	NE	-	36	0	0	0	0	0	0
<u>Menidia menidia</u>	DF	Tr	6	69	2	1	Tr	0	0
	DE	4	10	3	10	2	1	0	0
	NF	3	32	44	44	7	4	2	0
	NE	-	1	45	262	16	2	1	5
<u>Scophthalmus aquosus</u>	DF	0	0	0	0	0	Tr	0	0
	DE	0	0	0	0	0	Tr	0	0
	NF	0	Tr	0	0	0	0	2	1
	NE	-	0	0	0	0	0	15	2

Table 5. Checklist by family of fish species taken during nighttime plankton collections on flood tides, Indian River Inlet, Delaware. Total numbers collected and common names are indicated.

Family species	Numbers collected			
	1958-- 59	1959-- 60	1960-- 61	
Elopidae <u>Elops saurus</u> Linnaeus	-	-	1	Ladyfish
Clupeidae <u>Alosa aestivalis</u> (Mitchill)	3	22	22	Blueback herring
<u>Alosa pseudoharengus</u> (Wilson)	-	3	5	Alewife
<u>Brevoortia tyrannus</u> (Latrobe)	920	9,592	1,336	Atlantic menhaden
<u>Clupea harengus harengus</u> Linnaeus	-	31	112	Atlantic herring
Engraulidae <u>Anchoa hepsetus</u> (Linnaeus)	-	2	-	Striped anchovy
<u>Anchoa mitchilli</u> (Valenciennes)	146	27,814	4,335	Bay anchovy
Anguillidae <u>Anguilla rostrata</u> (LeSueur)	992	8,056	9,308	American eel
Congridae <u>Conger oceanicus</u> (Mitchill)	4	7	54	Conger eel
Belonidae <u>Strongylura marina</u> (Walbaum)	-	2	3	Atlantic needlefish
Hemiramphidae <u>Hyporhamphus unifasciatus</u> (Ranzani)	-	3	1	Halfbeak

Table 5 - continued

<u>Cyprinodontidae</u>					
<u>Cyprinodon variegatus</u> Lacépède	-	1	1	1	Sheepshead minnow
<u>Fundulus heteroclitus</u> (Linnaeus)	-	3	3	1	Mummichog
<u>Fundulus majalis</u> (Walbaum)	-	1	1	-	Striped killifish
<u>Lucania parva</u> (Baird and Girard)	-	5	5	-	Rainwater killifish
<u>Gadidae</u>					
<u>Enchelyopus cimbrius</u> (Linnaeus)	1	3	-	-	Fourbeard rockling
<u>Gadus morhua</u> Linnaeus	-	45	17	17	Atlantic cod
<u>Pollachius virens</u> (Linnaeus)	3	4	10	10	Pollock
<u>Urophycis chuss</u> (Walbaum)	-	-	5	5	Squirrel hake
<u>Urophycis regius</u> (Walbaum)	85	68	33	33	Spotted hake
<u>Gasterosteidae</u>					
<u>Apeltes quadracus</u> (Mitchill)	1	2	3	3	Fourspine stickleback
<u>Gasterosteus aculeatus</u> Linnaeus	-	10	20	20	Threespine stickleback
<u>Syngnathidae</u>					
<u>Hippocampus erectus</u> Perry	2	3	11	11	Spotted seahorse
<u>Syngnathus fuscus</u> Storer	8	121	127	127	Northern pipefish
<u>Serranidae</u>					
<u>Centropristis striata</u> (Linnaeus)	-	-	12	12	Black sea bass
<u>Pomatomidae</u>					
<u>Pomatomus saltatrix</u> (Linnaeus)	-	2	3	3	Bluefish
<u>Pomadasyidae</u>					
<u>Orthopristis chrysoptera</u> (Linnaeus)	-	-	4	4	Pigfish
<u>Sciaenidae</u>					
<u>Bairdiella chrysura</u> (Lacépède)	-	3	2	2	Silver perch
<u>Cynoscion regalis</u> (Bloch and Schneider)	-	-	1	1	Weakfish
<u>Leiostomus xanthurus</u> Lacépède	117	1	1	1	Spot
<u>Menticirrhus americanus</u> (Linnaeus)	-	-	1	1	Southern kingfish
<u>Menticirrhus saxatilis</u> (Bloch and Schneider)	-	3	5	5	Northern kingfish
<u>Micropogon undulatus</u> (Linnaeus)	30	3,582	29	29	Atlantic croaker

Table 5 - continued

Family species	Numbers collected			
	1958- 59	1959- 60	1960- 61	
Scombridae				
<u>Scomber colias</u> Gmelin	-	-	1	Chub mackerel
Gobiidae				
<u>Gobionellus</u> sp.	-	18	44	
<u>Gobiosoma bosci</u> (Lacépède)	-	1	5	Naked goby
<u>Gobiosoma ginsburgi</u> Hildebrand and Schroeder	-	454	570	Seaboard goby
<u>Gobiosoma</u> sp.	-	-	649	
Triglidae				
<u>Prionotus carolinus</u> (Linnaeus)	21	25	162	Northern searobin
<u>Prionotus evolans</u> (Linnaeus)	-	-	4	Striped searobin
<u>Prionotus</u> sp.	-	-	2	
Cottidae				
<u>Myoxocephalus aeneus</u> (Mitchill)	1	62	2	Grubby
Cyclopteridae				
<u>Liparis atlanticus</u> (Jordan and Evermann)	-	1	-	Seasnail
Ammodytidae				
<u>Ammodytes americanus</u> DeKay	10	7,664	316	American sand lance
Uranoscopidae				
<u>Astroscopus guttatus</u> Abbott	-	2	-	Northern stargazer
Ophidiidae				
<u>Rissola marginata</u> (DeKay)	1	194	4,378	Striped cusk-eel

Table 5 - continued

Stromateidae					
	<u>Poronotus triacanthus</u> (Peck)	-	1	1	Butterfish
Mugilidae					
1	<u>Mugil cephalus</u> Linnaeus	20	-	-	Striped mullet
-	<u>Mugil curema</u> Valenciennes	-	16	16	White mullet
-	<u>Mugil</u> sp.	-	-	2	
Atherinidae					
2	<u>Membras martinica</u> (Valenciennes)	399	14,125		Rough silverside
1	<u>Menidia beryllina</u> (Cope)	5	3		Tidewater silverside
191	<u>Menidia menidia</u> (Linnaeus)	1,017	4,131		Atlantic silverside
Bothidae					
4	<u>Etropus microstomus</u> (Gill)	19	34		Smallmouth flounder
153	<u>Paralichthys dentatus</u> (Linnaeus)	535	100		Summer flounder
36	<u>Scophthalmus aquosus</u> (Mitchill)	201	202		Windowpane
Pleuronectidae					
8	<u>Pseudopleuronectes americanus</u> (Walbaum)	1,810	3,461		Winter flounder
-	<u>Symphurus plagiusa</u> (Linnaeus)	1	-		Blackcheek tonguefish
Tetraodontidae					
4	<u>Sphoeroides maculatus</u> (Bloch and Schneider)	5	283		Northern puffer
Diodontidae					
-	<u>Chilomycterus schoepfi</u> (Walbaum)	-	1		Striped burrfish
Batrachoididae					
-	<u>Opsanus tau</u> (Linnaeus)	1	1		Oyster toadfish

Appendix Table 1. Mean monthly catch per haul of larval and juvenile fishes collected in plankton nets during flood current at night, Indian River Inlet, Delaware. Fork length (mm) range of samples is underlined. In multimodal distributions, the separate length ranges are indicated.

Species	Sampling series	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Elops saurus</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0
<u>Alosa aestivalis</u>		0	0.1	0	0	0	0	0	0
		0	29	0	0	0	0	0	0
	1958-59	-	-	0	0	0	0.6	0	0
	1959-60	0	0	0	0	0	59-80	0	0
		0	0	0.7	0.1	0.3	0.8	0.1	0.8
	1960-61	0	0	62-94	83	76-84	75-88	162	67-80
	0	0	0.3	0.1	0	0.7	0	1.3	
	0	0	46-84	57	56	58-88	60-96	79-84	
<u>Alosa pseudoharengus</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0.2	0.1	0	0
		0	0	0	0	89-94	162	0	0
		0	0	0	0	0	0	0.1	0.4
		0	0	0	0	0	0	243	66-84
<u>Brevoortia tyrannus</u>	1958-59	-	-	0.8	0.5	1.0	153.6	34.5	1.7
	1959-60	0	0	18-25	25	24-26	17-28	19-32	31-40*
		4.5	2.2	156.6	428.8	441.1	47.9	40.8	6.0
	1960-61	15-25	15-25	18-33	14-31	13-31	15-32	17-31	21-43*
		0	1.9	69.3	66.0	0	0.7	2.3	8.6
		0	18-26	21-34, 97-104	21-32	0	0	19-33	23-32

Species	Sampling series	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Urophycis chuss</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0.1	0	0.1	0	0.1	0	0.1
		0	32	0	80	0	84-112	0	38
<u>Urophycis regius</u>	1958-59	-	-	0	0	0	5.6	13.8	0.7
	1959-60	0	0.6	0	0.3	0	49-92	45-58	88-99
	1960-61	24	33-61	53-83	40-104	47-100	45-50	36-130	35-142
		0.7	0	0	0	1.0	1.0	2.0	0.6
		6-24	0	0	0	0	33-101	49-87	40-76
<u>Apeltes quadracus</u>	1958-59	-	-	0	0	0.3	0	0	0
	1959-60	0	0	0	0	35	0	0	0
	1960-61	0	0	0	0	0.1	0.1	0	0
		0	0	0	36	0	39	0	0
		0	0	0.1	0.1	0	0.1	0	0
		0	0	46	31	0	51	0	0
<u>Gasterosteus aculeatus</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0.6	0	0.1	0	0.1
	1960-61	0	0	0	55-64	58-62	60	0	38
		0	0	0	0	0.4	0	0	1.9
		0	0	0	0	59-66	0	0	16-24
<u>Hippocampus erectus</u>	1958-59	-	-	0	0	0	0	0.5	0
	1959-60	0	0	0	0	0	0	42-52	0
	1960-61	11	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0.1
		0	0	0	0	0	0	1.3	40
		0	0	0	0	0	0	48-73	40

Appendix Table 1 - continued

Species	Sampling series	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Cynoscion regalis</u>	1958-59	-	0	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0
<u>Leiostomus xanthurus</u>	1958-59	-	0	0	0	0.3	15.6	9.5	0
	1959-60	0	0	0	0	16	9-17	13	0
	1960-61	0	0	0	0.1	0	0	0	13
<u>Menticirrhus americanus</u>	1958-59	-	0	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0.1	0	13	0	0	0	0
<u>Menticirrhus saxatilis</u>	1958-59	-	0	0	0	0	0	0	0
	1959-60	0	0.3	0	0	0	0	0	0
	1960-61	0	60-90	0	0	0	0	0	0
			0.6						
			81-132						

Appendix Table 1 - continued

Species	Sampling series	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Gobiosoma</u> sp.	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0
<u>Prionotus</u> <u>carolinus</u>		10.8	0.1	0	0	0	0	0	0
		6-12	10	0	0	0	0	0	0
	1958-59	-	-	0	0	0	0.8	4.3	0
	1959-60	0	0	0	0	0	51-66	29	0
	1960-61	0	0	1.8	0.1	0	0	0.5	0.2
<u>Prionotus</u> <u>evolans</u>		0	68-87	25-92	53	0	0	52-100	64
		0	0.1	0	0	0	0	19.4	0.7
		0	53	0	0	0	0	35-97	55-109, 284
	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
<u>Prionotus</u> sp.	1960-61	0	0	0	0	0	0	0	0
		0.7	0	0	0	0	0	0	0
		71-80	0	0	0	0	0	0	0
<u>Prionotus</u> sp.	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0
	0.2	0.1	0	0	0	0	0	0	
	10	8	0	0	0	0	0	0	

Appendix Table 1 - continued

Species	Sampling series	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Poronotus triacanthus</u>	1958-59	-	0	0	0	0	0	0	0
	1959-60	0	0	0.1	0	0	0	0	0
	1960-61	0	0	2.1	0	0	0	0	0.1
<u>Mugil cephalus</u>	1958-59	-	-	0	0	0	0.2	0	0
	1959-60	0	0	1.1	0	0.3	27	0.9	0
	1960-61	0	0	25-30	0	28-29	0	25-32	0.2
		0	0	0	0	0	0	0	29
<u>Mugil curema</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0
<u>Mugil sp.</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0.1	0.1	0	0	0	0	0
	0	24	26						

Appendix Table 1 - continued

<u>Membras</u> <u>martinica</u>	1958-59	-	0	0	0	0	0	0	0.3	0
	1959-60	93.3	0	0	0	0	0	0	79	0
	1960-61	43-99	0	0	0	0	0	0	4.3	0
		2336.0	0	0	0	0	0	0	74-104	0
		34-100	0.6	0	0	0	0	0	11.6	0
			33-80	0	0	0	0	0	75-107	0
<u>Menidia</u> <u>beryllina</u>	1958-59	-	0.1	0	0	0	0	0	0	0
	1959-60	0	48	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0.5	0
		0	0	0	0	0	0	0	47-54	58
		0	0	0	0	0	0	0	0.1	0
		0	0	0	0	0	0	0	56	0.2
		0	0	0	0	0	0	0	52-56	0.2
<u>Menidia</u> <u>menidia</u>	1958-59	-	1.1	5.3	2.0	19.8	3.3	3.3	2.7	0
	1959-60	0	49-110	46-85	49-86	48-106	55-97	55-97	6,70-107	0
	1960-61	0.5	23.9	14.0	14.9	31.8	8.4	8.4	9.5	0
		87-104	49-116	40-122	50-116	55-110	59-111	59-111	6-24, 63-109	0
		3.8	264.3	40.6	7.5	14.2	4.0	4.0	8.4	0
		20-64	45-138	40-115	52-109	54-113	52-116	52-116	5,73-109	0
<u>Etropus</u> <u>microstomus</u>	1958-59	-	0	0	0	0.8	0	0	0	0
	1959-60	0	0	0	0	36-62	0	0	0	0
	1960-61	0	0	0	0.6	0.5	1.1	1.1	0	0
		0	44	0	36-55	41-50	36-56	36-56	0	0
		0	0	0.1	0	1.8	6.9	6.9	0	0
		0	0	57	0	37-63	32-98	32-98	0	0
<u>Paralichthys</u> <u>dentatus</u>	1958-59	-	0.3	6.0	10.8	17.0	0	0	0	0
	1959-60	0	16	16-20	14-20	11-19	0	0	0	0
	1960-61	3.0	15.9	9.4	21.7	3.4	4.0	4.0	0	0
		10-14	11-18	12-18	12-17	12-16	11-16	11-16	0	0
		0	5.8	5.2	0	0	0	0	0	0
		0	11	13-20	0	0	0	0	0	0

Species	Sampling series	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<u>Scophthalmus</u> <u>aquosus</u>	1958-59	-	-	0	0.3	0.3	3.4	0.5	5.0
	1959-60	0	0	0	4	48	<u>12-82</u>	<u>54-66</u>	<u>4-7</u>
	1960-61	0	<u>1.1</u>	2.0	2.5	3.2	2.5	7.6	7.2
<u>Pseudopleuronectes</u> <u>americanus</u>	1958-59	0	8-12,35	8-16,40,45	8-16,37,64	6,22-65	<u>15-77</u>	<u>27-64,207</u>	<u>4-12,65</u>
	1959-60	0	0.4	0.2	0	0.4	3.9	19.3	0.2
	1960-61	7	<u>7-21</u>	<u>7-38</u>	0	<u>26-38</u>	<u>31-47</u>	<u>27-75,174</u>	<u>54-70</u>
<u>Symphurus</u> <u>plagiusa</u>	1958-59	-	-	0	0	0	0	1.8	0.3
	1959-60	0	0	0	0	0	0	4-8	6
	1960-61	0	0.2	0	0	0	0	6.8	292.3
<u>Sphoeroides</u> <u>maculatus</u>	1958-59	0	<u>236-314</u>	0	0	0	296.9	4-9	5-18
	1959-60	0	0	0	0	0	3-10	77.0	19.2
	1960-61	0	0	0	0	0	0	<u>4-14</u>	<u>6-18</u>
<u>Symphurus</u> <u>plagiusa</u>	1958-59	-	-	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0.1	0	0	0	0	0
<u>Sphoeroides</u> <u>maculatus</u>	1958-59	-	21	0	0	0	0	0	0
	1959-60	0	0	0	0	0	0	0	0
	1960-61	0	0	0	0	0	0	0	0
<u>Sphoeroides</u> <u>maculatus</u>	1958-59	-	-	0	0	0	0	0	1.3
	1959-60	0	0.1	0	0	0	0	0	<u>94-193</u>
	1960-61	0	<u>15</u>	0	0	0	0	0	<u>0.7</u>
<u>Sphoeroides</u> <u>maculatus</u>	1958-59	0	0.1	0	0	0	0	0	<u>142-265</u>
	1959-60	0	0	0	0	0	0	0	29.1
	1960-61	0	6	0	0	0	0	0	<u>90-300</u>

ANALYSIS OF A NURSERY GROUND

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ABSTRACT

The present paper examines two environments, one of high salinity and the other of low salinity, believed to be typical of many comparable areas reputed to be important nursery grounds in the middle Atlantic coastal region. In this study, only the low salinity area proved to serve a nursery role for a variety of coastal species.

Each of the two environmental types is evaluated in terms of three broad criteria the author feels must be met if an area is to serve a significant nursery role. These criteria are:

1. The area must be physiologically suitable in terms of chemical and physical features;
2. It must provide an abundant, suitable food supply with a minimum of competition at critical trophic levels; and
3. It must in some way provide a degree of protection from predation.

It is believed that both areas meet satisfactorily the first two criteria but that they differ significantly with respect to the third.

The York-Pamunkey River nursery ground has a resident fish fauna in which the biomass is dominated by three brackish water species, the hogchoker, Trinectes maculatus, the white perch, Morone americanus, and the white catfish, Ictalurus catus. The concentration of such a large percentage of the biomass in a few units may be significant in leaving niches vacant to be occupied by the juveniles

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of a variety of species. While this latter point is certainly speculative, it is almost certainly significant that none of these major resident species is to any degree piscivorous. The adult piscivorous coastal fishes are largely excluded by the low salinity.

The high salinity area of Virginia's Eastern Shore, on the contrary, has a diverse summer fauna of subadult and adult fishes that are highly piscivorous. Thus, this area is better characterized as a feeding area for adults than as a nursery ground and fails to meet the criterion of providing protection from predation.

This author derived these comments from research supported in part by the Bureau of Commercial Fisheries under the provisions of the Commercial Fisheries Research and Development Act, Project 3-19-R.

DISCUSSION

Herke asked if Joseph conducted his study in open waters rather than marsh area. Joseph answered that both of his study areas have extensive marsh development, but he conducted his work primarily in the open water channels. He noted that the marsh in one area was of a high salinity while the other was of brackish water.

Herke then asked about the comparative productivity of the marsh sections and the open water sections.

Joseph replied that one expects a slightly higher productivity within the marshes, but he cannot substantiate this with actual findings. In the sample area of lower salinity, which is easier to delimit because of its greater length, the highest productivity of zooplankters and the highest biomass of fishes occurred at the general point in rivers where there was the greatest amount of associated marsh development.

Brown cited a situation in the classification of estuarine areas in which problems arise when describing passage of young shrimp through a nursery. Particular model sizes occur at particular points along the estuary throughout the growing season. Smaller shrimp can be recruited from upstream but they move toward the inlet and then to the sea as they grow. Estimation of size and frequency at particular points along their path is, therefore, essentially static during the entire season unless there is a major disturbance like a hurricane. However, there can be a 20-mm difference in size between comparable points in weighing nurseries. In Pamlico Sound, where the salinity is almost uniform, there is a small amount of indiscriminate movement but the movement is again toward the saltwater.

Frisbie commented that in studies of Georgia marshes, shrimp movement back and forth was associated with tidal currents and, to a certain extent, with phases of the moon.

Brown described a shrimp tagging study, marking 30,000 shrimp. Only four shrimp were found upstream from the small bay area of their release. They moved down the Cape Fear River, in which there is a large amount of tidal current, rather than the Pamlico and other similar areas of less current. Brown, therefore, associated the upstream movement with the tidal current.

Joseph pointed out that the migrations of coastal fishes to low salinity nursery grounds may be related to a physiological need of the animal. This should be investigated before questioning the necessity or usefulness of a marsh.

Lunz then commented that postlarval shrimp, stopped in the high salinity area (26‰) and held in experimental ponds, continue to grow; their growth rates are directly proportional to the temperature and salinity. Lunz suggested that this occurrence may be due to something in the ponds which replaces the shrimp's migration to freshwater and return. Joseph agreed that growth is not related to the mechanical transport of the fish. He then said that the absence of predators may instigate the travel to low salinity waters. Whatever the cause, the pattern is widespread.

Cronin asked if all juveniles travel to low salinity areas or if they are found there because of random distribution. Joseph answered that the entire population moves into an area where the salinity is lower than the region in which spawning occurred; but not all move to the area of lowest salinity. He did work which led him to believe that juvenile croakers, at least, grow faster in low salinity waters.

Hettler said he had experimented with menhaden which grew from the metamorphosis stage to the juvenile stage in highly saline water.

Clark said fish distribute according to species and sometimes, when they migrate to freshwater, must make physiological adaptations in order to survive.

Joseph agreed that salinity is secondary, e.g., the lack of it can provide protection from predators by exclusion of them.

Graham substantiated this by pointing out variations in distribution of larval herring. Some are spawned and develop on Georges Bank in the Gulf of Maine; others which are spawned in the autumn move immediately into estuaries where they can undergo most of their development, and still others are spawned in the spring and do not enter the estuaries until prior to or soon after larval metamorphosis.

Herke described a paper in the Proceedings of the Gulf and Caribbean Fisheries Institute² which reports the occurrence of several species of fish in bays around Caracas where the salinity is 35-38‰, although these species are normally classified as estuarine fish. These species presumably occur in low salinity waters because they tolerate, rather than need, low salinity. Herke added that this paper identified dissolved organic matter as the attraction for the fish.

White said that the larvae of spot, croaker, and pinfish are available around the wharves at Pivers Island (near Beaufort, North Carolina) during the winter. They are abundant along the shore at times, although they are not found further out. Lunz suggested that this varying distribution may be related to temperature.

²Kristensen, I. 1964. Hypersaline bays as an environment of young fish. Proc. Gulf Caribb. Fish. Inst., 16th Annu. Sess., p. 139-142.

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ABSTRACT

Morone saxatilis, the striped bass, has no external features by which one can distinguish males from females; only when the adult fish are running ripe are there differences in body shape. Sex determination, therefore, usually depends on gonad examination by histological techniques, autopsy, or biopsy. The first method is time-consuming and the latter two fail in juvenile fish. Also, the young striped bass goes through a period of sex indifference before its gonads differentiate into ovaries or testes. The aims of our work were to determine: (1) at what size and age the gonads of the striped bass differentiate, and (2) a fast, yet accurate, method of determining the sex of the juveniles.

Examination with the naked eye of the gonads of juvenile fish yields no differences between indifferent, male, and female gonads. When the gonad is placed under a dissecting microscope, a very subtle difference can be seen between ovaries and testes. The surface of the ovary shows a faint granularity, while the surface of the testis is smooth. In the most recent differentiated gonads, however, these differences are extremely difficult to detect. More accurate is the examination of smears of juvenile gonads. Smears without stain give nearly as good resolution as those treated with methylene blue. The smear of the ovary shows a prominent granularity, each rather large granule representing an egg follicle. The testis has a much finer granularity. The smear of the indifferent gonad is very smooth and structureless and is not easily distinguished from that of an immature testis.

We prepared and examined microscopically histological sections of the gonads of 65 striped bass ranging in fork length (FL) from 7.8 to 22.5 cm to determine sex differentiation. We found initial differentiation of the gonads to occur in fish between 13 and 15 cm (FL). From the results of scale and

length-frequency studies, we conclude that the gonads differentiate sometime between winter of the first year and summer of the second year of growth. There appears to be no difference between males and females as to size or age at which gonadal differentiation occurs. Therefore, in fish greater than 15 cm (FL), or more than 1 year old, it is very likely that gonad differentiation has occurred, and examination of smears of gonadal tissue is a fast and accurate method of sex determination.

DISCUSSION

Moe asked if Miss Shubart worked with stains other than methylene blue and if she fixed the fish before making smears of them.

Miss Shubart said she fixed the fish, had tried other stains but they made little difference. She made histological sections from one gonad, identified it as male or female, and then made a smear of the second gonad.

Clark questioned the occurrence of hermaphroditism. Miss Shubart answered affirmatively, but said the occurrence was infrequent. She commented that one fish examined had a female gonad on one side and a male gonad on the other.

GROWTH OF JUVENILE STRIPED BASS, MORONE SAXATILIS,
AS DETERMINED BY TAGGING AND RECAPTURE

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ABSTRACT

Much of our present knowledge on the growth of striped bass (Morone saxatilis) has been obtained by indirect methods, such as length-frequency studies and scale-back calculations. This paper presents findings on monthly growth rates based on tagging experiments.

We conducted one experiment in a laboratory aquarium where we reared both tagged and nontagged juvenile striped bass in their second year of life, averaging 176 mm fork length (FL), from September to June. By continuously recording water temperature and measuring and scale sampling fish at approximately monthly intervals, calculated monthly growth rates were: October, 8.8%; November, 3.8%; December through April, 0%; May, 4.6%; and June, 9.1%; we lacked data for July, August, and September. From September to June, the striped bass grew from a mean length of 176 mm to 227 mm, a gain of 29%. This growth related to water temperature. When temperature dropped below about 10.0°C, fish stopped feeding and growth stopped. Growth rate reached a maximum when water temperature rose above 20.0°C.

Field tagging experiments were conducted in Patuxent River and upper Chesapeake Bay from 1966 to June 1968. Most of the striped bass tagged belonged to the 1966 year-class. We analyzed for growth a total of 395 recaptures which provided valid length information. All tagged bass at large during the months of November through April showed virtually no gain in length. For the other months, because the number of recaptures is small, it is not possible to calculate precise monthly growth rates. Data indicate, however, that the most rapid growth occurred in July, followed by August, June, September, May, and October.

From length-frequencies of striped bass of the same year-class which were sampled in 2 consecutive years, we estimate that juvenile striped bass gain a total of 74% in length from their first summer to their second summer of life. Based on our experiment, about 30% of the growth occurs during the months of May, June, October, and November. Since no increase in length occurs in the period from December through April, we estimate about 44% gain in length occurs in the months of July, August, and September.

DISCUSSION

Koo described difficulties in use of his three-dimensional graph. Details are masked when presenting the vertical column as percentage of growth, because the percentages change with the length of the fish.

Clark encouraged Koo to compare differential growth of young fish from Chesapeake with those from New England. Koo already recognized differences coinciding with variations in water temperatures. However, some other differences could be attributed to calculation methods and to the growth rates of fish from different areas.

MOVEMENTS OF JUVENILE STRIPED BASS IN THE ESTUARY
AS DETERMINED BY TAGGING AND RECAPTURE

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ABSTRACT

Beginning in July 1966 and nearly monthly for 9 months following, we applied a total of 3,102 green Carlin tags to juvenile striped bass in the Patuxent River, Maryland. From June 1967 to May 1968, we applied 4,404 tags in the upper Chesapeake Bay. The tagged fish consisted primarily of the 1966 year-class. By May 1968, we recovered 664 fish (21.4%) from the Patuxent tagging and 401 fish (9.1%) from the upper bay tagging.

Patuxent tagging results can be summed up according to two major release sites. The first site was at the mouth of the river, where we tagged and released juvenile bass of hatch-of-the-year during July to October. All recaptures made in the same summer occurred in the same general area, indicating that these fish stayed in the shoal area for the entire summer. After October, however, these fish disappeared from the tagging site. No recaptures were made upriver to date, but three recaptures were made 5 to 16 months later from upper Chesapeake Bay about 50 or more miles away.

The second release site was some 17 to 33 miles upriver. Here we tagged and released bass, mostly of the same year-class as above, in fall and winter. Recapture patterns indicated that within the same seasons juvenile bass moved up and down the same section of river, with some indication of a net upriver movement, extending into virtually freshwater areas as the season progressed.

However, starting with the following summer and thereafter, recaptures have been made in the river, downriver, and out in upper bay, indicating a definite out-of-river migration. Recaptures also took place at the original release sites in the river after a time lapse of more than a year. It is not possible to say whether these fish stayed in the river all this time or moved out of the river and returned.

Upper bay tagging, started in June 1967, also involved mainly 1966 year-class of fish. Most of the recaptures to date were confined to the same general area of release; they became more widespread toward fall and winter and some fish were recaptured during winter in the freshwater areas at the extreme upper reaches near the Maryland entrance of the Chesapeake and Delaware Canal. Five recaptures have been made in lower Delaware Bay, indicating a definite through-the-canal movement by these young striped bass.

DISCUSSION

Frisbie asked if Ritchie recovered his fish with commercial gear or by some other method.

Ritchie answered that some of the sublegal size fish came from the commercial fishery, because the tags made them more vulnerable to capture, while others were recaptured with a beach seine. For several days, the fish stayed where they were tagged, especially off Drum Point. During October, there were 123 recaptures after 5 days of freedom; however, recaptures declined in November and none occurred in December. In Brambles Inlet, near Tolchester Beach, where there is freshwater runoff from a pond which seems to attract the fish, 50 to 100 could be caught daily, although they were not recaptures. The tagged fish must have moved further south. Koo added that sport fishermen recaptured many fish which had been at liberty for over a month, near the river mouth and the head of the bay.

Moe asked if Ritchie experimented with other types of tags, specifically the small internal type. He also questioned possible injury to the fish from the tag, and wanted to know the longest period between tagging and recapture of a fish carrying this tag.

Ritchie answered that he tested single bar and double bar tags and Eipper's type, but with poor results -- fish died and the tags moved. On the other hand, there were no losses when using the Carlin tag for a 9-month test period in the aquarium tank. In answer to Moe's second question, Ritchie replied that 50% of the tags have been returned still attached to the fish. There have been no bad or necrotic fish, and the tag wounds have usually healed, unlike bass tagged with nylon streamers. These tags stay on for several years. The maximum liberty period before recapture yet recorded is over 700 days. The tagging can be done at a rate of 50 to 100 fish per hour. In response to a question by Carlson, Ritchie added that he has successfully tagged fish of all sizes from as small as 50 mm. For the modal size of 70-78 mm, he suggested using a dorsal attachment point rather than the peduncle.

Clark asked if Ritchie had encountered trouble with air bladders of fish caught in a midwater trawl. Clark had trouble tagging stripers in 10.0 to 13.3 m (30 to 40 feet) of water in the Hudson during winter because they had difficulty sounding.

Ritchie suggested that the fish may have been shocked by the coolant effect of the ambient air temperature. Clark conjectured that the fish were perhaps in a physiologically inactive state and they could not compensate for the change in depth quickly enough by releasing pressure from their air bladders.

Ritchie said that he encountered this problem only when trawling fish from waters over 20 m (60 feet) near the Chesapeake Bay Bridge. He released swim bladder pressure by puncturing but none of the fish have been recaptured. Ritchie described a situation in which he tagged 32 fish showing signs of inflated bladders and had one fish returned after 111 days. He also recalled Nichols and Miller¹ had similar occurrences during Chesapeake tagging.

¹Nichols, P. R. and R. V. Miller. 1967. Seasonal movements of striped bass, Roccus saxatilis (Walbaum), tagged and released in the Potomac River, Maryland, 1959-61. Chesapeake Sci. 8: 102-124.

LIFE HISTORY ASPECTS OF THE HOGCHOKER, TRINECTES MACULATUS,
IN THE PATUXENT RIVER ESTUARY, MARYLAND¹

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ABSTRACT

This paper presents information on the abundance and distribution of life history stages of the hogchoker in the Patuxent River, Maryland. Egg collections indicate that the spawning area is located in the lower river in waters having salinities greater than 9.0‰. After hatching, the larvae move upstream and congregate in a low salinity nursery area close to the salt/freshwater interface where they remain during winter. During the first 4 years of life, maturing hogchokers follow two distinct movements: upstream toward the nursery area in fall, and downstream toward the spawning area in spring. As these fish mature, they increase their range of travel away from the nursery ground. We determined movements of fish following hatching by monitoring the large 1963 year-class, identified by using the polymodal length-frequency technique; and verified movements by regression analyses.

Brief comments are made in relation to protecting the integrity of the entire estuary for completion of some life history cycles.

DISCUSSION

Massmann asked about the abundance of hogchoker in relation to other fishes. In Virginia, this species is one of the most abundant of all fish, yet is disregarded by predators. Dovel knew of no functional role of the hogchoker.

¹This paper was published in Chesapeake Science, Vol. 10, No. 2, pp. 104-119. June 1969.

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According to the distribution of eggs shown on Dovel's graphs, Joseph thought that Dovel sampled on the fringe of the spawning range in the lower Patuxent. Dovel replied that he had more information than was indicated. One year he sampled from Hooper Island, halfway up Chesapeake Bay, to the end of the bay and into the Patuxent River. In reference to high salinities, the density of fish was greater in the 10 to 15‰ salinity area of the river, which ranged to 24‰ in some parts.

Joseph noted that he found the greatest concentration of eggs in the lower Chesapeake Bay during August. The water temperatures were the same as those in the upper bay, where Dovel found the greatest densities in July. Since the light conditions are the same for the two locations, water temperature may cause the lag of a month.

In answer to a question from Koo, Joseph explained that his sampling further south is at the mouth of the bay. Incoming ocean waters keep the temperatures lower than those of the shallow waters further north.

Carlson asked Dovel if thermal effluents of power plants alter the behavior and growth rate of young fish in estuaries. Dovel replied that he plans to gather more information and design a plan for study of the Chesapeake, but he is not yet prepared to answer this question.

Davis said that his major group of hogchokers ranged from 1 to 3 years in age and estimated 3 and 4 year olds to average about 120 mm in length. Dovel reiterated that the Patuxent fish were placed in different year-classes according to length-frequency aided by using the 1963 year-class mode.

Cronin stressed the importance of knowing all stages of energy flow in estuaries. For instance, it is known that ctenophores eat zooplankton, as does Chrysaora, the sea nettle; but the next step in the flow of energy is unknown. The same thing is true for hogchokers. A problem in estuarine biology is to determine what happens to bound energy in the upper trophic levels.

Joseph commented that hogchokers comprise 36% of the total fish biomass in the low salinity nursery ground of Virginia. Although this fish is susceptible to capture, it is unavailable to trawls for part of the year, including both off seasons, and thus ties up considerable biomass.

LARVAL AND JUVENILE FISH RESEARCHES AT THE
FLORIDA BOARD OF CONSERVATION MARINE LABORATORY

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ABSTRACT

Research efforts at the Marine Laboratory are concentrated on study of reproduction, early development, and distribution of indigenous species. Advances have been made in the identification and description of: leptocephali, scombrids, pomadasyids, lutjanids, and serranids. Species of sciaenids, gerreids, and blenniids have been raised to juvenile stages from wild plankton in special temperature-controlled tanks.

INTRODUCTION

The Marine Laboratory, under the leadership of Robert M. Ingle, Director of Research, has long realized the importance of research on larval and juvenile forms. An understanding of the early life stages is indispensable in developing an adequate knowledge of our important marine animals. Consequently, our research with specific organisms has emphasized reproduction and early development, and all collections of plankton and juveniles have been carefully preserved and maintained for that time when personnel and funds would be available. Strong initial efforts at this research have begun, and this material is now being utilized. The purpose of this presentation is to provide a brief account of the collections available at the Marine Laboratory and the projects currently underway. Interested individuals are encouraged to write to the Marine Laboratory for more information.

PLANKTON COLLECTIONS: PAST AND PRESENT

The following listing of plankton collections includes material from projects with completed fieldwork and from projects currently in the stage of active collecting. Most of the collections have been sorted for larval fishes, which are maintained separately in 3-5% buffered formalin. These collections are listed geographically, beginning with the northeast coast and extending around to the west coast.

1. A series (1962-63) of monthly collections from inshore waters of northeast Florida and the offshore waters of St. Augustine.
2. A 2-year series (1963-65) of monthly, bimonthly, and daily collections from the St. Lucie Inlet and Jupiter Inlet areas. A listing of these collections has been published.
3. Collections currently being taken in the waters of the Florida Current between the east coast of Florida and the Bahamas.
4. A 2-year series (1962-64) of bimonthly collections taken from inshore areas along the expanse of the Florida Keys. A published listing is available. Many incidental collections have been made in this area, and a current sampling regime includes 15 samples per month at three bridge stations and one offshore station.
5. A 1-year series (1962-63) of monthly collections taken in the Yucatan and Florida Straits areas. A listing of these collections has been published.
6. A series of collections spaced 6 to 10 weeks apart currently being taken in the Yucatan Straits area. These plankton collections will supplement those of the previous project. Whenever possible, night-light and nekton net collections are also taken. Collections from the Dry Tortugas area and from several stations between Fort Myers and Dry Tortugas are also made during these trips.
7. A 2-year series (1961-63) of monthly collections from inshore and offshore stations in the Tampa Bay area. A listing of these collections has been published.
8. A series of 28 monthly collections at five specific stations at 6.6 m (20 ft), 10, 20, 30, and 40 fathoms due west of St. Petersburg, and at five analogous stations due west of Sanibel Island, taken from August 1965 to November 1967. These collections have been sorted for larval fish.

Many additional plankton collections taken from various Florida waters are stored at the Marine Laboratory, but these cannot be detailed here, since they are not part of a systematic sampling program.

CURRENT RESEARCH PROJECTS AT THE TIME OF THE WORKSHOP

1. Identification and description of leptocephalid larval forms in the Marine Laboratory collections. This is the oldest larval fish project at the laboratory and has produced a number of publications to date. These are listed under references. Bonnie Eldred is the project leader.
2. Identification and description of the larval stages of Scomberomorus. Work is well underway on this project and larval forms of S. maculatus and S. cavalla have been provisionally identified. A developmental series of larval Atlantic wahoo, Acanthocybium solanderi, has been identified and separated. Michael Wollam is the project leader.
3. Identification and description of larval pomadasyids, lutjanids, and serranids from the Tampa Bay area. This project is in the initial stages of development. The material has been sorted and preliminary identifications are in progress. Robert Presley is the project leader.
4. Hatching and rearing of fish eggs and larvae from wild plankton. Constant temperature apparatus for maintaining larval fishes and eggs in circular tanks has been designed and constructed and several species have been reared from the early larval form to the juvenile stage. Bairdiella chrysur, Eucinostomus gula, and Hypsoblennius hentzi have been reared from pelagic larvae to juveniles. Frank Hoff, Jr., is the project leader.

REMARKS

Plankton samples are generally taken with 1-m and 0.5-m-diameter nets of various mesh sizes. Large nets with small mesh netting are used in offshore areas. Specific gear descriptions for each sampling program are available in publications resulting from these projects. The most effective method of sampling for larval fishes is the technique of night-lighting, which occasionally results in exceptional catches.

Offshore sampling for larval forms is important to research on estuarine fishes, since many inshore and nearshore species must migrate to deeper offshore waters to spawn and then depend on favorable currents and good environmental conditions for inshore movement and survival of the year-class. Spawning grounds and nursery areas for many valuable fishes have yet to be delimited and only offshore sampling will provide the necessary data. The stocks of certain areas may be dependent on the spawning success of populations in other areas. For example, the relationship of Caribbean, Gulf of Mexico, and Atlantic populations of mackerel is unknown at this time. Sampling for larval fish and other research techniques will provide basic information on these populations.

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DISCUSSION

Joseph mentioned the problem of the volume of collections along the Atlantic coast. He directed his concern toward the wasted material that is collected and never examined because the number of biologists working on the collections is small in relation to the volume of material on hand.

Moe discussed another aspect of this same problem, in which an individual working on a particular species makes collections to obtain samples, although unsorted collections contain what he needs.

De Sylva asked what net equipment the Florida Board of Conservation used. Wollam described the apparatus: a 4-m-long nekton net with a 1-m opening. The net is towed on the surface at 4 to 5 knots velocity. Although leptocephalus larvae are damaged in the cod end, the large netting allows juveniles to be caught undamaged.

Hettler asked if anyone from the Board of Conservation studied the Indian River estuary in Florida. Witham mentioned larval fish collections, taken incidental to studies on plant phosphorus, including plankton samples from the Indian River and the St. Lucie Inlet. However, hard rain and the resulting discharge of vast amounts of freshwater from the flood control structures lowered the salinity to such an extent that it apparently killed both postlarval and juvenile stages of spiny lobster. There may have been a similar effect on fishes in these waters.

Moe pointed out that the collections from the Indian River have not been sorted except as they have been picked over for particular species by interested people. Herke suggested the Entomological Research Center as a possible source of information.

Hettler then explained that he asked his question because a large body of menhaden spawns in the Indian River. This estuary is atypical because of a limited amount of freshwater draining into the northern part of the river. Because young menhaden usually seek low salinity areas, the fate of the resulting eggs and larvae could be a topic meriting special study.

FOOD AND FEEDING HABITS OF ATLANTIC MENHADEN IN
RELATION TO METAMORPHOSIS OF LARVAE INTO JUVENILES¹

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ABSTRACT

We studied the food of young Atlantic menhaden (Brevoortia tyrannus) primarily to determine the kinds of organisms required for rearing this species in captivity. Food of larvae consisted of zooplankton (chiefly copepods), but shifted to phytoplankton during and following metamorphosis into juveniles. Close correspondence appeared between the alimentary tract contents of the fish and the composition of the plankton community. Changes in feeding habits during metamorphosis were associated with gross changes in the alimentary tract and related structures. Laboratory studies disclosed that larval feeding behavior, digestion rate, and responses to capture and preservation probably contributed to the high incidence of empty alimentary tracts and the low numbers of organisms per tract.

¹Published as "Food of young Atlantic menhaden, Brevoortia tyrannus, in relation to metamorphosis." 1971. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Fish. Bull. 68: 493-512.

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DISCUSSION

Carlson asked if anyone present used rose bengal dye as an aid in the sorting of fish egg and larvae collections and if they had encountered difficulties in terms of identifying specific larvae. A Hudson River survey group uses this dye to aid separation of striped bass and white perch eggs and larvae from collections. Rose bengal dye has been mentioned in California publications and on this coast Walter Murawski (New Jersey) has experience with it. It appears to be specifically useful for separating eggs and larvae viewed over a light background. The dye is introduced into the formalin used as a field fixative.

Cronin pointed out another use of the dye, described by Kromfied in Copenhagen. Live phytoplankton takes up more dye than dead phytoplankton when fixed in formalin with a small amount of rose bengal; this can be a useful technique for evaluation of the effects of power plants on phytoplankton mortality.

Berry raised the problem of the effects of rose bengal dye on melanophores of embryos and small larval forms and also wanted to know whether the dye could be removed once it had been introduced into the sample. No information on the first question was available and Cronin volunteered a negative answer to the second.

Sweat added that he used this dye on Florida samples, but stopped doing so pending some evaluation of its effects on melanin.

Lewis asked if adult menhaden accepted zooplankton, such as Artemia, as food. Carlson replied that this food is taken by adults but the capacity to take small organisms increased during metamorphosis. He commented that Artemia alone do not fulfill the nutritional requirements however. Hettler noted that he fed menhaden from 20 mm to adult size a diet of granulated chopped food.

Joseph asked if pigment extraction could be used in examination of amorphous material for gut analyses. Carlson imagined it to be reasonable although he had never tried the method.

DISTRIBUTION STUDIES

Chairman

Ernest Mitts

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ABSTRACT

A 1-year study of the seasonal occurrence of eggs and larvae of fishes in the Weweantic River estuary entering Buzzards Bay, Massachusetts, was conducted from January 1966 through December 1966 as a phase of a longer term program on the ecology of fishes in this system. The estuary is 7.5 km long and was sampled monthly at six stations using a 0.5-m net for surface tows and a bottom macroplankton sampler for bottom hauls. Salinity and temperature data were collected concurrently. A detailed sediment analysis was also carried out on the river as well as gill netting, beach seining, and otter trawling at selected stations for juveniles and adults. Fifty-two species of fishes either in the egg, larval, juvenile, or adult stages, or in combinations thereof, have been collected in the estuary of the river since the larger project's inception in December 1964. Fish eggs and larvae of 28 species have been identified from samples collected during the study year. The sampling program is continuing with weekly sampling during the spring and summer, vice the monthly sampling of the first year's study.

The seasonal cycle of eggs, larvae, and juveniles during 1966 was similar to other studies in Connecticut and Rhode Island estuaries; numbers and variety gradually increased in the spring to a peak in abundance in summer followed by a decline in fall and winter. Two notable peaks of egg and larval abundance occurred; one during March was composed primarily of rainbow smelt, winter flounder, and tomcod, and a second one in June, primarily of cunner and tautog.

¹Supported by: Massachusetts Water Resources Research Center Grant WR-2 and Massachusetts Cooperative Fishery Unit

²This paper was presented at the workshop by C. F. Cole.

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SPAWNING SITES AND NURSERIES OF FISHES
OF THE GENUS ALOSA IN VIRGINIA

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ABSTRACT

The paper presented is a progress report covering the first year of a project designed to extend 5 years or more and conducted under provisions of the Anadromous Fish Act (P.L. 89-304) through the Bureau of Commercial Fisheries (Project No. Virginia AFC-1). Objectives that are germane to this conference are:

1. Geographical delimitation of spawning sites and nurseries of Alosa aestivalis, blueback; A. pseudoharengus, alewife; A. sapidissima, American shad; and A. mediocris, hickory shad.
2. Description of communities, chemical and physical features of spawning sites and nurseries.
3. Determination of criteria for successful spawning and growing.

The four species spawn in fresh tidal waters. The alewife and blueback spawn both in the mainstream and in small tributary streams, while American shad spawns primarily in the mainstream. The major spawning of hickory shad appears to be in the mainstream at the fall line, but some may spawn further downstream and in tributaries.

Juveniles remain in freshwater until the temperature drops in October and November. The juveniles move further downstream as fall progresses. Most American shad leave the estuaries in early fall. Alewife remain well into fall, and some blueback herring remain through winter. Some young of the three species overwinter in lower Chesapeake Bay. Additional work is needed on determining the departure time of juveniles.

DISCUSSION

Turner asked if blueback and alewife stay in the estuaries until winter. Davis answered affirmatively and said that some blueback may remain throughout the winter as school fish.

Massmann asked if the juveniles left the estuary or the nursery area in the fall. Davis answered that some juveniles were found in the ocean in the early fall, although by spring some blueback were still in the lower reaches of the river and in the bay, citing the catch of two blueback at Fredericksburg in March as an example.

Brown added that he found herring during the summer at the lower sections of the rivers. They were absent in sounds other than Albemarle, which is mostly freshwater, where apparently schools of blueback and alewife occurred in summer. Movement out of, or through, the sounds probably occurs after the shrimp trawling season is over, from Christmas through February.

White commented that there is a sport fishery for adult shad off the ocean piers in Virginia. Brown substantiated this remark, citing the catch of 200 adult shad off one of the ocean piers in April.

Alperin noted the catch of juvenile and adult hickory shad in a surf zone of Long Island from April to November. Schaefer published this information in the New York Fish and Game Journal¹.

¹R. H. Schaefer. 1967. Species composition, size and seasonal abundance of fish in the surf waters of Long Island. N. Y. Fish Game J. 14: 1-46.

OCCURRENCE AND ABUNDANCE OF LARVAL ATLANTIC MENHADEN,
BREVOORTIA TYRANNUS, AT TWO NORTH CAROLINA INLETS
AND A LIST OF ASSOCIATED SPECIES¹

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ABSTRACT

A comparison was made of the relative abundance of Atlantic menhaden larvae entering Beaufort and Bogue Inlets in Onslow Bay, North Carolina. Two years of study at Beaufort Inlet, 1966-67 and 1967-68, and a 1-year study at Bogue Inlet showed that larvae entered the inlet from November to April and were abundant in March. Examination of larvae showed condition factors (weight/length³) changed with time and increased as larvae drifted back and forth with the ebbing and flooding currents and fed on plankton. The larger larvae left the lower estuary and moved upstream. A list is given of the other species collected with the menhaden.

Atlantic menhaden spawn off the North Carolina coast of the United States during the winter and early spring (Higham and Nicholson, 1964). The eggs hatch in 2 days and the larvae are probably carried by currents from the spawning site to an ocean inlet. Our purpose was to determine the relative abundance of larvae entering Beaufort and Bogue Inlets in Onslow Bay, North Carolina. We recorded larval indices (number of larvae per 100 m³ of water) for use in expressing relative abundance between years and locations and for comparing the abundance of larvae with that of juveniles later in the same year in the nursery area upstream. Abundance indices for juvenile fish are used to predict year-class strength.

¹An expanded version of this paper appeared in Transactions of the American Fisheries Society, Vol. 100, No. 2, pp. 296-301.

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During our regular sampling seasons (November to April), we used a channel net (Lewis et al.) at a bridge inside of Beaufort Inlet (1966-67 and 1967-68) and at a bridge inside of Bogue Inlet near Swansboro, North Carolina (1967-68). The net, which was fished for 30 minutes, had a 1-m by 3-m opening and a current meter attached at the mouth. At Beaufort, two to four collections were made each day, while at Bogue four to six collections were made two or three times per week.

Atlantic menhaden larvae entered Beaufort Inlet from November through April (Table 1). In 1966-67, a minor peak of abundance appeared in late November, but the main influx of larvae was during March. During 1967-68, abundance was considerably less than 1966-67; no pronounced abundance peak occurred. A comparison of larval abundance for the 2 years revealed that larvae were about 13 times as abundant in 1966-67 as in 1967-68.

In 1967-68, menhaden larvae at Bogue Inlet showed seasonal changes in abundance similar to those at Beaufort Inlet, although they were only about one-half as numerous as at Beaufort (Table 1).

We calculated condition factors for the larvae obtained from our 1967-68 Beaufort larval collections. The condition factor ($10,000 W/L^3$, where W = weight in mg and L = length in mm) was determined for each specimen and then the mean for each collection was calculated. We also calculated the mean for all the collections in a month. These means and their associated statistics are given in Table 2 for December through March; the samples from November and April were too small to be included.

Menhaden larvae were slender when they first entered the lower estuary. As they drifted back and forth with the ebbing and flooding currents and fed on plankton, their weight increased at a greater rate than their length. As a result, the larvae that had been in the lower estuary for a time had a higher condition factor than those that had just entered. In general, condition factor increased with increasing length.

The means of the condition factors were low in December, higher in January and February, and lower in March. The steady increase from December through February was probably due to: (1) growth of larvae already in the estuary, (2) the entry into the estuary of groups of larvae with progressively higher condition factors, or (3) little recruitment of small larvae. In March, the general decline from the previous month resulted from the entry of numbers of larvae into the lower estuary and the upstream movement of many of the larger larvae. Water temperature increased and food was abundant during this time.

The following immature fishes were collected in association with larval menhaden. The first seven species listed were the most abundant. Spot, Leiostomus xanthurus; pinfish, Lagodon rhomboides; striped anchovy, Anchoa hepsetus; bay anchovy, A. mitchilli; Atlantic croaker, Micropogon undulatus;

striped mullet, Mugil cephalus; speckled worm eel, Myrophis punctatus; ladyfish, Elops saurus; silver anchovy, Anchoviella eurystole; mummichog, Fundulus heteroclitus; hakes, Urophycis spp.; northern pipefish, Syngnathus fuscus; silver jenny, Eucinostomus gula; pigfish, Orthopristis chrysoptera; several genera of gobies, Gobiidae; searobins, Prionotus spp.; southern stargazer, Astroscopus y-graecum; striped cusk-eel, Rissola marginata; butterfish, Poronotus triacanthus; Atlantic silverside, Menidia menidia; several genera of flounders, Bothidae; and filefishes, Balistidae, in part.

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A channel net for catching larval fishes. Center for Estuarine and Menhaden Research, Beaufort, North Carolina (typewritten report), 2 p.

DISCUSSION

In response to Graham's questions of local conditions, Lewis said the channel at Beaufort is 7 miles long; the tide is not mixed but the currents are 2 to 3 knots. He noted there were day-night differences in catch.

Carlson commented on the problem of defining variability, specifically that which occurs diurnally throughout the season within sampling areas. In sampling for fish eggs and larvae over an extended area in the Hudson River, data obtained on a 24-hour basis showed no relation to data obtained during day and night sampling. Carlson commented that spatial and temporal variation limits must be known to compare areas, and recommended a 24-hour basis of sampling to obtain adequate data.

Schwartz questioned the effect of the bridge on the currents, which in turn could affect the distribution of larvae. He asked if the water flow around the bridge caused eddies behind the pilings that could divert the larvae into areas other than where the net sampled. In response, Lewis said the pilings were about 7 m apart, and currents were fairly strong. When the tide slackened, larvae would often become unavailable and reappear in waters along the side of the channel. He also noted that sometimes a flooding current in the channel accompanied an ebbing current along the shores, but he had observed no larvae alongshore being swept by such currents.

Graham mentioned that the distribution of eddies within a mean flow of current is usually random. Lengthy sampling time should, therefore, yield an average estimate of the relation between larval distribution and current.

Brown asked if any cross-section or vertical sampling were conducted, especially in slower tides, to compare the inlet's vertical strata. Lewis answered that he had made some limited sampling attempts; vertical sampling at the bridge indicated little difference in larval concentration between top and bottom during the day, and larvae apparently favored slower bottom currents at night.

Table 1. Mean biweekly indices (number per 100 m³ of water) for Atlantic menhaden larvae at Beaufort Inlet, 1966-67 and 1967-68, and at Bogue Inlet in 1967-68.

Beaufort Inlet				Bogue Inlet ⁴
First day of biweekly period	Larval index	First day of biweekly period	Larval index	Larval index
Nov. 6, 1966	0.22	Nov. 6, 1967	0.08	-
Nov. 20	3.76	Nov. 19	0.01	-
Dec. 4	0.71	Dec. 3	0.02	0.08
Dec. 18	1.20	Dec. 17	1.94	0.81
Jan. 1, 1967	0.73	Dec. 31	1.01	0.25
Jan. 15	2.95	Jan. 14, 1968	1.50	0.45
Jan. 29	4.40	Jan. 28	0.85	0.14
Feb. 12	14.70	Feb. 11	2.56	1.92
Feb. 26	32.22	Feb. 25	1.71	0.73
Mar. 12	81.09	Mar. 10	3.59	3.07
Mar. 26	51.11	Mar. 24	2.48	0.89
Apr. 9	4.91	Apr. 7	0.28	0.04
Apr. 23	0.31	Apr. 21	0.05	0.15

⁴The biweekly sampling periods at Bogue Inlet were the same as at Beaufort Inlet in 1967-68, except that no samples were taken during November.

Table 2. Condition factor of Atlantic menhaden larvae collected at Beaufort Inlet in different months in 1967-68 (the mean condition factor of each sample during a month was treated as an individual observation).

Month	Number of samples ⁵	Condition Factor		
		Mean	Range	Standard deviation
December	9	23.56	18.78-30.31	4.55
January	22	28.44	25.29-34.44	2.32
February	21	31.10	24.52-39.44	4.22
March	25	24.29	17.48-34.76	4.51

⁵Most of the samples were based on 25 larvae.

REARING MENHADEN LARVAE (PART 1)

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ABSTRACT

In the late 1950's, we began laboratory studies to understand environmental effects on the survival and behavior of larvae and early juvenile menhaden. Collections of viable larvae were made by connecting a small live car, lined with plastic screening, similar to a crab float, to a conventional meter net. The apparatus, set in a flowing tidal current, had a forward partition to reduce water velocity in the area into which larvae funneled. After capture, larvae were sorted and transferred by dipping, rather than netting, to reduce handling mortality. Larvae held in black-walled containers had a mortality of less than 5%, considerably less than those held in clear glass containers. In feeding behavior studies, most field collected larvae had empty alimentary tracts. Unless MS-222 was used prior to preservation, larvae emptied out all or most of their gut contents.

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REARING MENHADEN LARVAE (PART 2)

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ABSTRACT

We have attempted to rear larval yellowfin menhaden, Brevoortia smithi, from eggs stripped from a wild, ripe female. The menhaden were reared in 150-liter fiberglass tanks; seawater was maintained at 30‰ salinity and 20.0°C temperature. Twelve hours of light were provided and each tankful of larvae was fed 3 ml of concentrated sea urchin blastulae per day. Twenty larvae (9 mm) were alive at the end of 2 weeks and one larva lived 32 days and attained a length of 14.9 mm.

Our interest in rearing menhaden larvae lies primarily in identifying environmental factors that influence the success or failure of a year-class. Year-class strength may be determined before menhaden larvae reach the estuaries. On the other hand, fluctuating annual carrying capacities of estuaries may regulate year-class size, as long as the generation of larvae exceeds a certain minimum level. Variations in the survival of young stages, presumably caused by fluctuations of environmental factors, disrupt the direct relation between spawning potential of the parent stock and recruitment. Slight changes in the mortality rate of the young stages could result in great changes in year-class strength. Some of the major factors suspected of causing mortality in the neritic larval stage are shown in Figure 1.

Research into techniques that will permit us to rear experimental stocks is an integral part of the menhaden investigations at the Beaufort Laboratory. Without this capability, many physiological-ecological studies could not be completed. In the ocean, the collection of undamaged larvae for experimental work is extremely difficult. Viable yolk-sac larvae are far less abundant in plankton collections than are the eggs. The fragile larvae apparently disintegrate and pass through the meshes of the plankton net, whereas the more resilient eggs are seldom severely damaged. Rearing also provides fish that have been subjected to known conditions; for example, temperature, salinity, photoperiod, diet, and larval density. With a history of rearing conditions, we can more accurately interpret the effects of the variable factors under study.

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Laboratory cultured larvae produced by a single female would eliminate some genetic variation assumed to be present in larvae caught at sea and would thus provide stocks to determine the amount of phenotypic variation among siblings held in identical environments. Questions about hybridization among sympatric populations of menhaden could be answered if we could rear larvae from eggs of known parents. For example, we have observed a predominance of males in the catches where hybrids are abundant. Whether this unbalanced sex ratio is real, or whether these fish segregate by sex, could be determined by rearing hybrids to a size that can be sexed. Another obvious benefit from rearing would be to assemble a complete developmental series of all menhaden species for taxonomic and anatomic studies.

The successful techniques developed for rearing menhaden could be applied to more valuable fishes in the reawakening field of aquaculture. New methods may be developed for inducing spawning in captive fish, for providing new foods in diets, and for handling the delicate larvae in an artificial environment, which could be useful in commercial fish farming.

Marine clupeids are difficult to rear from eggs. The major obstacle to successful rearing has been providing an acceptable diet at the time larvae shift from yolk nutrition to external food sources. Menhaden are particularly difficult to rear because their mouths are nonfunctional until after the yolk is absorbed. There is very little time, perhaps less than 2 days, for a menhaden larva to begin feeding on plankton after its yolk reserves are exhausted. Early attempts were unsuccessful in rearing larvae beyond the yolk-sac stage presumably because planktonic food, small enough for the 4-mm to 5-mm (TL) larvae, was not provided in sufficient concentrations to be encountered by the larvae.

Yellowfin menhaden, Brevoortia smithi, were reared from eggs to 15-mm larvae in February 1968. Eggs were stripped from a ripe female taken in a gill net fished in the Indian River near Melbourne, Florida. They were manually fertilized and shipped to the Beaufort Laboratory in plastic bags contained in insulated cartons. Each carton held 10 liters of seawater and about 500 eggs. The eggs, which began hatching upon arrival at the laboratory 48 hours later, were transferred to 150-liter fiberglass tanks. Seawater, at 30‰ salinity or higher, flowed into the tanks at about 10 liters per hour. Overflow water left through screened standpipes. Water temperature was maintained at 20.0°C with thermostatically regulated glass immersion heaters. Twelve hours of light per day was provided by a 75-watt full-spectrum fluorescent tube mounted 20 cm over each tank.

We attribute the success of the rearing experiment to feeding the larvae initially with swimming blastulae of the common sea urchin, Arbacia punctulata. The blastulae were obtained by mixing sea urchin eggs and sperm. Within 3 to 6 hours, the fertilized eggs became motile and were suitable for feeding larvae. The daily ration per 150-liter tank was 3 ml of concentrated blastulae. We also added enough unicellular flagellated algae, Platymonas, to the rearing tanks to color the water pale green. There was no evidence

of the larvae feeding on the algae, but 4 days after hatching the larvae could be seen coiling at and striking the blastulae. Figure 2 shows an 8-mm larva preparing to strike an 80- μ -diameter blastula. Individuals that succeeded in catching prey had conspicuously dark guts. From approximately 2,000 eggs, about 100 larvae survived through the fourth day after hatching. When the larvae had reached a length of about 9 mm 2 weeks after hatching, brine shrimp nauplii were added to their diet. At this point, only about 20 larvae remained. The last larva, 14.9 mm long, died 32 days after hatching. Much of the mortality of the larger larvae was blamed on embolism, as the seawater flowing into the rearing tanks was usually supersaturated with air.

Rearing larvae beyond the critical yolk-sac stage was a major step towards providing laboratory cultured experimental stocks, but several other problems still exist. The biggest problem is obtaining viable gametes from species of menhaden other than the yellowfin menhaden. We wish to rear the Atlantic menhaden next, but no running ripe females have been observed by our biologists during 15 years of sampling the commercial catch. Ideally, we would like to induce gonad maturation in adults held in our tanks so that we can strip, fertilize, and rear the eggs. Another problem is to acquire methods for culturing various foods for the larvae. As the larvae grow, a logical feeding sequence would be: (1) fertilized eggs of bivalves and echinoderms, (2) rotifers, (3) barnacle nauplii, (4) brine shrimp nauplii, and (5) large zooplankton, such as copepods. The importance of plant material in larval diets needs to be evaluated. In general, other rearing requirements need to be improved, such as providing good quality seawater, to rear menhaden successfully and satisfy our experimental needs.

DISCUSSION

Cronin commented on the Princeton symposium (fall, 1967) which dealt with the rearing of marine animals. The proceedings will be published and he stressed the importance of including a section on rearing procedures.

In answer to Clark's questions on Figure 1, Hettler asserted that his graph data were hypothetical although based on work by Shumann, Blaxter, and others. He stressed two critical periods -- the prolarva shift to postlarva and the feeding shift -- as the times of highest mortality proportional to the number of spawning menhaden.

Clark asked if the photoperiod was controlled. Hettler answered affirmatively; he used a fluorescent tube admitting fluorescent UV light with a balanced spectrum duplicating natural sunlight. This vitro-light was set on a 12-hour-on, 12-hour-off phasing but could be shifted to match the day-night cycle of the typical spawning season in a longer study of rearing.

Hettler reported that all his fish were lost at 15 mm. When he discovered that the larvae ate 300- μ nauplii, he fed them only Artemia. Since he believes this food resulted in their death, future experiments will utilize a mixed diet.

Clark asked what happened to the uneaten sea urchin eggs. Hettler said that they are motile and stay suspended in the water column for awhile, but he didn't know their ultimate fate. Kalber remarked that sea urchin eggs, if left alone, become settling sea urchin eventually. He then noted the dissatisfaction of his group with feeding Artemia nauplii to their larvae. One food supplier shifted his source of Artemia cysts to a Salt Lake City supply, and these cysts contained plant alkaloids and DDT. The larvae assimilated these products from the nauplii and the alkaloids and DDT became toxic in some stage of metamorphosis.

Kalber also mentioned algae feeding; the green flagellate, Dinellialla salina, which is apparently high in vital nutrient requirements of some invertebrates, was used in a study which took place on the west coast.

Carlson referred to Hettler's loss of his larvae at 15 mm. He cited his collection in Delaware in which the smallest larvae was 18 mm. The larvae fed on a mixed copepod population soon after their establishment in the aquarium. Carlson suggested the use of locally obtainable copepods as a temporary diet for larvae until they can be brought to accept another artificial diet. Hoff cited a similar experience in which he lost larvae around 15 mm and transferred 50 of the survivors to another aquarium. He considered a change in the diet at this stage dangerous because of the low resistance of the larvae, but one survived on the new diet of Caprella.

Koo asked if Hettler maintained the salinity or changed it as the larvae grew. Hettler considered salinity to be of little importance. He used ambient salinity, which was about 30‰, coming in from the Beaufort Channel. He had reared larvae from 15 mm to young adults in this high salinity on other diets.

Figure 1. Generalized flow of the major environmental factors causing mortality among menhaden larvae in the ocean.

MAJOR ENVIRONMENTAL FACTORS CAUSING MORTALITY

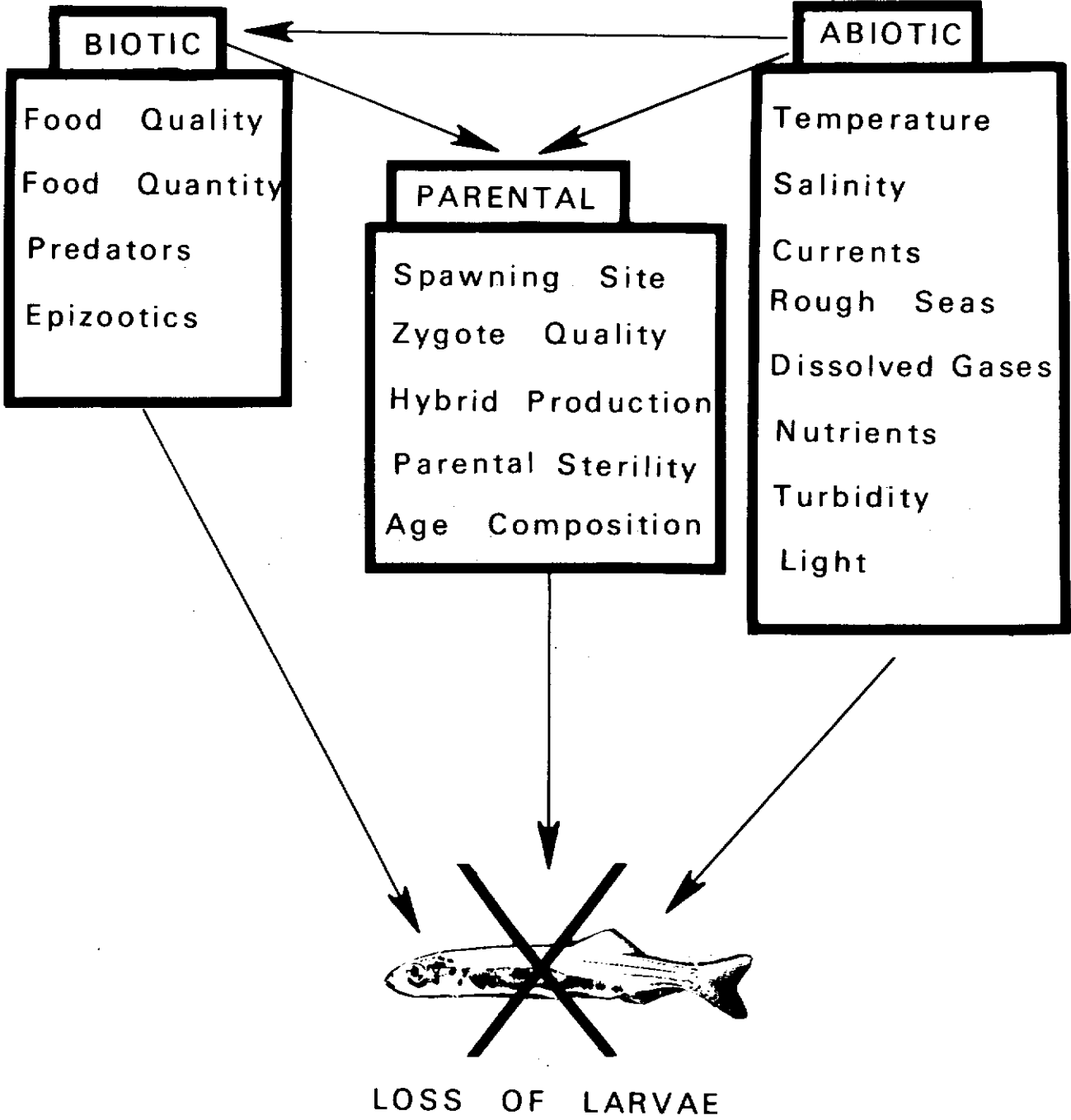
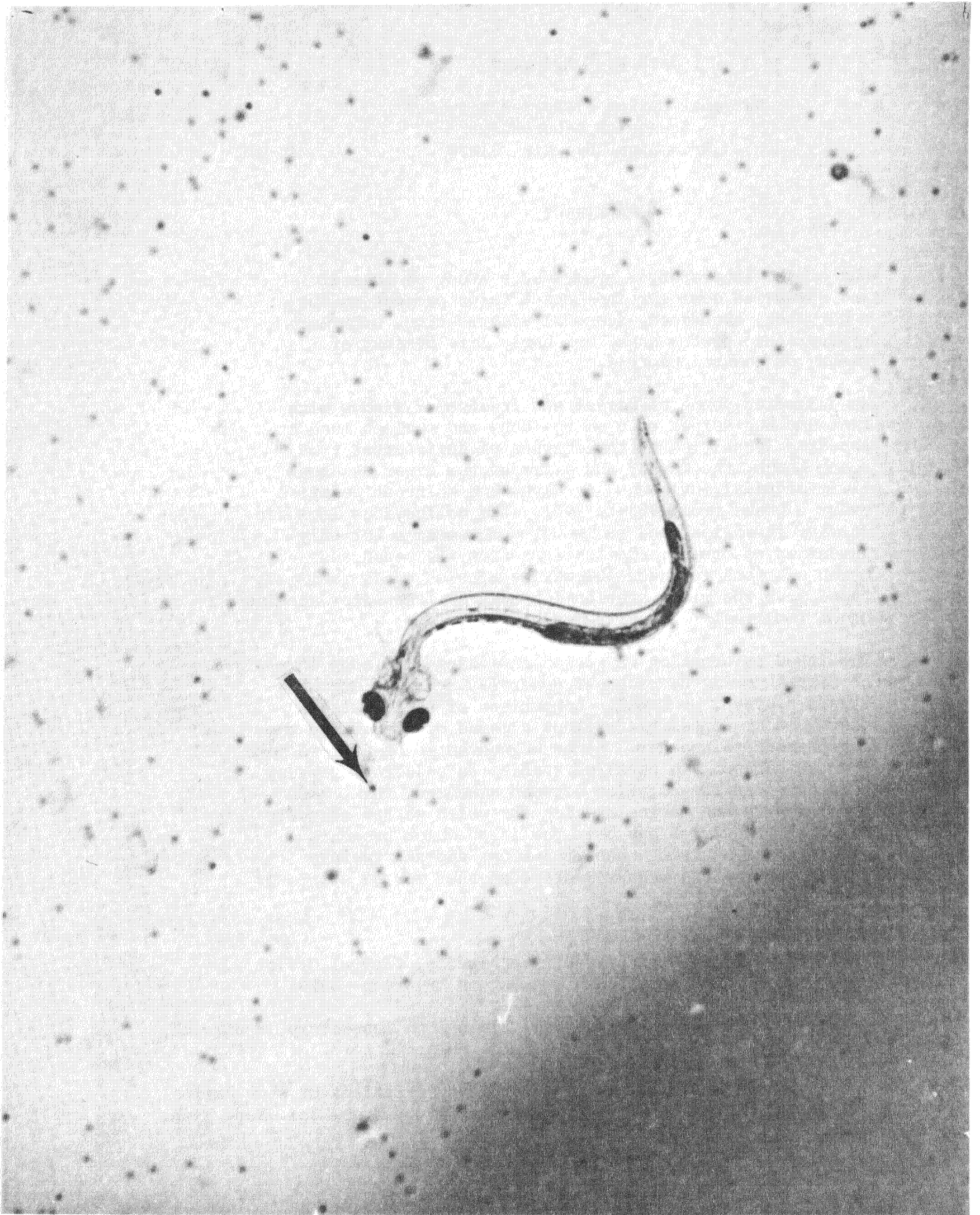


Figure 2. Ten-day-old menhaden larva, about 8 mm long, preparing to strike an 80- μ -diameter sea urchin blastula. The target is indicated at the tip of the arrow. Evidence of successful feeding by this larva is seen by the fullness of the dark gut.



YOUNG FISHES OF A TIDAL ZONE IN COASTAL GEORGIA

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ABSTRACT

One of the laboratory's programs, a study of coastal and estuarine ecology, includes a major project on the occurrence, abundance, seasonal distribution, apparent hydrographic preferences, and early life history of fishes of coastal Georgia.

We collected young of marine and freshwater fishes with flat and bag seines of 6-mm ($\frac{1}{4}$ -inch) and smaller mesh at selected localities in three types of environment (the ocean beach, the marsh, and a freshwater river at upper limit of tidal influence) in Glynn and McIntosh Counties every 2 weeks from 1953 to 1961. The collections included larvae, juveniles, and adults of some species but only juveniles of others. Collections from the beach and marsh stations included 104 marine species of 44 families; those from the river station included 38 freshwater species of 11 families.

Published information on growth and changes in body form of fishes during development generally records length as standard, fork, or total. Comparison of these data is difficult or impossible without a means of converting one measurement to another. Since we wanted to be able to make such comparisons in detailed studies on selected species, we determined the relation between standard, fork, and total length for marine species for which we had adequate data. A manuscript has been published which presents statistics describing these relations and the factors for converting one measurement to another for 82 species³.

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³Jorgensen, S. C., and G. L. Miller. 1968. Length relations of some marine fishes from coastal Georgia. U. S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. No. 575, 16 p.

We determined length-frequency distribution by month for all samples of the 104 marine species occurring in the ocean beach and marsh collections. Collections of freshwater species from the river station were too sparse to be analyzed in this manner. Since the sampling effort lacked uniformity, we combined by month data for individual samples over the 8-year period. The combined data are indicative of relative abundance.

LARVAL FISH STUDIES AT THE BUREAU OF COMMERCIAL FISHERIES
BIOLOGICAL LABORATORY, BRUNSWICK, GEORGIA

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ABSTRACT

Larval fish studies at this laboratory have two main objectives: identification of the larvae in our area, and an understanding of the abundance, distribution, and ecology of these larvae.

The basic material for these studies is a collection of eggs and larvae from plankton samples taken by the R/V T. M. Gill in 1953 and 1954. The samples are from an area that extends from Cape Hatteras, North Carolina, to Jupiter Inlet, Florida, and eastward into the Gulf Stream and the Bahama Islands. The collection has been supplemented by material taken later and by material from other areas.

We have found the following array of reference tools particularly useful for our program:

1. A library containing literature on the young stages of fishes
2. A file of literature citations that should be acquired
3. A file containing copies of published illustrations of the young stages of fishes
4. A file of X-rays of the fishes of our area

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5. A file of information concerning the meristics and spawning of the fishes of our area
6. A file of sketches which show significant qualitative features, such as details of the caudal skeleton, of the local fishes
7. A collection of cleared and stained specimens of the fishes of our area.

ESTIMATION OF MORTALITY RATES

Chairman

Ernest Mitts

CAN MORTALITY RATES BE DETERMINED FOR
ESTUARINE ICHTHYOPLANKTON POPULATIONS?

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ABSTRACT

This study concentrated on the early life history of the winter flounder, Pseudopleuronectes americanus (Walbaum), in the Weweantic River estuary in Massachusetts, using samples drawn from 1965 to 1968. Comparisons are made with a similar study in the Mystic River, Connecticut. Sampling problems and interpretation of variation for estimating year-class strength, larval mortality rates, and the related estuarine environmental factors are discussed.

INTRODUCTION

In September 1964, the Massachusetts Cooperative Fishery Unit and the University of Massachusetts began a long-term study of the fishes of the Weweantic River estuary in upper Buzzards Bay. The Massachusetts Water Resources Research Center (WR-2 and -19A) and the Federal Water Pollution Control Administration (WP-01204) later completed this project with their support. We chose initially a problem similar to Percy's 1962 study on the early life history of the winter flounder, Pseudopleuronectes americanus (Walbaum) in the Mystic River. This study developed into the question posed by the title of this paper. Robert Topp selected the Weweantic River estuary, a relatively untouched estuary, to document the dynamics and mortality of a year-class of winter flounder. This paper will deal with some of his results as well as those from our subsequent studies on the flounder and certain problems associated therewith.

Subsequent to the initial year's study by Topp (unpublished thesis, 1967b), the following students have participated in the Weweantic program and have variously contributed to its success through their own thesis activities and their participation in the coordinated longer range program: Robert Lebida, on the seasonality of ichthyoplankton and juveniles during 1966; Roderick Smith, on pesticide residues in winter flounder; John Stolgitis, tautog life history; Arnold Howe, tomcod life history; David Crestin, American smelt life history; Fredric Serchuk, cunner life history; David Frame, energy flow through the juvenile winter flounder population (Ph.D.); and Roderick Smith, further studies on pesticides in winter flounder (Ph.D.). None of these studies except Topp's is yet available, but a preliminary report (Cole, 1967) discusses in more detail the scope of the program.

OBJECTIVES

During Topp's initial study, we wished to confirm Percy's earlier work (1962) on mortality rates of the 1959 year-class of winter flounder in the Mystic River. After the first year's work, we expanded our goals and have proceeded toward two stated objectives: (1) documentation of the variation in strength and mortality of year-classes of winter flounder and other species in the estuary and a review of related factors, and (2) documentation of the accumulation and degradation of pesticide residues by pre- and post-spawning winter flounder in the estuary and the effects of pesticides on year-class success.

STUDY AREA

The Weweantic River arises in the township of Carver, Massachusetts, and flows some 23 km through flat agricultural and swamplands to its outlet in Buzzards Bay between the towns of Wareham and Marion. The estuary begins at the foot of the dam forming Horseshoe Pond, 7.5 km upstream from the channel markers at the mouth of the estuary. The small dam at the pond prevents a further intrusion of saltwater and also blocks passage of anadromous fish; outflow from the dam gives the area a freshwater appearance. Passing downstream one enters a shallow, widening, and slowly moving tidal estuary bordered by a narrow salt marsh. Three sampling stations are located in this upper estuary area. The lower estuary begins 4.0 km above the mouth at an earth-fill causeway and bridge with two narrow overpasses; a sampling station exists at the bridge. Definite tidal channels run beneath each of these overpasses and meet at the end of a large bay where the estuary narrows for the remaining 3 km before passing into the bay through a rock-strewn entrance. Three stations exist in the lower estuary. Average salinities within the estuary vary from 30.‰ at the mouth to 0.‰ at Horseshoe Dam; considerable seasonal fluctuations exist due to variability in runoff. This is particularly evident in an examination of the salinity data before and after the end of the recent drought in New England in 1966.

Temperatures range from -0.6 to 26.0°C ; the coldest temperatures occur either in late January or February. Each year in February, the entire estuary normally freezes except for the constricted area beneath the bridge. During the 1968 season, not only the estuary but much of Buzzards Bay was frozen for nearly 6 weeks, making sampling impossible during the early portion of the flounder spawning. Differences in yearly temperature patterns, especially when coupled with differing runoff and salinity patterns, seem to have a marked effect on spawning and the subsequent distribution of larval fishes within the estuary.

We selected this estuary in part for its general morphometric and biological similarity to the Mystic River in Connecticut, in which Percy (1962) carried out a very detailed study of the population dynamics of winter flounder larvae. During the first summer of study, we realized that this estuary was not as pristine as we originally thought. The river and estuary drain approximately 4,000 acres of boglands which are now under intensive cranberry cultivation, and its shores attract a large summer tourist and weekend resort traffic. Management of insects and plants in the area has resulted in heavy pesticide spraying programs. The next speaker will discuss the details of this program and its implications to the yearly flounder production.

METHODS

Topp initially selected six stations within the estuary, which he sampled monthly, surface and bottom, for salinity and temperature data and plankton during the 1965 season. During the summer, he also sampled by seining, gill netting, and fyke netting. In 1966, Robert Lebida, adding an additional station, sampled seven stations, and collected by seining, gill netting, and fyke netting during this summer and fall. During the 1967 and 1968 spawning periods, Lebida's seven stations were occupied weekly from mid-March until mid-August and monthly throughout the rest of the year as conditions permitted. A 5.3-m (16-ft) otter trawl was also used for sampling since 1966.

Although Topp took his plankton samples with a Turtox net, all surface plankton samples since 1965 were taken with a Gemware 0.5-m plankton net, mesh size 0. For bottom samples, we used two benthic sled-type samplers. Occasionally, we used the 0.5-m net near the bottom using a 5-pound batwing depressor attached by a short length of line to the bottom of the net rim (Percy, 1962). This depressor was used to "feel" the bottom and to keep the net from porpoising into the mud interface. All tows lasted for approximately 5 minutes at a standardized speed. During the summer of 1967, we attached a flow meter to the center of the net and all samples taken subsequently have meter readings in addition to time duration of tow. These procedures essentially duplicated Percy's operations.

We preserved all samples in the field in 5% formalin and seawater and sorted them later. Percy noted no significant specimen shrinkage following a similar practice. All eggs and larvae from the 1966, 1967, and 1968 seasons have been stored in 3% formalin. It was not easy to standardize sampling gear and to ensure uniformity in sampling procedures among operators between years.

SUMMARY OF WINTER FLOUNDER EARLY LIFE HISTORY

The winter flounder, an important species in the offshore bank fishery in New England, is apparently obliged to return to a home estuary to spawn (Bigelow and Schroeder, 1953; Perlmutter, 1947; and Percy, 1962). In the Weweantic, adult winter flounder become sexually mature by age 3 (Smith, unpublished manuscript), move into the lower estuary during late fall and then into the upper estuary during midwinter. From late February through early April, they lay demersal eggs which hatch within 15-18 days into benthic larvae, about 3 to 3.5 mm long. Percy (1962) postulated that their benthic nature favors their retention within the more saline wedge in the typical two-layered estuarine system and prevents their being flushed from the estuary. The larvae remain closely associated with this bottom until transformation takes place at about 9 mm. Using nets with round openings, Percy noted six times as many larvae in his bottom hauls as in the surface tows and Topp noted even higher concentrations near the bottom when he used a plankton sled with a rectangular opening. Percy then estimated mortality rates in developing larvae by compiling a post-recruit catch curve, using size as a criterion of age and declining numbers at size intervals summed throughout the sampling period as the basis for the curve. His catch curve, based on over 3,000 larvae, is concave to the right of the peak; this concavity indicates a very high mortality rate, lessening with age. Percy expressed this rate in mathematical terms.

RESULTS FROM TOPP'S STUDY AND CURRENT WORK

Without tracing the full details of the assumptions used by Percy and then by Topp, it may be difficult to appreciate the full complexity of the problem. However, Topp concluded that for the 1965 year-class in the Weweantic, the initial rate of decline from the point of full recruitment was roughly twice that obtained by Percy for the 1959 year-class in the Mystic River. Of course, we have no idea of the equivalent rate in 1965 for the Mystic River population and unfortunately for the purposes of this discussion we do not yet have the samples from the 1967 and 1968 field seasons fully processed. Topp and I visited the Mystic River during August 1965 and suspected high initial mortality after we were unable to locate many young-of-the-year flounders in the Weweantic. Although we were told by workers at the Noank Laboratory that there had been a good year-class of larval flounder, we found no transformed flounders when we seined at one of Percy's stations. We later used the same seine in a small cove near Popanasset Beach on Cape Cod in early August 1965 and here we collected more young-of-the-year flounders (1953) in two short hauls than had been collected in the Weweantic (1946) through an entire summer of seining operations. Unfortunately, we do not have any notion of the abundance of larval flounders in the Popanasset site prior to transformation.

Lebida studied the 1966 year-class during his year's study and found it to be apparently even smaller than that of 1965; additionally, he took most of his larvae in the upper water column in contrast to both Topp's and Pearcy's studies. This indicates the role that high stream runoff may play in washing flounders from a very shallow estuary. We suspect the construction of the Route 6 bridge has played a strong role in increasing sedimentation in the upper estuary and thereby has fostered flushing at times of high rainfall. When high runoff occurs during or following spawning, its effects on flounder densities can be serious. As yet, we are unable to sample upper Buzzards Bay except directly at the front of the estuary and have little idea what role the bay itself may play in the lives of flounders that have been washed from the surrounding estuaries.

The 1967 year-class in the Weweantic apparently has been the most successful to date. Approximately 2,000 flounder larvae have been collected and are now being processed. These numbers are not equivalent to those taken by Topp (536) or by Lebida (about 200) since we conducted the 1967 sampling on a weekly basis. However, the year-class appears strong, as the seining and otter trawling operations carried on throughout the summer of 1967 and into the present year are revealing. We used a Turtox triangle net dredge this summer to capture flounder just after transformation.

The 1968 year-class apparently was a very small year-class, as judged from a limited sorting of samples, but good numbers of recently transformed winter flounder, ranging from 15 to 25 mm long, were found very close inshore over mud and sand. Therefore, although limited numbers of flounder larvae were found in the plankton this year, their survival rate up to the point of transformation may be far higher this year than last year. There is evidence suggesting that the small numbers of larvae present in 1968 may be correlated with the small size of the 1965 year-class studied by Topp since the bulk of the spawning population is made of age 3 fish. We do not suggest that there is a correlation between ultimate success of year-class and the size of the spawning adult population; indeed the current year's evidence to date supports the contrary view. We do suggest, however, that the total numbers of eggs and larvae are related to the number of adult spawners in the estuary.

DISCUSSION OF METHODOLOGY AND ITS WEAKNESSES

We feel that our approach to inshore ichthyoplankton populations has advantages; however, we are not yet satisfied with our success in determining larval mortality rates. We must understand more about the factors regulating numbers of eggs deposited, hatching success, and the effects these numbers have on future population sizes. Certain sampling factors must be considered if we are to understand year-class variations. Though the larval catch curve first used by Sette (1943) and later modified by Pearcy (1962) has not gained wide acceptance, this device does provide a conceptual framework from which one can begin to visualize larval mortality as part of the larger problem. Some of the weaknesses we have encountered in developing a quantitative program are reviewed below:

1. Sampling gear. We chose the 0.5-m net because many areas of the estuary are too small to permit a larger net. Larvae from 4 to at least 6 mm are vulnerable to our sampling gear. Its small size precludes capture of the later growth stages before transformation; however, this loss of the larger larvae may be due only to escapement.

The center-mounted meter now being used by us has been condemned by most recent studies on the hydrodynamics of plankton nets (Mahnken and Jossi, 1967). These studies have revealed that such meters cause turbulence and thus impair efficient filtering. We tested a small Clarke-Bumpus sampler as a quantitative device but judged it to be awkward and fragile in shallow water and thus not suited to our needs. Thus, to date, we have found nothing more serviceable than a 0.5-m net and a bottom sled. Unfortunately, results can be quantified only in the most crude terms. We have not yet tested the small boat plankton pump (Johnson, 1967); this may be the only suitable method for quantifying data gathered from detritus-laden, shallow water estuaries. Finally, once a project has begun, a change in gear makes comparability among the data more difficult.

Plankton sampling in the Weweantic, as in most estuaries, is greatly affected by net clogging (Williams and Deubler, 1968). Unfortunately, only when clogging is gross are new samples likely to be taken. However, a skilled operator can sample quite close to the bottom with little debris accumulations; Topp was able to get very good results with his plankton sled (1967a; unpublished thesis, 1967b).

2. Station selection. At the onset of any study, one makes certain arbitrary decisions about sampling design which may adversely affect the project outcome. Station selection is usually done with only general knowledge of events likely to occur during the year at those stations. Many times no information is available about what may occur at other points in the system. Spawning sites will probably vary from year to year and thus rigid station sampling could be misleading. Patchiness or nonrandom distributions in flounder larvae has not been noticed by workers to date, but those whose sampling programs do not give due regard to patchiness may find themselves confusing mortality with their failure to find larvae.

3. Data replication. A single sample at a station will provide a fixed number of larvae from that station, but only when the data are replicated does one appreciate the unevaluated interplay between the inaccuracies of timed tows and the real variation in numbers taken at close proximity to the station being sampled. Taft (1960) has presented a recent review of sampling error in an estimation of Pacific sardine (Sardinops caerulea) eggs. He posed several questions which must be faced by each planktologist while dealing with estimating plankton populations: "How well does the sample represent the volume of water sampled?" and "How well does this sample from a particular volume of water represent a larger surrounding volume?" A wide range of literature exists for the worker who must answer these problems (Ahlstrom, 1954; Cassie, 1963).

Since the number and size of larvae found at each station are used to construct a catch curve, it is important to understand the variability that occurs among multiple samplings made at each station. Percy (1962) made 10 pairs of plankton tows at the same station within minutes of each other and got coefficients of variation ranging from 1.2% to 57% (mean: 23%). He then made collections every 2 hours at one station over four tidal cycles and obtained coefficients from 52% to 146% (mean: 96%) for similar type of tows. Percy does not show the raw data from which one can visualize variability, but I created some pairs of numbers, each pair averaging 15, and then determined their coefficient of variation. If the numbers are 14 and 16, the coefficient is 10% and when they are as different as 5 and 25, the coefficient is 100%. In terms of Percy's mean coefficients, had they been as different as 12 and 18, the coefficient would have been 30%. The effects of such variation between samples from the same volume of water within minutes must well be considered before credence is placed on the creation of catch curves from nonreplicated data.

4. The catch curve. Ricker (1958) creates catch curves from the logarithm of the number of a particular age fish caught against the age at time of capture and assumes complete vulnerability past the time of full recruitment. When a rate of mortality is constant with no major fluctuations in year-class abundance, and if sampling is representative of the true population age structure, mortality rates can then be evaluated directly from the curve. As yet, there is no way of aging larval fishes except by comparing their length at capture with a known time-length relation between hatching and the commencement of exogenous feeding. We have followed Percy's (1962) method, whereby larvae are aged using a known time-length series of larvae.

Thus, if one can assume an unbiased sampling program, a lack of significant change in growth rate, and an unbiased netting procedure, it would be possible to construct a catch curve in which the x-axis is day-length and the y-axis is the logarithm of total number of larvae at that particular age, summing all larvae caught throughout the season. The shape of the curve to the right of the peak is the expression of mortality. It is with the initial slope that Percy's and Topp's data differ. The question is whether Topp's conclusion that the rate of decline, twice that of Percy's, is really a valid expression of larval mortality within the system or only a statistical happenstance. I cannot answer this question except to state that one further weakness in Topp's study lies in our decision to sample monthly. If sampling is too infrequent, a bias in the catch curve will result. This can be visualized in a model estuary where a fixed number of eggs are spawned and become randomly distributed into the estuary every 5 days. If this population of larvae undergoes a set mortality rate, an efficient sampling program conducted every fifth day would reveal the true rate. If, however, the sampling program is carried out less frequently, though it may still be as efficient, it will provide data that begin to generate a biased mortality rate.

CONCLUSION

We are not yet convinced that mortality rates for estuarine ichthyoplankton can be estimated with the degree of exactitude claimed by some. When the 1967 and 1968 data are more completely analyzed, we expect to be in a position to talk more affirmatively. We see a definite need for workers to develop programs leading toward quantification of estuarine data and the examination of the dynamics of larval populations over several year-classes. Regardless of whether the precision claimed is in fact warranted, efforts in this direction are bound to be informative and should provide the researcher with perhaps his first opportunity to relate environmental factors with subtle changes in the larval population structure caused by those factors.

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DISCUSSION

Graham commented on a study of the mortality of larval herring. Sampling nets are arrayed in four rows in the estuaries: two in the upper portion and two in the lower. At both locations, nets are set at surface and bottom levels, fished for 6 hours of each tide, and changed at slack water. A factorial analysis determines differences in catch between tides, location, and depth. There is a winter period when larvae are not migrating, and during this period estimates of mortality are obtained. Four years of data are available and indicate a correlation between mortality and condition factor as well as some association to the spring return (migration) into the estuaries. Only 1 year of commercial landings is available; however, the highest rate of mortality observed was 52%. This was associated with the lowest catch rate in the spring (about 9 fish/100 m³), the lowest condition factor, poor feeding conditions, and one of the lowest contributions to the 2-year-old sardine fishery. It is not known how this technique will serve as a predictive device, but it holds promise.

PESTICIDE RESIDUES AS A POSSIBLE FACTOR
IN LARVAL WINTER FLOUNDER MORTALITY

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ABSTRACT

Unusually high mortality of larval winter flounder occurred in the Weweantic River estuary, Wareham, Massachusetts, during the 1965 spawning season. Pesticide residues were suspected to be the possible lethal agent because of large-scale use of these compounds in the watershed. The procedure followed included analyses of winter flounder tissues for pesticide residues, using electron capture gas chromatography, monthly from July 1966 to June 1967. Evidence of seasonal patterns of accumulation and metabolic breakdown appeared for DDT, DDE, heptachlor, and heptachlor epoxide. Dieldrin was present in relatively small quantities in all the monthly samples. Parathion appeared only in the July 1966 sample. A relation between the life history of the winter flounder and the accumulation of pesticide residues was evident. Female flounder concentrated certain of the pesticides in the ripening ovaries as the spawning season approached. Chromatographic patterns from the Weweantic flounder analyses proved to be qualitatively unique when compared to analyses on flounder from other areas off the Massachusetts coast. The possibility of pesticidal influence on the survival of larval winter flounder is thought to exist.

INTRODUCTION

In 1965, a study of larval winter flounder (Pseudopleuronectes americanus) mortality in the Weweantic River estuary, Wareham, Massachusetts, revealed excessive mortality which was perhaps nearly complete in the post yolk-sac stage of development (Topp, 1967, unpublished). Later in the study, identical sampling techniques for juvenile winter flounder were much more successful in areas other than the study estuary, reinforcing the suspicion of unusually high larval mortality in the Weweantic estuary. No immediate reason could be found for this occurrence.

In an ensuing search for possible agents for mortality, we considered pollution. The estuary was originally chosen as a study area for its apparent lack of pollution or modification. However, on closer inspection of the estuarine and river watersheds, pollution appeared as a definite possibility. Cranberry bogs were the dominant feature of the Weweantic River drainage, with over 4,000 acres under active cultivation. Cranberry culturing requires extensive chemical pest control measures directed at insects, weeds, and fungi.

Translocation of the pesticides into the adjacent waters occurs due to the unique management practice of intermittently flooding and draining the bog acreage; often the river is used as a water source. In addition to this possible source of environmental contamination, further pollution by pesticide residues is possible through annual mosquito extermination programs carried on directly in the river and estuarine drainage system, and through pesticide use by local tree wardens and residents.

Realizing the potential for pesticide contamination of the estuarine environment, we undertook a study of the possible effects of pesticide residues on winter flounder in the Weweantic estuary in March 1966. The general objectives of this study were to determine whether environmental contamination by pesticide residues does take place in the Weweantic estuary, the magnitude of occurrence, and the effect on the estuarine biota, in particular the winter flounder.

METHODS AND PROCEDURE

The winter flounder was chosen as the test species because of an apparent problem of larval survival, because of the importance of this fish in the sport and commercial fishery in this area, and because of the need to limit the scope of the study, as each species of fish seems to exhibit its own characteristic response when exposed to each pesticide compound.

We collected winter flounder from the Weweantic estuary using a 4.9-m (16-ft) headrope semiballoon trawl, hoop nets, and gill nets. Flounder from other areas of the Massachusetts coast were obtained with the trawl or from commercial trawlers.

We chemically processed fresh flounder tissues for analyses by gas chromatography using a modified version of the Food and Drug Administration recommended method for cleanup of animal tissue containing 2% or more fat (Barry et al., 1965). The bulk of the samples were analyzed using a Perkin-Elmer 801 gas chromatograph, equipped with a column of 5% Dow 11 on Chromosorb W (60-80 mesh), and a Wilkens Aerograph model 550 gas chromatograph with a diphasic column of 50%-10% DC-200 on Gas Chrom Q, and 50%-12% QF-1 on Gas Chrom P (100-120 mesh) was used as a qualitative cross-reference. Electron capture detectors were used in both cases, and, for further qualitative verification, partition coefficient values.

From analyses on muscle tissue, conducted monthly from July 1966 to June 1967, we obtained an estimate of the magnitude of the pesticide pollution reaching juvenile flounder residing in the estuary, and elucidated the dynamics of pesticide accumulation and metabolic breakdown in the fish tissues. Analyses made on water and bed soils from the Weweantic estuary, on blue mussels, Mytilus edulis, a sessile inhabitant of the estuary, and, for comparative purposes, on tissues of winter flounder from other areas off the Massachusetts coast, related any residues found to pesticide use in the specific watershed.

Because adult winter flounder undertake seasonal migrations, whereas the immature inhabit the estuary year-round, we made analyses on flounder of different age groups to determine whether residue accumulations are in any way affected by such behavior. To assess the possibility of pesticide residue influence on reproduction and survival of larvae beyond the post yolk-sac stage of development, we made sequential analyses on developing ovaries from fall 1966 to the time of spawning in 1967.

RESULTS

From the monthly analyses, we discovered definite patterns of accumulation and metabolic breakdown for DDT and heptachlor. The greatest concentrations of DDT occurred in the spring and summer, and decreased during the fall and winter. As DDT decreased in quantity, concentrations of DDE, the metabolic breakdown product, increased. The maximum concentrations of DDE occurred in the midwinter sample. Heptachlor occurred in greatest quantity in the flounder muscle tissue during the winter; concentrations dropped to trace quantities by midsummer. Heptachlor epoxide followed the same pattern, indicating more immediate metabolism of this compound when compared to DDT. Dieldrin was present in flounder tissues throughout the year with no pattern of accumulation or metabolic breakdown demonstrable. Parathion appeared in only one sample, that of July 1966.

Analyses of estuarine bed soil samples showed 4 ppm DDT and trace quantities of DDE; otherwise these samples lacked significance. Water samples showed no measurable concentrations of pesticide residues. Whole-body analyses of blue mussels yielded a chromatographic pattern similar to that of the flounder. The tissue analyses of flounder from other areas off the Massachusetts coast, including the offshore banks, differed markedly from the Weweantic data as well as from each other. Flounder from each area appeared to have their own characteristic chromatographic pattern.

We found immature winter flounder to contain greater concentrations of the identified pesticides than adults. The qualitative patterns, however, appeared essentially the same in both cases. Adult female flounder showed increased concentrations of DDT, DDE, and heptachlor epoxide in the developing ovaries as the spawning season approached, while heptachlor decreased in concentration. Dieldrin occurred in all the ovarian samples but in relatively small quantities.

DISCUSSION

The potential hazard of pesticide pollution from cranberry bog runoff has not gone unnoticed. Studies conducted at the Cranberry Experimental Station of East Wareham, Massachusetts, reveal that dieldrin, a commonly used insecticide on cranberry bogs, is persistent in the bog soil for up to 10 years, and that small quantities are transported from the bogs via drainage waters (Miller, 1966). Another investigation (Miller et al., 1966) found that, under model conditions, runoff from cranberry bogs following parathion and diazinon applications and a simulated frost protection flood created extensive mortality in experimental mummichogs (Fundulus heteroclitus).

Similarly, the hazards of salt marsh mosquito control programs to estuarine species of fish have been documented. DDT used at 0.8 pounds per acre on salt marshes for mosquito control is reported to have caused significant mortality among mummichogs (killifishes) and tidewater silversides (Springer and Webster, 1951). In Florida, DDT applied at 0.2 pounds per acre proved lethal to fish and shrimp (Croker and Wilson, 1965). Another of the commonly used insecticides in mosquito control programs, malathion, is reported to be lethal to mummichogs held in artificial containers after applications of 0.5 pounds per acre in the salt marshes (Darsie and Corriden, 1959). Both of the above-mentioned compounds are used in the mosquito control program in the Weweantic drainage system (Plymouth County Mosquito Control Office, personal communication, 1968).

The finding of DDT, DDE, heptachlor, heptachlor epoxide, dieldrin, and parathion in the tissues of the winter flounder indicates that pesticide residue pollution in the Weweantic estuary exists. The unique character of the chromatograms from the Weweantic winter flounder analyses, when compared to those of flounder from other areas of the Massachusetts coast, and the finding of the same chromatographic pattern in the blue mussels from the estuary, tend to implicate the watershed as the major contributing source of pesticidal contamination in the Weweantic. The absence of any residues in the estuarine water samples, and the finding of only DDT and DDE in the estuarine bed soils by no means negates this contention. Pesticide compounds are hydrophobic molecules. Thus, they spend little time in the water and may easily elude detection. Further, residue concentrations too small to detect in the bed soils or water may well appear in fish tissue through the well-documented process of biological magnification (Stickel, 1967).

The seasonal residue accumulation and metabolism patterns described for DDT and heptachlor indicate juvenile winter flounder are capable of surviving, metabolizing, and voiding the present concentration levels of these pesticides encountered annually in their environment. The fact that seasonal patterns occur is significant in that time of year plays an important role in determining the presence, absence, or quantity of a particular pesticide or its metabolic breakdown product. Further, the time of maximum accumulation may be related to a specific application or runoff conditions existing in the associated watershed. For example, Butler (1966) has used the time of maximum accumulation as a tool to pinpoint the specific source of pesticide contamination.

The absence of any seasonal pattern involving the accumulation or breakdown of dieldrin by the winter flounder remains to be explained. However, the single occurrence of parathion in the flounder tissue is explained by the supposed ephemeral nature of the parathion molecule in the water environment (Keith et al., 1964; Sato and Kubo, 1965). This single documentation of parathion does not imply that this formulation plays a minor role in the ecology of the Weweantic estuary. Because of its relatively short life in the water environment, it is naturally more difficult to detect and its presence may be easily overlooked in a monthly sampling program. This insecticide is acutely toxic to fishes (Weiss, 1959) and is one of the more commonly used pesticides on cranberry bogs. Therefore, further study on this aspect of the problem is recommended.

Winter flounder, age 2 and younger, inhabit the Weweantic estuary on a year-round basis, while older individuals undertake seasonal migrations and are absent from the estuary during the warmer months of the year. The results of analyses conducted on flounder of different age groups indicated that such behavior affects the quantitative accumulation of the pesticide residues. Flounder of age groups 2 or younger contained far greater concentrations of the residues identified than did their older, migrating counterparts. Since the older fish represent those individuals participating in spawning, such a difference may prove significant.

The approximate time of near total mortality of larval winter flounder in the Weweantic estuary suggested mortality similar to that of lake trout fry in New York waters observed by Burdick et al. (1964). The cause of the post sac-fry mortality in the New York lake trout was traced to DDT residues passed on to the fry in the yolk material by the adult female. While in the yolk material, the residues were harmless and presumably bound to fat molecules. When the developing fry finally utilized the fat, the DDT was liberated into the bloodstream where it became toxic and eventually lethal. Allison et al. (1964) reported a similar case study for cutthroat trout. This effect may exist in the winter flounder spawning in the Weweantic estuary.

Sequential analyses of flounder ovarian tissue as spawning season approached demonstrated increased concentrations of DDT, DDE, and heptachlor epoxide. Whether the final concentrations at spawning were great enough to effect mortality at the post yolk-sac stage of development is not at present known. However, the potential is real, since ovarian concentration did occur. An intensive investigation currently underway hopefully will provide an answer to this problem.

SUMMARY

Excessive mortality of larval winter flounder in the Weweantic estuary prompted an investigation into the possible causative agents. We suspected pollution by pesticides because of its extensive use in the associated watershed. Tissues of juvenile and adult flounder contained DDT, DDE, heptachlor, heptachlor epoxide,

dieldrin, and parathion. The presence of these compounds in the flounder tissues related circumstantially to pesticide use in the associated watershed. Seasonality, with respect to accumulation and metabolism of the pesticide residues, occurred for DDT and heptachlor. The life history of the winter flounder proved to affect residue accumulation by the flounder because migrating individuals contained lower concentrations of the pesticides identified than did the year-round inhabitants of the estuary. Female flounder concentrated DDT, DDE, and heptachlor epoxide in their developing ovaries as spawning season approached.

Current study is directed toward determining what pesticide concentration levels in the ripe ovaries constitute a threat to the survival of the developing fry. Also underway is an investigation of acute toxic conditions following pesticide application in the watershed.

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DISCUSSION

De Sylva asked if Smith did laboratory experiments on malathion and DDT. He further noted a potential problem for fish, drawing an example from mammals -- although they may metabolize malathion, DDT affects such metabolism to produce a synergistic effect.

Smith reviewed ideas for future projects, commenting that DDT and malathion applications do not occur concurrently. DDT is usually sprayed in winter, while malathion is applied in the summer. Malathion breaks down in the biological system and should be effectively dispelled by the time of the DDT spraying.

Belt then recommended a review of George Woodwell's work from the Brookhaven Laboratory on the half-life of DDT. He further suggested that there must be a large amount of dieldrin in the organic soil, since 1 pound of DDT per acre per annum lasts 150 years on the half-life basis. Dieldrin is 20 times stronger than DDT, and Belt said it would enter the estuary when flood gates open.

Smith noted that fishing was not discontinued in the area and it was shown that dieldrin generally remains in the top 10 cm of soil, although there is some translocation of suspended soil.

Dow asked about the pesticide monitoring program. Smith referred to a recently completed State program in Massachusetts. The university group does its own monitoring each year, and uses only winter flounder.

In response to a question by Clark on the concentration of DDT residue found in the ovaries, Smith stated that the maximum was 0.6 ppm. While this figure is below that which Burdick reported as causing mortality in lake trout, Smith said possible differences in methodology make results of the two studies incomparable.

Brown discussed an incident which occurred at the Institute of Marine Sciences in North Carolina. When they fed Fundulus, taken from a drainage ditch along the highway, to a group of winter flounder, the flounders died overnight. An analysis by the Gulf Breeze Laboratory revealed DDT residues in the stomach contents of both the flounder and mummichogs. It became apparent that Fundulus can assimilate small doses of DDT and accumulate them, whereas flounder are much more sensitive to it.

Smith commented that he used winter flounder because of their varied adaptability to concentrations of DDT. Carlson suggested the Atlantic menhaden as a prime organism for study of pesticide uptake. Because it is a filter feeder, the menhaden intercepts pesticides at an earlier level of concentration.

Kinnear asked for information on where to send samples for pollution analysis. Brown said his group sent oyster samples quarterly to the Gulf Breeze Laboratory for pesticide analysis. Frisbie added that pesticide monitoring of oyster samples is also being conducted in Georgia.

MORTALITY RATES OF PLANKTONIC EGGS OF THE CUNNER,
TAUTOGOLABRUS ADSPERSUS (WALBAUM), IN LONG ISLAND SOUND¹

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ABSTRACT

This study is based mainly on planktonic eggs of cunner, Tautogolabrus adspersus (Walbaum), collected from a variety of habitats along the south shore of Long Island Sound. Embryonic development has been divided into six growth stages, ranging from fertilization to hatching, with each stage representing about one-sixth of the development. A method for determining mortality rates, called "embryonic survival ratio" (ESR) was developed, based on use of the six-stage system. By the use of this system, it was determined that about one cunner egg in 20 survived to hatching in the study area.

INTRODUCTION

A planktonic fish egg clearly shows its stage of development, and, from collections of such eggs, one can compile a stage-frequency distribution as a kind of life table for the calculation of mortality rates. A number of workers have satisfactorily used this method. Ahlstrom (1954) reported that egg mortality is negligible in the Pacific sardine and data on a related Mediterranean species also indicated little loss (Gamulin and Hure, 1964). Mortality may be greater, perhaps 50%, for jack mackerel eggs on the Pacific coast (Farris, 1958, 1961), and for mackerel off Japan (Motoda, 1955). Fraser's (1961) study suggests about a 90% loss for cod and haddock in the North Sea. Data of Magnusson, Magnusson, and Hallgrimsson (1964) and of Serebryakov (1966) indicate a mortality of at least 90% for North Atlantic cod. Battle (1930) concluded that mortality was total for fourbeard rockling in Passamaquoddy Bay in eastern Canada.

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Other studies show egg mortality varies with time and place in the same species. Simpson (1959) reported annual loss, over a period of 11 years, varied from 25% to 75% in North Sea plaice. Buchanan-Wollaston (1926) estimated 70% to 90%. Reid (1930) studied geographic variation in cunner egg survival in inshore waters of eastern Canada. At best, one egg in four survived to hatching; at worst, one in a thousand. Sette (1943) estimated mackerel egg mortality at 5% per day or 59% from fertilization to hatching off the east coast of the United States. In Canadian waters, mortality was 100% (Sparks, 1930).

Some of the above conclusions are our inferences from data published for other purposes (in papers by Farris, 1958 and 1961; Fraser, 1961 and 1964; Gamulin and Hure, 1964; Magnusson et al., 1964; Serebryakov, 1966). The others are conclusions of the authors cited. These estimates vary greatly in reliability, and not even the best can claim real accuracy, but the information justifies the belief that loss is highly variable and may be heavy. Hempel's (1965) statement that egg loss is normally light and not a factor in determining year-class strength seems a bit premature.

The present study is mainly based on collections from within 12 km of Old Field Point (40°58'N, 73°08'W) on the south shore of Long Island Sound (Fig. 1). Within this area, we sampled a variety of habitats, including sheltered harbors, river mouths, and tidal sloughs, but made most of the collections from the sound. Here the sampling included surface waters and various subsurface levels down to 30 m, where depths permitted. We also made use of material collected in the 1950's by Sarah W. Richards for her survey of fish eggs and larvae of the sound.

We limit consideration to the cunner, Tautogolabrus adspersus (Walbaum), because we have more samples of this species than any other, and because its rapid development and long spawning season reduce certain difficulties of interpretation.

MATERIALS, METHODS, AND DEFINITIONS

We used a variety of collecting techniques and gear, always Clarke-Bumpus samplers for subsurface hauls, and usually with mesh openings of less than 0.5 mm, which should retain all fish eggs. We also include material from coarser nets, through which some eggs may have passed, because eggs do not change size as they develop, and incompleteness of a sample would not bias the relative numbers of developmental stages. On one cruise, a dozen or more samples were often taken, some from an inshore station (harbor or tidal channel) and the rest from various depths out in the sound, usually near the western or northeastern edge of the study area.

We collected in five different spawning seasons, but only in 1963 were regular (1- or 2-week-interval) collections made throughout the complete spawning season. In other years, we missed at least a month of the 4-month spawning season.

Published information on embryonic development of the cunner is sketchy. Even the best accounts, such as Agassiz and Whitman (1895) and Kuntz and Radcliffe (1918), provide no detailed schedule of development at even one temperature and we have not had facilities for producing such information. On the basis of the few published accounts, and by analogy with other species with similar eggs for which detailed developmental schedules have been published, we have divided development into six stages, with the aim of having each include about one-sixth of the total time from fertilization to hatching. It is important for our calculations that the first three stages account for about half of embryonic development². The stages are:

- I. Fertilization to 16 cells
- II. Seventeen cells to primitive streak, when marked elongation and bilateral symmetry are first apparent
- III. Primitive streak to 15 visible somites
- IV. Sixteen somites to elevation and extension of tail over yolk
- V. Tail elevation to completion of broad finfold around end of tail
- VI. Finfold completion to hatching

Previous workers have used a variety of stage classifications, two of which have some status as international standards. One is the five-stage system of Buchanan-Wollaston (1926), refined by Simpson (1959), and often used by northern European workers for gadids and plaice. The other is an 11-stage system used for Pacific sardine by Ahlstrom (1954) and Taft (1960), and for Mediterranean clupeids by Gamulin and Hure (1964). Our stages are based entirely on morphogenetic features that should facilitate comparison between species. Previously used topographic characters, such as the embryo extending 180 degrees around the yolk, are reached at different morphogenetic stages in different species. The same is true, unfortunately, of hatching. In the future, we intend to use morphogenetic criteria, but to use a larger number of stages, such as Ahlstrom's 11 stages, to permit day-class discrimination among slowly developing species.

²Experimental work completed after this paper was submitted supports our choice of the end of stage III as the midpoint. Actually, it seems to be slightly short of the midpoint, perhaps 45% of the way from fertilization to hatching, both at high (25.0°C) and low (13.0°C) temperatures. The inaccuracy means that our ESR values are a bit higher than they should be. Our new data indicate development should take about a week at the beginning of the spawning season, and less than 2 days at the maximum summer temperature in Long Island Sound.

Yolk membranes of stages I and II are readily ruptured by mechanical stresses (Rollefsen, 1930) such as occur in a plankton net towed at the usual speed of about a meter per second. Yolk escapes into the perivitelline space and the embryo rolls into an abnormal shape. It is difficult to separate stages I and II in such eggs and difficult to distinguish them from eggs already dead from disease or congenital defects. We concluded that most of the defective eggs were viable when collected, because most of the eggs taken gently, by drawing a net slowly through calm water, were free of defects. Only when we found structural disintegration of the embryo did we conclude the egg was dead before collection. These are not included in the tabulations.

We have tried several methods for calculating mortality rates. For the present, we believe the following simple technique is sufficient. We calculate the ratio of the total in the last three stages to the total in the first three and assume this represents survival for one-half of development. The square of this ratio would estimate the probability of surviving from fertilization to hatching, a number we call "embryonic survival ratio" (ESR).

STAGE-FREQUENCIES AND ESR

If all stages proved to be of equal duration and equal liability to collection, there would be a steady decrease in numbers from stage I to stage VI. The number in each stage divided by the number in the preceding stage would represent the one-stage survival rate for that part of development. We did not obtain this simple pattern (Table 1).

Table 1. Stage-frequencies and ESR's for each year of collection.

Year	S t a g e						No. sampled	ESR
	I	II	III	IV	V	VI		
1962	450	396	48	68	30	8	1000	.014
1963	551	2603	197	354	384	58	4147	.056
1964	204	2504	79	302	327	27	3443	.055
1965	18	276	55	26	79	28	482	.145
1968	13	21	7	5	1	0	47	.021
	1236	5800	386	755	821	121	9119	.052

Stage I is probably a bit briefer than II, and this would partly explain the shortage of I's in all years but one. Undoubtedly, another factor is the time of day of collection (Table 2). Stage I is abundant just after dawn and becomes less numerous as the day progresses. Apparently, most of the spawning takes place around sunrise. It is understandable that the collections, being mainly from the afternoon, would consist largely of II's. These would represent day-class zero, and the peak abundance of IV and V would be day-class one. This is in accordance with what is known of rates of development in the laboratory (Kuntz and Radcliffe, 1918).

Table 2. Percent of eggs in each stage at different times of day.

Hours after sunrise	S t a g e						No. sampled	ESR
	I	II	III	IV	V	VI		
0 - 4	28	25	27	11	9	0	56	.060
4 - 8	22	25	12	26	13	3	1578	.517
8 - 12	25	40	8	11	13	3	1495	.130
12 - 16	14	77	1	3	6	1	3328	.010
16 - 20	1	85	1	5	8	1	2420	.024
20 - 24	2	92	1	2	5	0	243	.004
Mean	15	57	8	10	9	1		.062

Several reports in the literature indicate planktonic eggs get heavier as they develop, so that later stages may sink. Since the bulk of our material comes from near-surface sampling, this factor could possibly be a source of bias. Comparison of near-surface with subsurface samples shows that this is not an important consideration. Stage I made up 12% of both near-surface (0.0 to 5.0 m) samples and samples from deeper water (12.0 m and down). Stages V and VI accounted for 15% of the near-surface specimens and 19% of those from greater depths. Only a small proportion of the total is found deeper than 5.0 m (Williams, 1968), and all stages show positive buoyancy in the laboratory at salinities prevailing in the study area (around 28‰). We suspect many of the reported changes in buoyancy resulted from weighting by microorganisms that grow on planktonic eggs in the laboratory (Oppenheimer, 1955).

At the beginning of the season, there may be eggs in the plankton without sufficient time having elapsed for any to have reached later stages. Cunnerns start to spawn in the spring when temperatures reach about 10.0°C. The first eggs of the season must take much longer to develop than the 2 days (at about 23.0°C) reported by Kuntz and Radcliffe (1918, see also footnote 2). Stage-frequencies from early in the season might, therefore, give spuriously low ESR's. In addition, survival to hatching might well be lower in the cooler

part of the season because of the more prolonged exposure of the embryo to environmental hazards. Late in the spawning season (September) temperatures are still high and development rapid. If spawning stopped abruptly, there might be a period in which later stages are still present but no early ones. Hence, there are reasons for expecting that ESR's calculated for the cooler part of the season might be much lower than those calculated for the warmer. This expectation is not borne out. The midpoint of the temperature range at which cunner eggs are found is 18.0°C. If we divide the samples into two groups, according to whether surface temperatures in the sound were above or below 18.0°C, we find that ESR's for 1963 and the total collection are higher for the cooler part of the season (Table 3). In 1963, we took 754 eggs at 10.0° to 18.0°C on 3 different days, and 3,393 eggs at 8.0° to 26.0°C on 10 days. The difference for the other years is slight, and unreliable, because it largely involves comparing samples from warm water in 1962 and 1964 with cool water in 1965 and 1968. Even if the comparison is accepted, the similarity in the ESR's must mean that survival per unit time is greater in cool water than in warm.

Table 3. ESR's for earlier (cooler) and later (warmer) parts of spawning seasons.

<u>°C</u>	<u>1963</u>	<u>Other years</u>	<u>ESR</u>
10 - 18	.213	.041	.104
18 - 26	.039	.050	.045

To extend the temporal and geographic range of the investigation, we utilized cunner eggs stored in the Bingham Oceanographic Collection at Yale University. We used part of the material on which earlier surveys of fish eggs and larvae of Long Island Sound had been based (Wheatland, 1956; Richards, 1959). The east is represented by collections from east of 72°50' and the west by collections from west of 73°10'. ESR's for these regions are much the same. Unfortunately, the eastern series is represented entirely by material collected in 1952, and the western by material from 1953, 1956, and 1958. North (near New Haven Harbor) and south (our study area) are both represented by material collected in 1952, 1953, and 1956, much of it from collections on the same days in the two areas. The unrealistically high value for the south must be the result of an influx of later stages at a greater rate than their removal by death. The small number of specimens in an appreciable number of samples may stem from the same cause.

Note also that the ESR's for the 1950's (Table 4) are generally higher than those calculated for the 1960's. Other collections from the 1950's, for which we cannot find adequate locality data, also show higher ESR's than our specimens. The total of all cunner eggs found in the Bingham Oceanographic Collection gives an ESR of 0.34, much higher than our 0.05 for the 1960's.

Table 4. Geographic variation in ESR's based on material from Long Island Sound in Bingham Oceanographic Collection.

	<u>No. of samples</u>	<u>No. of specimens</u>	<u>ESR</u>
North	26	1410	0.029
South	23	127	1.828
East	7	105	0.079
West	17	424	0.171

DISCUSSION

It would appear that cunner egg survival in Long Island Sound is poor, with about one in 20 surviving to hatching; that survival may be better (per unit time at least) earlier in the season than later, despite the temperature difference; and that survival may have been at a generally higher level in the 1950's than the 1960's. Acceptability of these conclusions depends on how well we establish the stage-frequencies as a valid life table. The bias for afternoon collection times and any inaccuracy in our determination of the midpoint of development are obvious sources of error.

Undoubtedly, the most serious problem is the possibility of geographic bias. Wheatland (1956) found egg production to be greater in the western than the eastern part of the sound, and greater nearshore than farther out. Dispersal by currents would cause ESR's to be spuriously low in regions of abundant egg production, and high where spawning is light. The limited information (Table 4) suggests east-west transport would not seriously affect stage-frequencies in either region. The north-south comparison shows conditions must have been considerably different in the 1950's than those we encountered in the 1960's. The high apparent ESR and paucity of eggs in the south indicate that the eggs found there were mainly later stages that had drifted in from elsewhere. In the later material from the south, early stages consistently predominated and indicated abundant spawning locally. If any considerable fraction of the later stages originated outside the area, the difference in ESR between the 1950's and 1960's must be even greater than our figures indicate.

What we know of water movements in our study area makes it unlikely that egg transport produces any great distortion of our stage-frequency distributions. Riley (1956) showed that surface waters in the sound move in general from west to east and that net transport may be as much as 6 km per tidal cycle. So, at times, a cunner egg might completely cross our area in four tidal cycles, which is undoubtedly much less than the period of development during the cooler part of the spawning season. Nevertheless, such sustained water movement may be infrequent and Riley emphasized its variability and dependence on the wind. Later (Larkin and Riley, 1967), the variability proved true, and a chart showed net movement in opposite directions at different distances from shore. Thus, it must often happen that cunner eggs originate and complete their development within our area, especially in the warmer part of the season.

Moreover, there is no reason to believe that eggs carried into our area would have different stage-frequency distributions from those carried out. There is little east-west gradation of salinity or other hydrographic conditions, and cunner are common and presumably spawn all along the coast. In comparing stage-frequencies from different parts of our study area, we find only one difference worth noting. Stage I makes up 18% of the eggs from harbors and tidal inlets and only 12% of those from deep water in the sound. This suggests predominantly nearshore spawning, but has scarcely any effect on ESR's.

Thus, neither the gross nor local geographic comparisons, nor information on circulation patterns indicates any strong regional influences on stage-frequency distributions. We concede, however, that the narrowness of our geographic coverage is a serious shortcoming of the material collected from Stony Brook.

We regard the apparent difference in ESR between the 1950's and 1960's not as an effect demonstrated, but merely as a possibility to be kept in mind for future work. The establishment of differences in ESR between specific years, or any sustained trend through the years, will demand a more concentrated investigation than we have been able to conduct.

Likewise, the apparently greater survival per unit time, and perhaps to hatching, in the earlier, cooler part of the season is merely an interesting possibility to be watched for in future work. It bears on the problem of assigning causes of the mortality that takes place. We believe physical or chemical stresses and parasitism can only be of minor importance as direct causes of death, because there are so few dead or grossly defective eggs in the plankton. Whatever causes death normally removes the eggs from the plankton. We feel, then, that predation is the primary destructive agent. A chemical factor, a pollutant for instance, may perhaps act indirectly by retarding development so as to allow more time for predation. Unless our stage II is considerably longer than the other stages recognized, our data might be interpreted as indicating an accumulation of individuals in this stage.

We suspect ctenophores and medusae may be among the more important predators. Both are strikingly abundant in the warmer months, when the ESR seems to be low, and we often find fish eggs in jellyfish stomachs. Fraser (1964) amassed evidence that ctenophores in nature can rapidly deplete zooplankton communities.

Our work agrees with Reid's (1930) in assigning a low egg survival to the cunner. If any generalization is warranted by this and other work reviewed earlier, it is that planktonic fish eggs have low survival rates where we would expect suitable predators to be abundant, as in coastal waters and in boreal oceanic waters in the spring. Where planktonic predators are sparse, as in warmer oceanic waters, fish egg survival is high. There is no reason to expect a similar pattern for larvae. We might expect them to survive better in a rich plankton that provides them with an abundant food. The apparently low survival of cunner eggs in Long Island Sound and Canadian

coast waters (Reid, 1930) need not mean that they do not produce successful year-classes in these areas. A 0.5-km female cunner would not be extraordinary. If she produced a tenth of her weight in eggs in a season (probably a conservative estimate), this would mean about 100,000 eggs. At the calculated ESR of 0.05, her one-season effort would result in 5,000 larvae. Perhaps more adults would result from this 5,000 in the productive waters of the sound than from many times this number in a less nourishing environment.

OTHER SPECIES

We have compiled stage-frequency distributions for other species with planktonic eggs in Long Island Sound. We believe calculated ESR's are unreliable for the fourbeard rockling (Enchelyopus cimbrius) and windowpane (Scophthalmus aquosus) because their slow development makes stage-frequencies largely a function of date of collection and aggravates the problem of dispersal and geographic variation in stage-frequencies. For the bay anchovy (Anchoa mitchilli), we have indications of localized spawning and strong geographic variation in stage-frequencies. For other species, we do not yet have sufficient material.

In general, calculated ESR's for all these species are low, compared to most other values reported in the literature. It would appear that 0.2 would be an extraordinarily high ESR for any species in Long Island Sound. While we assume our ESR for a given species is unreliable, the fact that they are generally low lends credence to our conclusion of a low value for the cunner.

Except for the anchovy, ESR's based on our collections from the south central part of the sound in the 1960's are lower than the ESR's for the same species based on the Bingham material from the 1950's.

SUMMARY

The cunner, Tautogolabrus adspersus (Walbaum), spawns planktonic eggs mainly around dawn in Long Island Sound. These eggs are subject to heavy mortality, and only about one in 20 survives to hatching. Survival is at least as high in the early, cooler part of the season as it is later on, and it may have been higher in the 1950's than in the 1960's. Predation is probably the most important cause of death.

ACKNOWLEDGMENTS

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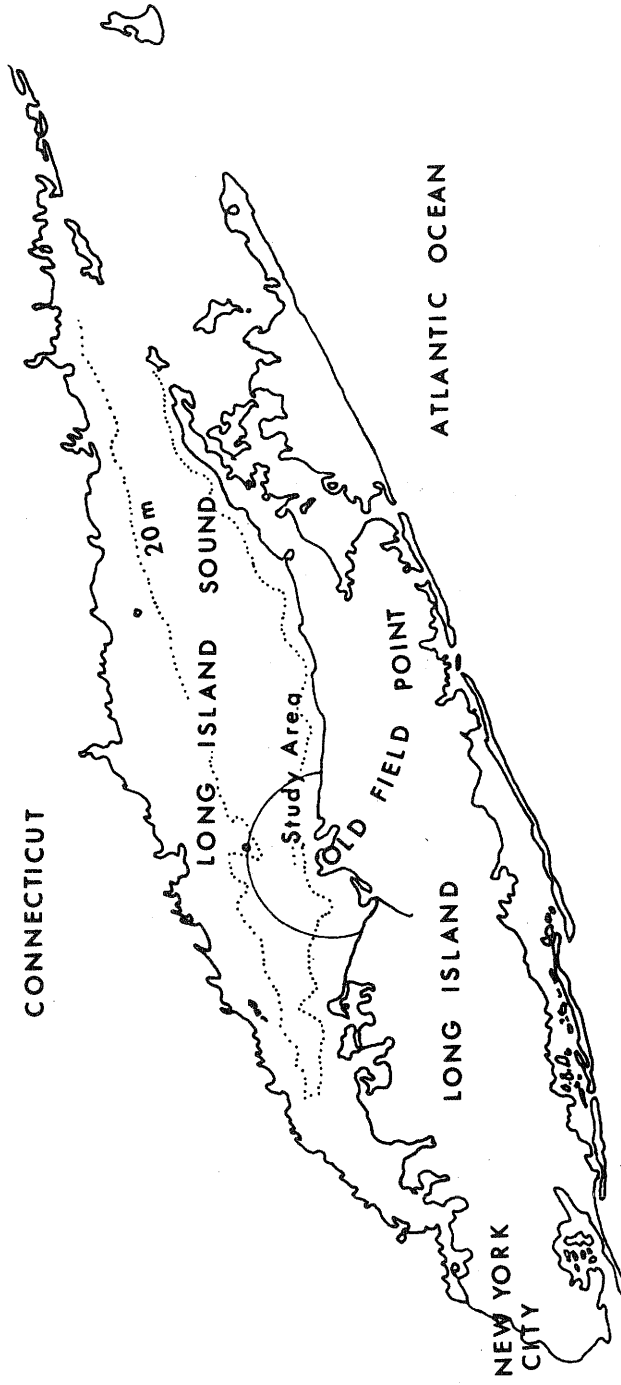
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Figure 1. Long Island Sound, showing approximate limits of study area.

73°



41°

41°

73°

0 kilometers 50

ENVIRONMENTAL ADAPTATIONS

Chairman

Edwin P. Joseph

RESEARCH ON OSMOTIC AND IONIC REGULATIONS IN
FISH EGGS AND LARVAE WITH COMMENTS ON POLLUTION

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ABSTRACT

Prior to the measurement of osmotic and ionic regulations, it is important to determine when the egg or larval system comes into equilibrium with the environment. Before considering the effect of any environmental parameter on osmotic or ionic regulation, it is necessary to establish whether the egg or larval stage osmoregulates, osmoconforms, or combines both processes. When an egg or larva is found in a condition of varying salinity, it does not necessarily mean the organism osmoregulates since cases of extremely tolerant osmoconformity have been shown to exist.

Adults and larvae must be examined separately for their capacities to regulate ionically and osmotically. Research in the osmotic and ionic regulation of larval stages of invertebrates has revealed it is improbable that larvae will show the same osmoregulatory patterns as adults. In this sense, it is improbable and likely impossible to transfer information about osmotic regulation between adults and larvae. Planktonic invertebrate larvae, for example, represent a totally independent pattern of osmoregulation from adults of a species. Generally, invertebrate larvae are more tolerant of environmental extremes. Virtually no research of the same experimental character has been done for fish eggs and larvae. Checking of osmoregulatory capacity must be preceded by determination of salinity tolerance using LD₅₀ techniques.

Effects of pollution on normal osmotic and ionic regulatory patterns in fishes can be observed since most domestic and nondomestic pollution affects osmotic regulation. A recommended approach to this problem is the use of a standard imitation of the pollutant; however, samples of polluted water from the actual environment in question would probably yield more accurate and more ecologically appropriate results. The physical nature of pollutants should be isolated from

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their chemical effects. Working first with the chemical effect, the physical nature of the pollution can be imitated by use of an inert physical substitute in the test environment. Many organic compounds are biologically inert and have the same surface and physical characteristics as those found in polluted waters. Adjuvant and synergistic effects, such as the effect of temperature on the specific toxicity to the osmoregulatory mechanism of chemical effluents, should be carefully examined.

DISCUSSION

Schwartz asked what effect excision of the membrane, exposing the larvae, would have on the osmotic and ionic regulation. Kalber replied that the effect would probably be considerable. In experiments on invertebrates, the animals exhibit a reaction in varying depressive amounts of osmotic regulation and water permeability; both survival and growth rates are affected.

Carlson questioned the feasibility of putting a portable laboratory in the effluent canal of a power plant. Kalber maintained that this is a good idea but only if the viability of the effluent is maintained. Carlson added that, when there is an interest in determining effects of nuclear power plant thermal effluents, chlorination effects should also be considered.

INTERACTIONS OF CHRONIC GAMMA RADIATION, SALINITY, AND TEMPERATURE
ON THE MORPHOLOGY OF POSTLARVAL PINFISH, LAGODON RHOMBOIDES¹

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ABSTRACT

We determined interactions of three environmental factors (chronic gamma radiation, salinity, and temperature) upon the morphometrical growth of postlarval pinfish, Lagodon rhomboides, with a 3³ factorial design experiment. We used combinations of three radiation levels (0, 0.83, 1.28 rads per hour), three salinities (10, 20, 30‰), and three temperatures (15.0°, 20.0°, 25.0°C) in the experiment and measured nine different body characteristics on each of 1,215 fish. Statistically significant effects of the environmental factors are described only for the terminal sample (45 days) of 405 fish. Radiation affected two of the measured characteristics, salinity affected five, and temperature affected all nine characteristics. Interactions between radiation and salinity caused changes in four of the characteristics, and interactions of radiation and temperature altered eight. Salinity and temperature did not interact to alter the growth of postlarval pinfish. The second order interaction between radiation, salinity, and temperature affected seven of the nine characteristics measured. In general, temperature exerted the major influence on the growth of these animals, with an increase in temperature usually causing an increase in growth. Ecological implications are discussed.

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INTRODUCTION

Estuarine organisms have always been exposed to chronic low levels of ionizing radiation from cosmic rays and naturally occurring radioisotopes. In addition, these organisms have been exposed to widely fluctuating temperatures and salinities. Animals inhabiting the estuaries and lower reaches of rivers have the ability, under normal circumstances, to adapt readily to these natural changes in their environment. Since 1942, the existing levels of background radiation have increased many times because of nuclear weapons tests and the effluents of nuclear reactors. Increased water usage and diversion have sometimes altered the temperature regimens in rivers and estuaries and caused the estuarine salt wedge to penetrate further upstream. Possible effects on aquatic species of exposures to these increased levels of chronic ionizing radiation, temperature, and salinity are largely unknown and have become a subject of increasing concern.

Estuaries are unstable environments with tidal cycles and annual weather cycles that cause wide variations in temperature and salinity. In the study area, Beaufort, North Carolina, daily estuarine water temperatures vary as much as 5.0°C, while salinities vary 1‰. Seasonal water temperatures may range from 2.0° to 30.0°C and salinity may vary as much as 2‰ over a 12-month period. If the effects of one environmental factor on an organism were independent of other factors, existing levels in the environment probably would not be detrimental. Any single factor, however, is rarely independent of all other environmental factors. Rather, there exists an interaction that we know little about. Hence, as many factors as possible have to be considered simultaneously to determine synergistic or antagonistic effects.

The effects of salinity, temperature, and their interactions on estuarine animals and the tolerance of euryhaline species to these factors are well documented (Kinne, 1963; 1964). Only recently have the effects of radiation, salinity, and temperature interactions on an estuarine teleost been described (Angelovic et al., 1969). The purpose of the present study was to expand our knowledge of environmental interactions by exploring the effects of low levels of chronic gamma radiation, salinity, and temperature, and their possible interactions, on the morphology of an estuarine teleost, the pinfish, Lagodon rhomboides (Linnaeus), during its transformation from postlarva to juvenile.

EXPERIMENTAL DESIGN AND PROCEDURES

The experiment was a randomized 3³ factorial design with three temperatures (15.0°, 20.0°, 25.0°C), three salinities (10, 20, 30‰), three radiation exposure levels (0, 0.83, 1.28 rads per hour), and three replications at each combination. Fish received either no radiation (controls) or accumulated doses of 865 rads or 1,335 rads during the experiment which lasted 45 days. There were 81 aquaria in the design, each with 30 fish. Random samples of five fish were taken from each aquarium at 45 days after irradiation had begun. These five fish made up one replication for any combination of radiation, salinity, and temperature. Five fish samples were also removed randomly at 15 and 30 days to minimize the effects of crowding.

Postlarval pinfish were irradiated with a 5-curie cobalt 60 source for an average of 23.17 hours a day for 45 days. Aquaria were placed at random in two concentric circles around the source (27 aquaria per circle) to give the two dose rates used in the experiment. Radiation dose rates were measured in the center of the aquaria with glass rod dosimeters calibrated to read directly in rads. This reading was used to calculate the dose to the fish based on the assumption that the fish moved randomly throughout the aquaria.

Measurements of 405 fish were made to the nearest 0.01 mm using a micrometer in a binocular microscope. These measurements included: standard length (SL), head length (H), snout-to-vent length (S-V), greatest body depth (D), eye diameter (E), last dorsal spine length (DS), first dorsal ray length (DR), and second anal spine length (AS). After blotting off all excess moisture, wet weights (Wt) were determined to the nearest milligram on a single pan balance. All measurements other than standard length and wet weight are presented as ratios of standard length in order to establish a base line for comparison. Standard lengths are presented in millimeters and weights in milligrams wet weight per millimeter standard length (mg/mm).

The mean measurements \pm 1 standard error of 50 fish at the beginning of irradiation were:

SL-----	11.98	\pm 0.08	mm
SL/H-----	3.77	\pm 0.02	
SL/S-V-----	1.99	\pm 0.01	
SL/D-----	4.77	\pm 0.03	
SL/E-----	10.04	\pm 0.06	
SL/DS-----	17.74	\pm 0.28	
SL/DR-----	11.57	\pm 0.21	
SL/AS-----	14.23	\pm 0.18	
Wt/SL-----	1.32	\pm 0.03	mg/mm

ENVIRONMENTAL FACTORS AND INTERACTIONS AFFECTING GROWTH

After the fish had been maintained for 45 days under the described conditions, an analysis of variance (Ostle, 1954) showed that all nine body characteristics measured were significantly changed by temperature, five by salinity, and only two by radiation (Table 1). The interactions between the three variables of radiation, salinity, and temperature also caused significant changes in the measured characteristics (Table 1). The interactions of radiation \times salinity and radiation \times temperature caused significant changes in 12 of 18 possible instances. Effects of the interactions between salinity \times temperature, however, did not significantly alter any measured characteristic during the 45 days of this study. The interaction of radiation \times salinity \times temperature had a significant effect on seven of the nine measurements. Interactions in nature appear to be the rule rather than the exception, especially in estuaries which are in a constant state of flux; therefore, these interactions may be more important in affecting the external body form than any one independent factor.

DIFFERENCES IN BODY CHARACTERISTICS AFTER 45 DAYS

Standard length and body depth were altered significantly by radiation, temperature, and their interactions. Weight and snout-to-vent length also were affected significantly by temperature and the radiation \times temperature interaction but the main effect of radiation was not significant (Table 1). The main effect of radiation was to cause a somewhat longer, deeper-bodied fish at the lowest radiation level of 0.83 rads per hour (Table 2), while an increase in temperature generally caused a longer, deeper-bodied, heavier fish with a relatively longer snout-to-vent length (Table 3).

Head length, eye diameter, and lengths of the last dorsal spine, first dorsal ray, and second anal spine were changed significantly by temperature and by salinity (Tables 3 and 4). In general, the independent effect of these two environmental factors resulted in relatively larger body parts as temperature and salinity levels increased, except for the effect of salinity on eye diameter. In this instance, the relative size of the eye was larger at the lowest salinity.

The diameter of the eye and the lengths of the last dorsal spine, first dorsal ray, and second anal spine were changed significantly by the interaction between radiation and salinity (Fig. 1). The general result was the same as that for the main effect of salinity, i.e., as salinity increased, body parts tended to become longer. This indicates salinity was the controlling factor in the interaction with radiation acting as the modifier. Once again, the reaction of the eye was different.

The interaction surface formed by the action of radiation and temperature showed longer, heavier, deeper-bodied fish with relatively longer body parts at 15.0°C as radiation levels increased (Figs. 2 and 3). At 20.0°C, the fish receiving 0.83 rads per hour were longer, heavier, and deeper-bodied than either fish in the control group or the group receiving 1.28 rads per hour (Fig. 2). There was no change in the relative length of the head, last dorsal spine, first dorsal ray, and second anal spine with increased radiation levels at 20.0°C. As temperature increased from 15.0° to 25.0°C, the general trend of increasing size with increasing levels of radiation was reversed (Fig. 3).

The interaction of radiation, salinity, and temperature changed all measured body characteristics significantly except the last dorsal spine length and first dorsal ray length (Table 1). Based on the significance of the main effects and their interactions, the significance of the three-way interaction is considered real and not an accident of random fluctuation.

ECOLOGICAL IMPLICATIONS

Effects of low levels of chronic radiation on organisms in the marine environment are not well known. Levels as low as 0.50 rads⁴ per day and 0.41 rads per day of chronic cobalt 60 irradiation caused no observable effects on eggs and alevins of the anadromous chinook salmon, Oncorhynchus tshawytscha, and coho salmon, O. kisutch, respectively (Donaldson and Bonham, 1964). These eggs are spawned in freshwater and the alevins migrate to sea to grow to adulthood. There have been relatively few studies describing the effects of acute doses of radiation in the marine environment. Angelovic et al. (1969) have shown that the tolerance of the mummichog, Fundulus heteroclitus, to acute radiation doses is altered by salinity and temperature. Radiation levels required to kill 50% of a population of animals (LD₅₀) have been established for several marine and estuarine species by White and Angelovic (1966). Postlarval pinfish were shown to have an LD₅₀ (50 days) value of 2,083 rads at 18.0°C. The accumulated doses used in the present study on this species (865 rads and 1,335 rads) are, therefore, assumed to be sublethal since most organisms can tolerate larger amounts of chronic irradiation than acute radiation.

Temperature appears to have more effect on the overall growth of irradiated and unirradiated fish than salinity or radiation. In general, as temperature levels increase, the growth of the fish increases. Temperature is known to control the distribution, reproduction, growth, and meristic structure of aquatic animals (Kinne, 1963). The temperature of the aquatic environment is of particular concern since most poikilothermic fishes have body temperatures very close to that of their surrounding medium. Fossil fuel and nuclear plants, as well as other water-using industries, slightly increase the temperature of river and estuarine water over a relatively small area. If postlarval pinfish, products of a winter spawn, enter an area of relatively higher, gradually increasing temperature in the estuary, it is possible that the fish might experience accelerated growth rates. Increased temperatures, not reaching the maximum in winter that they do in summer, may therefore be beneficial. It should be noted also that, while an increase in temperature in the summer might exceed the tolerance limit for a given species, many species of fishes by nature seek cooler waters and will tend to leave an area of elevated temperature.

The finding that salinity per se did not exert a significant influence on the growth of pinfish under the conditions of this experiment does not agree with Gibson and Hirst (1955), who found that increased salinities caused an increase in the growth rate of the guppy, Lebistes reticulatus, and Canagaratnam (1959), who found that various salmonids grew more rapidly in saline water. In these instances, however, growth in saline water was contrasted with growth in freshwater and the effects were observed over a longer period of time, which may account for the disparity of results. Others have shown that the weight of postlarval summer flounders, Paralichthys dentatus (Deubler and White, 1962), and southern flounders, P. lethostigma (Deubler, 1960), tended to increase with increasing salinity. For pinfish, the relative size of certain body parts also increased significantly with salinity. If the fish were under osmotic stress

The unit of radiation dosage used by Donaldson and Bonham (1964) and by White and Angelovic (1966) was the roentgen. For purposes of clarification, roentgen units have been changed to rad (radiation absorbed dose) units by dividing by the conversion factor of 1.08.

in low salinity water, it is possible that, under the conditions of a constant diet, growth was suppressed as a result of increased energy requirements for routine metabolism. Salinity, in addition to influencing growth, can limit the distribution of fish (Gunter, 1961; Kinne, 1964), and modifies the response of estuarine organisms to ionizing radiation (Angelovic et al., 1966).

Fish exposed to the lowest level of radiation were slightly longer and deeper-bodied than unirradiated fish or those exposed to higher levels of radiation. This suggests a stimulation of growth by radiation. Similar effects have been noted in experiments with salmon (Donaldson and Bonham, 1964) and the blue crab, Callinectes sapidus (Engel, 1967). Since the radiation \times temperature interaction at 15.0°C produced a heavier and deeper-bodied fish with relatively longer body parts as radiation levels increased, stimulation of growth could be a possible factor in the present experiment. If stimulation of growth were real and could be reproduced, this combination of environmental factors might be used in aquaculture. Low radiation levels would be relatively easy to produce by suspending a small radiation source above a body of water. A temperature near 15.0°C also would be easy to maintain in the winter by proper utilization of heated power plant effluent. Postlarval pinfish caught and placed in a holding pond of sufficient size under these conditions should grow at a faster rate than normal. If the postlarvae of commercial winter spawners were also stimulated in growth by low levels of chronic radiation under specific environmental conditions, the chances for marine fish farming on a commercial scale might be enhanced. Further study along these lines is needed.

The genetic effect of low level chronic irradiation in the estuary on future generations of fish is an important consideration. Genetic materials in the developing gonad are very susceptible to ionizing radiation and may undergo mutations that would not appear until the F₁ or later generations. The mutations could lead to a stronger or weaker population of fish, depending on the action of the mutation. Reduction in life span, reproductive capacity, resistance to disease, and tolerance of environmental changes in the irradiated population or their progeny are detrimental effects which must be considered as distinct possibilities.

The subjects of chronic irradiation and thermal additions and their combined effects on estuarine populations require far more attention than they have received. Probably of equal importance is a need for studies of the potentially beneficial effects that might be derived by manipulating these environmental factors. It should be reemphasized, however, that inhabitants of the estuary are not controlled by any single factor. While the action of one factor, such as elevated temperature, may by itself promote the growth of an animal, another factor, such as salinity or radiation, may be either synergistic or antagonistic in its interaction with temperature. Therefore, as many variables as possible must be studied simultaneously to understand and utilize the effects of man on the estuarine environment and its inhabitants.

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DISCUSSION

Graham asked if White examined the residuals from his individual samples to determine other characteristics or influences that were not controlled. By residual, Graham implied that these might reflect a trend of some unknown influence. White said many characteristics could be measured although he tried to control all variables. He did not plot his residuals to see if they fit a normal curve because he ran replications and no difference appeared among these replications except for greatest body depth. This difference was unexplainable.

In answer to Davis' questions on feeding, White stated that the pinfish received an excess amount of Artemia salina nauplii daily, supplemented with dry fish food.

De Sylva asked if White planned to rear his pinfish to spawn them and thereby obtain information on succeeding generations. White replied that the eggs of this species are unknown. Although he had ripe pinfish in the laboratory, he found it impossible to strip them.

In answer to Kalber, White remarked that he did not manipulate temperature to stimulate spawning. He commented on the advantages of experimenting with pinfish because the species ranges from Cape Cod to Yucatan and may extend well into estuaries, occurring in waters with salinities as low as 0.1‰.

Kalber also asked for a clarification of terminology. White referred to the migration of young to the estuary as a transition from a stable to a harsh environment. Kalber suggested not equating instability with harshness, because this instability might be biologically required and therefore not harsh in that sense.

Table 1. Composite results from the analyses of variance.

Source of Variation	Measured Characteristic ⁵								
	SL	SL/H	SL/S-V	SL/D	SL/E	SL/DS	SL/DR	SL/AS	WT/SL
Replications	-	-	-	*	-	-	-	-	-
Treatments:									
Radiation	*	-	-	**	-	-	-	-	-
Salinity	-	**	-	-	*	**	**	**	-
Temperature	**	**	**	**	**	**	**	**	**
Radiation × salinity	-	-	-	-	**	*	*	*	-
Radiation × temperature	**	**	**	**	-	**	*	*	**
Salinity × temperature	-	-	-	-	-	-	-	-	-
Radiation × salinity × temperature	**	**	**	**	**	-	-	**	**

⁵Measurements described in experimental design

- Not significant
- * Significant at the 5% level
- ** Significant at the 1% level

Table 2. Table of means for the significant effects of radiation after 45 days of exposure.

Characteristic	Radiation Level in Rads/Hour		
	0	0.83	1.28
Standard length (mm)*	14.80	15.16	14.76
Standard length/greatest body depth**	3.14	3.02	3.08

* Significant at the 5% level

** Significant at the 1% level

Table 3. Table of means for the significant effects of temperature after 45 days of exposure.

Characteristic	Temperature (°C)		
	15	20	25
Standard length (mm)**	14.68	14.27	15.75
Standard length/ greatest body depth**	3.11	3.16	2.96
Standard length/ snout-to-vent length**	1.73	1.75	1.71
Wet weight/ standard length (mg/mm)**	5.40	4.90	6.65
Standard length/ head length**	3.52	3.50	3.44
Standard length/ eye diameter**	8.70	8.44	8.45
Standard length/ last dorsal spine length**	10.83	10.56	9.82
Standard length/ first dorsal ray length**	7.56	7.51	7.05
Standard length/ second anal spine length**	11.88	11.28	10.51

** Significant at the 1% level

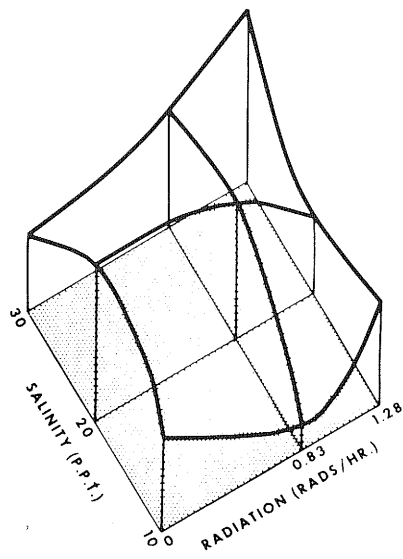
Table 4. Table of means for the significant effects of salinity after 45 days of exposure.

Characteristic	Salinity (‰)		
	10	20	30
Standard length/ head length**	3.52	3.49	3.46
Standard length/ eye diameter*	8.43	8.59	8.57
Standard length/ last dorsal spine length**	10.56	10.64	10.01
Standard length/ first dorsal ray length**	7.47	7.48	7.17
Standard length/ second anal spine length**	11.38	11.44	10.84

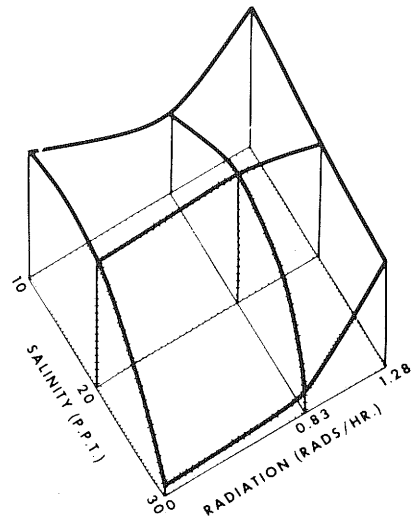
* Significant at the 5% level

** Significant at the 1% level

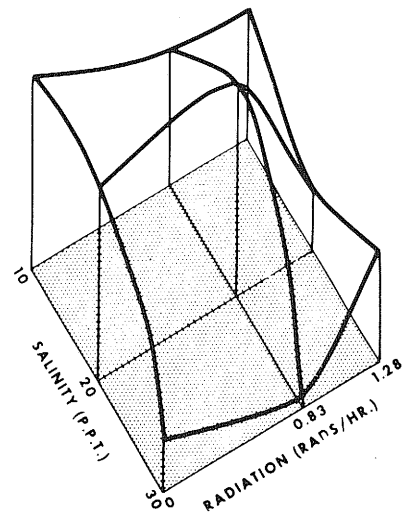
Figure 1. The interaction surface formed by the ratio of the standard length to (a) eye diameter, (b) second anal spine length, (c) first dorsal ray length, and (d) last dorsal spine length of pinfish exposed to three levels of salinity and three levels of radiation for 45 days.



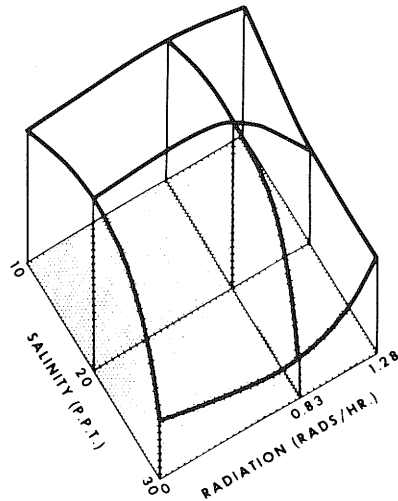
S.L./E.
8.8
8.6
8.4
8.2



S.L./A.S.
12.0
11.5
11.0
10.5

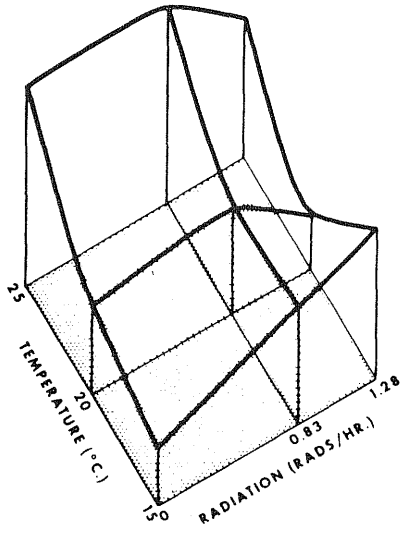


S.L./D.R.
7.8
7.6
7.4
7.2
7.0



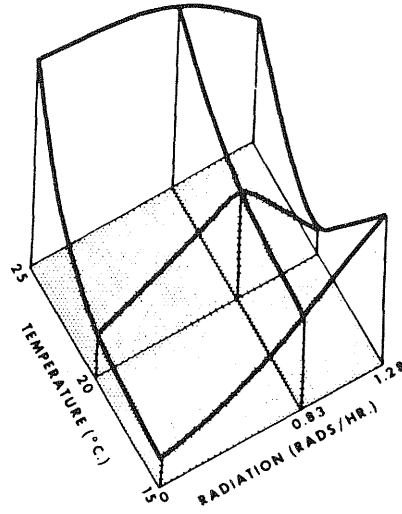
S.L./D.S.
11.0
10.5
10.0
9.5

Figure 2. The interaction surface formed by (a) the standard length, (b) the ratio of wet weight to standard length, (c) the ratio of standard length to greatest body depth, and (d) the ratio of standard length to snout-vent length of pinfish exposed to three levels of temperature and three levels of radiation for 45 days.



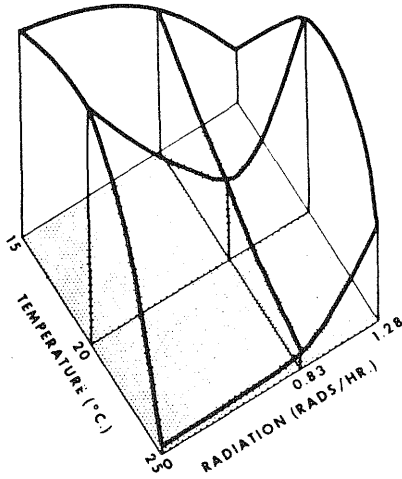
S.L. (MM.)

17.0
16.0
15.0
14.0
13.0



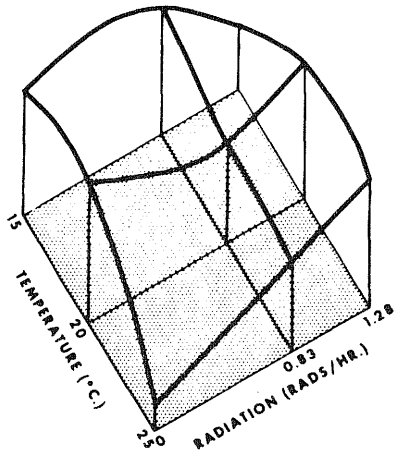
WT./S.L. (MG./MM.)

8.0
7.0
6.0
5.0
4.0



S.L./D.

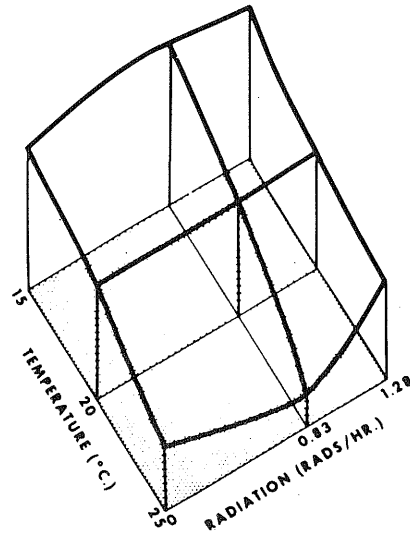
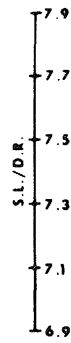
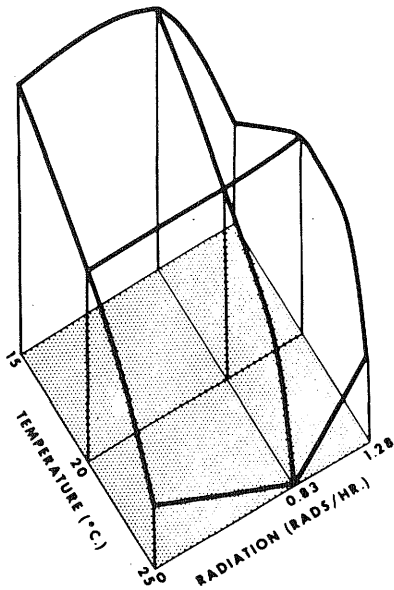
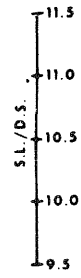
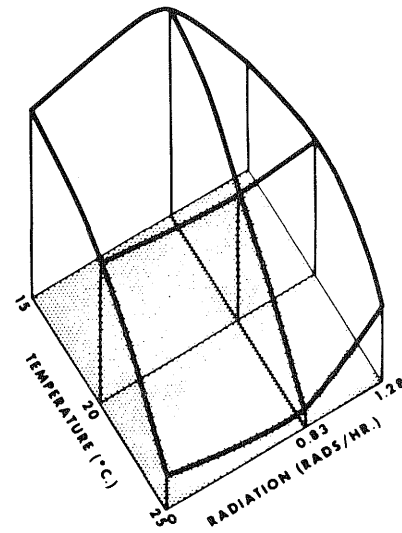
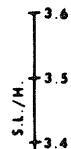
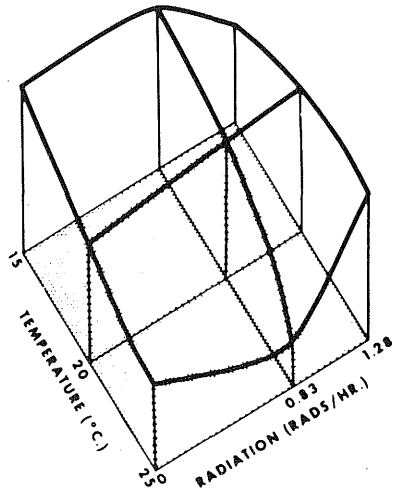
3.3
3.2
3.1
3.0
2.9



S.L./S-V

1.80
1.75
1.70
1.65

Figure 3. The interaction surface formed by the ratio of the standard length to (a) head length, (b) last dorsal spine length, (c) first dorsal ray length, and (d) second anal spine length of pinfish exposed to three levels of temperature and three levels of radiation for 45 days.



METABOLISM OF LARVAL ESTUARINE FISH¹

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ABSTRACT

We determined the metabolism of two species of postlarval estuarine fish -- pinfish, Lagodon rhomboides, and croaker, Micropogon undulatus -- by measurement of their routine oxygen consumption (oxygen consumed by specimens whose only movements are spontaneous) under laboratory conditions. We compared oxygen consumption rates of the postlarvae with consumption rates of juveniles and adults of the same species. A large range in fish sizes necessitated use of two methods to measure oxygen consumption: a differential respirometer for fish up to 500 mg and a flowing water respirometer for larger fish. We determined oxygen consumption of postlarval croaker at four salinities (10, 20, 30, and 40‰) and three temperatures (15.0°, 20.0°, and 25.0°C) after the fish were acclimated to the conditions.

Routine metabolism of the postlarval fish, measured as oxygen consumption per unit weight of fish, changed very little over the size range used. Slope values, k , of regression lines calculated from the weight of the postlarval fish versus the amount of oxygen consumed, a , were close to unity (1.12 for croaker and 0.95 for pinfish). In larger fish, oxygen consumption per unit weight decreased as the fish increased in size. Routine metabolic rate of the croaker showed no significant difference at the four different salinities. Routine oxygen consumption of the croaker was significantly greater, however, at the higher temperatures. The Q_{10} values for croaker were 1.77 for the temperature range of 15.0° to 20.0°C and 0.77 for the range 20.0° to 25.0°C. Results of pinfish were similar.

¹This research was supported through a cooperative agreement between the U. S. Fish and Wildlife Service and the U. S. Atomic Energy Commission.

²Formerly: Bureau of Commercial Fisheries, Radiobiological Laboratory, Beaufort, North Carolina 28516

DISCUSSION

Witham criticized 25.0°C as the high limit of temperatures. Hoss replied that this was the range used in this study, and seemed to be a reasonable limit based on seasonal temperatures experienced by postlarvae.

Kalber asked if White determined a-values for the progression of ranges of sizes or species. He commented that the a-value as a simple figure, since it is a coefficient in terms of constant proportionality, would be useful for a regression determination of the exponential k.

Hoss had calculated a-values and Kalber then asked how they varied. Hoss said he agrees with Mann of England, who accepts Windberg's work with the k-value but says a-values differ with species. Hoss said he should have shown all the a-values.

Kalber commented that k is simply a relation between weight and oxygen consumption and Hoss actually equated oxygen consumption, metabolism, and respiration. He said a, or, at any rate, the difference between the slopes of the regression lines, may represent a dependence on a different metabolism during the midphase versus the initial or terminal phases; a would be an effective single factor expressing this difference since it discounts weight-oxygen consumption relationship and is a constant of proportionality. The real value seemed to Kalber to lie in calculating a for subgroups, not for entire species.

COMPARISON OF THE FISH FAUNA OVER SAND-FILLED AND NATURAL
BOTTOMS OF GREAT SOUTH BAY, NEW YORK - A PROGRESS REPORT

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ABSTRACT

We captured a total of 297,795 fish (weighing 303,477 grams) of 29 species in 62 seine hauls made over natural bottoms in Great South Bay between mid-May and mid-October in 1967 (exclusive of the month of June). Atlantic silverside, fourspine stickleback, and mummichog were principal species encountered over this environment. A total of 320,665 fish (weighing 486,201 grams) of 24 species were captured with equal effort during the same time period over adjacent sand-filled bottoms. Atlantic silverside and striped killifish dominated the catches made over sand-filled bottoms. Several species found in large numbers in one environment were either absent entirely or taken in considerably lower quantities in the other. In addition, we observed different size distributions for the same species in each of the two bottom types.

INTRODUCTION

Great South Bay is located on the south shore of Long Island about 40 miles east of New York City. It is approximately 26 miles long and varies from 2 to 5 miles in width. It is continuous with and bounded by South Oyster Bay to the west and Bellport Bay to the east. The southern boundary is a barrier beach, broken by Fire Island Inlet. Except in the vicinity of Fire Island Inlet and in dredged boat channels, Great South Bay is relatively shallow, with few areas exceeding 3.3 m in depth.

Dredging for the improvement of existing channels, for the creation of new channels, and for the further development of land has resulted in the loss of much of the original wetlands surrounding the bay. Fill has been deposited upon many of the islands in the bay. This fill, in addition to destroying wetland areas on the islands, has encroached upon the bay bottoms adjacent to the spoil areas. Considering the continued pressure for increased dredging, we decided to study the effects of sand-filling on the fish fauna inhabiting waters adjacent to islands used for spoil deposition. When complete, the

study will present two field seasons of data concerning the number of fish species and their relative abundance over sand-filled and adjacent natural bottoms. The present paper, it must be emphasized, is merely a progress report covering the first field season. The data presented, although tabulated, are basically untreated and have yet to be subjected to statistical analysis.

DESCRIPTION OF THE STUDY AREAS

We chose three islands -- Captree, Cedar, and Grass Islands -- in Great South Bay as study sites. All have been used as spoil areas and all have areas of sand-filled bay bottom adjacent to natural bottom. Maximum water depth of the areas seined ranged to about 1.3 m at Cedar Island and to about 0.6 or 1.0 m at Captree and Grass Islands.

The bottoms of the natural areas were mostly mud with a dense growth of eelgrass (Zostera marina) and associated epiphytic flora. Some growth of Ulva lactuca, Enteromorpha sp., and Chaetomorpha sp. was also present. During July and August, the eelgrass became thickly entangled with floating masses of Cladophora gracilis.

We found the sand-filled bottom areas to be mostly barren of vegetation in May, but from July through mid-October varying amounts of detached, floating blades of eelgrass were observed. Often, these blades of eelgrass became sanded in, giving one the impression of growing plants. As occurred in natural areas, thick masses of Cladophora gracilis appeared in July and August. At Cedar Island, we found some Enteromorpha linza growing attached to large pebbles close to shore in September, and also at Cedar Island floating masses of Polysiphonia sp. in abundance in late September and October were encountered.

TECHNIQUES

The sampling gear consisted of a 2- × 100-m (with warp) nylon beach seine composed of 3.81-cm stretch mesh in the wings, 9.64-cm knotless mesh in the bunt, and 0.32-cm knotless mesh in the bag. This seine was set using an 18-foot skiff, in a pattern to conform as closely as possible to the shape of a rectangle encompassing 836 m² of surface area. Seining was conducted at each of three paired stations over adjacent natural and sand-filled bottoms at the collecting sites. Inclement weather and filamentous algal blooms permitted seining on only 62 of 75 randomly selected dates from mid-May through mid-October (excluding the month of June).

Immediately after each net haul, water temperature and salinity at 0.33 m below the surface were recorded. From a record of time at the end of each haul, we determined tidal stage from a published tide table using U. S. Coast and Geodetic Survey figures and corrected for the area seined.

The captured fish were identified and separated by species. If we caught 100 or fewer of a species in a haul of the net, we measured all fish in the sample of that species on a standard measuring board to the nearest millimeter in total or fork length (dependent upon the conformation of the caudal fin of the species) and then weighed the entire sample on a Hanson dietetic scale to the nearest gram. If we took a species in numbers exceeding 100, we measured and weighed a random subsample of 100. The number of specimens in the total sample was subsequently estimated by dividing the weight of the subsample by 100 to obtain the average weight of each fish, and then dividing the weight of the total sample by the average weight of each fish. In cases where the total sample weighed less than 1 gram, biomass was determined by displacement to the nearest 0.1 ml in a 10-ml-capacity graduated cylinder.

Total percentage frequency distributions were calculated by size and graphed according to capture environment for those species taken in total numbers exceeding 100 each over each bottom type. Except for the winter flounder, Pseudopleuronectes americanus, for which we used all measured specimens, each graph was constructed from a subsample of 200 fish selected at random from the total measured sample of each species collected at each environment.

SPECIES AND RELATIVE ABUNDANCE

We captured a total of 618,460 fish (weighing 789,678 grams) of 32 species in 62 paired sets of seine hauls (124 hauls in all) made at the seining sites. Of these, we took 297,795 fish (weighing 303,477 grams) of 29 species over natural bottoms (Table 1), but 320,665 fish (weighing 486,201 grams) of 24 species over sand-filled bottoms (Table 2). An average of 10 species per haul were taken over natural bay bottoms, compared to an average of eight species per haul seined over sand-filled bottoms.

Three species of fish appeared in all 62 hauls made over natural bay bottoms (Table 1): Atlantic silverside, Menidia menidia; fourspine stickleback, Apeltes quadracus; and mummichog, Fundulus heteroclitus. Another species, northern pipefish, Syngnathus fuscus, occurred in all but one haul (at Cedar Island) made over natural bottoms. Atlantic silverside, fourspine stickleback, and mummichog were the only species captured in total numbers exceeding 10,000 each over natural bottoms. Ten other species were taken in total numbers greater than 100 each over natural bottoms: northern puffer, Sphaeroides maculatus; northern pipefish, Syngnathus fuscus; threespine stickleback, Gasterosteus aculeatus; Atlantic needlefish, Strongylura marina; striped killifish, Fundulus majalis; sheephead minnow, Cyprinodon variegatus; silver perch, Bairdiella chrysura; American eel, Anguilla rostrata; winter flounder, Pseudopleuronectes americanus; and oyster toadfish, Opsanus tau.

Striped killifish was the only species to occur in all 62 hauls made over sand-filled bottoms (Table 2). However, Atlantic silverside, although absent from one haul at Captree Island in May, constituted over two-thirds of all fish seined over sand-filled bottoms. Both of the latter were the only species taken in total numbers exceeding 10,000 each over sand-filled bottoms. We took nine other species in total numbers greater than 100 each over sand-filled bottoms: sheepshead minnow; fourspine stickleback; northern puffer; mummichog; striped mullet, Mugil cephalus; Atlantic needlefish; northern pipefish; northern kingfish, Menticirrhus saxatilis; and winter flounder.

Certain species found in abundance in one environment were often absent in the other, or encountered in much reduced numbers. Threespine stickleback and silver perch, for example, were abundant over natural bottoms, but absent entirely over sand-filled bottoms. Other species encountered in far greater numbers over natural bottoms than over sand-filled bottoms included: fourspine stickleback; mummichog; American eel; oyster toadfish; rainwater killifish, Lucania parva (captured only at Captree Island); and tautog, Tautoga onitis. On the other hand, striped killifish, sheepshead minnow, striped mullet, and northern kingfish were found in greater numbers over sand-filled bottoms than over natural bottoms.

SIZE

As indicated by the mean lengths shown in Tables 1 and 2, the sampling gear proved effective in taking juveniles of most species. Indeed, we seined specimens as small as 9 mm in total length (e.g., northern puffer).

Length-frequency distributions (Figs. 1-9) indicated differences for some species between environments. For example, we took the smaller specimens of Atlantic silverside and sheepshead minnow mostly over natural bottoms, while the smaller specimens of winter flounder and striped killifish were found in proportionately greater numbers over sand-filled bottoms. Though we did not capture young of the latter species less than 13 mm, we observed many at the water's edge of sand-filled, but not natural, areas in early July. The larger northern puffer were almost entirely absent from sand-filled bottoms. There appeared to be little size difference with regard to bottom type for fourspine stickleback, mummichog, Atlantic needlefish, and northern pipefish.

TEMPERATURE AND SALINITY

Temperature and salinity ranges for all species captured are presented by habitat in Table 3. Salinities ranged from 23.8 to 31.0‰ over both environments. Temperatures ranged from 50.0° to 80.0°F (10.8° to 26.7°C) over natural bottoms and from 50.0° to 81.0°F (10.8° to 27.2°C) over sand-filled bottoms.

DISCUSSION

In response to Massmann's comment that sand-filled areas would be comparable to open beach, Briggs said the sand-filled area is similar to an open beach area. However, his study was to compare such artificially created open beaches and, therefore, a drastically changed environment.

Davis asked how long it takes sand-filled areas to revert to their original condition. Briggs noted the oldest fill area of his study, Grass Island, which was started in 1959 or 1960.

Herke queried Briggs as to comparisons of the depths in both natural and sand-filled areas. Briggs said the depths are equal at Grass and Cedar Islands and there is little difference between the natural and the sand-filled at Captree Island. Depth probably had no effect on the study. Alperin added that tidal amplitude was only about 1.5 feet.

Massmann cited Merriman's study on a beach to note the difference of fauna at high and low tides. He found the difference in fauna between the exposed beach and the low tide area (which is similar to an unfilled area) to reflect that of two distinct ecological areas.

Briggs commented that few studies have compared adjacent sand-filled and natural areas. He noted the presence of fourspine stickleback and northern pipefish as indicative of movement from the natural area to the sand-filled.

In reply to a question pertaining to the species distribution response to the removal of grass by dredging, Briggs said his study encompassed only the filled areas. He noted that coverage of the grass by sand-fill will eliminate sticklebacks and also make the area more suitable for striped killifish and Atlantic silversides, which show up later when the floating grass comes in.

In answer to a question by Murawski on seining technique, Briggs reiterated that no outboard power was used during the sweeps. Graham asked about the presence of Ammodytes and their possible avoidance of net by burrowing into sand. Briggs said he suspected this was true because only three were taken, and added they occur more often in the inlet area and the north shore of Long Island.

Briggs responded to Alperin's questions on differences by saying that the biomass is greater in the sand-filled area, primarily because of the increased number of silversides. In response to Alperin's query as to the relation of predators in the two areas, Briggs noted there are few predators other than needlefish in the areas in which they seine, although adult flounder and swellfish move into the shallows to feed. Few snapper bluefish were captured. There were no night observations.

Presley asked about changes in temperature due to solar radiation because of the different reflections of the sand-filled and natural bottoms. Briggs answered that temperature and salinity were relatively constant for the paired hauls he made within an hour of each other.

Schwartz asked about variations in the human use of the areas. Briggs observed during summer that there is considerably more swimming and beach party activity in the sand-filled areas. Bait fishermen have not yet exploited the sandy beach zone.

Figure 1. Percent length-frequency of Atlantic silverside. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.

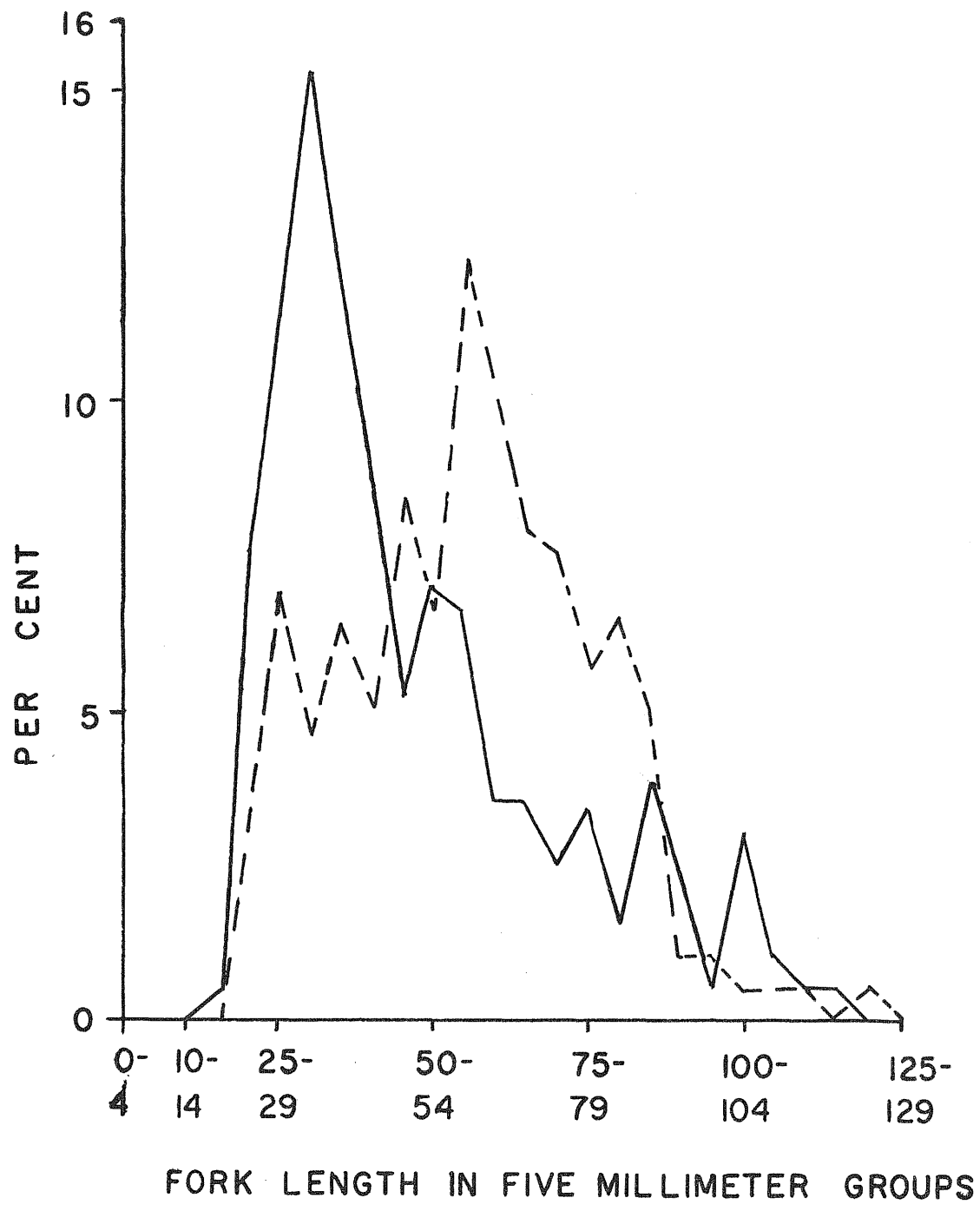
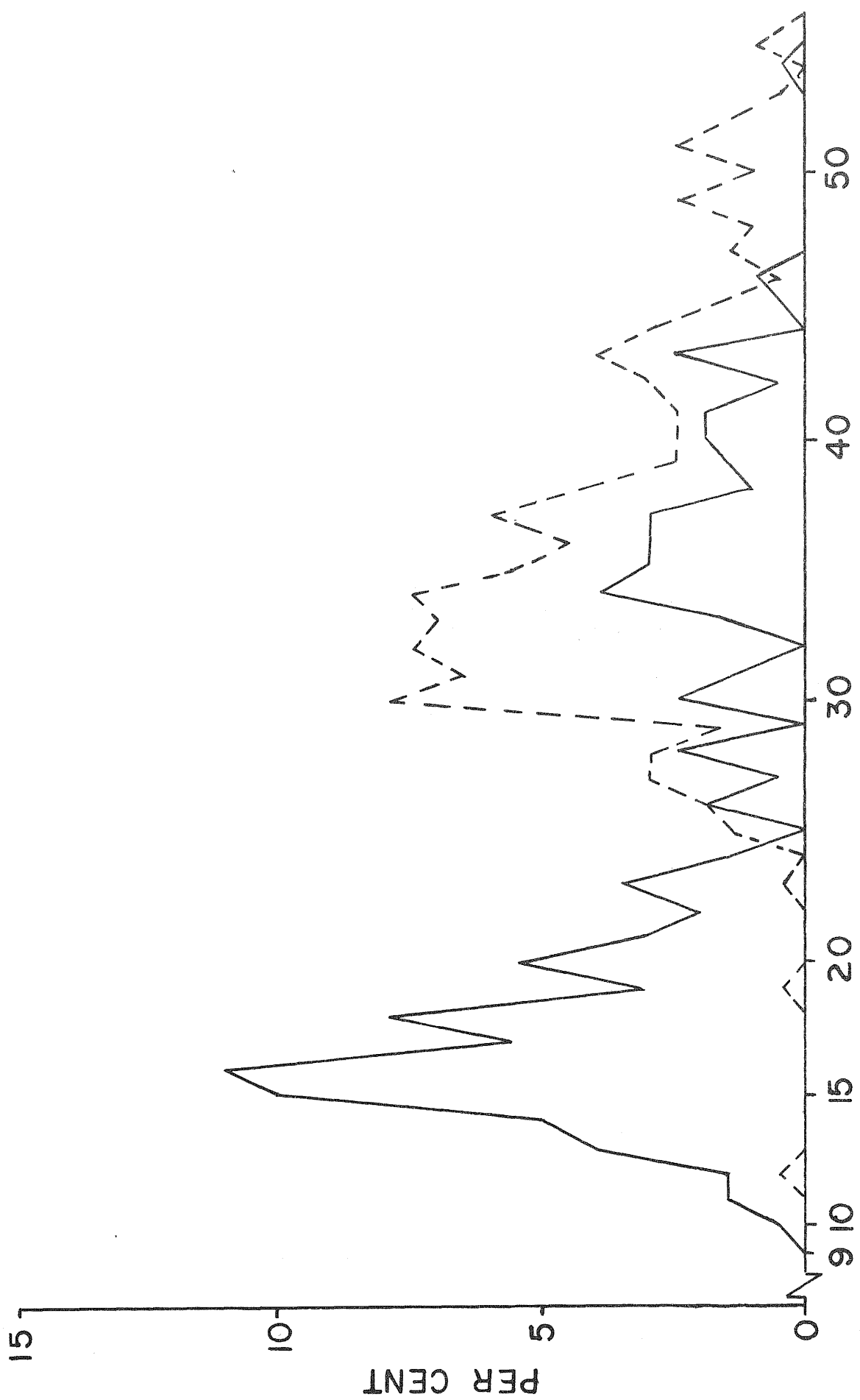
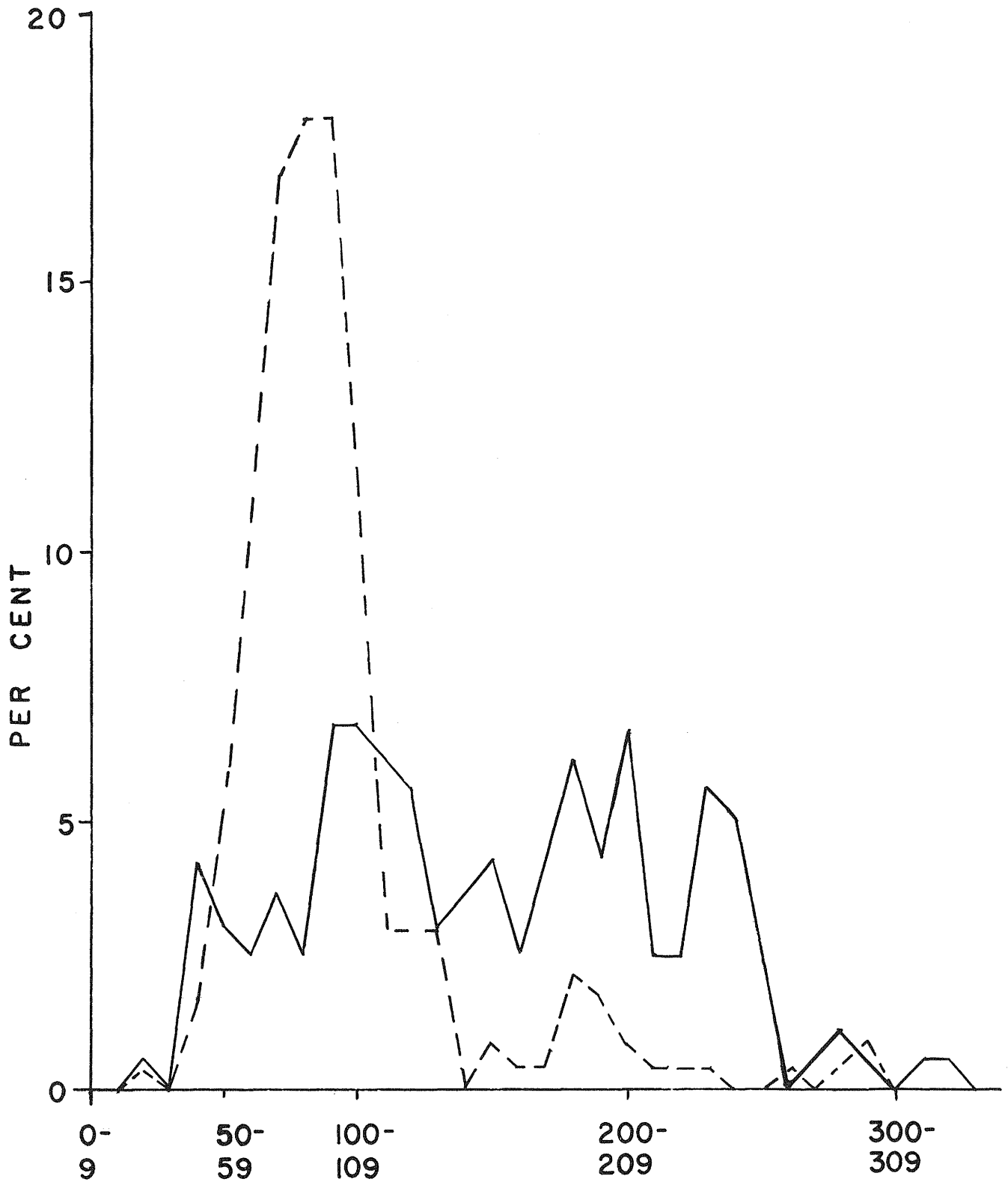


Figure 2. Percent length-frequency of sheepshead minnow. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.



TOTAL LENGTH IN MILLIMETERS

Figure 3. Percent length-frequency of winter flounder. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.



TOTAL LENGTH IN TEN MILLIMETER GROUPS

Figure 4. Percent length-frequency of striped killifish. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.

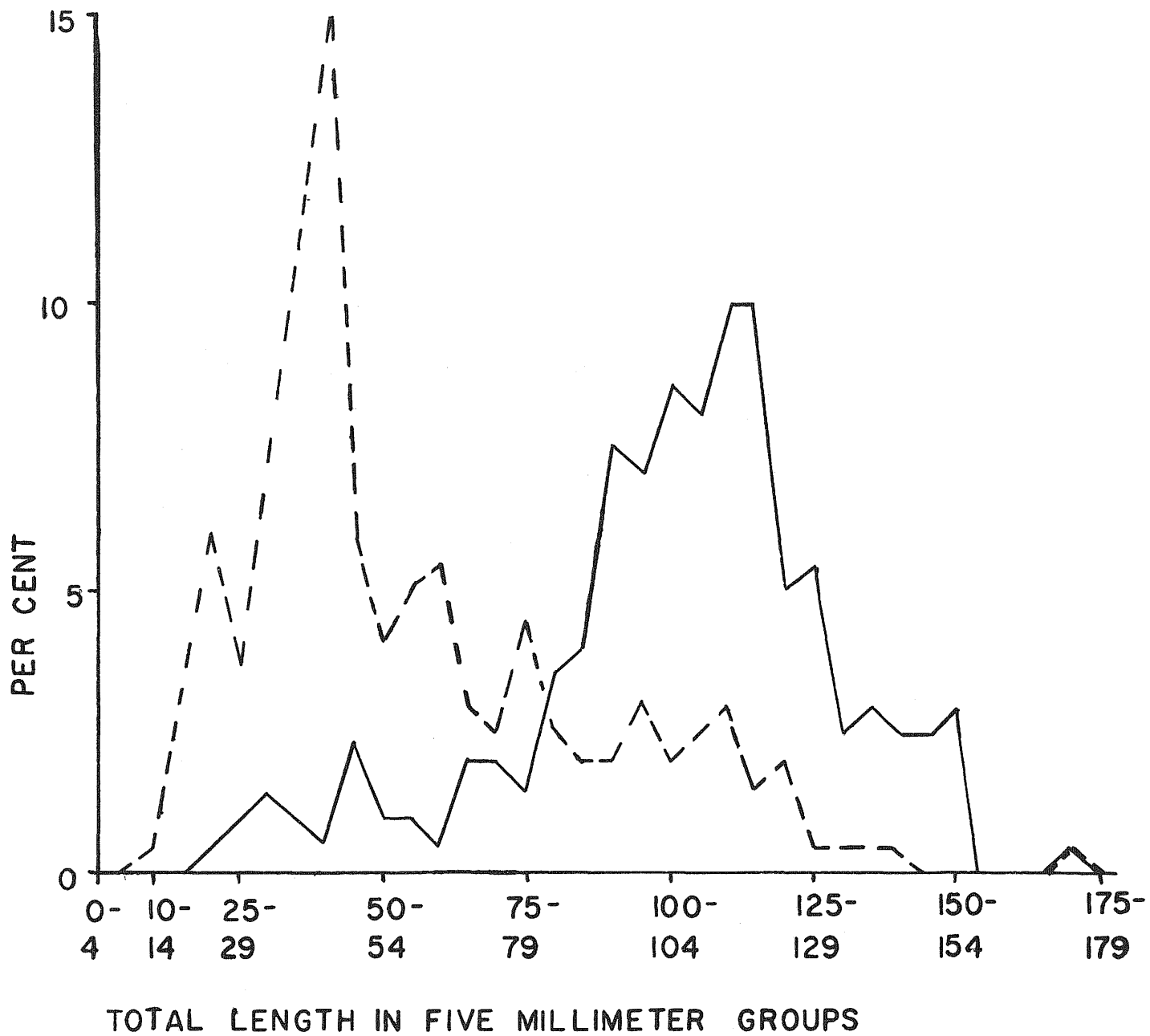
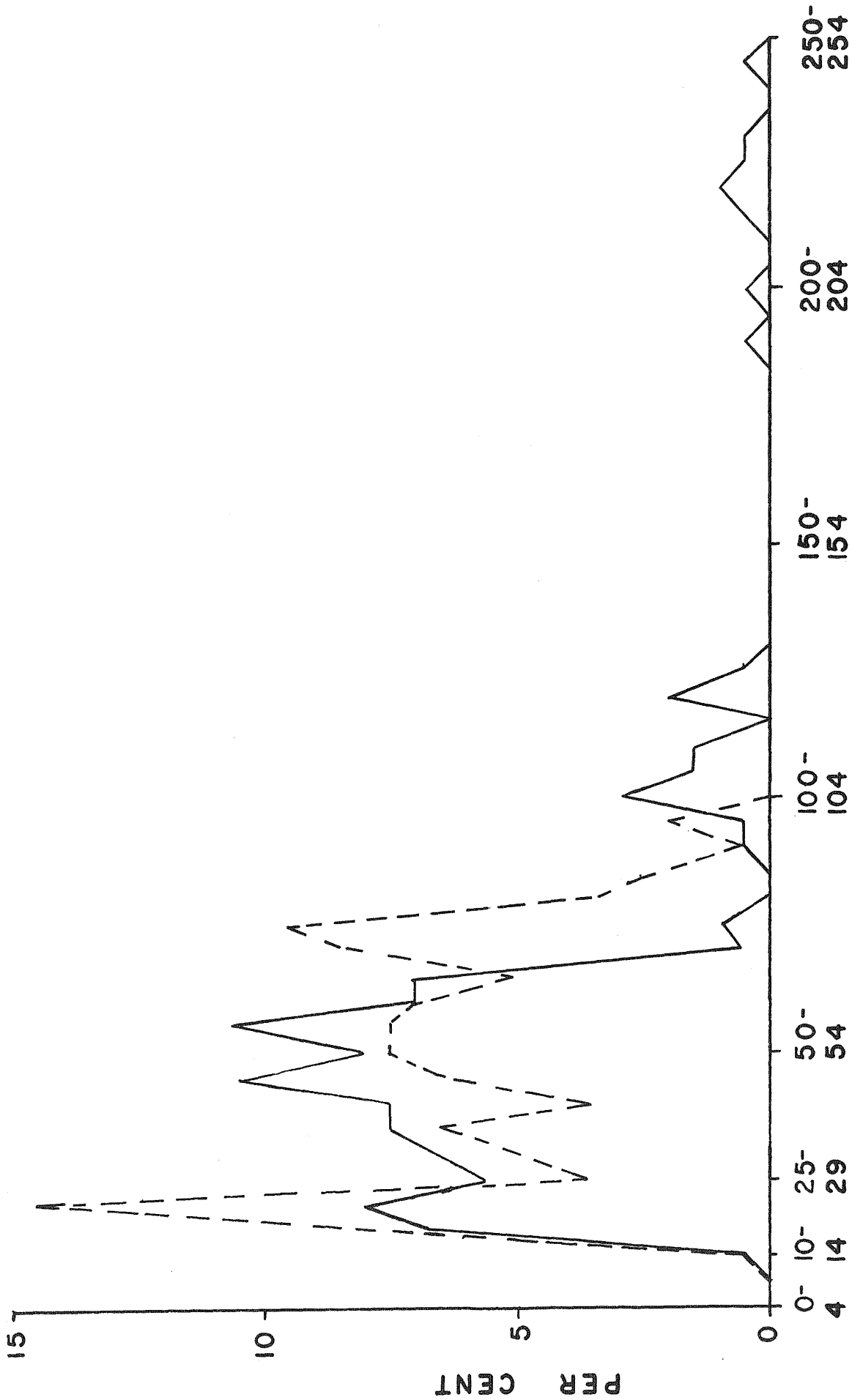
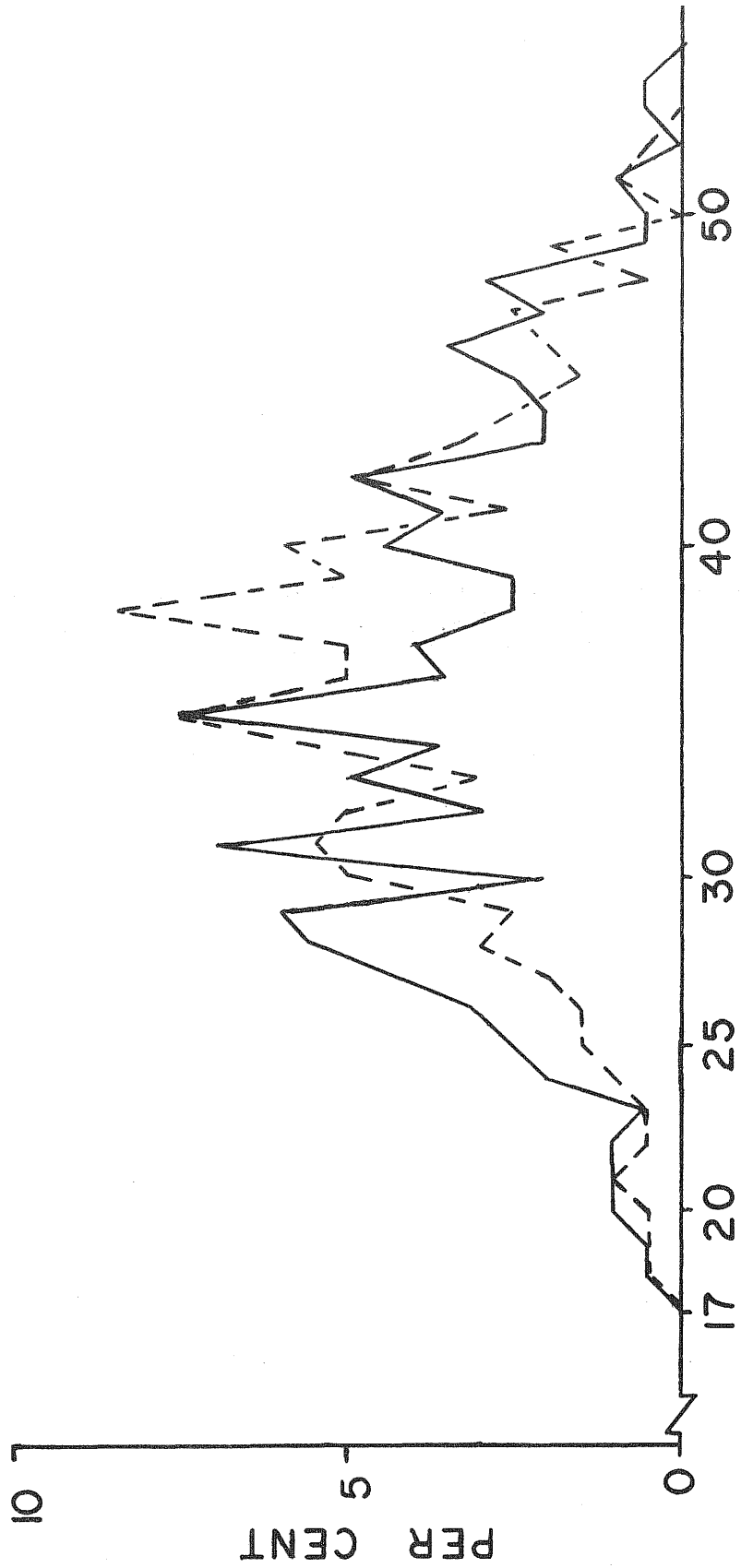


Figure 5. Percent length-frequency of northern puffer. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.



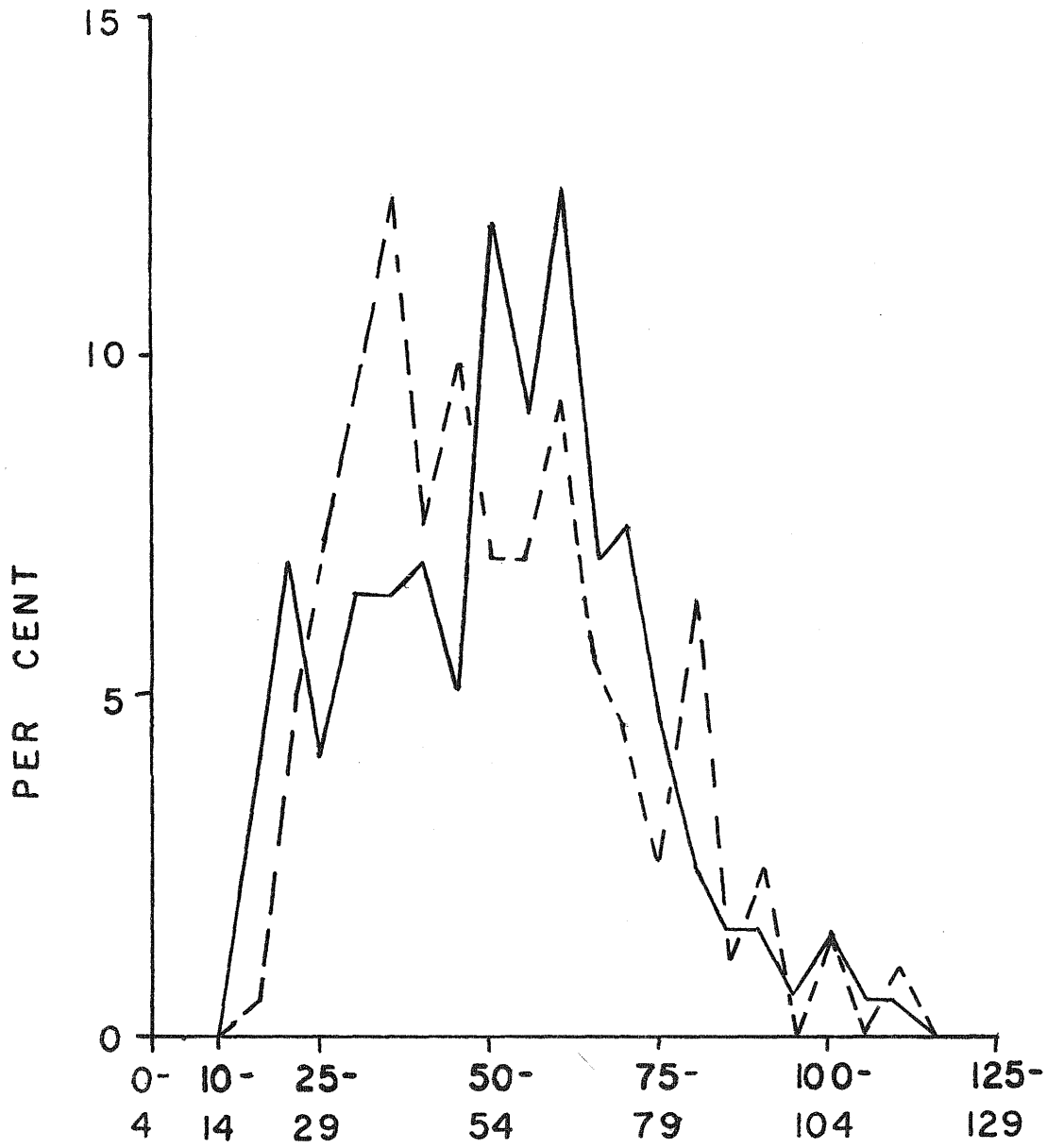
TOTAL LENGTH IN FIVE MILLIMETER GROUPS

Figure 6. Percent length-frequency of fourspine stickleback.
Solid line denotes fish from natural bottoms; dashed line
denotes fish from sand-filled bottoms.



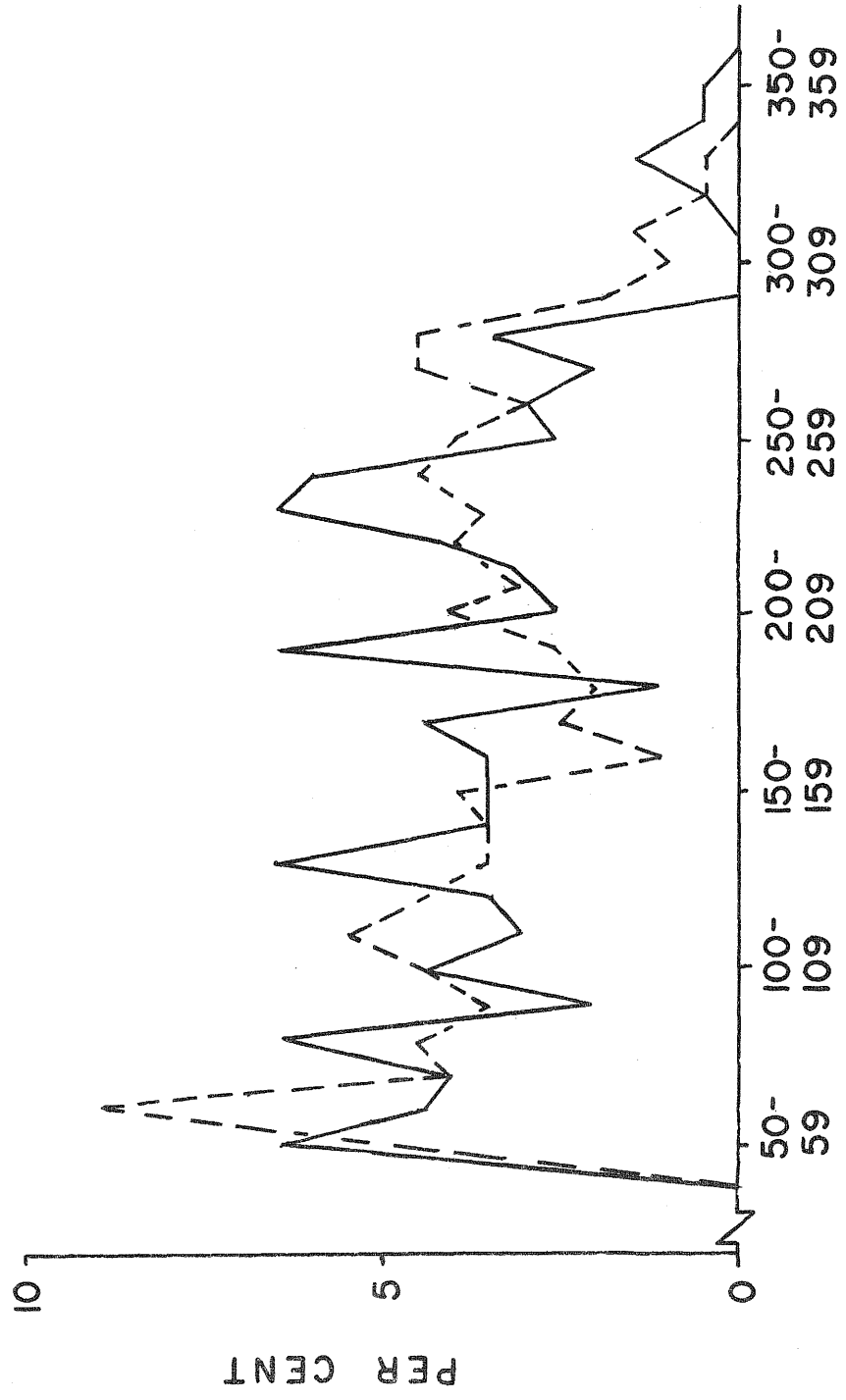
TOTAL LENGTH IN MILLIMETERS

Figure 7. Percent length-frequency of mummichog. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.



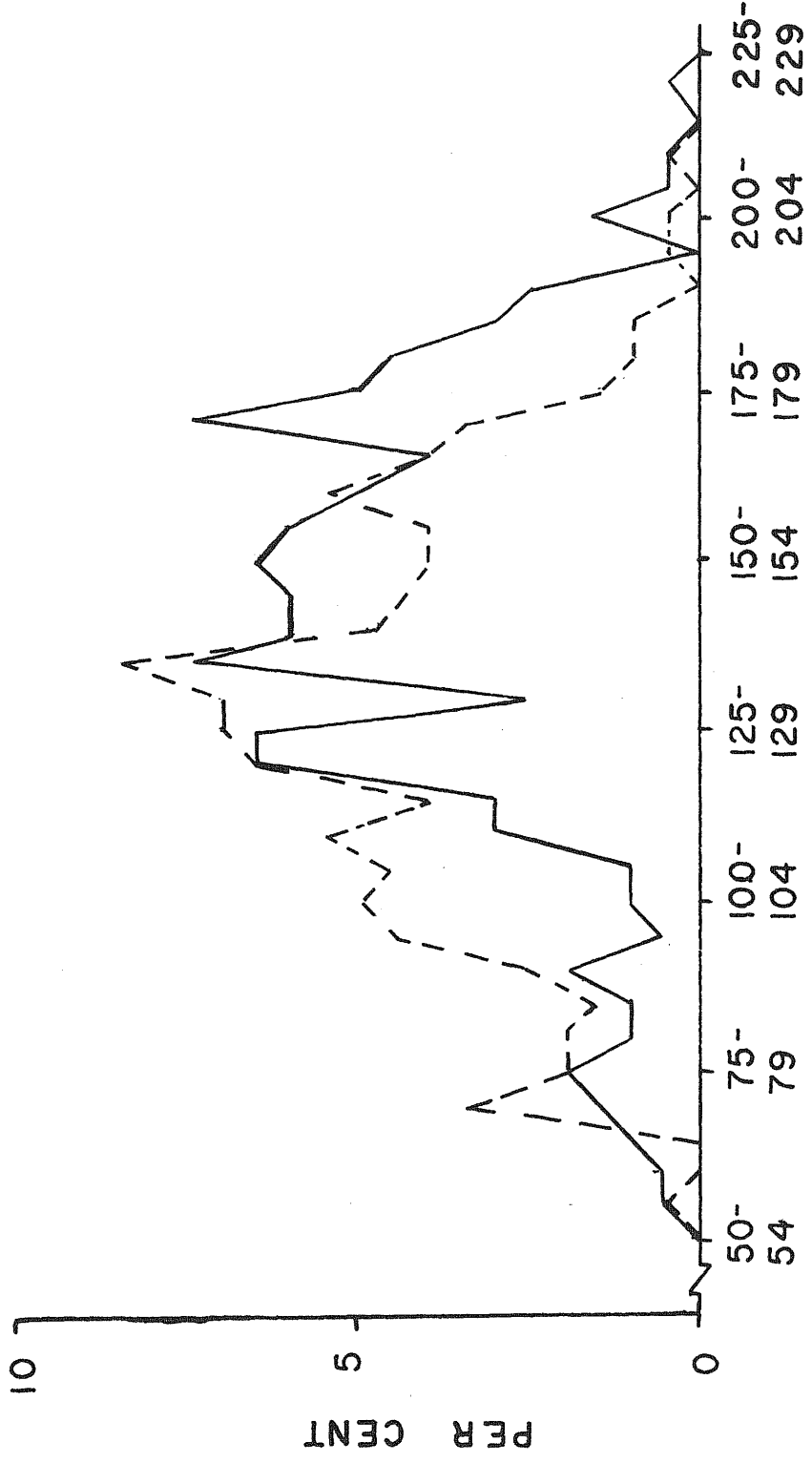
TOTAL LENGTH IN FIVE MILLIMETER GROUPS

Figure 8. Percent length-frequency of Atlantic needlefish. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.



TOTAL LENGTH IN TEN MILLIMETER GROUPS

Figure 9. Percent length-frequency of northern pipefish. Solid line denotes fish from natural bottoms; dashed line denotes fish from sand-filled bottoms.



TOTAL LENGTH IN FIVE MILLIMETER GROUPS

Table 1. Characteristics of fish taken over natural bottoms.

Species	Total Specimens (Number)	Total Weight (Grams)	Frequency of Occurrence (Number of Hauls)	Mean Length (Millimeters)
<u>Menidia menidia</u>	149,606	113,025.9	62	48.6*
<u>Apeltes quadracus</u>	110,457	40,911.5	62	35.1
<u>Fundulus heteroclitus</u>	26,729	65,656.0	62	49.8
<u>Sphaeroides maculatus</u>	4,030	20,626.6	38	55.2
<u>Syngnathus fuscus</u>	2,122	2,762.1	61	141.5
<u>Gasterosteus aculeatus</u>	1,521	477.1	43	31.7
<u>Strongylura marina</u>	877	5,954.0	43	167.9
<u>Fundulus majalis</u>	779	16,975.4	47	104.1
<u>Cyprinodon variegatus</u>	593	322.9	25	24.1
<u>Bairdiella chrysur</u>	279	4,722.9	17	98.4
<u>Anguilla rostrata</u>	269	15,404.8	43	197.7
<u>Pseudopleuronectes americanus</u>	161	12,089.2	34	154.8
<u>Opsanus tau</u>	107	2,306.3	23	68.5
<u>Lucania parva</u>	63	6.9	8	20.7
<u>Clupea harengus harengus</u>	45	43.6	3	51.4*
<u>Pomatomus saltatrix</u>	38	910.0	10	113.0*
<u>Menticirrhus saxatilis</u>	23	377.0	4	118.8
<u>Tautoga onitis</u>	20	285.5	7	79.6
<u>Alosa aestivalis</u>	18	97.0	3	97.6*
<u>Brevoortia tyrannus</u>	18	73.4	7	65.1*
<u>Pollachius virens</u>	14	83.0	3	77.4*
<u>Tautoglabrus adspersus</u>	11	65.9	6	43.2
<u>Microgadus tomcod</u>	7	265.5	4	146.2
<u>Ammodytes americanus</u>	2	9.0	1	126.0*
<u>Mugil cephalus</u>	2	22.3	2	71.0*
<u>Anchoa mitchilli</u>	1	0.3	1	34.0*
<u>Myoxocephalus aeneus</u>	1	0.8	1	38.0
<u>Trachinotus falcatus</u>	1	1.0	1	35.0*
<u>Urophycis tenuis</u>	1	1.0	1	59.0
Totals	297,795	303,476.9	62	....

*Fork length; others, total length

Table 2. Characteristics of fish taken over sand-filled bottoms.

Species	Total Specimens (Number)	Total Weight (Grams)	Frequency of Occurrence (Number of Hauls)	Mean Length (Millimeters)
<u>Menidia menidia</u>	275,791	306,529.6	61	54.8*
<u>Fundulus majalis</u>	24,431	111,393.5	62	59.7
<u>Cyprinodon variegatus</u>	5,286	7,132.8	39	36.6
<u>Apeltes quadracus</u>	4,935	2,390.1	56	36.6
<u>Sphaeroides maculatus</u>	3,877	23,258.4	28	54.8
<u>Fundulus heteroclitus</u>	2,965	8,510.2	58	50.3
<u>Mugil cephalus</u>	1,696	7,446.4	16	57.6*
<u>Strongylura marina</u>	629	4,584.4	32	160.6
<u>Syngnathus fuscus</u>	388	353.8	52	127.9
<u>Menticirrhus saxatilis</u>	319	7,325.8	16	131.5
<u>Pseudopleuronectes americanus</u>	231	5,039.6	39	98.4
<u>Clupea harengus harengus</u>	32	38.0	1	51.7*
<u>Pomatomus saltatrix</u>	29	1,590.0	5	158.1*
<u>Opsanus tau</u>	19	27.3	9	41.9
<u>Brevoortia tyrannus</u>	13	58.7	7	64.3*
<u>Anguilla rostrata</u>	9	423.1	8	158.4
<u>Trachinotus falcatus</u>	4	4.5	4	35.0*
<u>Lucania parva</u>	3	1.1	3	30.3
<u>Alosa pseudoharengus</u>	2	9.0	1	79.0*
<u>Scophthalmus aquosus</u>	2	81.0	2	121.5
<u>Ammodytes americanus</u>	1	0.2	1	37.0*
<u>Centropristis striata</u>	1	0.8	1	41.0
<u>Myoxocephalus aeneus</u>	1	2.5	1	55.0
<u>Tautoga onitis</u>	1	0.3	1	28.0
Totals	320,665	486,201.1	62	....

*Fork length; others, total length

Table 3. Temperature and salinity ranges for each species by environment.

Species	N a t u r a l		B o t t o m		S a n d - f i l l e d		B o t t o m	
	Temperature Range Centigrade	Salinity Range ‰	Temperature Range Centigrade	Salinity Range ‰	Temperature Range Centigrade	Salinity Range ‰	Temperature Range Centigrade	Salinity Range ‰
<u>Menidia menidia</u>	10.8-26.7	23.8-31.0	10.8-27.2	23.8-31.0	10.8-27.2	23.8-31.0	10.8-27.2	23.8-31.0
<u>Apeltes quadracus</u>	10.8-26.7	23.8-31.0	10.6-27.2	23.8-31.0	10.6-27.2	23.8-31.0	10.6-27.2	23.8-31.0
<u>Fundulus heteroclitus</u>	10.8-26.7	23.8-31.0	10.8-27.2	23.8-31.0	12.2-27.2	23.8-31.0	12.2-27.2	23.8-31.0
<u>Fundulus majalis</u>	10.8-26.7	23.8-31.0	10.8-27.2	23.8-31.0	10.8-27.2	23.8-31.0	10.8-27.2	23.8-31.0
<u>Syngnathus fuscus</u>	10.8-26.7	23.8-31.0	10.6-27.2	23.8-30.6	10.6-27.2	23.8-30.6	10.6-27.2	23.8-30.6
<u>Sphaeroides maculatus</u>	12.8-26.7	23.8-30.0	12.8-26.7	23.8-30.0	11.1-27.2	23.8-29.0	11.1-27.2	23.8-29.0
<u>Cyprinodon variegatus</u>	12.2-26.7	24.0-29.8	12.2-26.7	24.0-29.8	12.2-27.2	23.8-29.6	12.2-27.2	23.8-29.6
<u>Mugil cephalus</u>	20.6-23.3	24.0-25.4	20.6-23.3	24.0-25.4	13.0-27.2	23.8-29.6	13.0-27.2	23.8-29.6
<u>Gasterosteus aculeatus</u>	10.8-26.1	23.8-31.0	10.8-26.1	23.8-31.0	...	...	...	...
<u>Strongylura marina</u>	15.6-26.7	23.8-29.4	15.6-26.7	23.8-29.4	16.7-27.2	23.8-29.4	16.7-27.2	23.8-29.4
<u>Pseudopleuronectes americanus</u>	10.8-26.7	24.0-31.0	10.8-26.7	24.0-31.0	10.6-25.6	23.8-30.6	10.6-25.6	23.8-30.6
<u>Bairdiella chrysura</u>	12.2-25.6	24.2-29.8	12.2-25.6	24.2-29.8	...	...	...	...
<u>Anguilla rostrata</u>	10.6-26.7	23.8-30.6	10.6-26.7	23.8-30.6	12.2-25.6	23.8-29.4	12.2-25.6	23.8-29.4
<u>Menticirrhus saxatilis</u>	20.6-25.0	24.2-27.2	20.6-25.0	24.2-27.2	17.8-25.6	23.8-27.0	17.8-25.6	23.8-27.0
<u>Opsanus tau</u>	13.3-25.6	24.0-29.8	13.3-25.6	24.0-29.8	16.7-24.4	23.8-29.4	16.7-24.4	23.8-29.4
<u>Pomatomus saltatrix</u>	20.6-25.6	24.0-27.4	20.6-25.6	24.0-27.4	19.4-25.6	24.0-27.0	19.4-25.6	24.0-27.0
<u>Clupea harengus harengus</u>	12.8-13.3	29.4-30.0	12.8-13.3	29.4-30.0	12.8	30.0	12.8	30.0
<u>Lucania parva</u>	14.4-21.1	25.4-28.2	14.4-21.1	25.4-28.2	15.6-25.0	23.8-28.2	15.6-25.0	23.8-28.2
<u>Brevoortia tyrannus</u>	10.8-20.6	25.4-30.6	10.8-20.6	25.4-30.6	10.6-25.6	24.0-30.6	10.6-25.6	24.0-30.6
<u>Tautoga onitis</u>	14.4-25.0	24.2-28.4	14.4-25.0	24.2-28.4	16.7	27.0	16.7	27.0
<u>Alosa aestivalis</u>	12.8-23.3	24.0-30.0	12.8-23.3	24.0-30.0	...	...	...	...
<u>Tautogolabrus adspersus</u>	13.3-26.1	23.8-29.8	13.3-26.1	23.8-29.8	...	...	...	...
<u>Pollachius virens</u>	10.6-13.3	29.6-30.6	10.6-13.3	29.6-30.6	...	...	...	...
<u>Microgadus tomcod</u>	14.4-24.4	24.2-28.4	14.4-24.4	24.2-28.4	...	...	...	...
<u>Trachinotus falcatus</u>	15.6	28.2	15.6	28.2	16.7-23.3	24.4-27.4	16.7-23.3	24.4-27.4
<u>Scophthalmus aquosus</u>	...	...	...	...	15.0-24.4	25.2-31.0	15.0-24.4	25.2-31.0
<u>Ammodytes americanus</u>	10.8	29.0	10.8	29.0	12.8	29.4	12.8	29.4
<u>Alosa pseudoharengus</u>	...	...	...	...	16.7	29.4	16.7	29.4
<u>Myoxocephalus aeneus</u>	20.6	25.4	20.6	25.4	20.6	25.0	20.6	25.0
<u>Anchoa mitchilli</u>	20.6	26.2	20.6	26.2	...	...	...	...
<u>Centropristis striata</u>	...	...	...	...	16.7	27.4	16.7	27.4
<u>Urophycis tenuis</u>	12.2	27.0	12.2	27.0	...	...	...	...

RANGE AND DISTRIBUTION OF SOME ESTUARINE FISHES

Chairman

John R. Clark

CHAIRMAN'S INTRODUCTION

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Conservation agencies are united in proclaiming an urgent need to protect estuaries in the interest of sustaining marine resources. To accomplish this goal, we must have detailed knowledge of the value of estuarine habitats to all types of marine resources, including the juvenile stages of important coastal fishes. The need for information on nursery ground occurrence of juveniles is particularly pressing for the sciaenids, striped bass, snook, bluefish, flukes, winter flounder, and tarpon.

Data now available in published form are not adequate to describe, for even one species of marine fish, the patterns of distribution and the circumstances of occurrence of juvenile stages in estuaries along the Atlantic coast. However, there are collections of data in the files of various laboratories and agencies that are useful in evaluating estuaries as nursery grounds. We hope to learn of any unreported collections of data on estuarine occurrence of young-of-the-year species. Only by studying the data from many states will any of us be able to learn the estuarine requirements of the migratory species that cover long distances of coastline in their yearly travels. For example, one species may spawn off one state, have nursery grounds off another, feeding areas off another, and wintering areas off another.

Our efforts to find sufficient records of juvenile stages of saltwater fish in the literature met with limited success. Not only are there gaps in the reported information on distribution, but a large share of the data collected are not published; many of the collections are not sorted; the records of others are not available. We are now trying to decide whether to conduct a new and extensive survey of our own to obtain the juvenile data we need. We hope this expensive undertaking is not necessary. Perhaps this session will help us decide. We will show you maps of the records of juvenile distribution we have assembled. (Editor's note: Some data furnished at this session were added to the maps before publication.)

The interest of the Sandy Hook Marine Laboratory in juvenile fish distribution stems from a program stimulated by initial cooperative work through the Atlantic States Marine Fisheries Commission on the early life history of the summer flounder; specifically the relation between nursery grounds, spawning grounds, and areas of adult abundance. Cooperative cruises were conducted aboard the Sandy Hook research ship Dolphin in 1963 and 1964.

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We have completed an extensive ichthyoplankton survey with the Dolphin from Cape Cod to Palm Beach. We made eight cruises from Cape Cod to Cape Lookout (1965-66). We ran 14 transects from the shore to the edge of the Continental Shelf and at each of 92 stations sampled with Gulf V plankton samplers; one from the surface to 15 m and a second from 18 to 33 m. At many stations, we towed a scaled-down Cobb midwater trawl to collect juvenile fish. Hydrographic measurements included salinity to 50 m and temperature throughout the water column. We then made four quarterly cruises from Cape Hatteras to Palm Beach (1967-68). Sampling followed the format of the previous year except that new types of juvenile collecting equipment were used. The ichthyoplankton data from the 12 cruises are the core of the laboratory's information on areas and seasons of spawning of estuarine-dependent marine species. The basic sorting of the eggs and larvae into taxonomic groups has been completed for eight cruises.

Our goal is to relate the information on offshore and coastal spawning grounds to the occurrence of juvenile fish in estuaries. Using the bluefish data as an example, I would like to stimulate discussion on the location of data we have not found and have your appraisal of the map as a useful representation of estuarine nursery grounds of bluefish.

BLUEFISH

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The bluefish, Pomatomus saltatrix (Linnaeus), is widely distributed in both northern and southern hemispheres. It is the only species in the family Pomatomidae. On the Atlantic coast of North America, bluefish occur seasonally from the Florida Keys to Cape Cod and occasionally northward into the Gulf of Maine. Throughout this range, the species is particularly abundant in southern Florida, in North Carolina and Virginia, and from New Jersey to southern Massachusetts.

The Sandy Hook Marine Laboratory has accumulated considerable information on bluefish in the past several years, most of it yet unpublished. From our studies, it appears that the Atlantic coast population of bluefish is made up of several contingents, each with a different pattern of seasonal migration. Some of our tagged fish have migrated the length of the coast in a single season, from southern New England to southern Florida.

Spawning takes place along much of the Continental Shelf. In the south, bluefish spawn from April to May at the edge of the shelf (and probably beyond) from northern Florida to southern North Carolina. In the north, they spawn in July and August between the 15-fathom (27-m) isobath and the edge of the shelf from northern North Carolina to Long Island. On our 1966 Dolphin cruises (Clark et al., 1969), we found the maximum density of larvae in an area 30 to 80 miles east of the New Jersey coast within a temperature range of 20° to 22°C (68° to 71.6°F).

Young bluefish appear to lead a pelagic life for 1 to 2 months depending upon season, currents, water temperature, and other environmental variables. At the end of their pelagic phase, they arrive inshore along the beaches and move into inlets, penetrating the estuarine zone. We have collected some juveniles several miles offshore by dipnetting under lights at night or by towing juvenile fish nets, but most occurrence records are from beach seine collections. In the Middle Atlantic Bight, the young arrive inshore in two waves. The first wave occurs from late June to early July, when most juveniles range from 75 to 125 mm in length. We suspect these juveniles are recruited to the middle Atlantic from a spring spawning south of Cape Hatteras, and are carried north by the Gulf Stream. The second wave arrives later in the summer,

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from mid-August to September, when the young range in length from 30 to 100 mm. We believe these later arrivals come from northern spawnings in summer. Those of the first wave change from a diet largely of planktonic forms (crustaceans and fish eggs) to one of small fishes when they are 60 to 90 mm long. This occurs as they become abundant along the shore and in bays (we have not yet looked at stomachs of fish of the second wave). They grow very fast during the course of their first summer; those of the first wave reach 240 mm or larger before the end of the summer (unpublished data, Sandy Hook Marine Laboratory).

When they first arrive at the shore, juvenile bluefish tend to remain where salinities are high, along the outer beaches, around inlets, or in the protected waters not far from inlets. They may penetrate farther into the estuaries as summer progresses and are occasionally found in the most brackish water. They leave the estuaries in the first 2 weeks of autumn and resort to the open sea during winter.

Our search of available literature and our own collections indicate that young-of-the-year bluefish occur along the Atlantic coast from New England to Florida (Figs. 1 and 2). Many estuaries throughout this range that are probably inhabited by juvenile bluefish have not been sampled, or, if so, the collection records were not available. The apparent high densities of juveniles in certain areas, such as South Carolina and the New York Bight, may reflect greater sampling activity and availability of records for these areas. The environmental data available for the collections are too scanty to enable us to comment on ecology of nursery area bluefish. An example of existing puzzles is the occurrence of juveniles in the nearly freshwater of the upper Chesapeake system (Mansueti, 1955; Lund, 1961) where they may gain access from Delaware Bay via the Chesapeake and Delaware Canal.

We should note that earlier records may not reflect the current distribution of juveniles; e.g., we are reasonably sure that juveniles are not now found south of Daytona, Florida, even though in collections of 1896 to 1931 they were recorded south to Palm Beach (Evermann and Bean, 1898; Lund, 1961; Nichols, 1913). We have records for only a few locations in the Gulf of Maine (Bigelow and Schroeder, 1953; Lund, 1961; R. Boiland, personal communication, 1969), but even these few may give an impression of higher abundance than is probable, because bluefish rarely stray this far north (Bigelow and Schroeder, 1953).

STRIPED BASS

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The striped bass, Morone saxatilis (Walbaum), is an anadromous fish of the family Serranidae indigenous to the Atlantic coast of North America. Along the open coast, striped bass occur at various times of the year from Massachusetts to Cape Hatteras, North Carolina. North and south of this range, they are mostly confined to bays, estuaries, and rivers. In rivers, this species has been recorded as far north as the St. Lawrence in Canada and as far south as the St. Johns in Florida. There also are striped bass in some rivers entering the eastern Gulf of Mexico. Breeding populations are established in certain reservoirs in the southeastern states.

The species spawns in the spring and summer, beginning in April to the south and continuing into July to the north. Although the eggs are released in water within a temperature range of 14° to 22°C (58° to 71°F), the optimum appears to be in the range of about 15° to 20°C (60° to 67°F) (Raney, 1952). Spawning occurs in the fresh or brackish parts of rivers, most often near the transition zone between salt and freshwater. Depending upon salinity and other factors, spawning may occur within a river system anywhere from the mouth to more than 100 miles upriver (Tresselt, 1952).

After release, the semibuoyant eggs and the larvae are carried downstream until the developing young gain control of their movement. In a month or so, when they are about 40 mm or more in length, they move into nursery areas along the shores of a river or estuary. As they grow into their second and third years of life, they leave juvenile habitats to undertake more extensive movements. Usually, striped bass do not make extensive coastal migrations until their third year of life (Alperin, 1966b).

Juvenile bass are rarely found in Atlantic coastal waters and, because all other evidence indicates they remain in the lower reaches of their natal streams, their occurrence in any area usually indicates that they originated in a nearby river.

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All available records of occurrence of juvenile striped bass (specimens to 125 mm in length were classified as young-of-the-year) are plotted on Figures 1 and 2 (mostly from Murawski, 1958). These data indicate that the principal nursery areas on the Atlantic coast are in estuaries of the larger rivers. Juveniles of localized and landlocked populations are recorded for the St. Johns River, Florida (Tagatz, 1967; Barkaloo, 1967; Murawski, 1958), the Santee-Cooper reservoir system in South Carolina (Lewis, 1957; Fowler, 1945; Murawski, 1958), for several rivers in Georgia (Murawski, 1958; G. McBay, personal communication, 1969), and the Kerr reservoir in Virginia (Talbot, 1966). Landlocked populations are not included.

North of the Hudson River, juvenile striped bass are rarely seen. It is generally accepted that there are now no regular spawnings of significance in New England rivers (Alperin, 1966b; Raney, 1952). Although extensive sampling has been done on both the south and north shores of Long Island (Alperin, 1966b; Greeley, 1939a; 1939b; Neville et al., 1959), only a single juvenile has been collected. On the north shore of Long Island Sound, a few have been reported at the western end around Cos Cob Harbor, Connecticut (Raney, 1952). New England records report occurrences for the Parker River, Massachusetts (Merriman, 1941) and the Kennebunk River, Maine (Bigelow and Schroeder, 1953). However, farther north in the Gulf of St. Lawrence, records of juveniles from the St. Lawrence and the Mirimichi Rivers (Murawski, 1958; McKenzie, 1959) indicate that localized, self-perpetuating populations occur in certain rivers.

WINTER FLOUNDER

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Topp (1965) prepared an exhaustive annotated bibliography of literature on the winter flounder Pseudopleuronectes americanus (Walbaum). The number of reported capture sites of larvae and juveniles depicted in Figure 3 reflects the extent of known sampling and areas of concentrated sampling effort.

Catches of young have not been reported from many of the rivers and bays within the known range of the winter flounder. However, much of the literature stresses existence of local stocks and spawning probably occurs in most estuaries inhabited by adults.

Although winter flounder are considered estuarine spawners, we took their larvae at sea aboard the Dolphin. The importance of the Continental Shelf as a spawning and nursery area remains to be evaluated.

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SUMMER FLOUNDER

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The early life history of the summer flounder, Paralichthys dentatus (Linnaeus), is not completely resolved. Knowledge of occurrence of larvae and juveniles is based on relatively little information. It is generally accepted that spawning occurs at sea during fall soon after summer flounder begin their seaward migration. However, on our Dolphin cruises we have found eggs as late as early February south of Chesapeake Bay. The extent of the spawning grounds has not been described.

Juveniles have been collected in various estuaries along the coast, with most effort concentrated in and around Pamlico Sound, North Carolina. From the data at hand, it appears that this fish utilizes only estuarine waters for nursery grounds. As with the larval stages, the geographical extent of the nursery areas and their relative importance remain to be evaluated. Figures 4 and 5 show reported capture sites of larvae and juveniles.

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TAUTOG

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Tautog, Tautoga onitis (Linnaeus), range from Nova Scotia to South Carolina, but occur mainly between Cape Cod and Delaware Bay. During warmer months, tautog remain close to shore and enter the mouths of estuaries, particularly where rocky bottoms are found. During winter, they apparently move some distance offshore. Spawning takes place in late spring and early summer (Bigelow and Schroeder, 1953). Larvae were taken in estuarine studies in summer from Massachusetts to Virginia (Perlmutter, 1939; Pearson, 1941; Merriman and Sclar, 1952; Wheatland, 1956; Massmann et al., 1961; de Sylva et al., 1962; Percy and Richards, 1962). Juveniles were found in estuarine waters during summer and early fall (Bean, 1889; Sherwood and Edwards, 1901; Bean, 1903; Hildebrand and Schroeder, 1928; Perlmutter, 1939; Warfel and Merriman, 1944; Merriman, 1947; Bigelow and Schroeder, 1953; de Sylva et al., 1962; Schwartz, 1964; Fiske et al., 1967). Young-of-the-year apparently move slightly offshore with autumnal cooling (Bigelow and Schroeder, 1953). Available records of the occurrence of larvae and juveniles are plotted in Figure 3.

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CUNNER

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Cunner, Tautogolabrus adspersus (Walbaum), range from Nova Scotia to Chesapeake Bay. They occur over hard bottom close to shore off New England and further offshore to the south (Bigelow and Schroeder, 1953). Spawning occurs from late spring through midsummer (Bean, 1903; Sumner et al., 1913; Bigelow and Schroeder, 1953; Wheatland, 1956). Larvae occur from early June through September from Massachusetts to Virginia (Bean, 1903; Perlmutter, 1939; Merriman, 1947; Wheatland, 1956; Massmann et al., 1961; Percy and Richards, 1962). Juveniles were found in the same areas from June through October (Bean, 1887; 1903; Sumner et al., 1913; Greeley, 1939b; Merriman, 1947; Massmann, 1962; Percy and Richards, 1962; Richards, 1963). Cunner do not enter low salinity water, and the juveniles apparently move offshore in winter with the adults (Bigelow and Schroeder, 1953). The reported locations of larvae and juvenile cunner are shown in Figure 3.

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SCUP

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Scup, Stenotomus chrysops (Linnaeus), range from New England to South Carolina, intermingling with closely related sparids south of Chesapeake Bay. Scup migrate from wintering grounds off Chesapeake Bay shoreward and north in summer. Spawning occurs during or after this migration. In late spring and early summer, larvae occur offshore from Virginia to Woods Hole, Massachusetts (Sumner et al., 1913; Wheatland, 1956; Massmann et al., 1961), and in several estuarine surveys from Delaware Bay to Buzzards Bay, Massachusetts (Sumner et al., 1913; Perlmutter, 1939; de Sylva et al., 1962; Pearcy and Richards, 1962). Juveniles have been taken in inshore waters from Chesapeake Bay to southern Cape Cod in late summer and early fall (Bean, 1889; 1903; Sumner et al., 1913; Hildebrand and Schroeder, 1928; Greeley, 1939b; Perlmutter, 1939; de Sylva et al., 1962; Massmann, 1962; Pearcy and Richards, 1962; Richards, 1963). They occur in more saline parts of estuaries and apparently migrate offshore and south as fall cooling occurs. Reported locations of larvae and juveniles are shown in Figures 6 and 7.

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SHEEPSHEAD

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Sheepshead, Archosargus probatocephalus (Walbaum), presently range from Maryland to Florida, although formerly they extended to Cape Cod (Bigelow and Schroeder, 1953; Schwartz, 1964). The adults occur around jetties and pilings during warm months north of Cape Hatteras and year-round to the south. No eggs or larvae smaller than 6 mm were found in extensive sampling around Beaufort, North Carolina, where larger larvae and juveniles were common (Hildebrand and Cable, 1938). Possibly these fish spawn offshore and the early larvae migrate or drift to inshore nursery areas. Larvae and juveniles were found in eelgrass beds during the summer from New Jersey to Florida (Bean, 1889; Smith, 1907; Hildebrand and Cable, 1938; Gunter and Hall, 1963; Schwartz, 1964). In the fall, juveniles about 40 mm in length assume adult habits (Evermann and Bean, 1898; Hildebrand and Cable, 1938). Reported locations of larvae and juveniles are plotted in Figures 8 and 9.

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PINFISH

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Pinfish, Lagodon rhomboides (Linnaeus) occur from Cape Cod south to the Florida Keys and in the Gulf of Mexico. They are found inshore, mainly south of Maryland, during warmer months and offshore during fall and winter when they spawn. Hildebrand and Cable (1938) described the young and Caldwell (1957) reviewed their biology and systematics. The larvae move inshore in the spring from Delaware to Florida (Evermann and Bean, 1898; Smith, 1907; Hildebrand and Schroeder, 1928; Hildebrand and Cable, 1938; Caldwell, 1957; de Sylva et al., 1962; Gunter and Hall, 1963). Juvenile pinfish move with the adults to deeper water offshore in late fall (Greeley, 1939b; Pearse et al., 1942; Fowler, 1945; Caldwell, 1957). The reported locations of larvae and juvenile pinfish are shown in Figures 8 and 9.

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BUTTERFISH

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Butterfish, Peprilus triacanthus (Peck), is a migratory, schooling fish occurring seasonally from Nova Scotia to northern Florida. It spawns in spring during the northward migration (Bigelow and Schroeder, 1953). The larvae, incorrectly described by Kuntz and Radcliffe (1917), are illustrated by Colton and Honey (1963). The distribution of the young is affected by their symbiotic relation with jellyfish (Mansueti, 1963). Larvae were taken offshore from Georges Bank to Virginia (Sumner et al., 1913; Perlmutter, 1939; Bigelow and Schroeder, 1953; Massmann et al., 1961; Massmann et al., 1962) and in the mouth of Chesapeake Bay (Pearson, 1941; Mansueti, 1963). Juveniles occur in late summer and early fall offshore and in open estuaries from Nova Scotia to South Carolina (Smith and Kendall, 1898; Bean, 1903; Sumner et al., 1913; Greeley, 1939b; Perlmutter, 1939; Pearson, 1941; Fowler, 1945; Bigelow and Schroeder, 1953; Merriman and Sclar, 1952; de Sylva et al., 1962; Massmann, 1962; Mansueti, 1963; Richards, 1963). Reported locations of larvae and juveniles are plotted in Figures 8 and 9.

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SPOT

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Young spot, Leiostomus xanthurus Lacépède, occur along the eastern United States coast from Massachusetts to Florida, with the greatest abundance south of Delaware Bay. Reported locations of juveniles are shown in Figures 10 and 11. Spot spawn offshore in late fall and winter and the young migrate into the estuaries from late winter to summer. The smallest larvae reported, less than 10 mm (TL), were reportedly taken from December to April near Beaufort Inlet, North Carolina (Hildebrand and Cable, 1931), and in February in the Neuse River, North Carolina (Tagatz and Dudley, 1961). Other researchers reported young, from 10 to 30 mm (TL), appearing in inshore waters in winter and spring: April and May in Delaware Bay; January to June near Beaufort, North Carolina; April in South Carolina; and March through August at various localities in Chesapeake Bay (Hildebrand and Schroeder, 1928; Hildebrand and Cable, 1931; Young, 1953; Dawson, 1958; de Sylva et al., 1962). Once on their nursery grounds, smaller species are found well upstream in brackish water and occasionally in freshwater (Raney and Massmann, 1953; Massmann, 1954; Tagatz and Dudley, 1961; Tagatz, 1967). They remain in the creeks and marshes through the summer and move out to the ocean or into deeper parts of bays in the fall. They mature by the end of their second summer, and seasonally migrate between rivers and coastal waters (Dawson, 1958; Pacheco, 1962a; 1962b.

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ATLANTIC CROAKER

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The known range of young Atlantic croaker, Micropogon undulatus (Linnaeus), on the eastern United States coast extends from New York to Florida. Croaker are most abundant from the Chesapeake Bay south to the Carolinas (Figs. 1 and 2). Atlantic croaker spawn offshore in fall and winter; spawning begins earlier in the more northerly part of their range. Young move inshore to nursery areas in rivers and bays and remain inshore for their first year. Occasionally, they are found in freshwater (Raney and Massmann, 1953; Haven, 1957; Tagatz, 1967). At any given time, the youngest stages are found furthest upstream, gradually moving into deeper waters as they grow, staying near the bottom, and moving out of the inshore nursery areas by the end of their first summer (Wallace, 1941; Haven, 1957). The smallest specimens taken in these inshore areas occurred from July to October in Indian River Inlet, Delaware; September to March in Chesapeake Bay; September to May near Beaufort, North Carolina; November to April in South Carolina; and November to May in St. Johns River, Florida (Welsh and Breder, 1923; Hildebrand and Cable, 1930; Massmann et al., 1961; de Sylva et al., 1962; Massmann et al., 1962; Bearden, 1964; Tagatz, 1968).

The estuarine occurrence of young Atlantic croaker is well documented for most of the range. Data are lacking for Georgia and parts of the North Carolina and Florida coasts, where it would seem the young must regularly occur.

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ATLANTIC MACKEREL

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Documented occurrences in United States eastern coastal waters of young-of-the-year Atlantic mackerel, Scomber scombrus Linnaeus, are presented in Figure 6. Mackerel are primarily a species of open coastal waters, but the young are often found in larger bays and harbors. Spawning occurs from April to June and is concentrated between Long Island and Cape Hatteras, largely in the inner half of shelf waters (Sette, 1943; Sandy Hook, unpublished data). Larval and juvenile Atlantic mackerel are found from southern New England to Cape Henry, Virginia, extending to the edge of the Continental Shelf. The major nursery grounds for young are believed to be in the more northerly part of the range. Sette (1943) traced northerly movements of groups of the young to the Massachusetts coast. Based on statements by Goode (1884), Sette (1943, 1950), and Bigelow and Schroeder (1953), the most important nursery areas of young Atlantic mackerel are off the coast of southern New England from Cape Ann to eastern Long Island; some juveniles occur south to New Jersey and north to Casco Bay, Maine.

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BONEFISH, LADYFISH, AND TARPON

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Eggs and the spawning locations are undescribed, but all of the limited evidence suggests a protracted spawning season; development includes a pelagic leptocephalus stage that continues until conditions favorable to metamorphosis are encountered; the larval distribution can be influenced by the Gulf Stream; and the postlarvae and juveniles utilize estuaries or shallow oceanic bays as "nursery grounds."

The bonefish, Albula vulpes (Linnaeus), appears to utilize the estuarine zone of the eastern United States only by accident as a postlarva and juvenile (Figs. 4 and 5). In a widespread sampling program comprising nearly 3,500 tows over a 4-year period along both coasts of Florida, Eldred (1967) found larval or young bonefish in only four tows. The capture of 108 juvenile bonefish on Long Island, New York (Alperin and Schaefer, 1964), was most unusual.

The few sporadic reports of individual captures indicate young of the ladyfish, Elops saurus Linnaeus, are found inshore north of Cape Hatteras only as strays (Figs. 4 and 5). Gehringer (1959), Tagatz (1967), Eldred and Lyons (1966), and Harrington (1958) reported that Elops leptocephali metamorphose in estuaries. These studies also indicate the coasts of Georgia and Florida are primary nursery grounds for this game species. From observations around Beaufort, North Carolina, Hildebrand (1963) summarized some historically interesting work on the life history of the ladyfish.

Despite the interest in the tarpon, Megalops atlantica Valenciennes, as a game species, questions still remain regarding its life history. The estuarine zone south of Cape Kennedy is an important center of dispersal for the metamorphosing young (Harrington, 1958; Eldred, 1967) (Fig. 7). Estuaries in Georgia have been the object of studies on the ecology and growth of young tarpon (Wade, 1962; Rickards, 1968). North Carolina and South Carolina occurrences are limited to sparse, unpublished captures (Wade, 1962) or only briefly mentioned in larger faunal works (Fowler, 1945).

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ALEWIFE, BLUEBACK HERRING, AND AMERICAN SHAD

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Alewife, *Alosa pseudoharengus* (Wilson), blueback herring, *Alosa aestivalis* (Mitchill), and American shad, *Alosa sapidissima* (Wilson), support some of the principal river fisheries of the Atlantic coast. River stocks of all three species generally exist now at fractions of their former levels. Pollution, dams, and overfishing have all been implicated as contributors to the decline.

Coastal populations of alewife range from Nova Scotia to South Carolina; blueback, from Nova Scotia to the St. Johns River, Florida; and shad, from Newfoundland to the St. Johns River, Florida. These anadromous species must pass through estuaries to freshwater spawning areas. Spawning runs vary and earliest inshore appearances occur in southern portions of the range of each species. Alewives generally precede shad, which in turn precede blueback. The appearance of the spawners varies from season to season, probably as a function of temperature, and may differ as much as a month between years at particular locations.

The range of reported spawning temperatures differs for each species: alewife, 4° to 17°C; blueback, 21° to 24°C; and shad, 12° to 20°C. These variations reflect not only the timing of the run, but also habitat preferences of spawning. Alewives usually spawn in sluggish shallows of large rivers, streams and ponds, whereas blueback utilize either the fresh or brackish portions of rivers never far above tidal action or some ponds with a sea drainage. Shad spawn mostly in tidal freshwater with extensive flats and over sandy or pebbly shallows, often near creek mouths.

Larvae of all three species occur in fresh and brackish water near the spawning areas. As juveniles, they move slowly downstream. Fall is the time of the main seaward migration. Most go to sea, but some may overwinter in the deeper parts of bays and rivers.

The literature is quite inadequate in describing distribution of these species occurring as juveniles in coastal drainages (Figs. 12 and 13). This shortcoming has resulted from their being reported in studies either not directly concerned with the species or which utilized collecting gear notoriously inefficient for even semiquantitatively estimating the number of typically schooling fishes which occupy upper water levels. A valuable review of development stages and ecology of these species is given by Mansueti and Hardy (1967).

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STRIPED MULLET AND WHITE MULLET

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Next to menhaden, the mullets are probably the most abundant fish in southern inshore waters, particularly in estuaries and broad river mouths. Although, since colonial times, many observers have remarked on their great abundance, only fragmentary information is available on their life history features. This is due in large measure to their schooling habit and elusive swimming characteristics, both of which bias their capture in conventional sampling nets. Occurrence of juveniles of striped mullet, Mugil cephalus Linnaeus, has been reported from Rhode Island to Florida and white mullet, Mugil curema Valenciennes, from Delaware to Florida (Figs. 10 and 11). All reports are from studies which utilized seines during daylight hours.

In the northern portion of their range, mullets are seasonal migrants and immature forms usually occur in late summer collections. In southern waters, juvenile white mullet occur in estuaries from spring to late fall, whereas juvenile striped mullet have been collected during every month of the year.

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ATLANTIC MENHADEN

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The north-south limits of adult and juvenile Atlantic menhaden, *Brevoortia tyrannus* (Latrobe), extend from Nova Scotia (Leim and Scott, 1966) to Florida (Reintjes, 1964a). Coastal oceanic spawning at some time during the year throughout most of this range results in the occurrence of larval and juvenile menhaden in virtually every estuary along the Atlantic coast of the United States (Pacheco and Grant, 1965). The localities in which young stages have been reported are shown in Figures 6 and 7. The Bureau of Commercial Fisheries Center for Estuarine and Menhaden Research at Beaufort, North Carolina, has had increasing interest in the distribution of juvenile menhaden as part of its Menhaden Investigations. Since 1955, more than 140 Atlantic estuarine sites have been sampled (Table 1), and 60 are now sampled annually (June, 1958; Sutherland, 1963; Turner, 1968, 1970).

The cues that direct larval menhaden from spawning sites to estuaries are not thoroughly understood. Immigration can be interrupted by water temperature; temperatures of 3°C or less appear to prevent entry of larvae into estuaries and to restrict those present to areas with salinities near 15‰ (June and Chamberlin, 1959; Lewis, 1965; Pacheco and Grant, 1965). When temperatures are not critically low, larval menhaden migrate through a salinity gradient toward freshwater and occasionally penetrate well into freshwater (Ellison, 1951; Massmann, 1954; Reintjes and Pacheco, 1966).

Metamorphosis from larvae to juveniles takes place in the nursery area. Transformation begins at about 30 mm (FL) and is generally complete by the time the fish reach 40 mm (Hildebrand, 1963). June and Chamberlin (1959) suggested that migration to low salinities was necessary for metamorphosis, but larvae in experimental tanks have transformed at salinities ranging from 15 to 40‰ (Lewis, 1966). After metamorphosis in late spring, larval menhaden change from selective particulate feeders to omnivorous filter-feeding juveniles and grow rapidly -- as much as 20 or 30 mm per month. Rapid growth is accompanied by changes in population density and distribution within the estuarine nursery area; these changes are probably related to physical sorting by size and swimming speed as well as to the quantity and quality of the food supply associated with salinity. During June and July, 40-mm to 50-mm juveniles compose a major portion of the population and are generally found within a salinity range of 0 to 15‰ (Turner and Pacheco, unpublished data). Size and numbers are generally inversely related to each other as salinity increases.

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An exodus of juvenile menhaden from estuarine nursery areas in September and October corresponds to the seasonal decline in water temperature. By late fall, most of the juveniles have moved into the lower estuaries; some juveniles, however, overwinter in the moderately saline areas of larger rivers and bays. Juveniles from 115 mm to 190 mm appear in the commercial catch in Chesapeake Bay in the early fall and in the November-December fall fishery off the North Carolina coast (Nicholson and Higham, 1965). After leaving from the nursery areas, juvenile menhaden apparently migrate south along the coast and as 1 year olds contribute heavily to the fishery in Florida.

More detailed discussions of the relations of juvenile menhaden to estuaries can be found in June and Chamberlin (1959), Reintjes and Pacheco (1966), and Reintjes (1969). Bibliographies by Gunter and Christmas (1960); Reintjes et al. (1960); and Reintjes (1964b) include references to distribution records of adults and juveniles before 1964.

Figure 1. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile striped bass (left), bluefish (center), and Atlantic croaker (right).

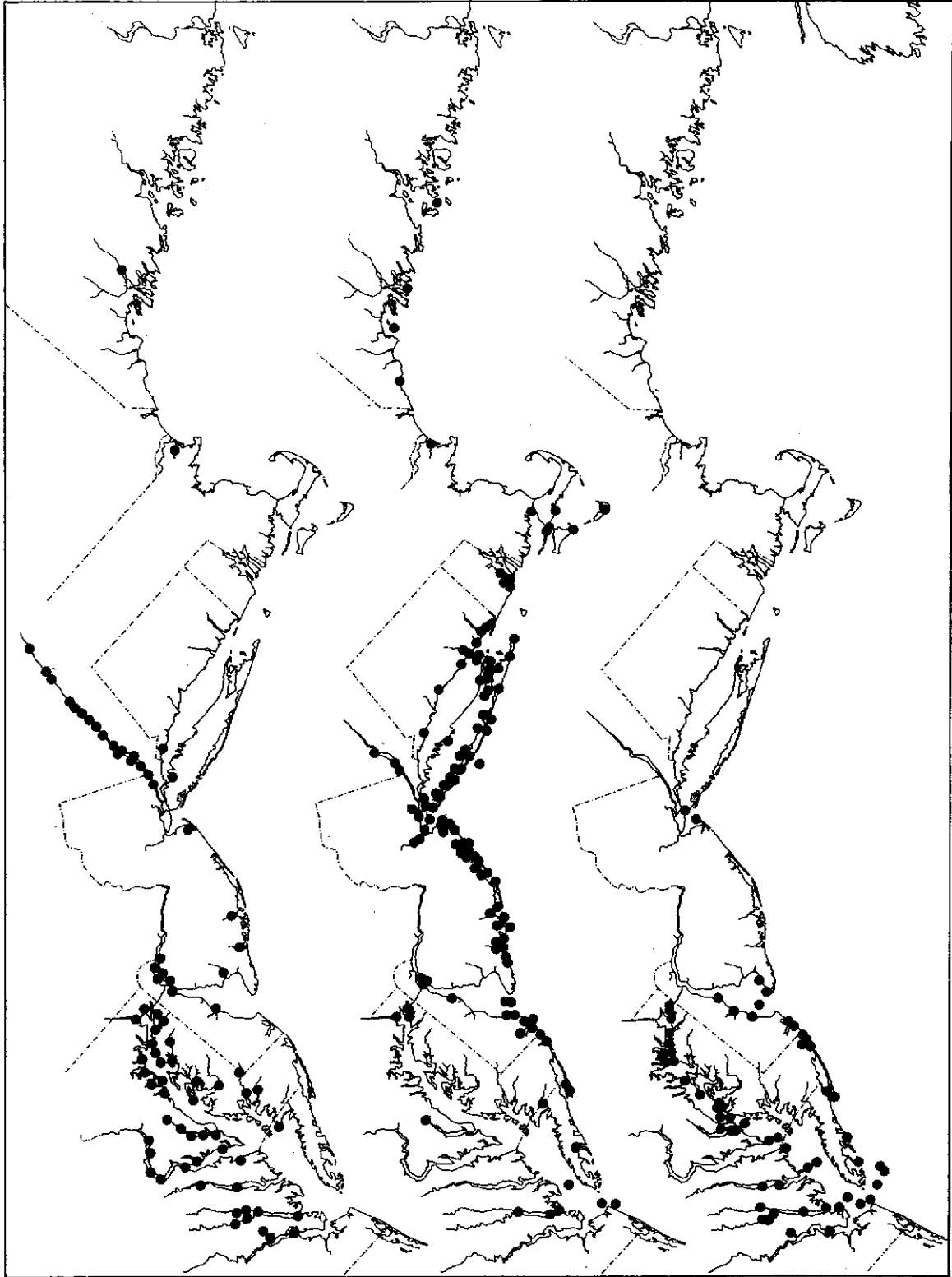


Figure 2. Outline map of U. S. Atlantic seaboard from Chesapeake Bay to Florida showing occurrence of larval and juvenile striped bass (left), bluefish (center), and Atlantic croaker (right).

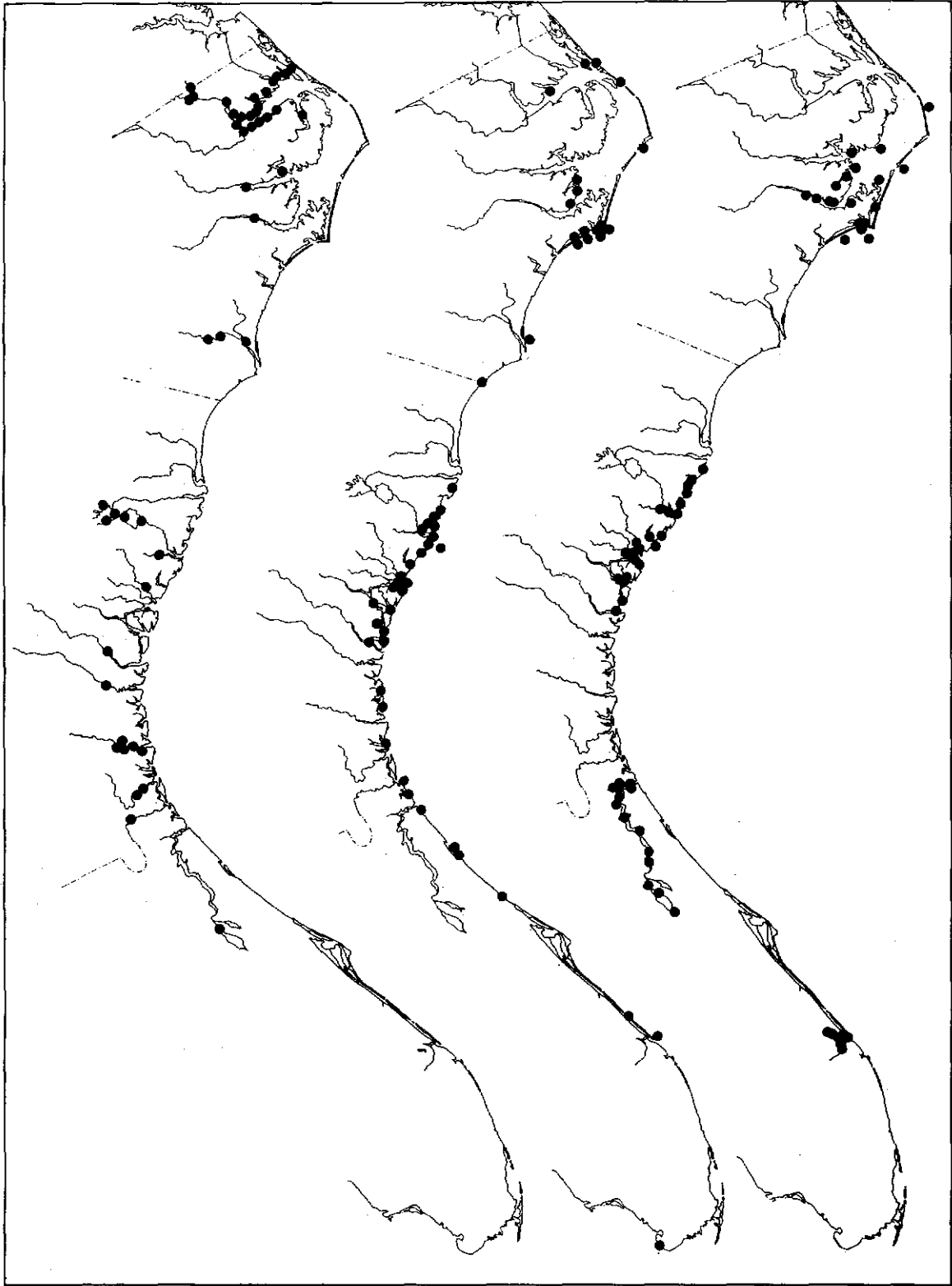


Figure 3. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile cunner (left), tautog (center), and winter flounder (right).

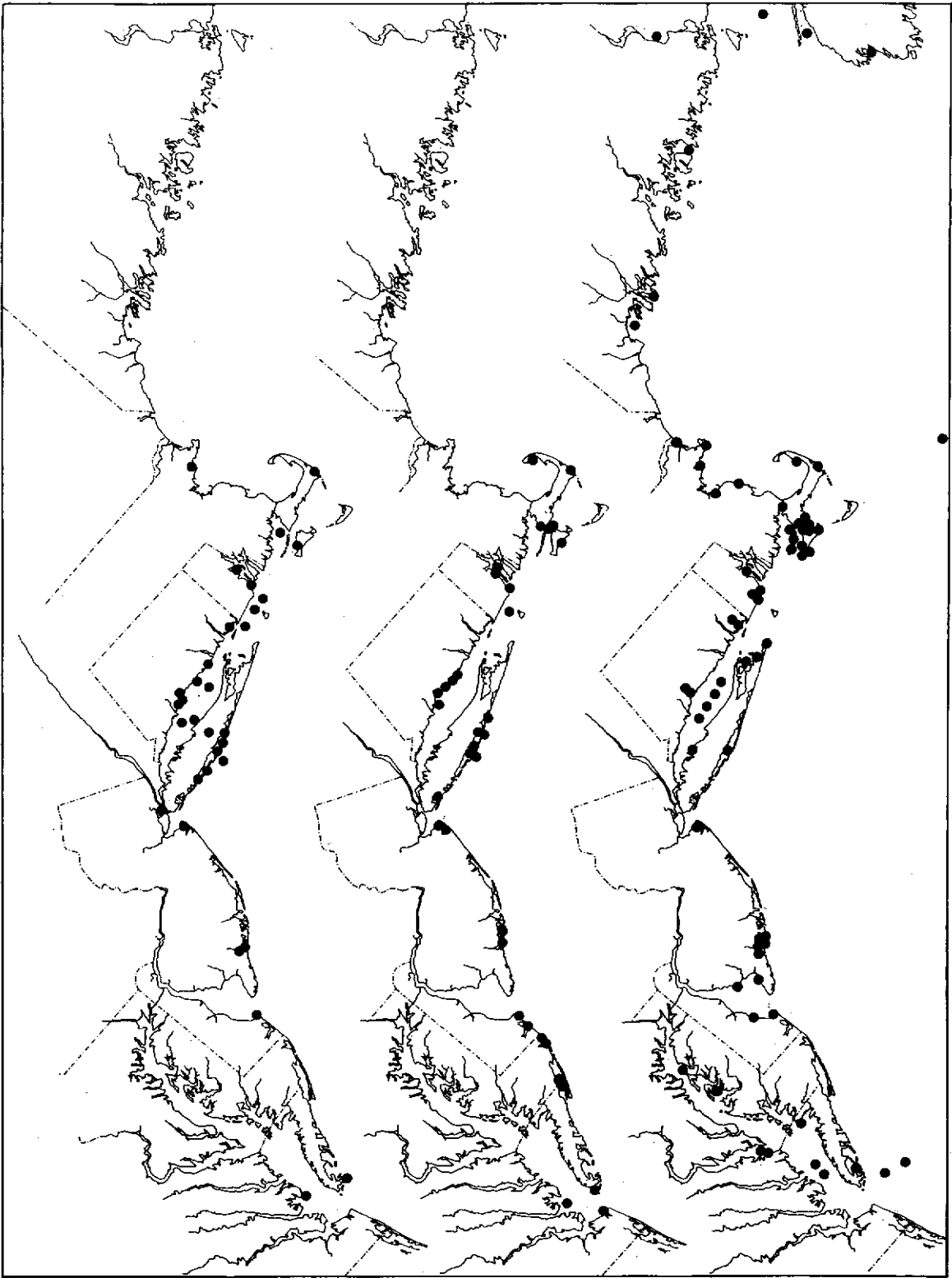


Figure 4. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile summer flounder (left), bonfish (center), and ladyfish (right)

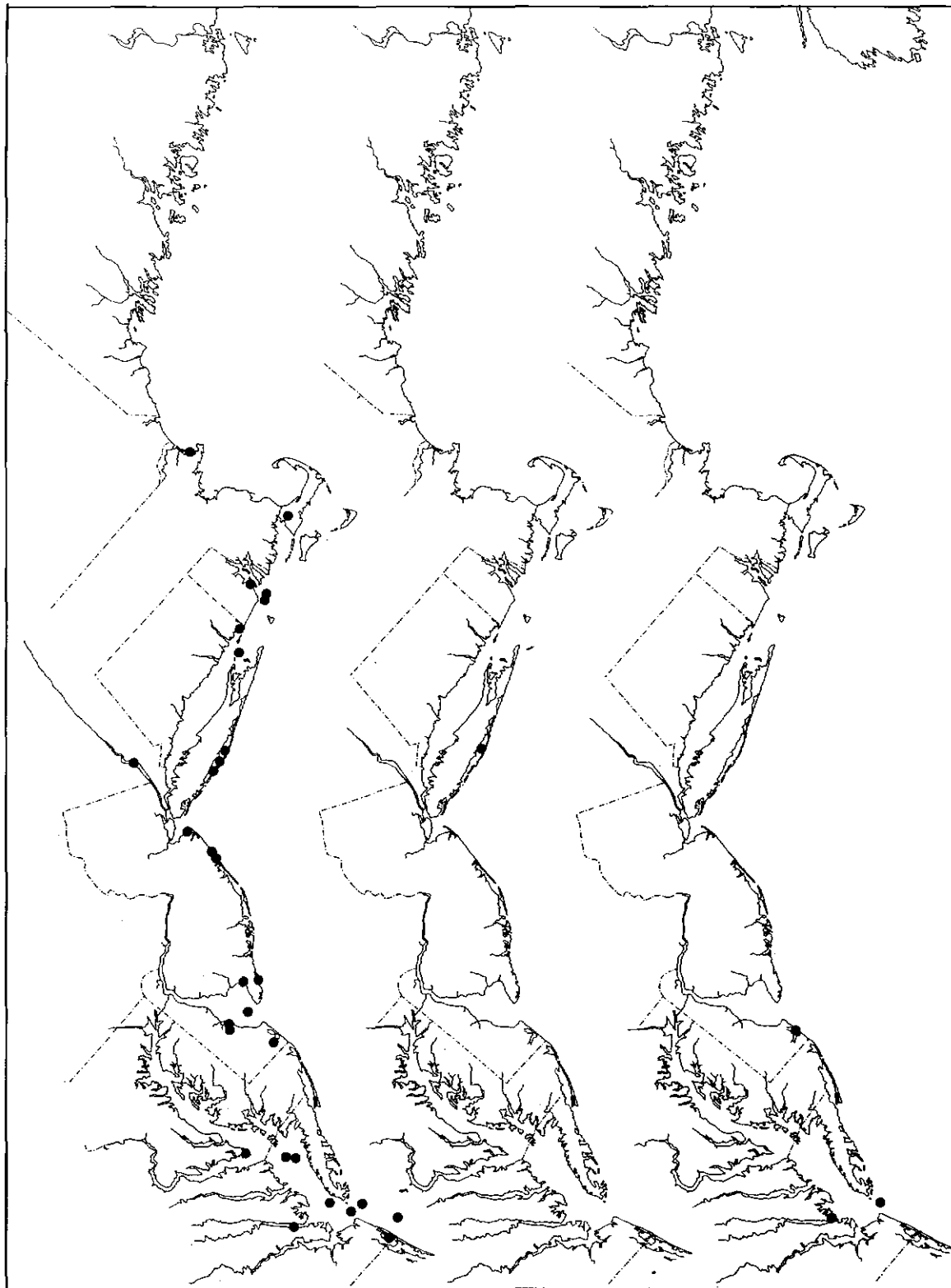


Figure 5. Outline map of U. S. Atlantic seaboard from Chesapeake Bay to Florida showing occurrence of larval and juvenile summer flounder (left), bonefish (center), and ladyfish (right).

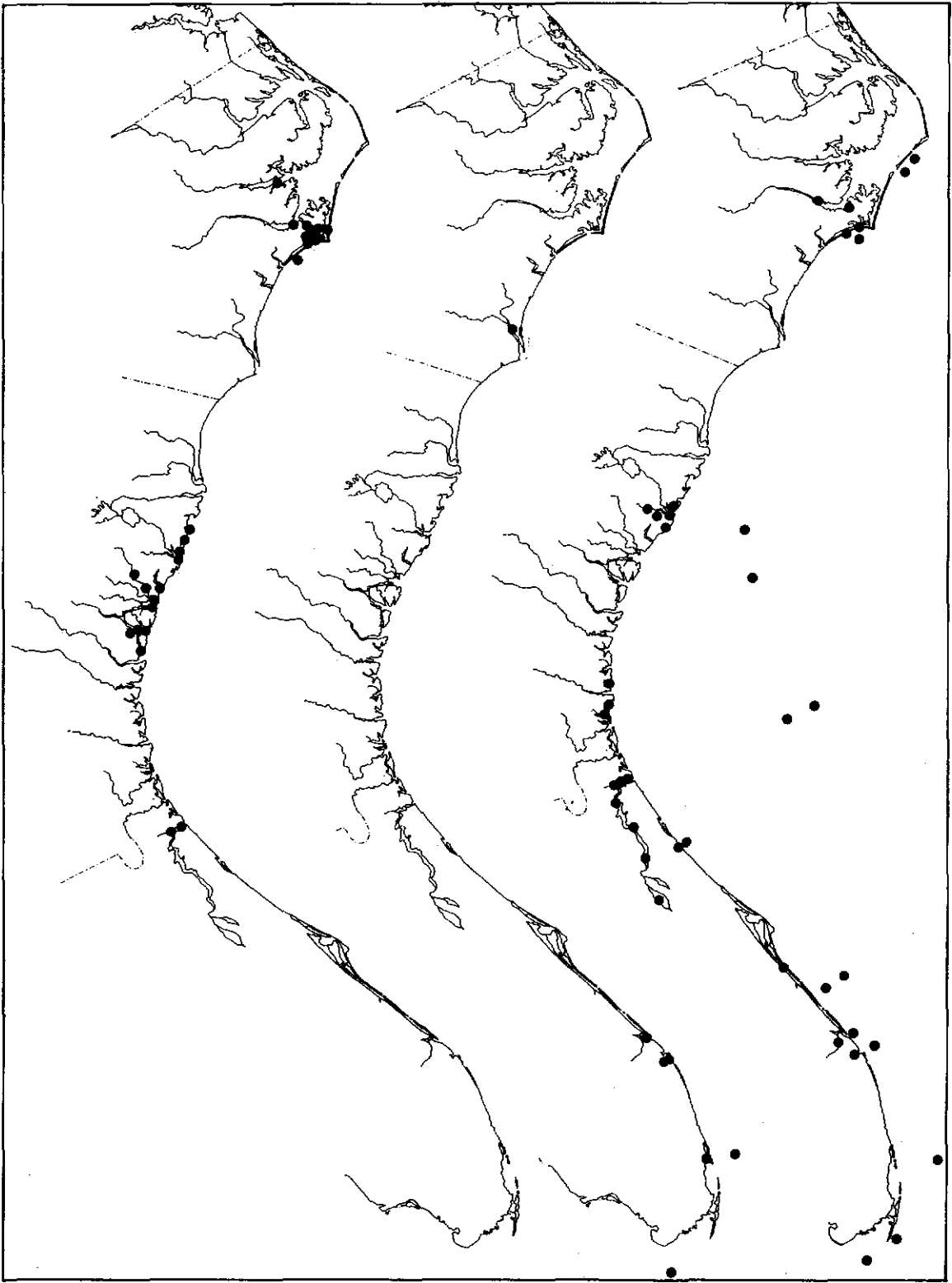


Figure 6. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile Atlantic menhaden (left), scup (center), and Atlantic mackerel (right).

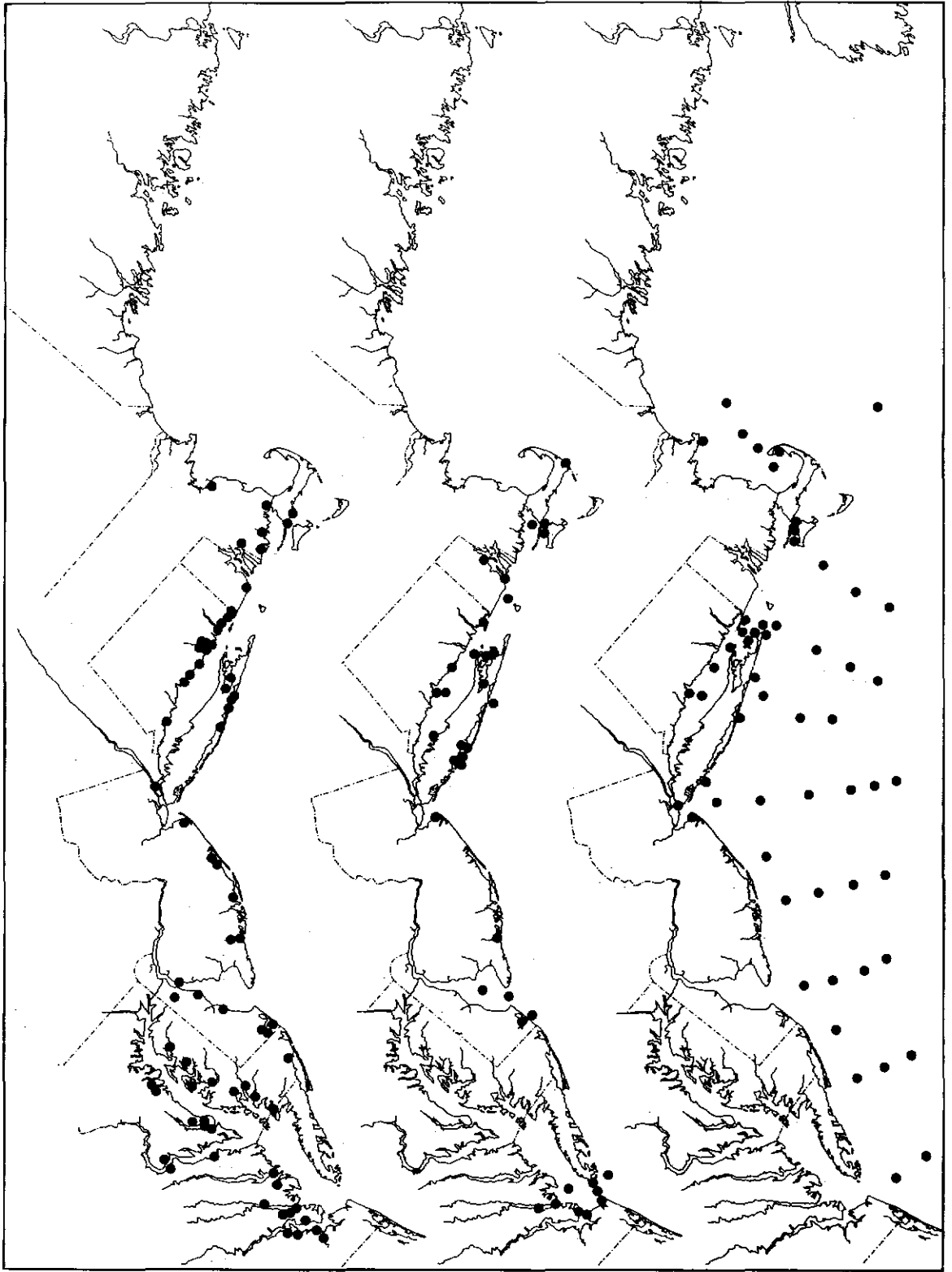


Figure 7. Outline map of U. S. Atlantic seaboard from Chesapeake Bay to Florida showing occurrence of larval and juvenile Atlantic menhaden (left), scup (center), and tarpon (right).

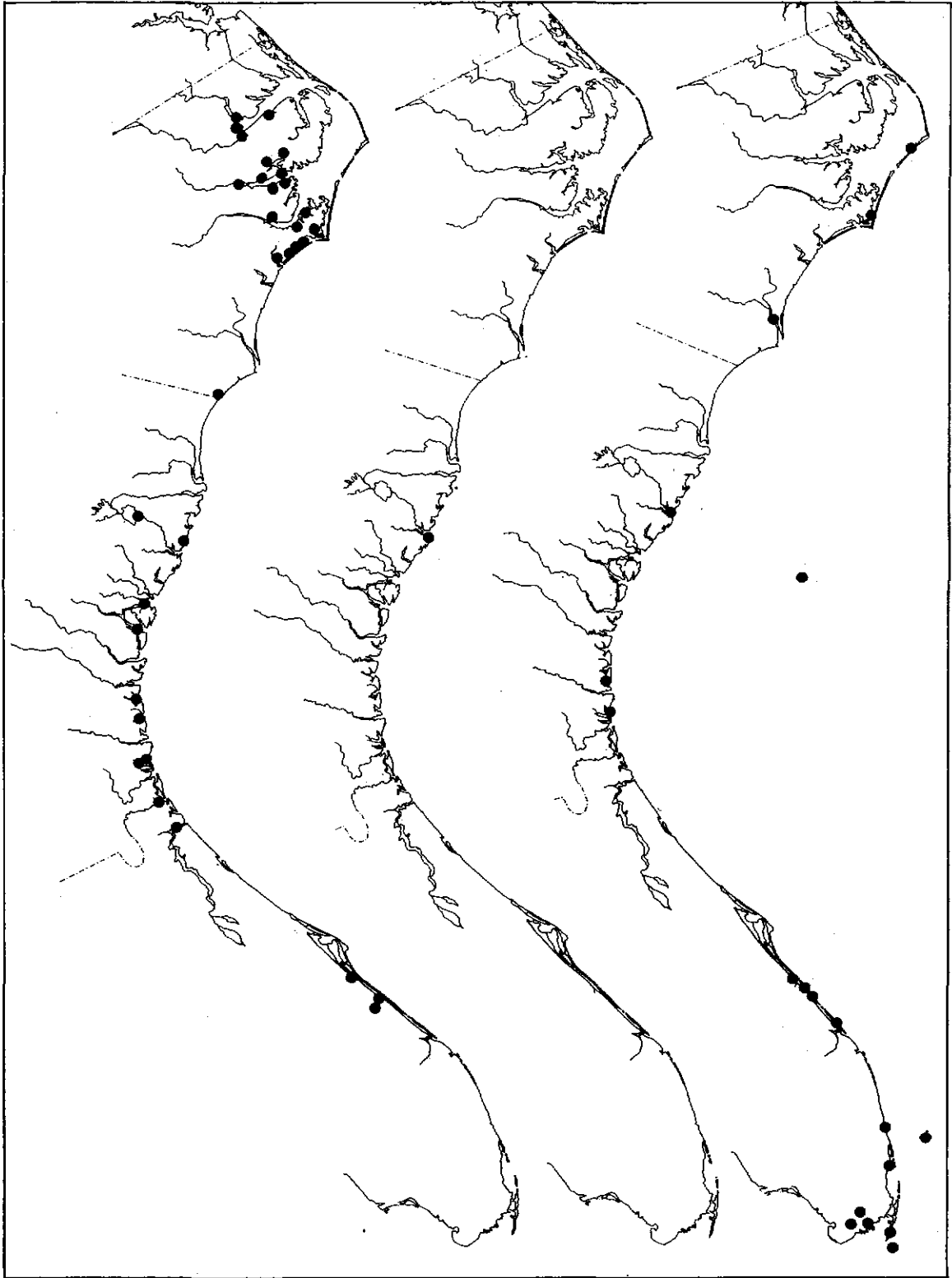


Figure 8. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile sheepshead (left), pinfish (center), and butterfish (right).

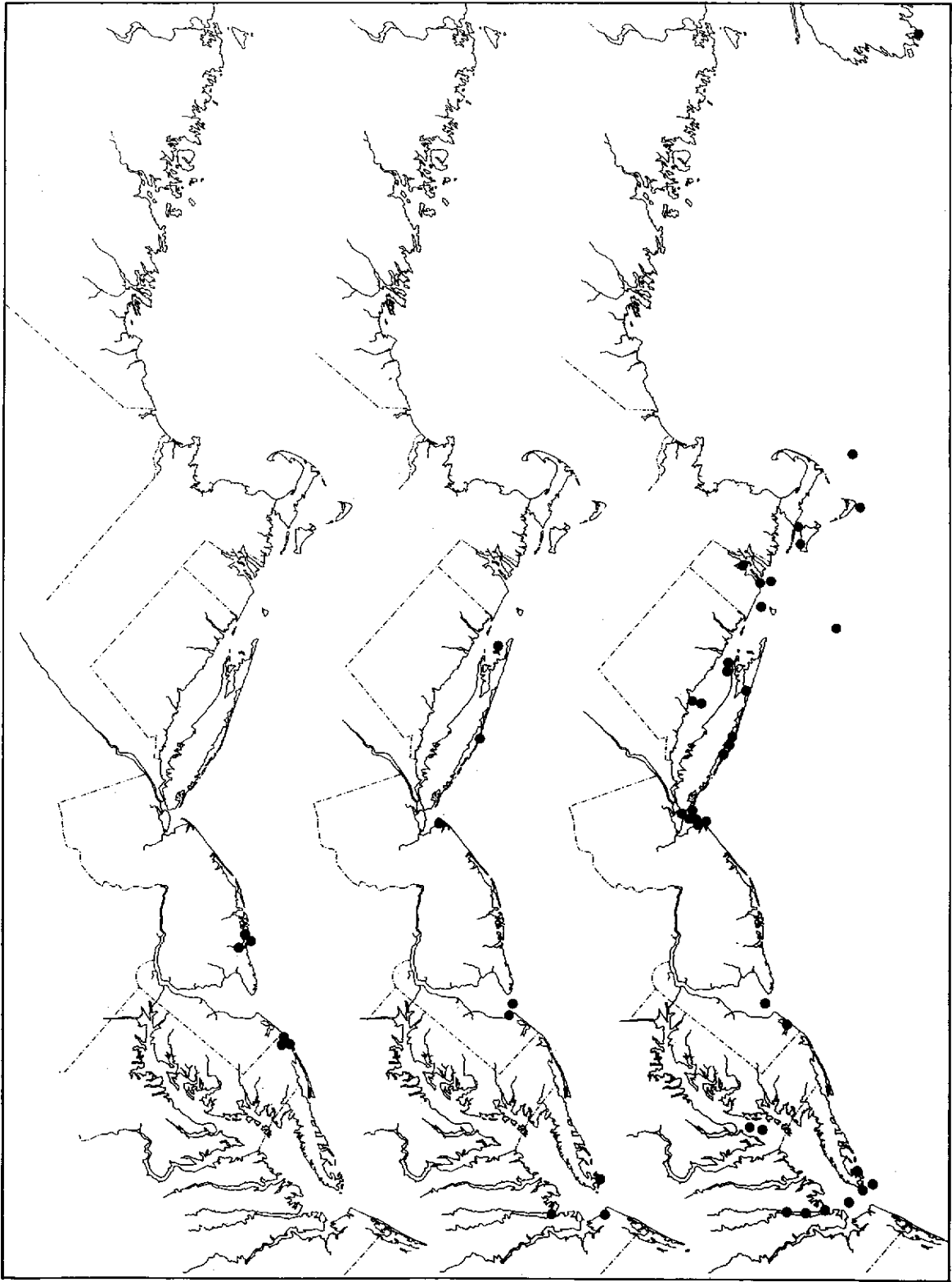


Figure 9. Outline map of U. S. Atlantic seaboard from Chesapeake Bay to Florida showing occurrence of larval and juvenile sheephead (left), pinfish (center), and butterfish (right).

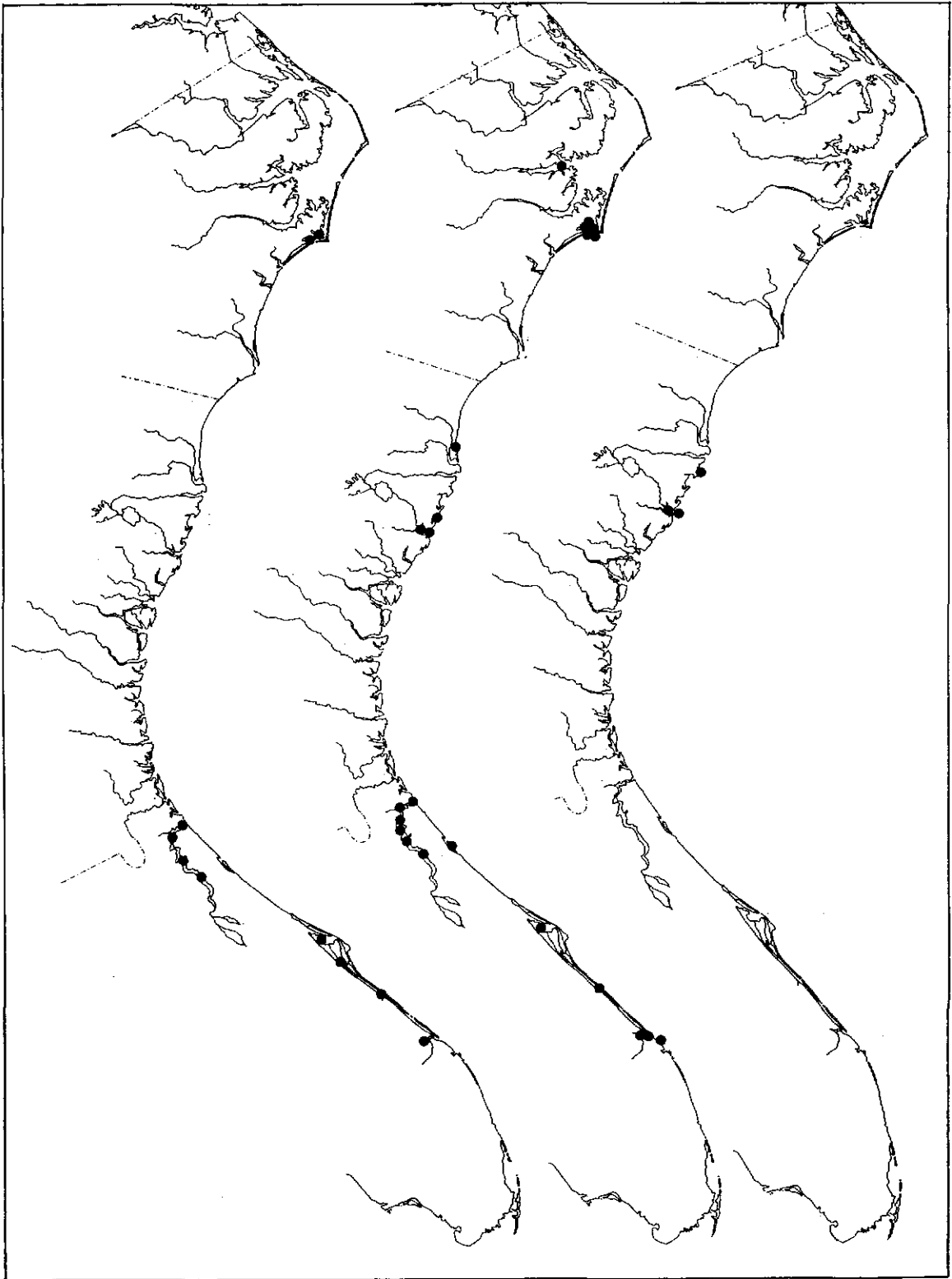


Figure 10. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile striped mullet (left), white mullet (center), and spot (right).

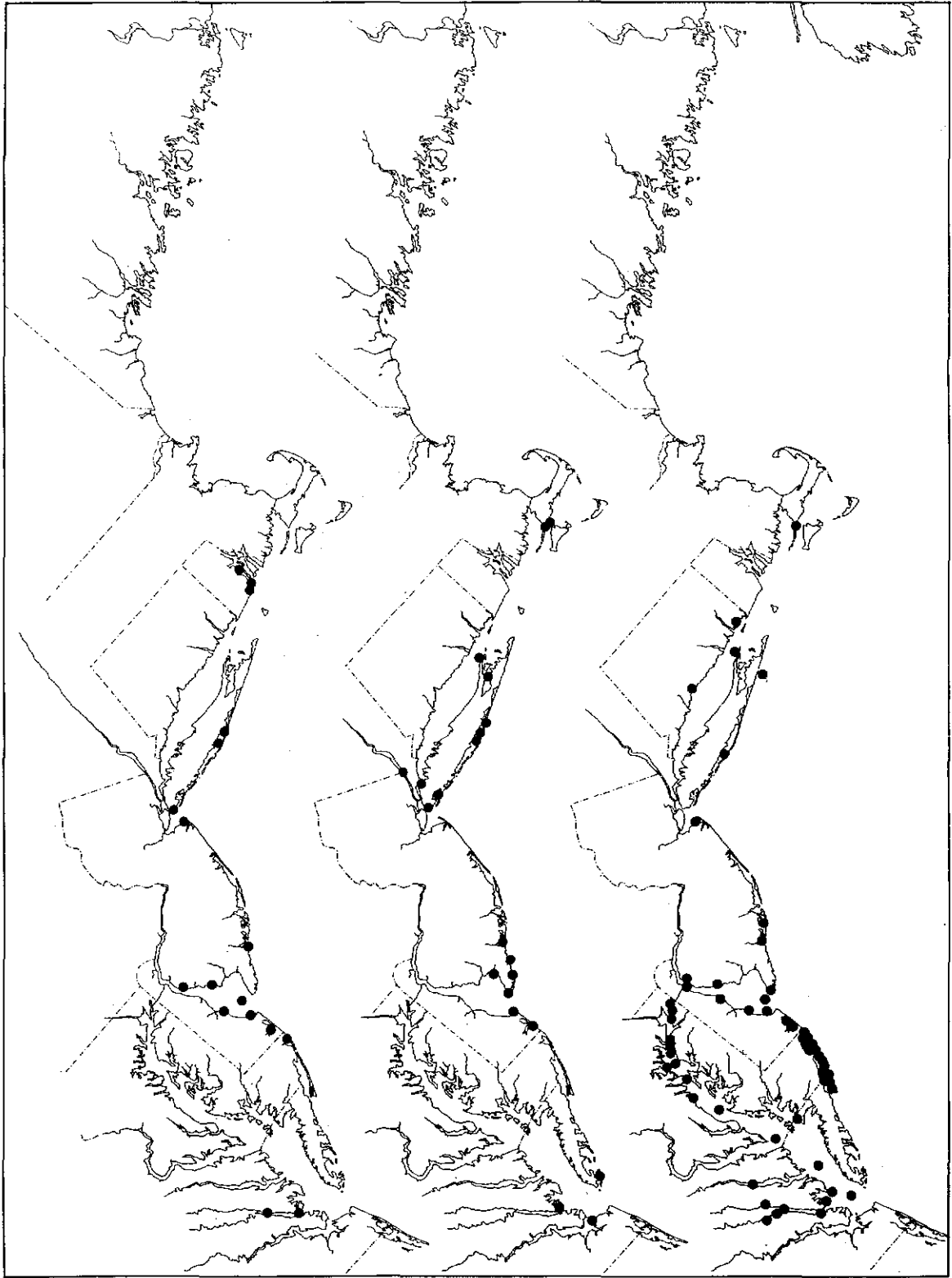


Figure 11. Outline map of U. S. Atlantic seaboard from Chesapeake Bay to Florida showing occurrence of larval and juvenile striped mullet (left), white mullet (center), and spot (right).

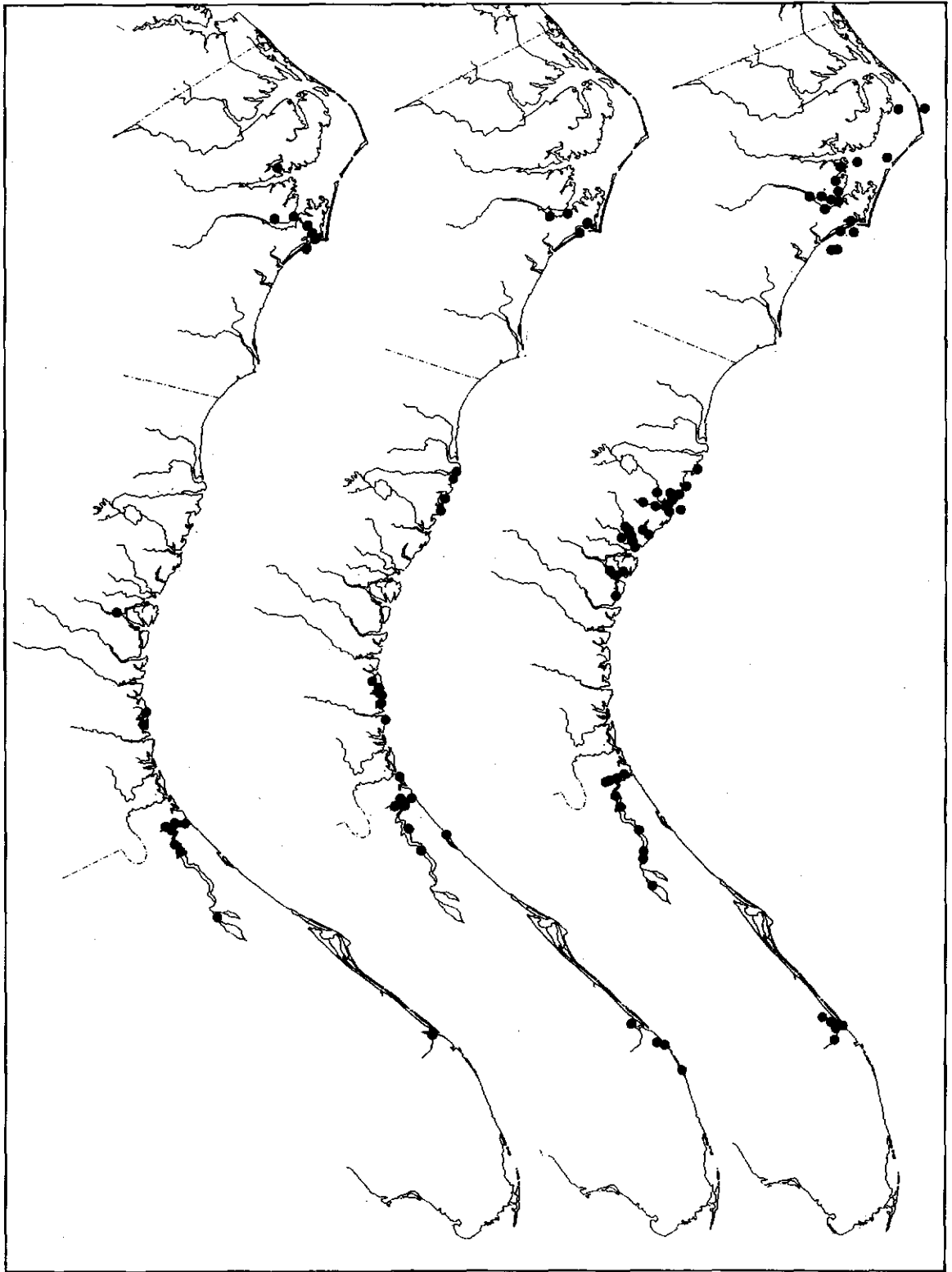


Figure 12. Outline map of U. S. Atlantic seaboard south to Chesapeake Bay showing occurrence of larval and juvenile alewife (left), blueback herring (center), and American shad (right).

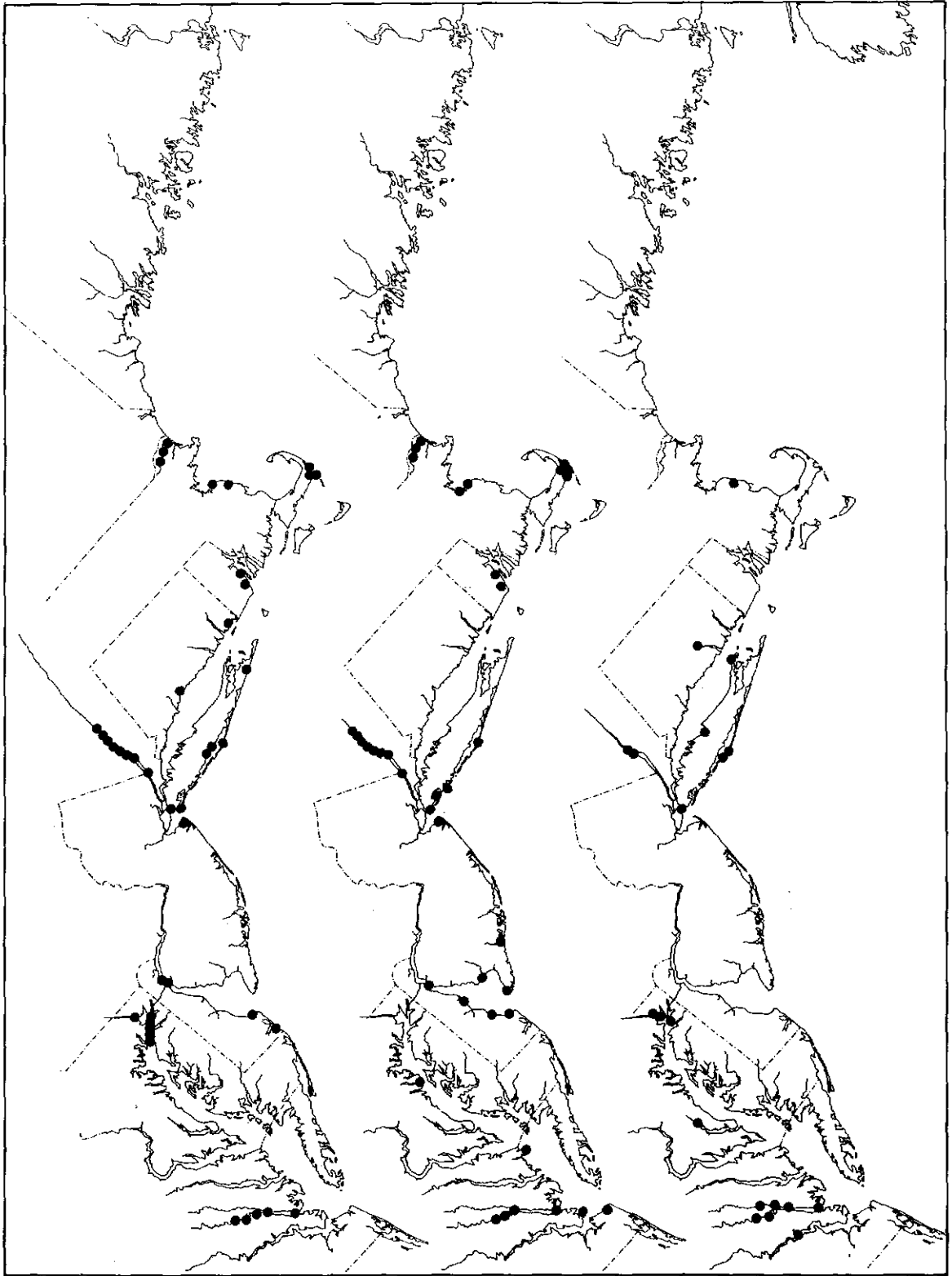


Figure 13. Outline map of U. S. Atlantic seaboard from Chesapeake Bay to Florida showing occurrence of larval and juvenile alewife (left), blueback herring (center), and American shad (right).

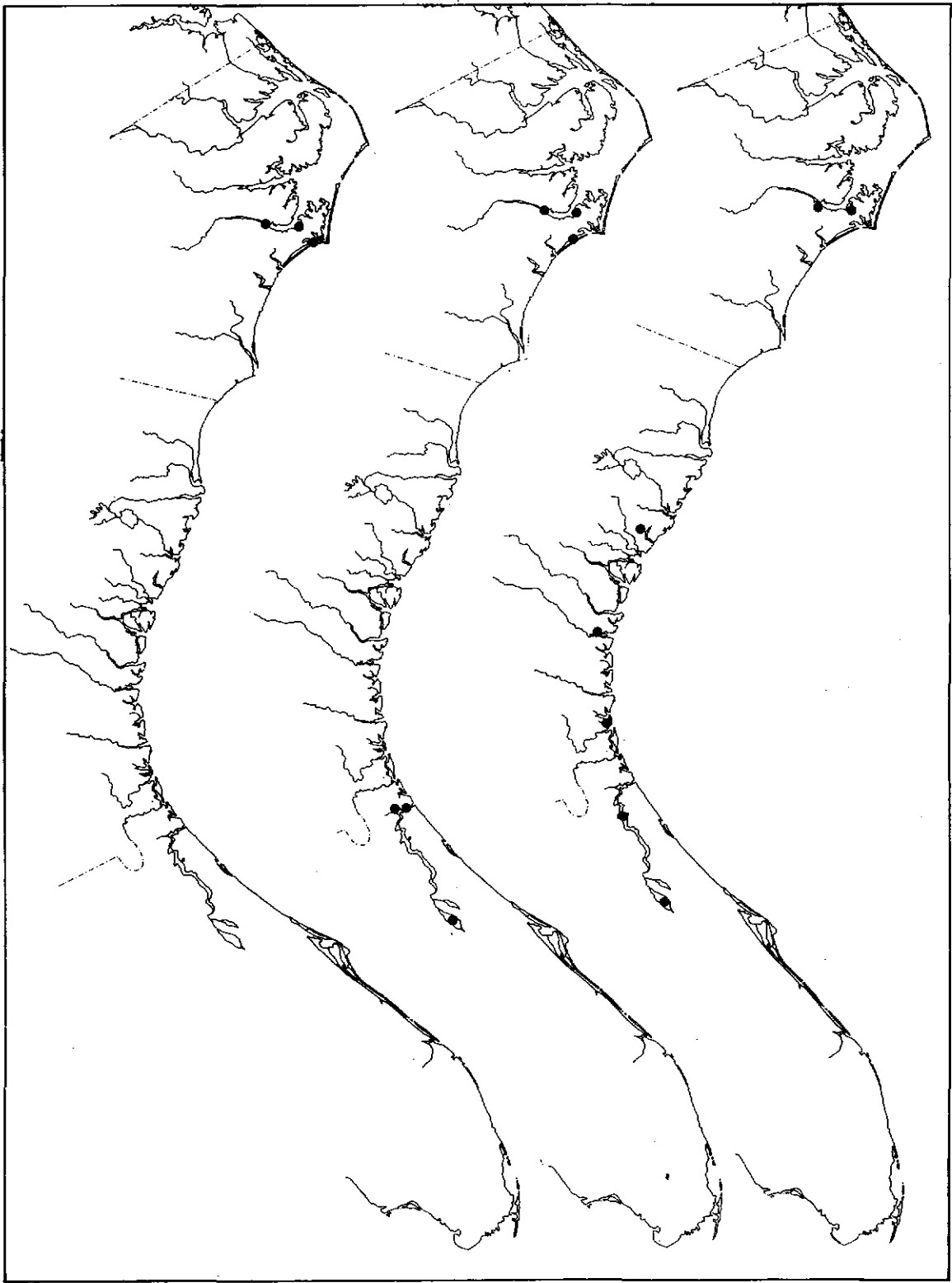


Table 1. List of sites sampled for juvenile Atlantic menhaden, 1955-67.

MASSACHUSETTS:

1. Weir Creek
2. Childs River*✓
3. Woods Hole
4. Acushnet River
5. Taunton River

CONNECTICUT:

6. Mystic River✓
7. Pogoanuck River
8. Thames River
9. Connecticut River
10. Old Town Landing✓
11. Old Ferry Creek*✓
12. Lieutenant River✓
13. Hammonasset River✓
14. Saugatuck River

NEW YORK:

15. Reeves Bay, Long Island
16. North Sea Harbor, Long Island✓
17. Herring Drain, Long Island
18. Pennimans Cove, Long Island✓
19. Quantuck River, Long Island
20. Carmans River, Long Island
21. Hudson River

NEW JERSEY:

22. Navesink River
23. Toms River✓
24. Oyster Creek*✓
25. Tuckerton Creek✓
26. Great Egg River

DELAWARE:

27. Indian River
28. White Creek*✓
29. Blackwater Creek

MARYLAND:

30. Colbourn Creek✓
31. Choptank River
32. Hunting Creek
33. Chester River
34. Broad Creek✓
35. Beards Creek✓
36. Patuxent River
37. Battle Creek*✓
38. St. Leonards Creek✓

VIRGINIA:

39. Nomini Creek✓
40. Lower Machodoc Creek
41. Great Wicomico River
42. Ball Creek*✓
43. Indian Creek✓
44. Dymers Creek
45. Rappahannock River
46. Hoskins Creek
47. Mallory Point
48. Naylor's Point
49. Mt. Landing Creek
50. Lowery Point
51. Island Point
52. York River
53. Felgate Creek*✓
54. Indian Field Creek
55. Sarahs Creek
56. Harrison Beach

NORTH CAROLINA:

57. Chowan River
58. Salmon Creek
59. Roanoke River
60. Scuppernong River
61. Sandy Point
62. Pamlico River
63. Blount Creek✓
64. Bath Creek✓

NORTH CAROLINA (cont.)

65. Durham Creek✓
66. North Creek✓
67. Campbell Creek✓
68. Flanners Beach
69. Adams Creek
70. North River
71. Gales Creek✓
72. Broad Creek*✓
73. Calabash Creek✓
74. Little River

SOUTH CAROLINA:

75. Jeremy Creek
76. Inlet Creek✓
77. Meggetts Creek✓
78. Mosquito Creek✓
79. Toogoodoo Creek✓
80. Dawho River
81. Edisto River
82. Sawmill Creek*✓
83. May River

GEORGIA:

84. Tibleys Creek
85. White Chimney River✓
86. Marsh at Valona
87. Atwood Creek✓
88. Jones Creek✓
89. Dunbar Creek✓
90. St. Marys River

FLORIDA:

91. Nassau River
92. Dunns Creek✓
93. Clapboard Creek✓
94. Halifax River
95. Crane Creek

* Haul-seine sites
✓ Surface trawl sites

List of prospective sites for sampling juvenile Atlantic menhaden
with surface trawl in 1963

MASSACHUSETTS:

1. Childs River ✓
2. Agwam River
3. Westport River
4. Taunton River

RHODE ISLAND:

5. Pettaquamscutt River
6. Pawcatuck River

CONNECTICUT:

7. Eight-mile River
8. Old Town Landing ✓
9. Old Ferry Creek ✓
10. Hammonasset River ✓
11. East River
12. Saugatuck River

NEW JERSEY:

13. Tuckahoe River
14. Stow Creek

DELAWARE:

15. Blackbird Creek
16. Leipsic River
17. Mispillion River
18. White Creek ✓

MARYLAND:

19. Trappe Creek
20. Wicomico Creek
21. Quantico Creek
22. Chiamacomico River
23. East Wye River
24. Broad Creek ✓
25. Hunting Creek
26. Nanjemoy Creek

VIRGINIA:

27. Aquia Creek
28. Upper Machodoc Creek
29. Mattox Creek
30. Nomini Creek ✓
31. Ball Creek ✓
32. Cat Point Creek
33. Piankatank River
34. Queen Creek
35. Felgate Creek ✓
36. Poropotank River
37. Warwick River
38. Gordon Creek
39. Grays Creek
40. Pagan River
41. Western Branch Nansemond River

NORTH CAROLINA:

42. Indiantown Creek
43. Perquimans River
44. Conaby Creek
45. Scuppernong River
46. Northwest Branch Alligator River
47. Pungo River
48. Pungo Creek
49. Tranter's Creek
50. Bath Creek ✓
51. Blount Creek ✓
52. Durham Creek ✓
53. North Creek ✓
54. Campbell Creek ✓
55. Upper Broad Creek
56. Hancock Creek
57. Newport River
58. Broad Creek ✓
59. White Oak River
60. Calabash Creek ✓

SOUTH CAROLINA:

61. Toogoodoo Creek
62. Ashepoo River
63. Coosawatchie River

GEORGIA:

64. Little Back River
65. Ogeechee River
66. White Chimney River ✓
67. Cathead Creek
68. Dunbar Creek ✓
69. Little Satilla River

✓ Surface trawl sites retained in 1968

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Appendix Table 1. References to juvenile fishes, subgrouped by location.

<u>Species</u>	<u>Maine</u>	<u>New Hampshire</u>	<u>Massachusetts</u>
1. Bluefish	13, 89, 146		7, 20, 89, 105, 117, 152, 154, 155, 160
2. Striped bass	13		105
3. Winter flounder	13		13, 46, 48, 49, 74, 75, 76, 87, 160
4. Summer flounder			20, 36
5. Tautog			13, 20, 46, 49, 152, 154, 160
6. Cunner	13		13, 46, 48, 49, 76, 154, 160
7. Scup	157		13, 46, 49, 152, 154, 157, 160
8. Sheepshead			13, 160
9. Pinfish			160
10. Butterfish	26		13, 46, 160
11. Croaker			
12. Spot			160, 174
13. Mackerel	54, 95, 151	54, 95, 151	13, 14, 20, 54, 95, 117, 150, 151, 152, 160
14. Bonefish			
15. Ladyfish			
16. Tarpon			
17. Alewife	13, 89, 146		48, 49, 74, 89
18. Blueback	13		74, 75, 76
19. Shad	145, 146		48
20. Striped mullet			
21. White mullet			20, 117, 154
22. Menhaden			78, 120, 161

Appendix Table 1 - continued

<u>Species</u>	<u>Rhode Island</u>	<u>Connecticut</u>	<u>New York</u>
1. Bluefish	66,89,109,166	89,90,126,173	3,7,11,55,59,81,82,89, 90,114,116,117,131,147
2. Striped bass		135	2,30,38,57,58,59,110, 115,132,133,137,139
3. Winter flounder	66,109,166	106,124,125,126, 142,143,173,175	3,114,130,142,143,175
4. Summer flounder	66,107,109	107,117,126	3,57,107,114,134
5. Tautog	23,27,28,107, 109,166	106,107,126,142, 173,175	3,59,107,114,117,131, 142,147,175
6. Cunner	13,65,107,109, 166	106,107,126,142, 143,173,175	3,11,59,107,117,131, 142,143,175
7. Scup	66,107,109,166	107,126,142,143, 175	11,45,59,81,107,114, 131,142,143,147,175
8. Sheepshead			11
9. Pinfish			11,59
10. Butterfish	13,66,107,117, 166	94,107,142,143	3,11,59,81,94,107,117, 131,142,143,147
11. Croaker			117,174
12. Spot		126,173	3,59,81
13. Mackerel	95,107	107,142,175	11,81,107,117,131,142, 147,150,166,175
14. Bonfish			3
15. Ladyfish			
16. Tarpon			
17. Alewife	89,109,166	89,126,173	11,55,57,58,89,131, 133,147
18. Blueback	13,109,166		55,57,117,133,147

Appendix Table 1 - continued

<u>Species</u>	<u>Rhode Island</u>	<u>Connecticut</u>	<u>New York</u>
19. Shad		119	11, 57, 58, 59, 117, 132, 133, 147
20. Striped mullet	109, 166		3, 11, 147
21. White mullet			3, 11, 55, 59, 81, 117, 132, 147
22. Menhaden	120	78, 161	78, 120, 161

Appendix Table 1 - continued

<u>Species</u>	<u>New Jersey</u>	<u>Delaware</u>	<u>Maryland</u>
1. Bluefish	6,7,10,15,17,25,33, 50,61,89,108,117	56,89,123,153	89,91,149
2. Striped bass	32,33,110,137,138	32,84,105,110	51,84,98,110,137, 145,170
3. Winter flounder	10,16,29,33,50	33,123	37,72,98,149
4. Summer flounder	16,33,108,111,112, 113	123	72,93,166
5. Tautog	10,29,33,50,117	33	72,149
6. Cunner	10,16,33	33	
7. Scup	10,16,33,117	33	98
8. Sheepshead	10		
9. Pinfish	10,33,117	33	
10. Butterfish	17,29,33,117	33	98
11. Croaker	29,33,174	33,123	37,51,98,149,166, 172,174
12. Spot	18,19,33,108,174	33,123	37,98,149,166,174, 177
13. Mackerel	16,18		
14. Bonefish			
15. Ladyfish		123	
16. Tarpon			
17. Alewife	33,89	89,123	51,72,73,89,92,98,149
18. Blueback	10,33,117	123,153	72,73,98
19. Shad		153	73,98,118
20. Striped mullet	16,33,117	123,153	72,149
21. White mullet	10,33,107	123	72
22. Menhaden	78,120,160,161	78,79,120,123, 141,161	120

Appendix Table 1 - continued

<u>Species</u>	<u>Virginia</u>	<u>North Carolina</u>	<u>South Carolina</u>
1. Bluefish	89,97,100,130,148	89,155,163,165	51,89
2. Striped bass	84,97,98,100,110, 129,137,138,164,167	22,47,52,84,110	51,84,110,159
3. Winter flounder	72,97,98,100,101		
4. Summer flounder	13,72,93,96,97,100, 101,128	5,34,35,53,70, 163,176	51
5. Tautog	72,100,101,130,148		
6. Cunner	97,100		
7. Scup	97,98,100,101		51
8. Sheepshead		71,72,155	
9. Pinfish		42,51,71,72,127, 155,163	51
10. Butterfish	97,98,100,101,130	44	51
11. Croaker	64,96,97,98,99,100, 101,130,138,148, 170,174	44,51,67,70,155, 163	12,51,174
12. Spot	96,97,98,100,121, 138,148,156,174	44,67,70,155,163	31,51,91
13. Mackerel	97		
14. Bonefish		51	
15. Ladyfish	101	52,69,163	51,52
16. Tarpon		51,68	
17. Alewife	72,89,97,98,100,138	9,89,163	89
18. Blueback	72,98,100,138	155,163	
19. Shad	97,98,118,119,138	118,163	51
20. Striped mullet	72,97,101	4,72,163	
21. White mullet	72	72,163	51
22. Menhaden	78,96,120,161	42,78,83,85,86, 120,161	78

Appendix Table 1 - continued

<u>Species</u>	<u>Georgia</u>	<u>Florida</u>	<u>Block Island Sound</u>
1. Bluefish	89	43,65,89	
2. Striped bass	110	8,110,162	
3. Winter flounder			
4. Summer flounder			107
5. Tautog			107
6. Cunner			107
7. Scup			107
8. Sheepshead		43,60,65,158,162	
9. Pinfish		21,43,60,65,104,158,162	
10. Butterfish			107
11. Croaker		60,104,162	
12. Spot		60,104,162	
13. Mackerel			107
14. Bonefish		1,24,39,87	
15. Ladyfish	52	41,52,60,62,104,162	
16. Tarpon	144,171	40,62,63,171	
17. Alewife	89	43,89	
18. Blueback		104,162	
19. Shad	118	104,118	
20. Striped mullet	4	4,60,104,162	
21. White mullet	51	4,51,60,104,162	
22. Menhaden	78,161	120,140,161	

Appendix Table 1 - continued

<u>Species</u>	<u>Long Island Sound</u>	<u>Chesapeake Bay</u>	<u>Delaware Bay</u>
1. Bluefish			33
2. Striped bass		110	32,33
3. Winter flounder	142,143,175	72,98	33
4. Summer flounder		53,72,93	33
5. Tautog	143,175	72	33
6. Cunner	142,143,175		33
7. Scup	45,142,143,175	98	33
8. Sheepshead			
9. Pinfish			33
10. Butterfish	142,143	94,98	33
11. Croaker		98,172,174	33
12. Spot		98,122,174	33
13. Mackerel	143,175		
14. Bonfish			
15. Ladyfish			
16. Tarpon			
17. Alewife		72,98	33
18. Blueback		72,98	33
19. Shad		98	
20. Striped mullet		72	33
21. White mullet		72	33
22. Menhaden		120,161	

Appendix Table 1 - continued

<u>Species</u>	<u>Offshore New England States</u>	<u>Offshore Middle Atlantic States</u>	<u>Offshore S.E. Atlantic States</u>	<u>Canada</u>
1. Bluefish				
2. Striped bass				103,110
3. Winter flounder				13,102
4. Summer flounder				
5. Tautog				
6. Cunner				13,77
7. Scup				
8. Sheepshead				
9. Pinfish				
10. Butterfish				157
11. Croaker				
12. Spot				
13. Mackerel				
14. Bonfish				
15. Ladyfish				
16. Tarpon				
17. Alewife				103
18. Blueback				
19. Shad				103
20. Striped mullet				
21. White mullet				
22. Menhaden	168,169	168,169	168,169	

GENERAL DISCUSSION

Alperin noted that recollections of personal experience could be used as a method by which to fill the information gaps. As an example, he cited the good fishery for snapper bluefish in all estuaries leading into Buzzards Bay, Massachusetts, noting particularly the Weweantic, Wareham, and Westport Rivers. He recalled having collected this species as far east as Pleasant Bay, Chatham on Cape Cod.

Joseph noted a basic problem -- that of separating chance or isolated occurrence from areas of expected abundance. He pointed out, as an example, a record at the confluence of the Mattaponi and Pamunkey Rivers to be misleading as a representation of bluefish nursery ground. Massmann remembered the particular capture and regarded it as unusual. Clark agreed that quantifying nursery areas for estuarine fishes is a problem of staggering difficulty.

Dow commented on the disagreement between northern and southern workers about estuarine-dependency of bluefish. To this observation, Clark replied that seining collections showed bluefish to occur along the open reaches near inlets and in high salinity estuarine areas. As the season progresses, they move farther up into fresher areas.

Berry suggested that surveys or stations where no fish are taken should be encoded, since negative results are also useful. Carlson suggested the discussion proceed progressively by state from south to north, with citations of the operations in each area. Moe said he took juvenile bluefish 50-80 mm SL in the surf at Daytona Beach, Florida, in May. Brown noted the catch of this species all along the east coast of Florida. Clark commented on a study of the Indian River that arose from a water control problem in the St. Lucie Canal; on Tagatz' survey of the St. Johns River; and a Sandy Hook-supported series of beach seine collections by Jacksonville University along the oceanfront from the St. Mary River to St. Augustine on a semiweekly basis in the summer of 1967. Joseph mentioned McClane's study of the St. Johns River collections deposited in the Florida State Museum.

Frisbie discussed the sampling program underway in three major estuarine systems along the Georgia coast. They sample every 2 weeks in each area from 5 miles offshore into the small tidal marsh creeks. Gehringer also mentioned a biweekly sampling program, conducted by the Bureau of Commercial Fisheries, which continued for 8 years and ended in 1961, and Dahlberg's collections of some 3 years at Sapelo Island and around St. Catherine Sound. Clark summarized data from South Carolina, compiled for Sandy Hook by the Bears Bluff Laboratories, from 15 years' sampling at lower estuary stations and along the coast within the range of the Bears Bluff research vessel. Clark also mentioned that Dr. Lund's collections (1961) included some from South Carolina. For North Carolina, Brown thought results from the Bureau of Commercial Fisheries' menhaden sampling included information on other species including bluefish, but he wasn't aware of larval occurrences inshore. Hettler spoke of plankton larvae and juvenile surveys at Pamlico Marine Laboratory by Dr. Horton. White also mentioned a trawl survey of the Newport River by the Radiobiological Laboratory. Clark recalled Tagatz' published report of monthly sampling around Beaufort and reports by Bayless and Smith of North Carolina Department of Fish and Game in their inventory sampling of North Carolina rivers.

Joseph discussed the information available from Virginia. A manuscript is in preparation on the distribution of fishes in the Eastern Shore area. Programs are underway to survey the James, Rappahannock, York and Potomac Rivers. In addition, Joseph said 10 years of trawl data, which does not include length information, are processed for ADP. The fish lengths must be obtained from raw data sheets.

Koo remarked that coverage for Maryland is available only for the Chesapeake Bay and its rivers. Catch information contains monthly trawl and plankton survey data, including lengths, on cards.

De Sylva discussed the work in Delaware, mentioning that he and Kalber published a review of larval bluefish in the Delaware River estuary, and that he and Bob Smith plan to publish on all larval fish of the river estuary and offshore. Some graduate students are sampling Indian River and Delaware Bay creeks and Dr. Raney will conduct a survey on upper Delaware Bay in the near future. Carlson mentioned a Rutgers' study by Mark Chittenden of factors responsible for year-class strength in the Delaware River, essentially bioassay tests of temperature and dissolved oxygen on eggs, larvae and juveniles. Kalber mentioned Bayside Laboratory monthly trawl surveys in the bay by Dr. Price.

Murawski gave an account of several studies in New Jersey. Rutgers and the New Jersey Division of Fish and Game cooperated on a survey of South Jersey estuaries (unpublished); he mentioned that the state will undertake a more extensive survey of many estuaries including the Mullica River-Great Bay area and possibly the Maurice River Cove, the upper Barnegat Bay or Manasquan River. Mr. Marcellas of Rutgers has an ongoing study of Forked River (Barnegat Bay).

Briggs said the New York Marine Division published results of most studies in the New York Fish and Game Journal. Williams said the Stony Brook staff planned to continue plankton sampling in Long Island Sound with occasional trawling and seining. He expected a staff increase and sampling to expand. Carlson discussed a survey initiated in 1966 on the Storm King Project, which covered the Hudson River from New York City to Albany. Data will be available after reports are approved.

Cole reported for Connecticut, stating that Dr. Lund sampled for juvenile bluefish in the Mystic River and other areas. Clark mentioned George Maltezos had ongoing studies in Connecticut.

Alperin discussed Massachusetts surveys of four estuaries in which usually six stations were sampled regularly for 1 year with beach seines, shrimp trawl, and commercial-size otter trawl. The University of Massachusetts is working on the Weweantic. Southeast Massachusetts Technical Institute was sampling a small estuary and Woods Hole (BCF) made some summer collections but most work is offshore.

Dow reported that there were some studies being made on the Piscataqua estuary in New Hampshire. He also cited state work in Casco Bay, Maine. Graham discussed Bureau of Commercial Fisheries' yearly sampling cruise along the coast -- four cruises of 15 stations from Cape Ann to Eastport, and four of 40 stations from Cape Porpoise to Eastport.

Clark mentioned the problem of using literature which omits data on fish size. Although one suspects "juveniles" to be in an area, this cannot be substantiated without size distribution data.

Moe stressed the importance of encouraging the publication of data. He asked what data would be most relevant to an analysis along the Atlantic coast and what standardization of information would be helpful. Clark replied that he hoped to obtain opinions on the matter of standardization from those present.

After speaking on the mapped array of juvenile fluke, Smith discussed the distribution of fluke larvae taken in the R/V Dolphin northern survey from December 1965 to December 1966. Smith used the Gulf V high speed sampler with 0.5-mm mesh net to take larvae of 3 to 7 mm in length. The October 1966 cruise yielded the largest capture of this species. Smith mentioned the ASMFC tagging of 2,000 juvenile fluke in the Pamlico Sound.

Kendall pointed out, from his mapped array of sparids, that pinfish and sheephead were reported from the Woods Hole area, but present range has shifted southward. Alperin noted that juvenile pinfish occur regularly on the south shore of Long Island, in all bays, every year and large adults occur in Peconic Bay.

Joseph raised the point that a coastal species might appear to be estuarine-dependent in one part of its range, but not in another. As an example, he would not consider scup to be an estuarine-dependent species, on the basis of his work in the Chesapeake Bay; however, further north this would be disputed. De Sylva mentioned that the A. E. Parr collection of juvenile fish (ca. 1929-31) showed scup throughout the Delaware Bay -- even into the estuary, where the species no longer occurs. He noted that Delaware Bay formerly had low salinities but high transparencies and that transparency might possibly be a more important factor in determining the estuarine-dependency of some fish than salinity. Kendall remarked that these occurrences suggest the limited importance of salinity in determining the range of this species. Clark said he would not define the scup as an obligate estuarine fish.

Kendall suggested that tautog, like scup, appear to be variably dependent on estuaries in different parts of their range. While the species is usually found inshore around fjord-like estuaries, it is found farther offshore and associated with hard surfaces, such as wrecks, in the Chesapeake area. Murawski noted he found far more larvae in northern New Jersey, which has more rock compared to southern New Jersey, than in the latter area, which is typically sandier.

Berry questioned the distribution of butterfish around the end of Florida. He conjectured that there could be disjunct populations, separated genetically and geographically. On the east coast, they go to Indian River, perhaps to Jupiter, but none occur along Dade, Monroe and Broward Counties. Brown reported 3- to 4-inch butterfish at 100 fathoms off Oregon Inlet. Joseph expressed doubt as to estuarine-dependence of butterfish. They are common in estuaries, but more common in the ocean.

Dow suggested that workers should write to people in the various laboratories and agencies and ask specific questions about the different species. As an example, he said that he had observed juvenile cunner from Cape Elizabeth to western Penobscot Bay, but had not known this information to be of immediate value. Some of this information is recorded, some is not. Alperin noted butterfish to be one of the most important species in the surf zone of Long Island's south shore.

Kendall noted that the association of butterfish with jellyfish and schooling fishes caused a problem in sampling.

During Berrien's review of spot, Alperin reported juveniles to occur in all south shore bays of Long Island and Brown said they occurred in numbers within the Carolina Sounds, noting the same sizes (7.5-12.5 cm) were taken 15 miles offshore by the R/V Dan Moore.

Berrien remarked that the R/V Dolphin larval croaker samples showed the largest number of 3.5-mm size group came from offshore and indicated a decrease in size with distance offshore. Kendall added that croaker larvae most likely extended beyond the area sampled. Murawski added he had some croaker larvae from New Jersey.

Berrien commented that the Atlantic mackerel is apparently not so estuarine-dependent; Sette's data from Cape Hatteras north to the Gulf of St. Lawrence indicate spawning of this species throughout the entire area. Berrien said the Sandy Hook data complemented these findings.

In the discussion of mackerel, Alperin noted the presence of spike mackerel in the high salinity water of the harbor areas of Massachusetts, Maine, and New York. He considered this a return to the question of what constitutes an estuary and, hence, estuarine-dependency. Murawski added that juvenile mackerel occur in some New Jersey estuarine areas -- Raritan and Sandy Hook Bays and the Shark and Manasquan Rivers -- but only during certain periods and then not far into the systems. Brown commented on a commercial gill net fishery for the Atlantic mackerel off Chincoteague in the winter.

Fahay noted that bonefish, ten-pound, and tarpon are primarily southern forms and their occurrences are usually isolated. Cruises of the R/V Dolphin yielded only one tarpon larvae -- one 39 mm in length. He cited Rickards (1966)¹ as the source of information that tarpons usually migrate back out

¹Rickards, W. L. 1966. A study of the ecology of first year tarpon, Megalops atlanticus Valenciennes, in a Georgia salt marsh with laboratory studies of growth rates and ecological growth studies. M.S. Thesis, Univ. Georgia. 67 p.

to sea when they are 200 to 250 mm in size. Witham mentioned a sport fishery for small tarpon in the northern portion of the St. Lucie River and volunteered his records of juveniles along the South Carolina coast (150 specimens). Schwartz suggested work of Vladykov (University of Ottawa) as an information source for Canadian survey data of southern U. S. waters. Kinnear recalled larval sampling at Swansboro, North Carolina, in November when he got some ten-pound leptocephali.

Following a comment by de Sylva on the tarpon fishery of Virginia, Joseph stated that neither juveniles or leptocephali have been collected in a survey of Virginia's Eastern Shore bays.

Pacheco noted that the lack of data on clupeid species and mullet as well relates to problems of collecting gear; seine surveys result in low catches for clupeids. Noting the paucity of documented information from New England, Dow mentioned there were data available from Maine and Alperin said 45 spawning runs exist in Massachusetts.

Carlson mentioned trawling in the Connecticut River by Jones of the Connecticut Department of Fish and Game as a data source on alewives and bluebacks for the past 2 years. Shad studies in the Connecticut River by the Essex Marine Laboratory staff were another possible source. R. Smith said a thesis was being prepared by Jay Watson at the University of Massachusetts on Connecticut River shad above the Holyoke Dam.

Cronin cited a 3-year sampling program of the Susquehanna by the Department of Chesapeake Bay Affairs. Brown added that Dr. Hassler of North Carolina State University conducted 13 years of trawling biweekly in North Carolina concentrating on Albemarle Sound, with similar data available for several years for the Cape Fear River.

To a question on estuarine-dependency posed by Dow, Pacheco considered alewife to be estuarine-dependent insofar as the species passes through and stays for a time in the estuary on its way to sea. Dow thought it best for anadromous species to forget estuary boundaries and consider the watershed in the adjacent marine area; he mentioned that some extensive potential spawning and nursery grounds for alewives in Maine are blocked by dams. Carlson remarked that in the Hudson River a salinity of 0.1‰ exists about 60 to 70 miles from the mouth, but the river is tidal for 140 miles. Alewife, blueback, and American shad occur farther upstream than the brackish water area.

Kinnear and Turner described menhaden sampling by the Bureau of Commercial Fisheries. There are 69 sites, ranging from Cape Cod to Fernandina Beach, Florida. Surface trawls are used for sampling and the scheme is to sample one site per 150,000 acres of estuarine water. This gear is efficient and highly selective for menhaden, which compose 90% of the catch. The most notable of the other species include striped mullet, ladyfish, and a small number of juvenile bluefish. These fish are sent to Fred Berry at Miami for verification and shelved for future reference. The sampling schedule is confined to a 45-day period, June 1 to mid-July. Samples are taken in the same manner and in the same areas of the same

streams each year. Two crews operated in the Gulf and one in the Atlantic and the work is done in 3 weeks. Clark recalled the R/V Dolphin larval menhaden catches. They were taken throughout the year, more northward from June to October and more southward and inshore from November to May.

Berrien stated that menhaden were taken on the Dolphin cruises in 1966 over most of the shelf north of Hatteras and throughout most of the year.

Clark asked for group opinion on the efficacy of a group or committee approach to the problem of understanding estuarine occurrence of juveniles. He cited a systematic, cooperative survey now in progress in the Gulf.

Cronin replied that lack of funds is a continuing deterrent. However, ASMFC provides one opportunity for a coastwide review and work could proceed through this channel. He remarked that it is possible that the Commission could recommend a central financing plan for this area of research.

Davis noted that extent of knowledge varies in different areas and with different species. He suggested listing of data gaps arranged in some priority for voluntary selection by those in the field or to be assigned areas of study for participant organizations. Clark viewed this idea as a valid suggestion perhaps to be explored by a small pilot group. In the area of a joint effort along the coast, Clark said the needs must first be decided. For example, the Sandy Hook Laboratory finds ocean work to be appropriate and will be inclined to continue these studies. However, if a strong need or mandate for work in estuaries arises, they would attempt to include such efforts in their program.

Cronin returned to the problems of a cooperative effort and outlined a proposal expressed by Walford for a base line of understanding about coastal environment and fish life. He stressed that joint efforts should be cooperative, not coordinated, i.e. be internally motivated, partly because budgets have been small and priority cannot favor offshore effort for many states.

Brown suggested standardization of gear in individual efforts for easier comparisons of results. He said PL 88-309 has set up a program to which others could be added to obtain information of such a nature.

Joseph summarized the status of information by describing two types of ignorance -- one reflected by formal literature and a different state of ignorance in reality available for local situations. Although the formal literature may not reflect information where it exists, many actions are taken on a local basis. It is not necessary to have a formal source of information prior to making management recommendations. Some information not available on a coastwide basis is still actually used.

SUMMARY AND PLANNING

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The objective of this afternoon session is to draw together a consensus of present knowledge on eggs, larvae, and fish of Atlantic coast estuaries and produce summary statements of what we know and what we will need in the future; the result being positive, constructive suggestions as to the best investment of time and the best use of support.

FIELD TECHNIQUES

Biologists frequently conduct field operations and gear evaluation in the least efficient manner. There is a tendency to sample first, return to the laboratory to decide if the gear is efficient, and then determine the interaction between the species and the gear. A more logical and effective procedure would be to: (1) define the problem, (2) determine gear efficiency, (3) understand interactions among gear, sampling techniques, and species escapement, and (4) determine the relation between effective sampling and distribution of species.

Tow length should be representative of the patchiness of an organism. Short tows are preferred over long tows in small sampling areas because: (1) plankton occurs in patches, (2) there is an increase in catch rate, (3) more information is gathered, (4) more accurate representations are made, and (5) part of the population is often missed in long tows. Results should always be based on replicated data.

STANDARDIZATION

Since each area has specific problems, standardization of gear is impractical. When there is a common problem in similar areas, however, standardization of gear is advantageous. A "reference net" collection series may be advantageous to relate studies. Unobstructed net mouth design is important and it has been recognized that night collections afford a different view of distribution and relative abundance than do day collections. Techniques such as night-lighting yield many species not taken in seines. In some areas along the coast, underwater TV or diver observations would be useful for corroborating information. Although we do not always know enough about efficiency of some types of gear, in certain instances it may be useful to express catch in terms of volume strained or ground passed over.

Workers should communicate more when beginning comparable efforts along different parts of the coast. There not only exists the problem of varied gear but also a lack of uniformity in handling resultant catches and data. Standardization of terminology is needed, particularly in representing measurements. Such elementary steps in uniform expression will enhance the efficiency of information exchange.

PRESERVATION TECHNIQUES

The performance of preservative fluids varies. Some fluids retain the structure of an organism whereas others retain color. When a preserving technique is successful, biologists should share experiences in order to obtain the best preservative and the best technique for specific purposes. It seems apparent that industrial suppliers are not aware of the need for better fish specimen preservatives.

IDENTIFICATION TECHNIQUES

Biologists encounter two major problems in identifying organisms: (1) there is no satisfactory way to distinguish larval stages of many specimens, and (2) there is an insufficient number of people trained to identify specimens brought into the laboratory. Though there is no immediate solution to these needs, suggested aids in identification include histological analysis of gonad development and a study of the spawning seasons and areas of different species.

It is important to keep in mind what degree of separation is necessary for the most accurate identification. Laboratory culture of many forms is necessary to fill in missing growth stages.

There would be an advantage in sending material to a center for quick and reliable sorting, but at the same time there are difficulties in concentrating efforts in a single center.

PERSONNEL

It is recognized that a dynamic balance exists between attractive professional opportunities along with a place to educate the individuals with the many special interests needed in the profession. It is obvious that not enough people are available to solve the problems we have at present. One problem is getting taxonomists interested in early life history stages -- there are simply not enough people engaged in this activity. This situation should improve since development of special facilities to rear larval fishes is now far more justifiable than it was 5 years ago.

COORDINATION

It was recognized that needs should be reviewed and suggestions made to facilitate studies. The ASMFC could implement such efforts. Suggestions included:

- 1) Periodic workshops similar to this one. Other topics might include adult fish, crustacea, and environmental changes.
- 2) ASMFC Biology Committee could establish a permanent subcommittee for eggs and larvae that meets informally once a year. A 5-year general meeting period may be effective for the group.

Other ideas included a laboratory session at future workshops so that gear and techniques may be seen, and papers mailed to participants in advance to allow preparation for discussion.

The success of this workshop can be attributed to the choice of subject and the continuity along one line of interest from Maine to Florida.

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