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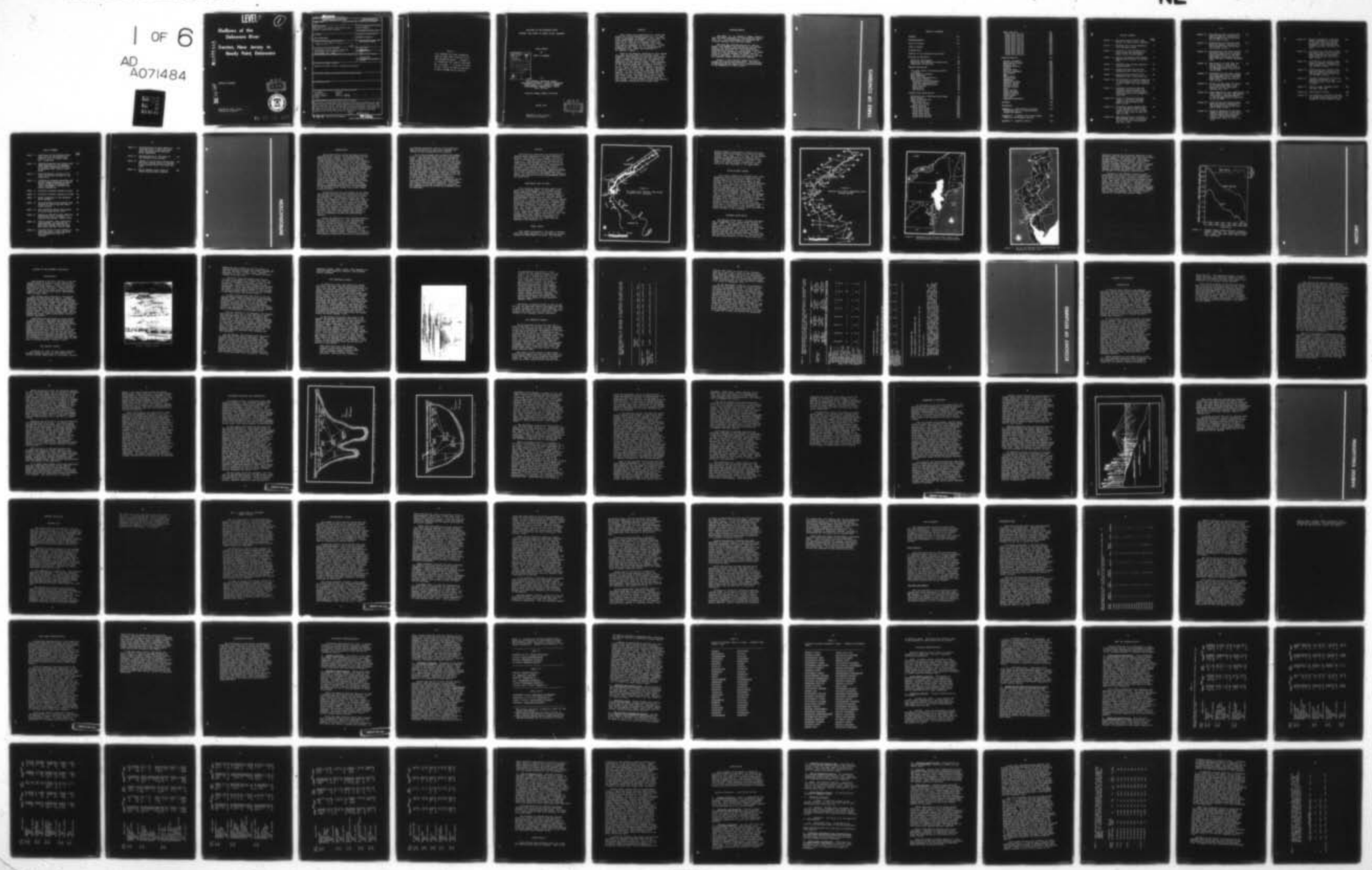

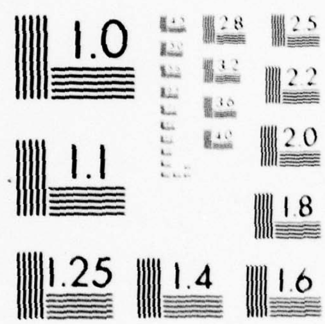

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Shallows of the Delaware River

Trenton, New Jersey to Reedy Point, Delaware

JOHN M. TYRAWSKI

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT

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This study is concerned with evaluating the shallow water resources of the upper Delaware Estuary, from Reedy Point, Delaware (river mile 58.6) to Trenton, New Jersey (river mile 133.4). Shallow water areas are defined as those areas from the mean low water line to the -10 foot mean low water contour. The purpose of the study is to define these areas, and to develop a system by which their ecological value to the estuary can be evaluated.

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SHALLOWS OF THE DELAWARE RIVER

TRENTON, NEW JERSEY TO REEDY POINT, DELAWARE

FINAL REPORT

by

JOHN M. TYRAWSKI

for

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March 1979

PREFACE

This volume is an adaptation of a study completed for the Philadelphia District, U.S. Army Corps of Engineers in September, 1978, under contract number DAW61-78-C-0022. The study is entitled "A Study of the Delaware River from Reedy Point, Delaware, to Trenton, New Jersey, with Special Reference to the Shallows". It was prepared by John Homa, Jr., of Ichthyological Associates, Inc., under the direction of Dr. Edward C. Raney.

Much of the material appearing in this volume was taken directly from the original study. Included in this category are the text and graphics found on pages 116 through 278, the graphics on pages 279 through 388, and data included in the appendices of the present volume. Also appearing in the original study were Figures 2 through 7, 9, 10, and 12 through 29; and Tables 1, 2, 10, 11 and 14. Many of these were, however, redrafted or modified for this volume. The text beginning on page 1 of this study and continuing through page 38, and that on pages 279 through 388, are revisions of the text appearing in the original work of Mr. Homa. The text beginning on page 39 and continuing through page 88 was written for this volume. It was included to more fully develop the concepts underlying the original study.

ACKNOWLEDGMENTS

John Homa, Jr., Dr. Edward C. Raney, Susan B. Lent and other personnel of Ichthyological Associates, Inc., are acknowledged for preparing the original Delaware River Shallows Study.

The help and contributions of Dr. John A. Burnes, Roy Denmark, William Mueller and Jeffrey Steen of the Environmental Resources Branch, Philadelphia District, U.S. Army Corps of Engineers are also gratefully acknowledged. Mr. Steen acted as a liaison between the author and the Corps of Engineers. Special thanks go to him for his insights, ideas and editorial comments.

Finally, a very special thanks to Ellen C. Ganzman for typing this manuscript. Her efforts, professionalism and support have contributed much to the completion of this project.

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INTRODUCTION

The Delaware River system has been, and will continue to be, central to the development of the Middle Atlantic region. Its abundant natural resources were of great importance to the native Indian populations of the area, and these resources and the location and navigability of the system were essential factors leading to the colonization of the area by Europeans. From the early settlements at Wilmington and Philadelphia, numerous communities have arisen within the Delaware River Basin. The salt, brackish and freshwater wetlands and flood plain forests which dominated the shores of the river and bay in the past, now exist in many areas only as pockets among numerous factories, power-generating stations, waste treatment facilities, housing developments, oil refineries, water treatment plants and piers, docks, wharfs and boat basins. Intimately connected with all of these shoreline modifications has been the development of the Delaware River system into a major transportation artery.

Concomitant with the development of the above uses of the waterway has been the continued use of the Delaware as a source of food and as a center for recreation. The Delaware estuary has supported many commercial fishing industries, some of which, while reduced in scope, still exist today. Further, large populations of weakfish, bluefish, flounders and blue crabs, and others, continually attract more and more recreational fishermen. Add to these the numbers of recreational boaters and waterfowl and small game hunters and trappers, and the picture of the Delaware that emerges is one of a tremendous natural and recreational resource.

While the potential of multi-faceted development is the essence of all river and estuarine systems, the realization of this potential is often the cause of significant problems. Frequently, use of the system for one purpose restricts the use for other purposes. Water which is used to dilute industrial wastes may not be suitable for domestic water supplies or for the survival of riverine fishes. Conversely, promoting environmental conditions beneficial to maintaining the highest ecological quality of the basin may lead to reductions in use of the waterway for industrial and transportational purposes.

It is this dilemma that prompted the present study of the shallow water areas of the Delaware River. Shallow water areas are here defined as those areas having a maximum water depth of ten feet at mean low water, and are, thus, those water areas within the photic zone and usually adjacent to the shoreline. It is these shore zone areas which figure most prominently in the development of the basin and which, as will be discussed in more detail later, are most critical to maintaining the ecological processes occurring within the Delaware Estuary. A rational approach to the use of shore zone and shallow water areas is of prime concern to the Philadelphia District, U. S. Army Corps of Engineers. Developing such an approach begins with identifying and evaluating the river's shallow water resources. This volume was created to provide a foundation upon which the identification and evaluation processes could be developed.

PURPOSE

This study is concerned with evaluating the shallow water resources of the upper Delaware Estuary, from Reedy Point, Delaware (river mile 58.6) to Trenton, New Jersey (river mile 133.4) (Figure 1). Shallow water areas are defined as those areas from the mean low water line to the -10 foot mean low water contour. The purpose of the study is to define these areas, and to develop a system by which their ecological value to the estuary can be evaluated. Such evaluations will assist personnel of the Philadelphia District, U.S. Army Corps of Engineers, in processing permit applications involving encroachments within the study area.

REFERENCES USED FOR MAPS

The following references were used to construct the enclosed maps: the Delaware River Basin Commission (DRBC) tabulation of National Pollution Discharge Elimination System (NPDES) dischargers dated 4/11/75; U.S. National Oceanic and Atmospheric Administration Nautical Charts, Numbers 12311, 12312, 12313 and 12314; U.S. Geological Survey 7.5 minute quadrangles: Delaware City, Salem, Wilmington South, Penns Grove, Marcus Hook, Bridgeport, Woodbury, Philadelphia, Camden, Frankfort, Beverly, Bristol, Trenton West and Trenton East; U.S. Corps of Engineers Surveys (1909, 1932, 1960, 1965, 1969); Appendix E of the Draft (EIS) of U.S. Corps of Engineers (1975); Daiber et al. (1976); DRBC (1975); Walton and Patrick (1975) and Disposal Area Maps (Sheets 1 of 2 and 2 of 2 Philadelphia to the Sea and Philadelphia to Trenton) supplied by the U.S. Army Corps of Engineers, Philadelphia, Pa.

STUDY DESIGN

This study is designed to be used in conjunction with that undertaken for the National Science Foundation-RANN Program entitled, "The Delaware

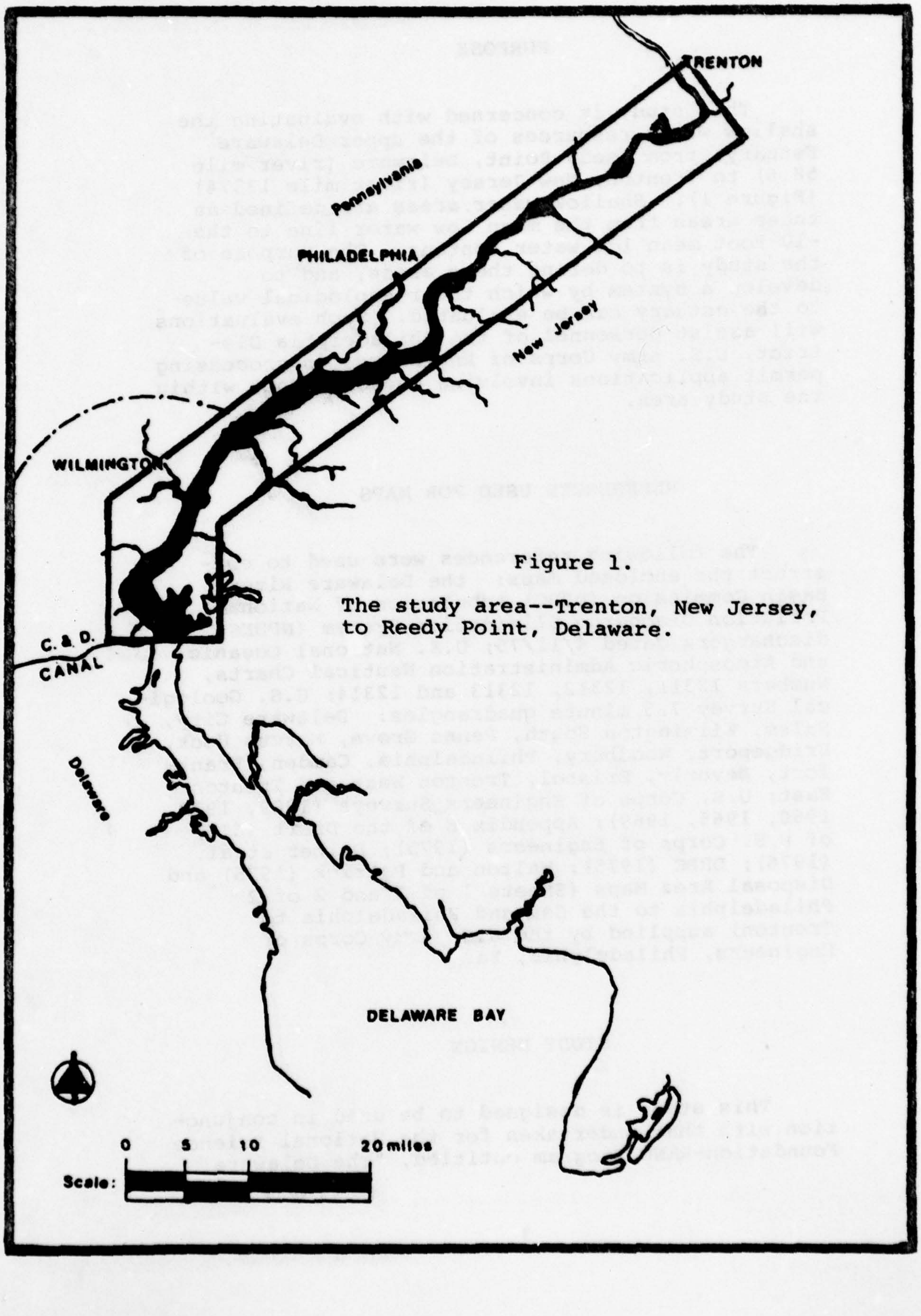

Figure 1.

The study area--Trenton, New Jersey, to Reedy Point, Delaware.

Estuary System: Environmental Impacts and Socio-Economic Effects--Delaware River Estuarine Marsh Survey" (NSF, 1973). To this end, the map symbols created in the RANN Report to identify point source dischargers and types of vegetation are used in the maps prepared for this text. This study also employs a data presentation format similar to that developed in the RANN study.

RIVER MILEAGE SYSTEM

This report adopted the Delaware River Basin Commission stream location and identification system based on river mileage (Figure 2). The mileage system for the Delaware River and Bay consists of a "mile zero" at the mouth of Delaware Bay and a line along which distances from mile zero are measured. Mile zero is located at the mouth of Delaware Bay at the intersection of a line between the Cape May Light, New Jersey, and the tip of Cape Henlopen, Delaware. From the "zero" point, to Trenton, New Jersey, the mileage line is the centerline of the navigation channel. Upstream from Trenton, river mileages of the Delaware River are measured along state boundaries as shown on U.S. Geological Survey maps. A similar mileage system is applicable to each tributary of the Delaware River by establishing a "mile zero" at the mouth of the tributary, and measuring the distance in miles above its mouth to points located on the tributary.

DELAWARE RIVER BASIN

The Delaware River Basin, including Delaware Bay, encompasses 13,547 square miles (Figure 3) (DRBC, 1975). The headwaters of the Delaware River arise on the western slope of the Catskill Mountains of New York. The river flows south some 420 miles and empties into the Atlantic Ocean between Cape May and Cape Henlopen. The head-waters form the east and west branches which join near Hancock, New York (Figure 4). From there the Delaware flows easterly to Port Jervis, New York;

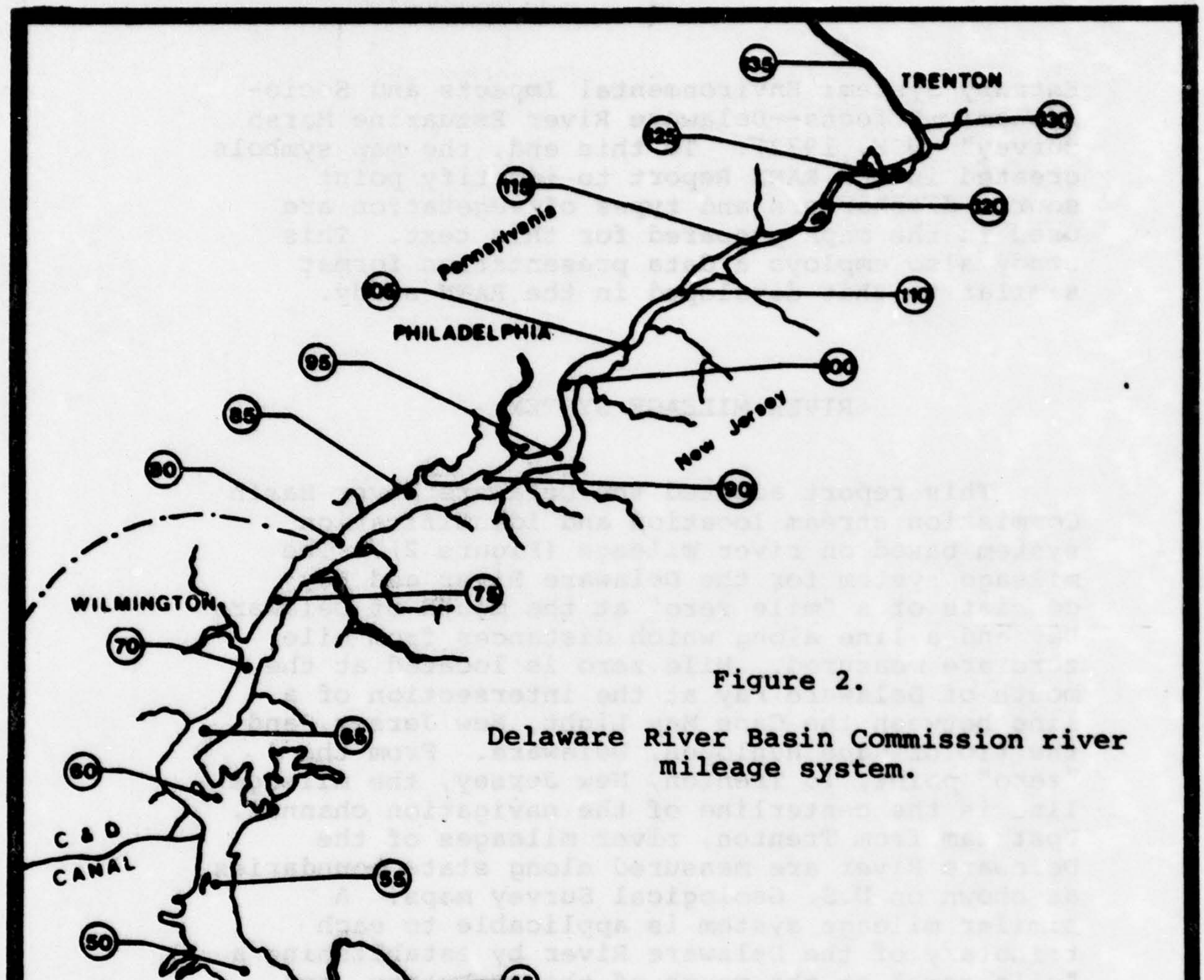

Figure 2.

Delaware River Basin Commission river mileage system.

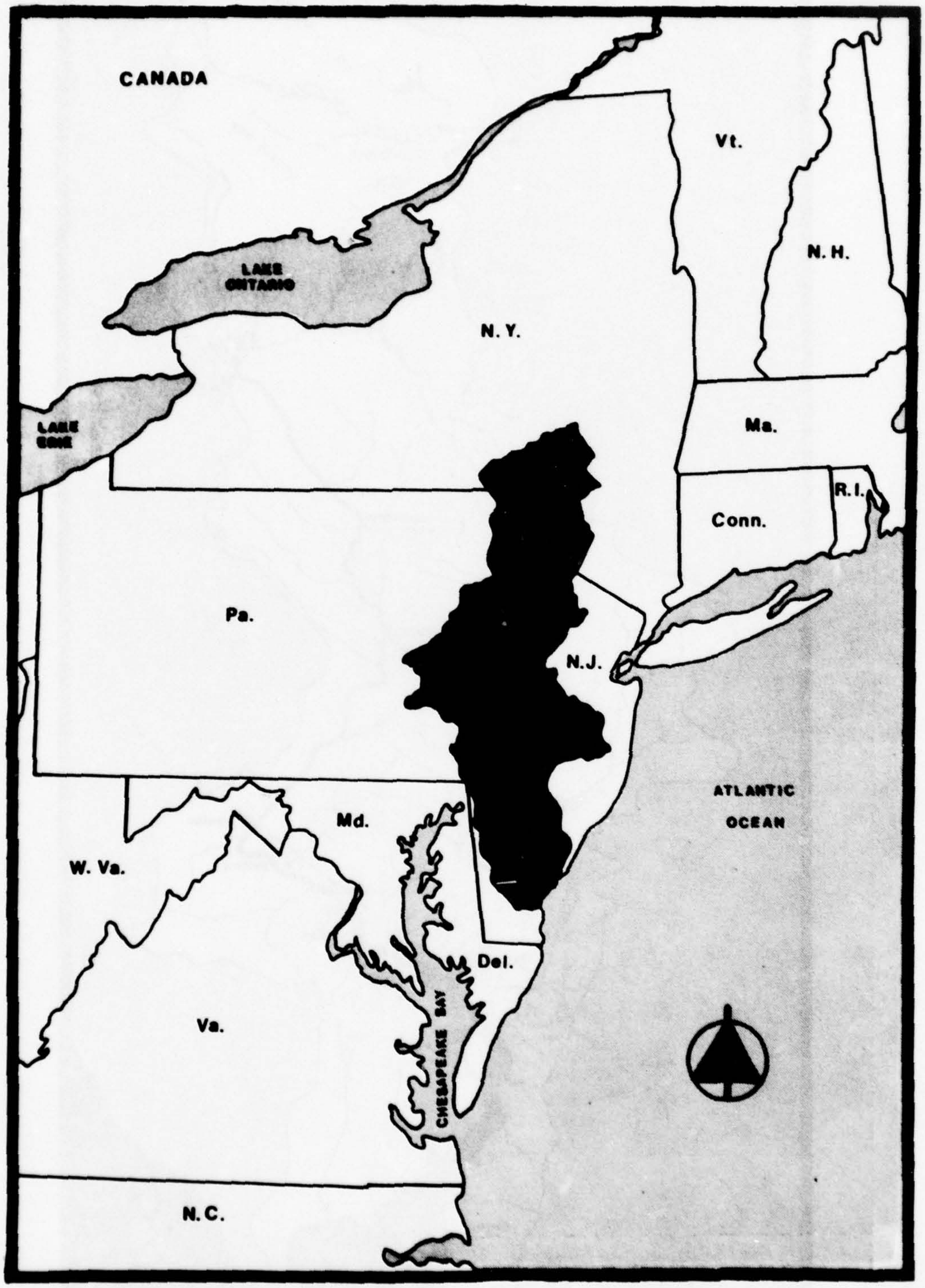

Figure 3. Location of the Delaware River Basin along the mid-Atlantic coast of the United States.

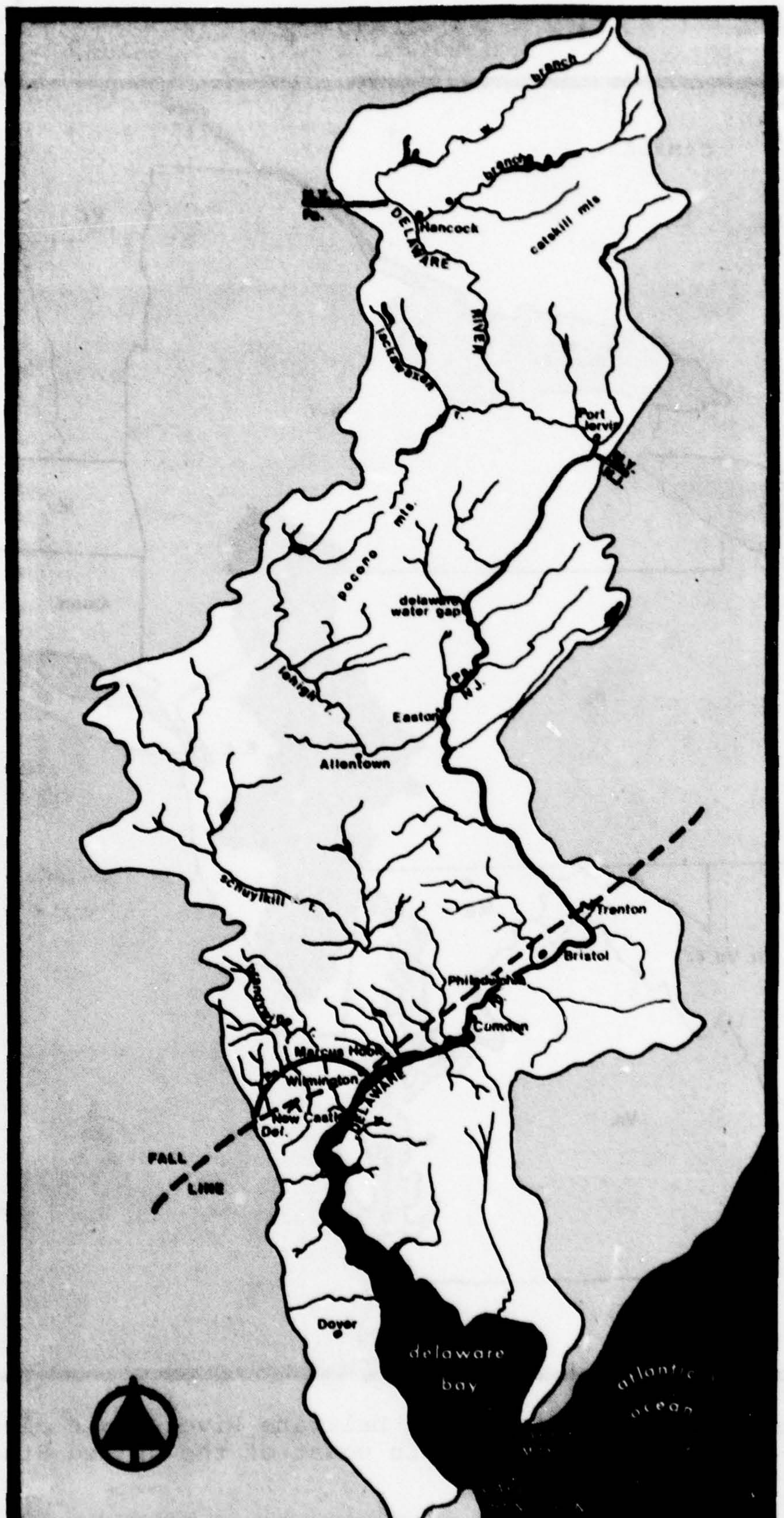

Figure 4. Map of the Delaware River Basin showing the location of the fall line.

southerly through the Kittatinny Mountains at the Delaware Water Gap and enters the hills and valleys of the piedmont. The Lehigh River joins the Delaware at Easton, Pennsylvania. The Delaware crosses the fall line at Trenton (Figure 4). Here the Delaware drops about eight feet to become a broad, navigable estuary. River flow in this section is altered by semidiurnal tides. The largest tributary, the Schyulkill River, enters the estuary at Philadelphia, Pennsylvania.

Salinity of the Delaware varies at high-water-slack tide from 30 parts per thousand (ppt) at the mouth of the bay, to about 0.02 ppt at river mile 78 near the Pennsylvania-Delaware state line. Mean depth, cross section and width of the estuary are shown in Figure 5. The major ports and cities of the Delaware are located along the 75 mile stretch from Trenton to the Chesapeake and Delaware (C & D) Canal. Below Wilmington, Delaware, the estuary widens into a bay surrounded by nearly flat, tidal salt marshes. The estuary finally narrows as it enters the Atlantic Ocean.

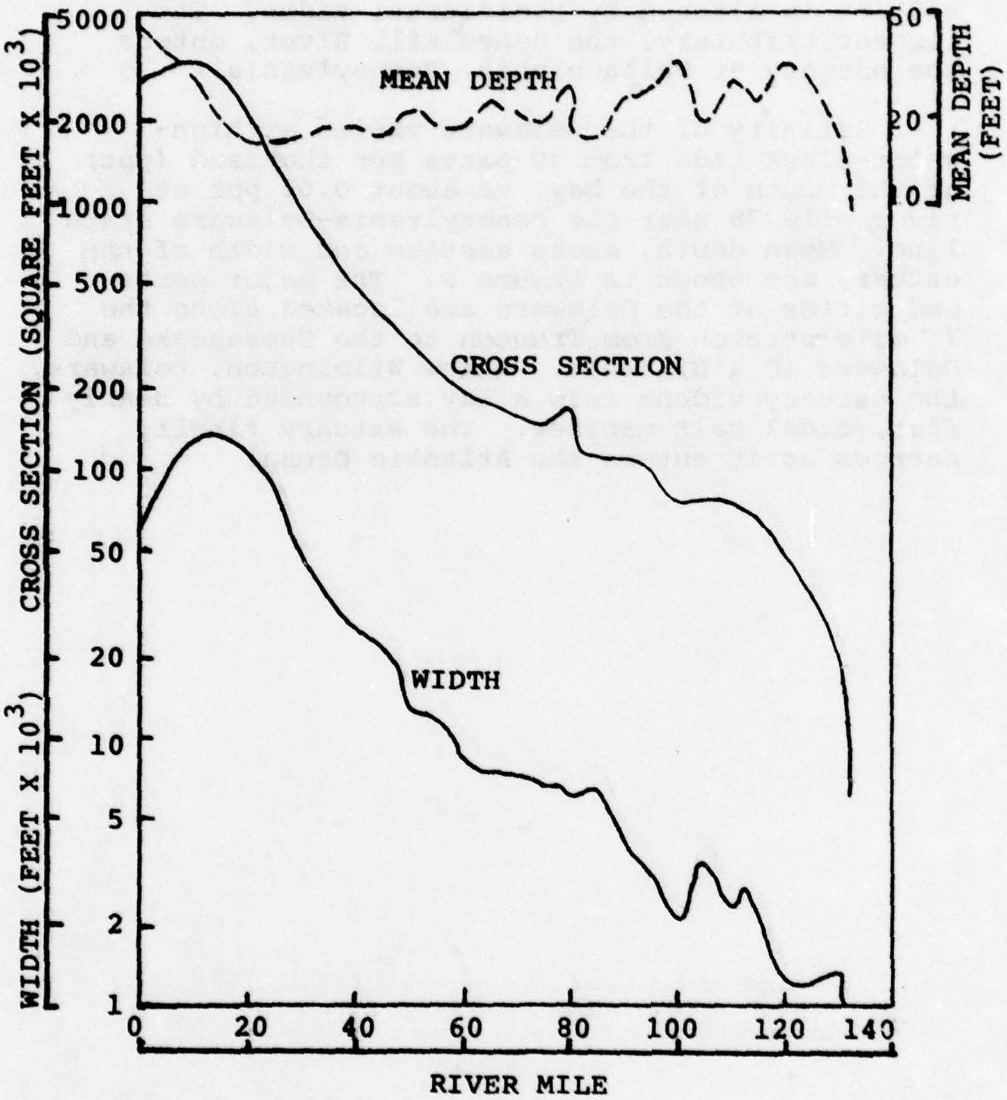

Figure 5. Delaware River Estuary physical characteristics. (Source: U.S. Corps of Engineers, 1975) Note: The above data refer to mid-tide elevations.

HISTORY

HISTORY OF THE DELAWARE RIVER BASIN

PRE-COLONIAL

The Delaware River Basin has had a long and varied history as a center of both Indian and industrialized societies. Before the arrival of Europeans in 1609, permanent Indian settlements were located within the basin. These were the villages of the Lenni Lenape which were established at least by the late 1300's (Heckewelder, 1820; Brinton, 1885).

The Indians were attracted by the natural abundance of food within the basin. Evidence indicates that before 1600, dense virgin forests and clear, silt-free streams were characteristic of the area (Mihursky, 1962). Within this environment, game was varied and plentiful. The bones of caribou, bison, lynx, wolf, beaver, elk, turkey, black bear, deer, and moose offer evidence of the varied wildlife of the area (Leidy, 1880, 1887; Mercer, 1897). Fish were also plentiful, and the anadromous fishes, shad in particular, were of special importance.

Techniques were perfected to allow capture of migrating fish. When shad began moving upstream to spawn, for example, the Indians built special stone dams in the river consisting of two wings converging into a pond or wooden trap. About a mile above the trap, wild grape vine loaded with brush was stretched across the river between several canoes. The barrier was towed downstream herding the shad into the dam and trap. The technique was apparently successful in capturing fish for it has been reported that "as many as a thousand are known to have been taken in this way in a single morning" (Loskiel, 1794).

THE COLONIAL PERIOD

On August 28, 1609, the Half Moon commanded by Henry Hudson entered the bay, and with its arrival another phase began in the basin's history.

EARLY INDIAN METHODS OF FISHING.

(Source: Meehan, 1893)

Naming the bay in honor of Lord De La Warr, a colonial governor of Jamestown, Hudson claimed the area for the Dutch (Wilder, 1940). Shortly thereafter in 1631, a Dutch settlement was established along the river.

The early Dutch settlements were quickly followed by settlements of Swedes and Finns, who in 1636 established a settlement at what is now Wilmington. Conflicts arose between the two groups, and in 1655 the Dutch captured the Swedish settlements. While this secured the position of the Dutch, it by no means assured it, for in 1664, the English gained control of all of the holdings of the Dutch within the Delaware Basin.

In 1682, William Penn took title to all the land presently known as Pennsylvania and Delaware (Wilder, 1940). Penn provided the impetus for the development of the region, for he unified the groups of settlers within the area and began designing and building the city of Philadelphia. Included in the designs were provisions for streets, parks, and importantly, a boat basin at the confluence of the Schuylkill and Delaware Rivers.

With the founding of Philadelphia, the Delaware Basin quickly grew into a major New World center. Settlers immigrated to the area throughout the 18th century. Some established prosperous farming communities in the outlying areas. Others remained in the cities developing the many industries, such as tanneries, brickyards, glassworks, papermills, and ship works. From this base, the area steadily grew. By the time of the American Revolution, the Delaware River Basin was the major center of American commerce, manufacturing, shipping and ship building.

As the Indians, the colonists were attracted to this area by its natural resources. Many accounts exist of the plentiful amounts of shad, salmon, striped bass and sturgeon that were present, and of how highly these resources were used. Penn, for instance, indicated that sturgeon were so plentiful they were a hazard to small skiffs within the river, and shad so plentiful that hundreds were caught at one try (Myers, 1912). Oysters were also numerous and a prosperous business developed around their harvesting. With the presence of game, timber, water, wide expanses of land and other essential elements, the colonies quickly expanded.

THE INDUSTRIAL PERIOD

In addition to the rich supplies of timber and water, the basin also had large supplies of coal, iron and lime. These materials provided the basis for further industrial development of the region. Water served to run early mills and factories such as the gun powder works established by the duPont family in 1803. Coal soon replaced water, however, as the major power source. Discovered in 1792, coal was soon being barged down the Lehigh and Delaware rivers to Philadelphia and throughout the basin. With coal, iron, lime and water came the establishment of iron works and steel mills. Their development made possible the construction of locomotives and railroads which in turn promoted westward expansion. By the mid-nineteenth century a well-established network of railroads and manufacturing facilities was present within the Basin (Wilder, 1940).

It was during this period that many of the present day problems regarding use of the river began. An 1861 map indicates 32 dams existing on the mainstream Lehigh River from the plateau region to Easton (Anonymous, 1867; cited in Mihursky, 1962). The Schuylkill and other tributaries were also dammed, and as these dams prevented fish from reaching spawning grounds, fish stocks declined (Meehan, 1897; Cobb, 1900; Marshall, 1976). Also contributing to their decline, was the basin's continually degrading water quality. Many authors of the period such as Henry (1860), Rupp (1845) and Mathews (1884), commented on this trend. A quote from Meehan (1895) creates a vivid picture of the degrading water quality and its effect on fish stocks:

> "But worse even than fish baskets, dynamite, deleterious substances and unfair fishing, because farther reaching, was another element--stream pollution. Saw mills were erected in

Shad Gill Nets at Night on the Delaware
(Source: Stillwell et al., 1903)

> the backwoods on the banks of trout streams and the sawdust dumped into the water. By this means millions of fish were killed. Within the coal bearing area mines were opened and the filthy culm, composed of carbon and clay, emptied into the water; and thereafter pure sparkling streams, richly populated by mountain trout, were emptied of their fish, and ran, black, filthy and malodorous, to the rivers, which thereby became befouled, and, in many cases, almost absolutely fishless. Two notable examples of this lamentable result may be named--the Lehigh River and the Upper waters of the Schuylkill" (Meehan, 1895).

The result of these problems is that by the turn of the twentieth century noticeable declines in shad, sturgeon and other fishes emerged. The Delaware was becoming one of the great industrial areas of the world, but was doing so at the expense of its abundant natural resources.

THE TWENTIETH CENTURY

As the discovery of coal and iron led to major development of the basin in the nineteenth century, the invention of the internal combusion engine led to significant development of the basin in the twentieth century. Transportation and manufacturing potential were increased enormously. Needs for new materials and industries arose. The basin was criss-crossed with highways and rail lines. Oil refineries, electric power plants, water and sewage treatment plants, chemical factories, airports and cities grew and expanded throughout the region. Rural areas, previously unaccessible, were linked with the cities, and people began moving into these areas, a trend which continues today.

The result of this growth is that almost eight million people now live and work within the 13,547 square miles of the Delaware River Basin (Table 1). Most of these people are located within the highly industrialized section from

Table 1. Estimated population (in thousands) of the Delaware River Basin and the sub-basins from Trenton, New Jersey to Liston Point, Delaware 1920-2020 (DRBC, 1975).

	Drainage Area (sq. mi.)	1920	1940	1950	1960	1970	1980	2000	2020
Delaware River Basin	13,547	4,004	4,712	5,297	6,225	7,099	7,979	10,060	12,559
Sub-basins from Trenton, N.J., to Liston Point, Del.	4,604	3,260	3,870	4,378	5,139	5,878	6,603	8,266	10,272

Trenton, New Jersey to Liston Point, Delaware. Both as a result and a cause of this population and industrial growth, the ports of the Delaware River lead the United States in total international commerce traffic, and rate second nationally and third internationally in total waterborne commerce (U.S. Corps of Engineers, 1975).

As the development trend of the nineteenth century has continued, so has the trend of deteriorating environmental quality. By the 1940's, the waters of the river around Philadelphia were so fouled that they were called the "black waters" (Philadelphia Water Department, 1970). The large amounts of domestic sewage pumped into the river led to depletion of the dissolved oxygen in the water and disappearance of many fish. Conditions have improved today, but some sections of the river still receive large amounts of domestic and industrial waste materials that lower the quality of the entire basin (Kiry, 1974). The region still supports significant populations of fish, birds and mammals, but these populations are small in comparison to what the basins once supported.

Table 2. Recognized present and future water uses according to the Delaware River Basin Commission and State of Delaware water quality standards. (Source: DRBC in U. S. Corps of Engineers, 1975)

Purpose of water use	ZONE 2 Trenton-Morrisville Bridge (RM 133.4)[1] to Torresdale (RM 108.4)		ZONE 3 Torresdale (RM 108.4) to Big Timber Creek (RM 95.0)		ZONE 4 Big Timber Creek (RM 95.0) to Del.-Pa. state line (RM 78.8)		ZONE 5 Del.-Pa. state line (RM 78.8) to Liston Point (RM 48.2)	
	Present	Future	Present	Future	Present	Future	Present	Future
Water supply (after reasonable treatment):								
Agricultural....	X	X	X	X	....	......	....	......
Industrial......	X	X	X	X	X	X	X	X
Public water....	X	X	X	X	....	......	....	......
Wildlife.........	X	X	?	X	?	X	?	X
Maintenance of.... resident fish and aquatic life	X	X	?	X	?	X	X	X
Propagation of.... resident fish and aquatic life	X	X	....	......	....	......	X[2]	X
Passage of........ anadromous fish	....	X	....	X	....	X	....	X
Recreation[3].......	X	X	X	X	?	X	X	X
Navigation........	X	X	X	X	X	X	X	X
Maintenance and... propagation of shellfish	....	......	....	......	....	......	....	......

X Denotes recognized use.

? Denotes marginal or questionable use.

[1]RM denotes river mile from the mouth of the bay.

Passage of anadromous fish	....	X	....	X	....	X	....	X
Recreation[3]	X	X	X	X	?	X	X	X
Navigation	X	X	X	X	X	X	X	X
Maintenance and propagation of shellfish	....	......	....	......	....	......	....	......

X Denotes recognized use.

? Denotes marginal or questionable use.

[1] RM denotes river mile from the mouth of the bay.

[2] From RM 70.0 to 48.2.

[3] Recreation is defined in the Water Quality Standards as follows: The streams in Delaware are generally small, shallow and murky. Water contact recreation (swimming, water skiing, etc.) is therefore, quite limited. However, other recreation, such as picnicking, hiking, fishing, etc., is feasible. In order to ensure safe usage, all municipal, domestic and industrial waste discharges contributing coliforms to the stream will be controlled to the extent required.

ECOLOGY OF ESTUARIES

ECOLOGY OF ESTUARIES

INTRODUCTION

In terms of their physical and chemical features, estuaries are areas in which fresh water draining from the land meets and mixes with the salt water of the oceans. Many types of estuaries exist, for this mixing can occur in a variety of geologic settings including river mouths, deltas and channels, bays and coves, and sounds behind barrier islands and beaches. In each of these systems, the patterns of mixing and the estuarine water masses created are somewhat unique. Whatever the differences, however, all estuaries may be defined as mixing zones, and it is the peculiar set of characteristics of the estuarine water mass and of the mixing process itself which distinguish estuaries from the types of systems and water masses they separate.

It is in terms of their biological characteristics, however, that estuaries may be most importantly defined. They are centers of abundant biological activity. The plant communities which line the estuarine shores and the phytoplankton and attached algae communities which exist in the shallow estuarine waters, form one of the most productive of all natural plant associations. Large populations of planktonic and benthic invertebrates, forage and predatory fishes, shore and wading birds, waterfowl, and fur-bearing mammals are also present. For some organisms, such as the striped bass, alewife and blueback herring, the estuaries represent spawning grounds. For others, such as the menhaden, bluefish, weakfish and drum, estuaries serve as nursery areas where young feed and develop through early life stages. For still others, such as the mummichog and catfishes, clams, mussels and snails, and muskrats and marsh hens, estuaries serve as permanent habitat.

These organisms are attracted by the plentiful food resources available within estuaries, and the presence of the particular environmental conditions and physical habitats required for their survival. The vegetated marshes, the small creeks and guts, the intertidal flats and shore zones, and the shallow and deep water areas of the estuaries all are unique natural habitats.

As with the creation of the estuarine water mass, the creation and maintenance of the biological structure of the estuary proceeds through a series of complex interactions occurring among the organisms themselves, and the organisms and their environments. The complexities of these interactions are often obscured by the efficiency at which they proceed. What is evident, however, is the result of these interactions -- the creation of a biological storehouse matched by few other natural systems.

THE ESTUARINE ENVIRONMENT

The physical and chemical characteristics of the water mass direct both the types and distributions of organisms associated with estuaries, and the levels at which their interactions proceed. Most important in this regard are the salinity tolerances of organisms and the particular salinity conditions within an estuary. Salinity is a measure of the amount of dissolved salts contained within a sample of water (or soil). Fresh water contains very little amounts of salts while sea water contains relatively large amounts, on the order of 28-32 parts for every thousand parts of water (28-32°/₀₀). For a variety of reasons, special physiological and behavioral mechanisms are needed by organisms to contend with the presence of dissolved salts in their environments. Some organisms possess the mechanisms which allow them to exist only in highly saline environments while others possess those mechanisms that allow them to exist only in fresh water environments. Still others, known as euryhaline species, possess mechanisms which allow them to exist in environments of widely varying levels of salinity. Since these mechanisms function efficiently only under particular salinity conditions and, since the proper functioning of the mechanisms is crucial to the survival of the organisms, plants and animals will not be found in those environments unsuited to their salinity requirements.

While all environments exhibit particular salinity characteristics, the estuarine environment is unique. A wide variety of salinity conditions exists in an estuary at any one time. Near the fresh and salt water sources, the estuarine environment approaches those of essentially fresh and salt water systems. Much of the estuarine water mass, however, exhibits salinities intermediate between those of fresh and ocean areas. In a long estuary such as the Delaware, which extends approximately 135 miles a range of salinities from 1 to 25°/₀₀ usually exists within the body of the estuary at any one time. In smaller estuaries the range of salinities may be much less, but some variation would exist.

These variations reflect the different amounts of salt and fresh water, and the changing influences of river flow and tidal flow at each point of the estuary. In the Delaware estuary, the effect of tidal movement may be apparent to Trenton (river mile 133.4), but because of the distance of Trenton from the tidal source, little salt water is present in this portion of the estuary. Similarly, near the mouth of Delaware Bay, the influence of river flow and of fresh water are overshadowed by the affect of the tides and salt water intrusion. Salinities in this reach remain relatively high. At intermediate points within the estuary such as Reedy Point, Delaware (river mile 58), and Bombay Hook, Delaware (river mile 40), mean water salinities are approximately 10°/₀₀ and 20°/₀₀, respectively.

Estuaries are also unique in that the salinity distributions are not static. On a daily basis, the ebb and flow of the tides result in constant changes in the proportions of salt and fresh water in the estuary and, hence, in constant changes in the salinity at all points within reach of the tides. In addition to the daily tidal changes, there are also weekly, monthly, seasonal and yearly tidal cycle variations. These variations are a result of changes in patterns of river discharge, precipitation and evaporation, wind, and air and water temperature. The constant change of all of these salinity determining factors results in dynamic and complex estuarine salinity distributions.

While salinity is the most obvious, and probably most important factor exhibiting such patterns, the changes in tidal and river flow, and in wind and weather, also result in complex distributions of other water quality parameters. Water depths, temperatures, sediment concentrations, dissolved oxygen levels, and nutrient concentrations also vary spatially and temporally.

It is under these dynamic and varied conditions that the biological structure of the estuary develops. The survival and distributions of sessile and attached forms, and free floating and mobile forms are directly dependent on the distributions and cycles of these water quality parameters as an example. The restriction of clearnose skate to the lower estuary during the warmer months, and of white catfish to the upper estuary, the presence of the salt marsh cordgrass in the higher salinity intertidal zones and of wild rice in the fresh water wetlands, and the movements of American eels, shad, menhaden, blue crabs and others into and out of the estuaries are all reflections of the effects that constant changes in salinity and in other water quality parameters have on the growth, survival and reproduction of estuarine organisms.

While such changes are experienced to some extent by all estuarine organisms, it is the sessile or attached forms which are most directly affected by the dynamic estuarine environment. Over the course of a single 12 hour tidal cycle, a mussel living along the estuarine shoreline may experience several hours of complete inundation in low, moderate and high salinity water as well as several hours of complete exposure to the air. As a result, it may experience changes in ambient temperature of 25-30°F, in dissolved oxygen levels of 5 or 6 mg/l and in light conditions from full sunlight to near darkness. Other parameters such as sediment and food concentrations, and the presence or absence of predators may also change drastically from hour to hour. Further, since high and low tides occur at different times each day, the mussel has to constantly contend with differences which exist between its diurnal cycles, based on patterns of the sun, and the changing tidal cycles. Many organisms are eliminated from permanent habitation within the estuary because they cannot adjust to the constantly changing conditions. For even the occasional estuarine inhabitant, the dynamic nature of the estuary has a major influence on the patterns of its existence.

ESTUARINE FOOD WEBS AND PRODUCTIVITY

The dynamic nature of estuaries makes them highly productive. All estuarine organisms are united by complex feeding chains and webs, or productivity cycles. Certain aspects of these cycles are depicted in Figures 6 and 7. The functioning of these productivity cycles is maximized as contact among the organisms involved is maximized. The constant movement of water between the various areas these organisms inhabit assures that such contact will occur. While feeding relationships and production cycles similar to those described here occur in all natural systems, it is in the estuaries, that due to the constantly moving water, such cycles operate so productively.

At the base of the estuarine food webs are the primary producers -- green plants which, in the presence of sunlight, use water, carbon dioxide and certain nutrients to produce organic compounds. Primary producers in estuaries can be separated into two major groups, emergent macrophytes -- or large grasses and broad leaf plants, and algae -- smaller rootless plants some of which, the phytoplankton, are free-floating and microscopic in size. The macrophytes are restricted to the intertidal marshes and shallow water areas. The algae may be found attached to the surfaces of marshes and intertidal mud flats, or floating in shallow water zones and in the surface layers of deep water areas. The distribution of all macrophytes and algae in aquatic systems is restricted by the depth of the photic zone, that portion of the water column through which light penetrates. Depending on water clarity, this depth can vary from a few feet in some systems to several tens of feet in other systems (Odum, 1971). In estuaries, the high sediment loads and concentrations of planktonic organisms generally restrict the photic zone to a depth of ten feet or less. This situation is characteristic of much of the Delaware Estuary (Acherman and Sawyer, 1972).

As with other estuarine organisms, the location of the macrophytes and, to some extent, algae vary throughout the estuarine system in response to water and soil salinities. In the Delaware Estuary, emergent vegetation characteristic of

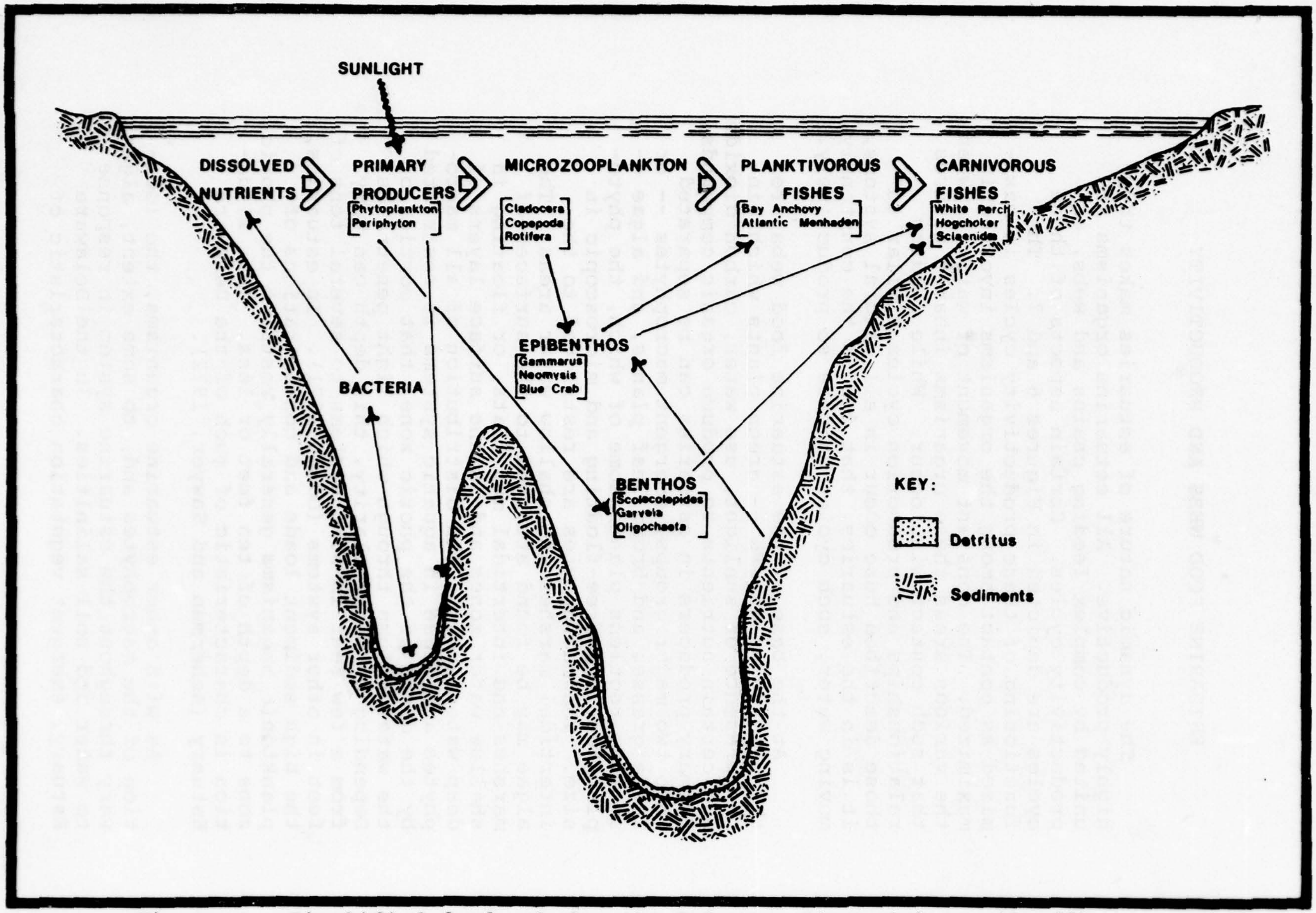

Figure 6. Simplified food web for the Delaware River (river mile 63).

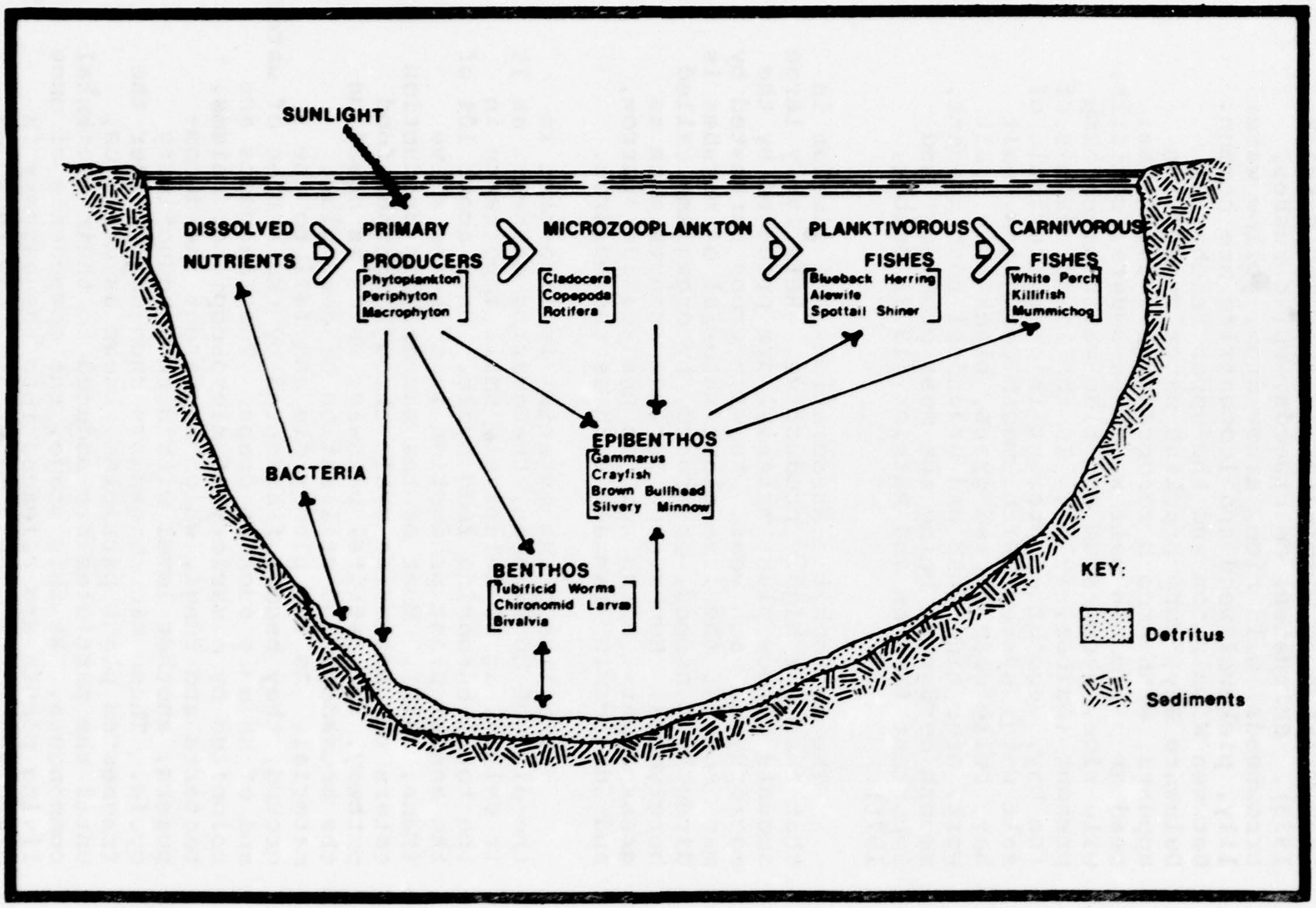

Figure 7. Simplified food web for the Delaware River (river mile 126).

freshwater marsh systems is present in the area from Trenton to Wilmington (Walton and Patrick, 1973). Bulrushes, smartweeds, spike rushes, arrowheads, wild rice, arrow arum, yellow water lily, pickerel weed and loosestrife are common. Between Wilmington and the upper reaches of Delaware Bay, more brackish water vegetation appears, with smooth cordgrass, big cordgrass, reed grass, marsh mallow, three-square, cattails, wild rice, arrow-arum and tide-marsh water hemp present (Daiber, 1976). In the lower reaches of the bay, vegetation present is characteristic of salt water systems with smooth cordgrass, salt hay, spike grass, reed grass, black rush, salt wort, high tide bush and groundsel bush present, smooth cordgrass being the most prominent and important (Walton and Patrick, 1973; Daiber, 1976).

The macrophytic associations are similar in that they are highly productive. Relatively large amounts of new plant material are produced by the macrophytes each year. As with crops harvested by man, some of the live plant material of marshes is directly consumed, or grazed, by organisms called herbivores. Herbivores include insects such as grasshoppers, birds such as the seaside sparrow, and fur-bearing mammals such as the muskrat.

While live plant material is important in the diet of herbivores, the grazing pathway, as it is called, is of relatively small importance in the total estuarine food cycle. Only about 10% of the annual plant production is consumed alive (Mann, 1972). Most of the macrophytic production enters the estuarine cycle through another food pathway, the detrital pathway, which is based on the breakdown and utilization of dead plant material. As the plants die and fall to the ground, they become fragmented by the action of water and of animals such as crabs. The fragments are colonized by a variety of microscopic organisms, bacteria and fungi, which represent the decomposers, another level within the productivity cycle. These microorganisms chemically alter the fragmented plant particles, known as detritus, until the particles are reduced to their elemental components. At this stage, the components of once living plants are released into the estuary in dissolved form. These materials, now known as dissolved nutrients, can be utilized by both larger macrophytes and smaller phytoplankton and algae for their own growth. In the case of phytoplankton, the nutrients are absorbed directly from the water. In the case of the macrophytes, the nutrients are first cycled through the marsh soil system, each tidal inundation of the marshes carrying dissolved nutrients to the marsh surface. Return of nutrients to the marsh completes one phase of the cycle.

If the detrital pathway involved only macrophytes, bacteria and algae, it would be of relatively little value to the estuary. Detritus, however, is also directly consumed by a host of animals, known as detritivores. Within the detritivore group are members of the zooplankton, small free swimming invertebrate animals, including the larvae, or immature stages, of other larger invertebrates; ichthyoplankton, the larvae of estuarine fishes; epibenthos, mobile invertebrates such as the opossum shrimp and blue crab that spend much of their time on the estuary bottom but which also move up into the water column; benthos, primarily sessile invertebrate organisms, such as clams and worms, which live in or on the estuary bottom; and planktivorous or filter feeding fishes. Some of the detritivores utilize the entire detritus-bacteria particle. Others simply strip off the bacterial colonies and return the particle, through their feces, to the estuary. Here the particle will be recolonized by more bacteria and reingested by some other detritivore. This ingestion, ejection and recolonization process continues until the detritus particle has been broken down to its elemental components, or until the particle is removed from the system, as through incorporation into bottom sediments.

Many of the organisms which injest detritus also ingest phytoplankton. As stated previously, phytoplankters are also important estuarine primary producers, and represent an essential source of food for many organisms. While some of the phytoplankton is cycled through the detrital pathway, much of the phytoplankton crop is consumed while alive. Important phytoplankton grazers include zooplankton, clams and oysters, larval and juvenile stages of most estuarine fishes, and adults of some fish species such as menhaden. Technically, these organisms act as herbivores while grazing on the phytoplankton crop, but since the ingestion of detritus and algae probably occurs simultaneously, the distinction is somewhat artificial.

The filter feeding detritivore-herbivore group is one of the most important in the estuary. It is the link between the primary producers and higher level animals such as birds and game fishes. The smaller zooplankton and fish larvae, which are the major consumers of detritus and algae, are fed upon by larger planktivorous fishes. These are, in turn, food of the important game fishes such as bluefish, weakfish, flounders, striped bass and drums. Other carnivorous fishes such as the hogchoker prey heavily upon benthic and epibenthic invertebrates. These carnivores roam the estuary and oceans until falling prey to other predators, including man, or until they die. Like plant detritus, they are broken down by decomposers and detritivores.

Other important organisms tied into the estuarine food web are the shorebirds, waterfowl, terrestrial mammals and amphibians. As with many of the filter feeding organisms, these animals consume a variety of food items and, hence, interact in the food web on a variety of levels. Shorebirds, such as herons, gulls, sandpipers, rails, terns and ospreys, and waterfowl such as mallards, teals, scaups, scoters, and black, canvasback and ruddy ducks, often forage in the shallows and marshes of estuaries for small fishes, snails, crabs, plant roots and seeds. Turtles and snakes, similarly, feed on a variety of organisms as do muskrats, shrews, voles, foxes, raccoons, weasels, otters, mink, and deer. All of these organisms are also prey for a variety of predators, including man.

The productivity or trophic cycle is much more intricate than can be described here. The characteristics of the detrital cycle, for example, have only been touched upon and much needs to be said about the sources of detritus, the rates of detritus production, decomposition, sedimentation and physical transport of detritus (Saunders, 1972). Similarly, much needs to be said about the additional interactions of estuarine organisms within other environments. Some estuarine organisms and nutrients are always leaving the estuary to interact in other systems, or are removed to be utilized by man. Their loss may or may not be compensated for by organisms and nutrients entering the estuary from other systems. In most of these cases the intricacies of estuarine cycles have not been unraveled and remain poorly understood.

Enough facets of the food cycles are understood, however, to indicate that disruptions at any level may have far reaching consequences on the entire system. Eliminating marsh and shallow water areas, for example, would eliminate many primary producers. This would reduce the amount of principal food sources available in the estuary. Similarly, increasing sediment loads within the system by mismanagement of adjacent upland areas, may seriously hinder the filtering efficiency of filter feeding organisms, and eliminate the link between primary producers and higher level consumers. Subtle changes in the chemistry of the water, as by additions of industrial waste chemicals to the estuary, may directly threaten the existence of very visible estuarine organisms such as fish, crabs, and birds, as well as of more obscure organisms such as the bacterial decomposers. In either case, the effects on the total estuarine system would be far reaching.

IMPORTANCE OF SHALLOWS

As indicated in the previous discussions, the ecological cycles occurring in estuaries involve a wide variety of organisms interacting within several different estuarine habitats. While important interactions occur within each of these habitats, it is within the shallow water areas that many of the critical interactions occur and in which much of the biological activity is concentrated.

Even as isolated environments, shallow water areas are often more productive than deeper waters (Brung, 1976). One reason for this difference is that shallow waters often have higher dissolved oxygen levels. Much oxygen enters water by diffusion from the atmosphere, a passive process which can be accelerated by constant mixing of a water mass. While not necessarily high energy environments, the force of the tides, river flow, wind and waves on the relatively small water mass of the shallows generally supplies sufficient energy to keep the entire water mass in motion. Subsurface water layers are constantly being brought to the surface and exposed to the atmosphere. Further, the water mass is continually being moved against shorelines, exposed flats and other obstructions common in the shore zone. The result of this water movement is that contact between the water mass and the air is maximized. This results in the distribution of relatively high dissolved oxygen levels throughout the water column.

In contrast, the forces acting upon the water masses of deep water areas are often not sufficient to bring underlying waters to the surface. Further, there are few obstructions adjacent to deep water areas to intensify the mixing process. A smaller proportion of the deep water mass is regularly exposed to the atmosphere. Whereas the oxygen utilized by organisms in the shallows is often readily replaced, that utilized by organisms in deep water zones often is not. Subsurface zones of these areas are commonly anoxic, without oxygen, and unsuitable for use by oxygen dependent estuarine organisms.

Another factor influencing the maintenance of higher oxygen levels within shallows is the higher proportion of green plants in or adjacent to shallow zones. Oxygen is a by-product of the photosynthetic activities of all green plants including the phytoplankton, periphyton and macrophytes. As shown in Figure 8, the distribution of these plants, due to their particular growth habits and need for light, is skewed towards shallows. While phytoplankton exist in both shallow water and deep water areas, the periphyton and rooted macrophytes are found only within the shallows and adjacent intertidal areas. The potential for plant produced oxygen is greater in the shallows, further contributing to the maintenance of more suitable oxygen conditions in shallow water areas.

Besides benefiting from the oxygen production of rooted macrophytes and algae, shallows are the direct recipients of organic materials produced by these groups. The large amounts of live and dead plant materials moving into or through shallows attract detritivores and herbivores which, in turn, attract secondary and tertiary level consumers. The eggs, larvae, juveniles and adults of hundreds of species of zooplankton, benthic and epibenthic invertebrates, planktivorous and carnivorous fishes, and birds and mammals have been found within the shallow water zones of the study area. They are present in these areas in large part because of the availability of food.

In addition to being attracted by favorable food and oxygen conditions, organisms are also attracted by the variety of specific habitat types present in shallow water and shore zones. Due to the location of the shallows adjacent to different sediment sources, the bottoms of shallow water zones can be composed of substances varying from large stones and pebbles to fine and coarse grained sands to very fine grained silts and muds. Conversely, deep water areas often have homogeneous bottom types composed mainly of the finer grained, lighter particles. Since the distribution and survival of benthic organisms are largely dependent on bottom type, greater variation within shallows promotes their colonization by a wider variety of benthic organisms than does the homogeneity of deeper areas.

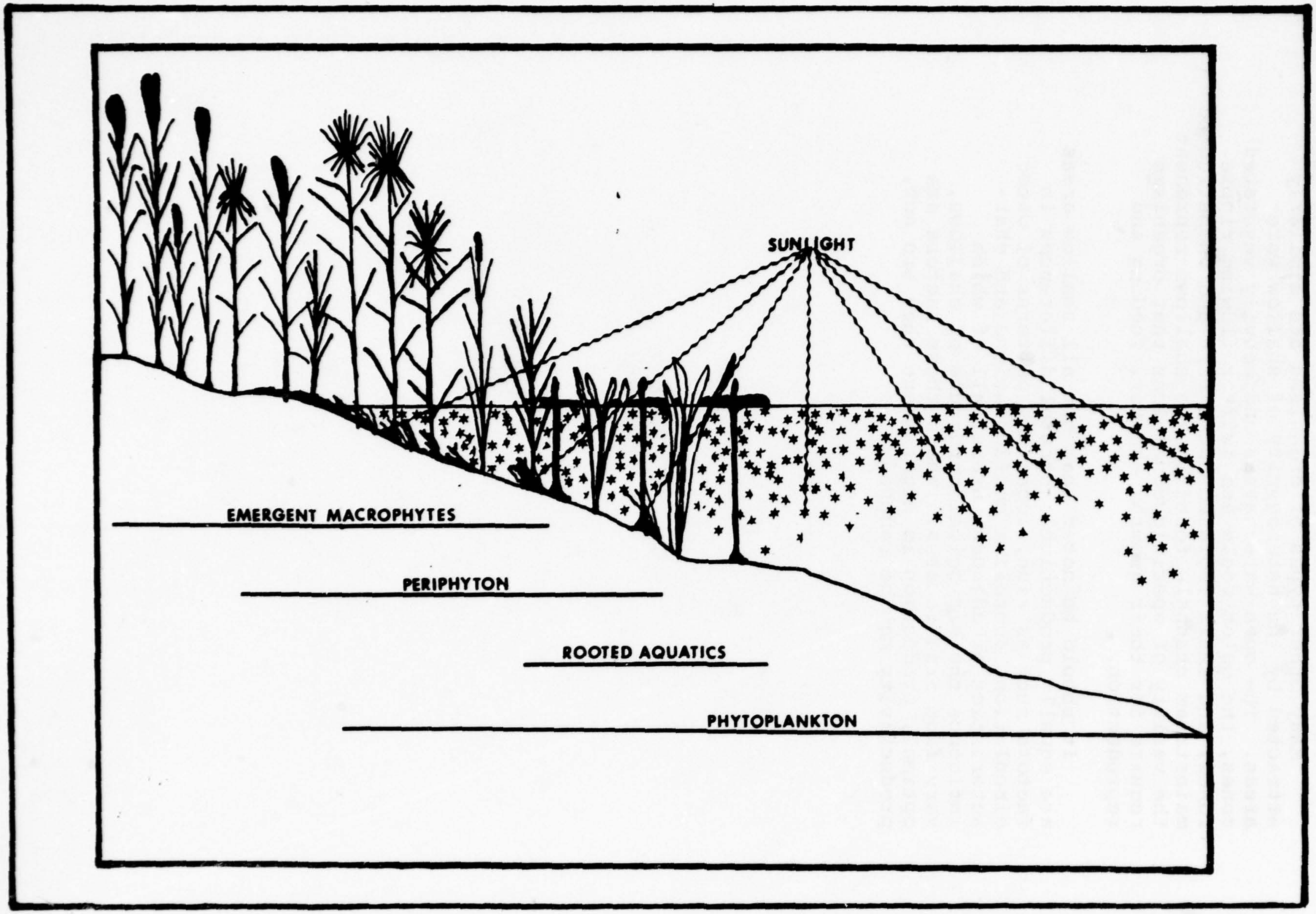

Figure 8. Distribution of primary producers in the Delaware River in relation to water depth and light penetration.

Many other types of organisms are similarly attracted by the heterogenity of shallow water areas. The open water areas and heavily vegetated zones, the quiet pools and swifter flowing ripple zones, and small isolated backwaters and unobstructed mainstream channels found in the shallows represent the variety of specific conditions that organisms require for their growth, shelter, feeding and reproduction.

It should be noted that not all shallow areas are equally productive. Natural differences in factors such as size, location, patterns of water circulation, shoreline configurations and characteristics of adjacent areas, all of which influence the biological structure of shallows, vary from area to area. Where these factors are optimal, production is high; where they are not, productivity may be reduced.

HABITAT EVALUATION

HABITAT EVALUATION

INTRODUCTION

The estuary and the shallows are, and will continue to be, involved in a variety of functions that are important in maintaining the economic and societal structure of this region. Although these uses do lower the ecological quality of the system, they are likely to continue, subject to regulation. The problem facing regulatory agencies and river basin planners is one of satisfying demands made of the system during river development while maintaining the basin's natural processes.

Inherent in such an approach is the realization that some part of the resource will be lost or highly modified. How much will depend on a variety of factors, not the least important of which is how well that development is planned. Much of the potential ecological damage could be reduced if conflicts of river development and ecological maintenance are minimized. One way in which this could be accomplished is by restricting development to those areas which are not less ecologically significant. Shallows of special importance could then be saved.

This approach is a logical one. Most resource bases are heterogeneous. Its success, however, depends on the ability to identify these ecologically critical areas. This has not been done for the shallow water areas of the Delaware estuary. The remainder of this study will concern itself with the identification and evaluation of the different shallow water zones within the study area.

The process of evaluating the biological value of shallow water areas involves analyzing habitat quality through the application of criteria to data available on individual areas. The criteria deal with the biological, physical, water quality and land use characteristics of the shallows. They are designed to reveal the role played by each area in maintaining the ecological processes occurring within the Delaware Estuary.

The larger the role, the higher the value given to the area. In developing the criteria, several factors have been considered. These included the types of habitat evaluations used elsewhere, the characteristics of the study area, and the data presently available on it., Before presenting the criteria and examples of their application, discussion of each factor is necessary.

THE U.S. ARMY CORPS OF ENGINEERS
PERMIT PROGRAM

The U.S. Army Corps of Engineers has been given the responsibility of administering several Federal laws which regulate certain activities occurring in specified fresh and salt waters of the United States. The principle laws administered include the River and Harbor Act of 1899, section 404 of the Federal Water Pollution Control Act Amendments of 1972 and section 103 of the Marine Protection, Research and Sanctuaries Act of 1972. These laws stipulate that anyone wishing to undertake a project involving work in or modification to any portion of the waters of the United States and their associated wetlands, must first obtain a permit from the U.S. Army Corps of Engineers. Those projects for which permits are not granted cannot legally be undertaken.

The decision to issue or deny a permit is founded on the effect the proposed project will have on the public interest. Projects for which it appears that the probable benefits to the public will outweight the probable detriments will be granted permits, while those for which the opposite is determined, will not. In assessing the probable benefits and detriments, Corps personnel are required to consider many factors, not the least of which is the effect of the project on the environmental quality of the waterway involved. More specifically, this would include the project's affects on the flora, fauna, physical structure and water quality of the system. As maintenance of the highest possible environmental quality is considered a benefit to the public, projects which will seriously degrade this quality will usually not be allowed.

In order to assess the probable affects of a project on the environmental quality of an area, the area's existing quality must first be determined. This involves describing and evaluating its physical, biological and water quality characteristics as fully as possible within the time that can be alloted to each permit requested. This volume was created to facilitate the permit application review process for proposals within the Delaware River from Reedy Point, Delaware, to Trenton, New Jersey.

ENVIRONMENTAL INDICES

One manner in which habitat evaluations can be made is through the use of numerical indices. Such indices are quantitative descriptions of habitat characteristics, the values of which are used as indications of relative habitat quality. There have been numerous habitat evaluation indices developed throughout this century (Oglesby, 1965). Most of these indices have arisen from the desire to measure the effects of pollutants on the quality of natural areas. The basic assumption used in each is that artificial disturbances of a system lead to a lowering of habitat quality.

Evaluation indices can be divided into two major types depending on the kinds of parameters measured (Cook, 1976). There are those which measure the physical and chemical characteristics of the environment and those which measure the biological characteristics. The first category includes water quality evaluations of organizations like the U.S. Environmental Protection Agency and the Delaware River Basin Commission. These indices deal with water constituents that have been determined to affect water use. Certain concentrations of cadmium, for example, are known to reduce the survival rate of catfish (Eaton, 1974a), bluegill (Eaton, 1974b) and grass shrimp (Eisler, 1971). Waters with levels of cadmium exceeding known toxic levels for these organisms are considered to provide unsuitable habitat for these species. Similar kinds of relationships have been determined to exist between other water quality parameters listed in the EPA and DRBC guidelines, and other organisms or water uses.

The second category includes a large number of studies dealing with the organisms themselves. Most organisms are affected in some way by presence of pollutants in their habitats. They may, then, be indicators of the kinds or levels of pollutants present in a particular area. The studies and indices of Fisher et al. (1943), Beck (1955), Pearson (1959), Burlington (1960), Butler (1965), Cairns et al. (1968), Wilham (1970), Chandler (1970) and Cook (1976) on benthic and planktonic invertebrates; of Patrick et al. (1954), Patrick and Strawbridge (1963), Patrick et al. (1963),

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Stein and Dennison (1967) and Copeland (1967) on phytoplankton; and of Beak (1954), Gray (1954), Allen (1960) and Stein et al. (1963) on fish, all represent important attempts to evaluate habitat quality by examining the biological structure of particular systems.

While most environmental indices developed from these studies have met with some success, there are problems inherent in each that deserve mention. In the case of direct measurement of the physical and chemical environment, the most obvious problem is that these conditions are not static. Changes within a water mass occur constantly. It is difficult to relate any one set of measurements to general habitat conditions. A case in point would be a situation in which an industrial waste is discharged into an estuary on a discontinuous basis. Water quality monitoring at times of zero discharge would indicate no pollution problem. Examining the benthic invertebrates, however, might indicate that a serious problem does indeed exist . These organisms reflect the effects of many individual waste discharges, and while non-detectable levels of pollutants were found during the water quality monitoring, the existence of debilated organisms would indicate a seriously polluted environment.

Other problems involving the use of physical and chemical data deal with the difficulties inherent in setting meaningful water quality standards. There are innumerable parameters which are known to affect habitat use by organisms, including man. As shown in the Appendix, the Environmental Protection Agency lists 21 parameters which have been shown to directly affect the well being of many species. Each of these parameters, and many others, are included as part of water quality programs.

A problem arises in that the parameters do not each affect all organisms, or even all life stages of any one species, in the same manner. Nor do they act independently of each other. For example, oxygen levels which are not suitable for bluefish will support healthy populations of mummichogs, while copper levels which are toxic to fish larvae may not be toxic to adult members of the same species (EPA, 1976). The toxicity of copper has been shown to be directly dependent on water pH, alkalinity and organic matter concentrations. Similar relationships exist between various groups of all of these parameters. Finally, there are both the lethal and sub-lethal affects of these parameters to consider. Whereas constant exposure to 1000 µg/l of lead will kill an oyster in several days, exposure of only 100 µg/l will lead to morphological and physiological changes within the oyster but not death (Calabrese, 1973; Pringle, 1968).

Water quality monitoring does not always indicate true environmental conditions, does not cover all possible complications, nor provide equal protection for all life forms. Both the setting of standards and their interpretation involve numerous compromises, many of which may seriously affect the suitability of water quality based habitat evaluation. These problems may be compounded in situations, such as the present one dealing with shallows, in which only moderate water quality monitoring has been undertaken. While some parameters such as dissolved oxygen and temperature are routinely and widely measured, others, such as the concentrations of heavy metals, are not. Even though temperature and dissolved oxygen may be the principal factors determining habitat value, other parameters also affect that value. The lack of data on them decreases the accuracy of the evaluations. Physiochemical data indicate some features of environmental quality and have been used effectively in many situations. As the optimal evaluation criteria, however, they leave much to be desired.

It is partially in response to these problems that biological indices were developed. While water quality data relate to discrete times or parameters, organisms reflect the sum total of all factors acting upon them during their lives, even those factors which scientists cannot measure. More so than any other parameter, the organisms present in an area are indicators of the quality of the habitat.

Serious problems, however, arise with the use of biological data. Most problems deal with the inability to accurately study and understand biological communities. They are extremely complex structures which, like the estuarine water mass, change both temporally and spatially throughout the system. Voluminous amounts of data are needed to accurately describe both the organisms and their communities, all of which takes considerable time, effort and planning. In most cases, none of these three requirements are met adequately, and scientists must draw conclusions about most biological communities from analysis of insufficient data.

In spite of these problems, a variety of biological indices have been developed based primarily on the concepts of indicator organisms and species diversity. In the first case, it is felt that the mere presence or absence of certain species can be viewed as a reflection of habitat condition. At the most basic level, these indices center around the presence or absence of only one species. More refined attempts using the indicator concept, such as those of Beck (1955) and Chandler (1970) involve analyzing the presence or absence of many species with known levels of pollution tolerance. Each of these species is given a value according to its tolerance, and a general community value created by adding all the values of each individual species collected in a sample. This score can then be matched against standard scores which have previously been determined to be indicative of certain pollution levels.

These types of indices have worked well, particularly in stream communities. Their use, however, is restricted to those systems for which the relationship between the indicator organisms and pollution levels has been previous investigated. Further, a specific index can be used only for those systems very similar to the one for which it was developed. This precludes use of many successful indices for the present situation.

In the second case, the important factor is not which organisms are present but how many different types and in what numbers. Health, or stability, of natural systems is thought generally to be reflected by the number of species present in a habitat, known as its diversity, and in the even distribution of numbers of individuals among these species. A test environment, for example, may have fifty species of organisms present, none of which is represented by more than 25 individuals nor less than 10. If this environment were to be disturbed, however, it may be found that only 20 species remain with one or two of these having hundreds of individuals and the rest few. The species intolerant of the disturbance have disappeared, and those tolerant species have increased their numbers drastically due to reduced competition. The diversity of the system has been reduced, and dominance established by a very few species. These changes would be interpreted as reflective of a lowering of habitat quality.

Several mathematical formulae have been developed to analyze aspects of the diversity and dominance phenomena, and these formulae are applicable to a wide range of systems. They have proven useful in phytoplankton communities of the oceans as well as with benthic invertebrates in stream systems. As with the presence/absence system, however, these are relative indices that need reference values to indicate specific habitat conditions. There is generally no single diversity value which indicates a stable system. Such values must be identified for each situation and perturbations then substantiated by noting deviations from the norm.

While some success has been achieved using biological indices, the fact that many exist demonstrates that biological indexing is not an exact technique. Each index uncovers only certain facets of the habitat and requires that particular types of data be collected and analyzed in certain manners. Depending on the habitat, study objectives, resources available and ecological premises under which the researchers are working, only certain types of indices are useful. All, however, have been shown to provide valid indications of habitat quality when they are employed in the proper situation.

Although all biological and physio-chemical indices differ in the specific types of data they require, most are similar in that they involve quantitative analyses of data. Habitat evaluations can also be based on predominantly qualitative data treatments. Such treatments are useful because the types of data involved are relatively easily gathered. Where a quantitative evaluation of a marsh area, for example, may involve measuring the productivities of the emergent macrophytes, a qualitative description of the area may involve determining through simple observation only whether it is densely or sparsely vegetated. Such a determination requires the creation of an a priori standard of vegetative abundance. Once such a standard is developed, however, qualitative evaluations are relatively easily accomplished.

While they are easily accomplished, evaluations based on qualitative data are only moderately useful. Since the data involved are not detailed, the evaluations produced are somewhat superficial. Although evaluations may uncover the gross habitat characteristics, they do not generally identify more subtle ones. Such identification emerges through the analyses of more quantitative data.

DATA SUMMARIES

The present study involved no field work. Only data generated in previous studies are available for manipulation. These data are presented in detail in a following section and in several appendices appearing at the end of the text. Brief discussion of them is necessary here, however, since the characteristics of the data partially direct the development of a shallows evaluation program.

Water Quality

Available water quality data are sufficient to indicate trends occurring in the major parameters of dissolved oxygen, temperature, oxygen demand, salinity, pH and possibly fecal coliform level. These data are site specific enough to only allow separation of shallows into large areas of similar condition. They can, however, be used as important criteria in the initial separation and evaluation of areas. Similar data are available on other water quality parameters. While trends are evident they have not been as fully substantiated as have trends in the above major parameters. These data should be used with caution and only as secondary indications of habitat quality. In both major and minor parameters it should be remembered that all water quality data relate to fairly discrete times from which extrapolation may be tenuous.

Land Use and Impacts

Data are available on the locations of major impacts and point dischargers in the study area, and whether or not the shoreline has been modified. The presence or absence of industrial or municipal facilities, the number of each, and the degree of shoreline modifications may be useful in determining habitat quality, if only circumstantially.

Biological Data

Most data available deal with the biological structure of the study area. Phytoplankton, zooplankton, ichthyoplankton, benthics, fish, birds and mammals have all been sampled within the study area at some points or at some times. These data represent the greatest potential source for creation of a site specific evaluation program. The success of this program, however, is limited by characteristics of this data and problems inherent in the use of biological data.

Of primary importance is the fact that no group of organisms has been investigated within every reach of the study area. The fishes have been fairly widely studied, but as shown in Table 3, these have not been sampled at all points. There is no species or group, therefore, upon which all habitat evaluations can be based. One reason for this pattern is that many of the biological studies have been undertaken only to document effects of specific point source discharges on the system. Much sampling has been done at power plant locations such as Artificial Island, Eddystone and Salem or near locations of similar existing or proposed installations. This pattern is especially true in the case of planktonic and benthic organisms which, unlike fish, have not generated much research interest in the study area outside the context of impact analysis.

The lack of sufficient data on benthic invertebrates and planktonic organisms is especially important. Some of the planktonic forms, such as fish eggs and larvae, are particularly sensitive to environmental conditions. More complete data on them would be valuable in developing habitat criteria. Benthic invertebrates, while not particularly sensitive, are generally sessile organisms that cannot escape periods of adverse environmental conditions. The type of benthic community present is often more indicative of conditions existing within the habitat than are those of mobile organisms. For this reason, many of the most successful biological indices result from examination of benthic communities. The lack of large amounts of benthic data within the study area precludes use of such an index at this time.

Table 3.

The availability of data on the biota of various sections of the study area. (X denotes existing data; - indicates no data available.)

River Miles	Phyto-plankton	Zoo-plankton	Ichthyo-plankton	Benthos	Fish	Macro-phytes	Birds	Mammals
55-59	-	-	-	-	-	-	-	-
60-64	-	-	X	-	X	-	X	-
65-69	-	-	-	-	-	-	-	-
70-74	X	X	X	X	X	-	-	-
75-79	-	-	-	-	-	-	-	-
80-84	X	X	X	X	X	-	X	-
85-89	-	-	-	-	X	-	X	X
90-94	-	-	-	-	-	-	-	-
95-99	-	X	X	-	X	-	-	-
100-104	-	X	X	-	X	-	-	-
105-109	-	-	-	-	-	-	-	-
110-114	-	-	-	-	X	-	-	-
115-119	X	X	X	X	X	X	-	-
120-124	-	X	X	X	X	X	-	-
125-129	X	X	X	X	X	X	X	X
130-134	-	-	X	X	X	-	-	X

Equally important to consider when analyzing the data is that they have been extracted from many different studies, the specifics of which vary greatly. The data were collected for different purposes, by different techniques and personnel, and in different seasons and years. Each of these variables can significantly affect the data's value when viewed collectively. Use of seines in shallow areas to sample fish, for example, does not sample the same population as do nets trawled from a boat or screens placed on the intake pipes of power generating stations. Data generated in these manners are not directly comparable. Collection problems are intensified by the fact that given one particular technique, variations occur in the efficiency with which that technique is applied. Variations in data of different studies reflect both true variation in the population as well as sampling variation arising from the use of different techniques or of different sampling efficiency.

The collection of data at different times of the day, and in different seasons and years, has a major impact on the ability to interpret data or to evaluate various habitats. Populations of all organisms exhibit distinct daily, seasonal and yearly cycles. Data gathered in any one study reflect not only the effects of specific habitat conditions on the population but also the effects of these various cycles. The degree of influence of both the cycles and habitat parameters must be determined before any definitive statements can be made about comparative habitat quality.

Such separations are not easily done. Some cycles, such as the vertical migration of zooplankton through the water column, or the movement of fish into and out of the estuary in relation to changing water temperature, have been studied and are somewhat predictable. Effects of these cycles can often by compensated for when comparing data concerning different habitats or time periods. Other cycles, however, such as the fluctuations which occur in the breeding and reproductive success of fish, are little understood and far from predictable. The effects of these cycles on population abundances cannot generally be quantified. A particular habitat exhibiting low fish populations one year may appear of much lower quality than a similar habitat exhibiting high populations in another. The ecological qualities of the two habitats may, however, be similar.

STUDY AREA CHARACTERISTICS

The primary characteristics of the study area which affect both the development and use of the evaluation criteria are its physical heterogeneity and its generally sub-optimal water quality. Variations exist in the quantity and types of wetlands associated with shallow water areas, the amounts of shoreline modification, the composition of the bottom sediments, and the sizes of the shallows, among others. Each of the shallow water areas is, therefore, somewhat different from all others within the study area. Such differences are important because they affect the degree to which each area may be utilized by common basin species.

Since the physical characteristics of the shallows vary throughout the study area, it can be suspected that biological potentials also vary greatly. Any habitat, however, may support fewer organisms than its biological potential would indicate. This situation appears to occur frequently within the upper Delaware Estuary. While most sections of the study area are utilized by a variety of organisms, the data indicate that all sections were utilized more intensely in the past and could be utilized more intensely in the future. This contention is based on the fact that sub-optimal water quality exists within most of the study area. Much of the problem arises from the large amounts of organic material that are discharged into the estuary. This organic load results in the creation and maintenance of low dissolved oxygen levels in a large portion of the study area. These oxygen conditions have been linked to the declining use of the upper estuary by fish such as shad (Sykes and Lehman, 1957; Chittenden and Westman, 1967; Chittenden, 1969; Miller, et al., 1971, 1972) and the striped bass (Raney, 1952; Chittenden, 1971). These problems, and others, can be suspected of affecting the use of the study area by many other species.

This factor becomes important in habitat evaluations when it is realized that major efforts are underway to improve the water quality of the entire Delaware Basin. If these efforts are successful, it is assumed that the use of most river sections by common basin species would increase. How large the increase would be depends on the potential each area has to support estuarine and riverine organisms. While increases may be noted in all areas after basin improvement, many areas would exhibit greater increases due to their greater productivity potentials. Areas which now support few organisms may conceiveably support large populations following improvement.

Given that water quality improvement may occur, there is a need to evaluate shallows not only in terms of their present status but also in terms of their potential values to estuarine organisms. Present values can be evaluated primarily from biological data, while evaluation of potential values depends primarily on consideration of an area's physical characteristics. The inclusion of criteria on the physical and land use characteristics of the shallows as well as on the biological characteristics partially reflects the need to consider their actual, as well as potential importance.

EVALUATION CRITERIA

The discussions of the factors considered in developing the evaluation criteria can be summarized as follows. To facilitate the permit review process, the criteria should provide insight into the biological value of shallow water areas. Biological and non-biological numerical indices would serve this function. The data available on the study area are, however, insufficient to allow such indices to be used as the primary criteria throughout the study area. Additional criteria, therefore, must be used in the evaluations. Since the relationships of many of the additional habitat characteristics to habitat quality have not as yet been quantified, these additional criteria are primarily qualitative in nature. The choice of criteria has also been influenced by the need to consider not only the existing values of the shallows but the potential values given the possibility of improvements occurring in the water quality of the study area. These considerations have resulted in the creation of the criteria presented below.

BIOLOGICAL CHARACTERISTICS

Biological characteristics useful in habitat evaluations include trophic structure, species diversity and distribution, presence and absence of indicator groups, use as spawning and nursery grounds, use as a migratory route and use by endangered species.

1. Trophic structure. Of concern is the number of trophic levels represented by the organisms associated with each shallow water area. Trophic complexity is considered indicative of ecosystem stability and health. The more complex the system, the more stable and healthy it is. The quality of shallow habitat increases as the number of trophic levels associated with the habitat increases.

2. Dominance and diversity. Given areas which are similar in their trophic level make-up, the diversity of species found within each and the distribution of numbers of organisms among those species can be used as an indication of habitat quality. As explained earlier, high species diversity and even distribution of numbers of individuals are considered indicative of healthy or high value habitats. As the habitat quality decreases, species diversity generally decreases and dominance by one or several species is often established.

There are numerous formulae which can be used to measure species diversity and evenness. The ones presently most useful are the following: S_T/N, $S_T-1/\text{Log } N$ and S_{10}/S_T where S_T = total number of species found, N = the total number of organisms found and S_{10} = the maximum number of species needed to include 10% of the total number of individuals sampled (Gleason, 1922; Margalef, 1958; Pearson, 1959). The first two are diversity indices, and the third a measure of distributional evenness. All other factors being equal, higher diversity values and lower dominance values reflect higher quality habitat.

While the above formulae permit easy calculation of species diversity and distribution, they have limitations. They have been shown, for example, to be sensitive to biological characteristics other than species richness and evenness. As such, values calculated with the formulae do not always reflect only the diversity and distribution phenomena. These formulae also cannot be used to compare different kinds of organism groups. Fish diversity of one area cannot be compared with benthic diversity of another. Relative habitat quality of areas in which only different groups have been sampled therefore cannot be determined. There are techniques which can be used to reduce some of these problems. They involve, however, much more complicated data manipulation than is presently justified. The formulae presented are much simpler to calculate and, for the effort involved, would give a good indication of relative diversity, dominance and habitat quality.

3. Indicator organisms. Dominance of the population by certain groups of species may be used as a relative indication of habitat quality. Some species in all organism groups are known to be tolerant of poor water quality, and others intolerant. Both kinds of organisms are generally present in a stable system so that the mere presence of pollution tolerant forms does not indicate a pollution problem. Dominance by such forms, however, is a reflection of poor quality.

Groups that may be of value include benthic organisms, fish and possibly phytoplankton. Benthic invertebrates such as tubifex worms (Tubificidae, particularly of the genus *Limnodrilus*), leeches (Hirudinae), fingernail clams (Sphaeriidae) and certain midge larvae (Chironomidae) are particularly tolerant of organically polluted conditions. Their dominance of any benthic community is a good indication of such a problem. Certain fish such as carp are known to be tolerant of waters with low oxygen and high organic levels. Other fish species such as the menhaden are much less tolerant. Thornton (1975) has rated the relative oxygen sensitivities of approximately 30 estuarine fishes common to the salt and brackish water portions of the Delaware Estuary. His analysis is summarized in Table 4. General requirements of other fishes can be found in a following section in which species common to the study area are described. With this type of information, a general understanding of the tolerance levels of various species to certain conditions can be generated. Dominance of the population by any of

Table 4. Grouping of selected estuarine and marine fishes according to physiological studies and studies on their resistance, tolerance and oxygen consumption. (Adapted from Thornton, 1975)

GROUP I*

Blueback herring (Alosa aestivalis)

Alewife (Alosa pseudoharengus)

Menhaden (Brevoortia tyrannus)

Silverside (Menidia menidia)

GROUP II**

Anchovy (Anchoa mitchilli)

Eel (Anguilla rostrata)

Weakfish (Cynoscion sp.)

Spot (Leiostomus xanthurus)

Croaker (Micropogon undulatus)

Striped bass or perch (Morone sp.)

GROUP III***

Sheepshead minnow (Cyprinodon variegatus)

Mummichog or killifish (Fundulus sp.)

Summer flounder (Paralichthys dentatus)

Hogchoker (Trinectes maculatus)

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*The active, migrating, streamline fishes of high oxygen consumption.

**The fishes of moderate activity, limited in daily travels and moderate consumers of oxygen.

***The sluggish species, more or less adapted for benthic existence and low consumers of oxygen.

the species tolerant of degraded water conditions can then be used as an indication of poor habitat quality.

Studies of phytoplankton indicate that this group may be useful in the present situation. Palmer (1963) has compiled a list of phytoplankton which are considered to be tolerant of primarily organically polluted areas. This list is presented in Tables 5 and 6. Patrick (1973) has similarly discussed such species. Situations in which these tolerant groups dominate the population may be indicative of poor water quality. Patrick et al. (1954), however, have cautioned against putting much emphasis on the presence or absence of phytoplankton indicators and feel that examination of the entire community structure is more important. They have shown that the graphic comparison of the number of species found in an area and the number of individuals per species is a better relative indicator of habitat conditions. Such a treatment involves much data manipulation which is beyond the scope of this report. The method does appear useful, however, for further analysis. Presently, the dominance of areas by phytoplankton known to be tolerant of poor conditions can be used as a relative indicator of habitat quality although only in support of other types of data.

4. Spawning and nursery areas. The existence of suitable spawning and nursery areas for estuarine and riverine fishes is critical to the maintenance of these species. Those areas which are used as spawning and nursery grounds are of more value than those areas which are not so used. The more an area is used in these capacities, the higher is its relative value.

5. Migratory route. Areas through which species migrate are extremely valuable habitat even if little used in any other capacity. Shallows which are located within a migratory route would, therefore, be considered of higher value than areas of similar characteristics which are not.

6. Use of area by endangered species. An area which supports any endangered species should be given special consideration (Endangered Species Act of 1973, PL 93-205). Most species are reduced to these critically low population levels because

Table 5.

Pollution tolerant genera of algae. (Adapted from Palmer, 1963)

Euglena	Arthrospira
Oscillatoria	Carteria
Chlamydomonas	Surirella
Scenedesmus	Cryptomonas
Chlorella	Agmenellum
Nitzschia	Lyngbya
Navicula	Eudorina
Stigeoclonium	Pediastrum
Phormidium	Oocystis
Synedra	Pyrobotrys
Phacus	Cymbella
Ankistrodesmus	Stephanodiscus
Gomphonema	Coelastrum
Spirogyra	Cladophora
Cyclotella	Golenkinia
Pandorina	Spondylomorum
Closterium	Achnanthes
Lepocinclis	Actinastrum
Melosira	Hantzschia
Chlorogonium	Spirulina
Anabaena	Pinnularia
Ulothrix	Stauroneis
Micratinium	Tribonema
Fragilaria	Cocconeis
Anacystis	Selenastrum
Trachelomonas	Cosmarium

Table 6.

Pollution tolerant species of algae. (Adapted from Palmer, 1963).

Euglena viridis	*Lepocinclis ovum*
Nitzschia palea	*Micractinium pusillum*
Stigeclonium tenue	*Eunorina elegans*
Oscillatoria tenuis	*Euglena deses*
Oscillatoria limosa	*Oscillatoria splendida*
Scenedesmus quadricauda	*Oscillatoria lauterbornii*
Chlorella vulgaris	*Euglena polymorpha*
Pandorina morum	*Lepocinclis texta*
Arthrospira jenneri	*Spondylomorum quaternarium*
Ankistrodesmus falcatus	*Actinastrum hantzchi*
Cyclotella meneghiniana	*Closterium acerosum*
Chlorella pyrenoidosa	*Anabaena constricta*
Gomphonema parvulum	*Anacystis montana*
Euglena gracilis	*Phacu pyrum*
Oscillatoria chalybea	*Scenedesmus obliquus*
Synedra ulna	*Cocconeis placentula*
Oscillatoria chlorina	*Achnanthes minutissima*
Nitzschia acicularis	*Coelastrum microporum*
Oscillatoria formosa	*Melosira varians*
Oscillatoria princeps	*Chlamydomonas reinhardi*
Oscillatoria putrida	*Pediastrum boryanum*
Euglena oxyuris	*Scenedesmus dimorphus*
Navicula cryptocephala	*Chlorogonium elongatum*
Phormidium uncinatum	*Euglena intermedia*
Agmenellum quadriduplicatum	*Euglena pisciformis*
Chlorogonium euchlorum	*Phacus pleuronectes*
Hantzchia amphioxys	*Tetraedron muticum*
Phormidium autumale	*Anacystis cyanea*
Surirella ovata	*Melosira granulata*
Euglena acus	*Phormidium foveolarum*

of habitat losses. Those habitats remaining need to be preserved if such species are to survive.

PHYSICAL CHARACTERISTICS

Physical characteristics useful in habitat evaluation include size, location, shoreline features and stability.

1. Size. In and of itself, size has no real effect on the quality of any habitat area. Small and large systems which exhibit equal productivity per unit area should be considered of equal habitat quality. They do, however, differ in their total contribution to the estuary, and in this respect larger areas are more important. All other factors being equal larger shallow zones should be considered of higher value than smaller ones.

2. Cross-channel location. The concern is whether or not a shallow area is immediately adjacent to emergent land. Occurrence of many chemical, physical and biological interactions depends on contact between water and intertidal flats, marshes, and river banks. Shallow zones where this contact is not possible, such as in completely submerged mid-channel shoals, would then be expected to be of less importance.

3. Shoreline features. Several features can be evaluated.

a. Streams and creeks. Since streams and creeks figure prominently in the activities of many estuarine species, shallows associated with them appear to be of more value to the estuary than those which are not.

b. Marshes. Given the importance of marsh macrophytes to estuarine cycles, shallows adjacent to marshes would probably be of more value than shallows adjacent to shorelines with other features. A marsh area/shallow area ratio could be used to differentiate the value between various shallows associated with marshes. The larger the ratio, the higher its value.

c. Presence or absence of bulkheads. For situations in which none of the shallow area of concern is associated with marshes, those shallows adjacent to bulkheaded shores would be of less value than those adjacent to natural shorelines. This is due to the reduction of land/water contact in bulkheaded areas. In certain cases, however, bulkheaded areas may be of higher quality than unbulkheaded ones. Shorelines which lack naturally stabilizing features such as rocks, trees and shrubs may be subject to erosion which seriously increases the turbidity of adjacent shallow waters. Such situations often occur due to disturbance of the shoreline zone. The value of such an area would be increased by restoring natural shoreline cover.

d. Intertidal flats. Intertidal flats often serve as important foraging areas for young fish, shore birds, waterfowl and mammals. Shallows associated with shorelines having intertidal flats would be potentially more highly utilized than those without these features. Tidal flat areas vary greatly in their biological importance. As a preliminary evaluation criteria, however, presence of tidal flats should be considered indicative of higher quality habitat.

4. Stability and depositional characteristics. All shallow water zones are unstable to some extent. Constant water movement across them causes some shifting of bottom sediments. Differences in the suspended sediment load result in variations in the amounts of material being deposited on the bottom. Some shallow zones, however, due to strong currents, shoreline configuration and/or proximity to sediment sources are particularly plagued with high deposition rates. These areas would probably be unsuitable habitat for many organisms particularly benthic invertebrates and smaller filter feeding planktonic forms. Areas exhibiting these problems would be of less value to the estuary than other more stable areas. Shallows which have developed in recent years and those which extend far out from shore would be expected to exhibit these characteristics more so than others.

LAND USE CHARACTERISTICS

Factors which may be of importance in determining habitat quality include presence or absence of point source dischargers, shoreline modifications, and modifications of adjacent land surfaces.

1. Point source dischargers. Since discharges of waste materials are principle factors leading to reduced water quality, shallows adjacent to active dischargers are of less value than those where no dischargers operate. Superficially, this potential would increase as the number of dischargers increases. The impact of each source, however, is not equal and more specific criteria on the amount and type of discharge are required to make further evaluations. Valuable data in this regard is found in Table 7 which presents the amounts of oxygen demanding materials discharged by major point sources per day in the study area. Although the most recent data are from 1970, they give a relative indication of the impact of each source on the estuary. Those areas receiving material of higher oxygen demand may be suspected of being less suitable habitat than those receiving lesser amounts of such substances.

Point source dischargers also discharge toxic materials and heated effluent. No useful data on the kinds and amounts of toxic substances discharged are presently available. Areas receiving heated effluent can generally be considered of lower quality than those into which no heated effluent is discharged. It should be noted that the relation between heated effluent and quality is not always negative. Small temperature increases generally stimulate ecosystem productivity, at least initially. In the long term, however, unnatural temperature conditions tend to lead to unstable systems. Further, in a system such as the Delaware River in which dissolved oxygen levels are often a critical parameter, elevated temperatures can be particularly harmful.

2. Shoreline modifications. This has been partially discussed in a previous section. Bulkheaded shorelines impart lower habitat quality than natural shorelines if the latter are not eroding. The presence of boat basins, wharfs and

Table 7.

Waste Discharges and Allocations in the Delaware River Estuary, pounds per day. (Adapted from Kiry, 1974)

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
134.5	Morrisville	510	---	557	1,960	3,446
to	Trenton	6,720	35,550	10,733	16,900	35,550
129.0	Trib	67,674	67,674	---	85,858	85,858
	Swo	1,360	1,904	---	1,360	1,904
	Total for section	76,264	105,128	11,290	106,078	126,758
129.0	Hamilton	1,810	6,500	2,220	1,345	4,830
to	Bordentown Twp.	90	---	115	585	---
125.3	U.S. Steel (Ind.)	2,850	4,212	(3,861)	3,298	16,933
	U.S. Steel (San.)	---	---		87	209
	Griffin Pipe	---	---	---	95	---
	Stephan Chem.	---	---	---	15	---
	Trib	4,096	4,096	---	4,096	4,096
	Swo	0	0	---	0	0
	Total for section	8,846	14,808	6,196	9,521	26,068
125.3	Florence	345	600	345	440	600
to	Paterson Parchment	1,880	0	1,207	1,070	---
122.0	Lower Bucks Mua.	3,140	9,640	2,847	4,150	14,442
	Penndel	95	---	59	131	826
	CFI Steel	---	---	840	---	---
	Trib	239	239	---	239	239
	Swo	0	0	---	0	0
	Total for section	5,699	10,479	5,298	6,030	16,107

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
122.0	Bristol Borough	840	850	756	1,385	1,967
to	Bristol Twp.	390	450	407	544	1,804
118.1	Rohm & Haas	2,750	0	1,957	2,800	819
	Hercules	210	0	210	216	0
	Burlington, La Gorce	70	0	70	60	0
	Burlington City	1,980	3,800	297	520	2,800
	Burlington Twp.	150	---	150	133	450
	Trib	1,154	1,154	---	1,154	1,154
	Swo	0	0	---	0	0
	Total for section	7,544	6,254	3,847	6,812	9,994
118.1	Tenneco Chem.	1,730	0	1,730	321	---
to	Falls Twp.	775	3,005	605	1,175	3,005
114.9	Beverly	265	---	265	164	---
	Bur. Army Ammo.	---	---	612	11	---
	Trib	2,009	2,009	---	2,009	2,009
	Swo	0	0	---	0	0
	Total for section	4,479	5,014	3,212	3,680	5,014
114.9	B.F. Goodrich	340	0	340	---	---
to	Willingboro	490	---	490	1,045	---
110.1	Riverside	400	3,600	400	845	3,600
	Delran	65	---	250	238	---
	Trib	6,633	6,633	---	6,633	6,633
	Swo	0	0	---	0	0
	Total for section	7,928	10,233	1,480	8,761	10,233
110.1	None	---	---	---	---	---
to	Trib	647	647	---	647	647
107.3	Swo	230	0	---	230	0
	Total for section	877	647	---	877	647

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
107.3	Riverton	130	1,595	130	113	(1,595)
to	Palmyra	315	---	315	454	
105.3	Trib	802	802	---	802	802
	Swo	1,580	2,212	---	1,580	2,212
	Total for section	2,827	4,609	445	2,949	4,609
105.3	Cinnaminson Sa.	795	1,040	575	630	1,040
to	Allied Chemical	100	0	137	---	150
104.4	Trib	50	50	---	50	50
	Swo	8,570	11,998	---	8,570	11,998
	Total for section	9,515	13,088	709	9,250	13,238
104.4	Georgia Pacific	7,550	0	4,375	3,640	0
to	Philadelphia Ne.	129,000	86,600	150,060	156,000	105,000
102.6	Pennsauken Stp.	2,750	856	3,675	2,680	856
	Camden N. Stp.	2,740	855	2,740	3,660	855
	Trib	55	55	---	55	55
	Swo	4,390	6,146	---	4,390	6,146
	Total for section	146,485	94,512	160,850	170,425	112,912
102.6	National Sugar	10,510	0	11,194	7,550	0
to	Trib	1,006	1,006	---	1,006	1,006
100.7	Swo	16,780	23,492	---	16,780	23,492
	Total for section	23,296	24,498	11,194	25,336	24,498
100.7	None	---	---	---	---	---
to	Trib	0	0	---	0	0
99.7	Swo	4,480	6,272	---	4,480	6,272
	Total for section	4,480	6,272	---	4,480	6,272

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
99.7	American Sugar	8,000	---	---	---	---
to	Camden Main	59,510	45,000	69,224	50,600	38,262
97.8	McAndrews & Forbes	12,625	0	5,446	920	---
	Publicker	1,300	0	2,352	180	350
	Trib	96	96	---	96	96
	Swo	7,410	10,374	---	7,410	10,374
	Total for section	88,941	55,470	77,022	59,206	49,082
97.8	Ruberoid	---	---	14,994	---	---
to	Philadelphia Se.	130,000	103,920	129,470	119,000	95,154
95.9	GAF Corporation	15,910	0	---	14,350	---
	Harshaw Chem.	1,789	0	1,860	1,792	---
	N.J. Zinc	3,560	0	3,232	---	---
	Bellmawr	3,450	(5,140)	520	1,090	(5,140)
	Mt. Ephraim	580		270	564	
	Brooklawn	425		425	564	
	Gloucester	2,150		1,307	1,460	
	Trib	2,646	2,646	---	2,646	2,646
	Swo	2,080	2,912	---	2,080	2,912
	Total for section	162,590	114,618	152,078	143,546	105,852
95.9	Atlantic Oil	21,940	0	24,967	9,963	22,338
to	Gulf Oil (Ind.)	12,900	1,000	25,436	41,900	---
92.1	Gulf Oil (San.)	---	---	---	18	1,000
	Texaco	3,955	592	4,863	4,600	592
	Old Fort Mifflin	---	---	7	5	---
	Army Eng. Dred. Dep.	3	0	3	1	---
	Woodbury City	3,320	2,000	2,835	4,100	2,470
	National Park	620	390	620	510	390
	Shell Chemical	4,810	0	4,810	860	---
	Union Tank Car	3	0	3	---	---
	Youth Development Center	---	---	133	---	---
	U.S. Naval Base	---	---	480	---	---
	Trib	22,943	22,943	---	22,943	22,943
	Swo	18,860	26,404	---	18,860	26,404
	Total for section	89,354	53,329	64,157	103,760	76,137

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
92.1	Philadelphia Sw.	165,000	138,335	139,185	136,000	113,298
to	Mobil Oil	25,652	6,748	32,372	24,000	6,313
88.3	Paulsboro	1,650	2,000	1,604	1,020	1,236
	Houdry Chem.	600	---	---	65	---
	Olin Corp.	4,700	---	---	627	---
	Trib	3,351	3,351	---	3,351	3,351
	Swo	0	0	---	0	0
	Total for section	200,953	150,434	173,161	165,063	124,198
88.3	Hercules, Gibbstown	8,096	4,000	2,256	215	4,000
to	Gibbstown	115	---	140	167	---
83.6	DuPont - Repauno	62,184	18,067	94,370	76,200	40,372
	Darby Creek Sa.	5,580	---	4,729	3,920	10,919
	Muckinapates	1,930	12,200	1,528	2,340	14,791
	Tinicum	260	---	73	119	752
	Central Delaware Sa.	16,000	21,870	3,043	8,500	10,573
	Eddystone Borough	840	---	416	169	253
	Union Carbide	---	---	---	705	---
	Scott Paper, Eddystone	145	0	148	283	55
	Trib	3,043	3,043	---	3,043	3,043
	Swo	1,950	2,730	---	1,950	2,730
	Total for section	100,143	61,910	86,700	97,611	87,488
83.6	Scott Paper, Chester	12,460	811	11,239	12,950	2,704
to	B.P. Oil	16,000	---	---	21,800	---
80.8	Chester Stp.	17,100	8,000	1,218	11,260	9,719
	FMC	4,300	0	1,595	2,220	175
	Sinclair	3,600	2,185	17,285	---	---
	Bryton Chem.	300	0	198	---	---
	Congolium Nairn	110	0	316	---	---
	Pa. Ind. Chem.	45	0	25	---	---
	Trib	3,040	3,040	---	3,040	3,040
	Swo	0	0	---	---	---
	Total for section	56,955	14,106	31,876	51,270	15,638

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
80.8	Marcus Hook	1,520	1,280	1,306	1,670	2,231
to	Monsanto	32,650	10,927	29,667	28,600	9,572
75.1	Sun Oil	28,730	0	43,895	19,900	2,825
	Allied Chemical	2,890	0	7,494	3,660	---
	Phoenix Steel	90	0	90	512	---
	Rollins - Purle	---	---	---	200	---
	Trib	1,331	1,331	---	1,331	1,331
	Swo	0	0	---	0	0
	Total for section	67,211	13,538	82,452	55,873	15,959
75.1	DuPont Edgemoor	19,300*	---	5,167	38,900*	---
to	B.F. Goodrich	---	---	---	41	---
72.2	Trib	437	437	---	437	437
	Swo	0	0	---	0	0
	Total for section	437	437	5,167	478	437
72.2	Wilmington	85,970	48,780	51,079	65,700	38,300
to	Penns Grove	1,140	---	942	898	---
70.5	E.I. DuPont-Carney Point	8,480	0	23,604	12,600	---
	Trib	12,476	12,476	---	12,476	12,476
	Swo	8,320	11,648	---	8,320	11,648
	Total for section	116,386	72,904	75,625	101,794	62,424
70.5	E.I. DuPont-Chambers	91,000	0	69,913	102,500	---
to	ICI Americas Inc. (Atlas)	18,800	0	71,971	22,400	---
68.4	Trib	65	65	---	65	65
	Swo	0	0	---	0	0
	Total for section	109,865	65	141,884	124,965	65
68.4	Pennsville	1,480	900	469	1,340	622
to	Upper Penns Neck	1,110	515	1,110	1,150	699
66.5	Trib	68	68	---	68	68
	Swo	0	0	---	0	0
	Total for section	2,658	1,483	1,579	2,558	1,389

Mile Point	Waste Source	1964 FSUOD	1964 NOD	1968 FSUOD	1970 FSUOD	1970 NOD
66.5	So. Christinaa Temp.	---	---	---	130	---
to	Trib	102	102	---	102	102
64.6	Swo	0	0	---	0	0
	Total for section	102	102	---	232	102
64.6	Amoco Chem.	---	---	---	1,425	---
to	Trib	210	210	---	210	210
62.9	Swo	0	0	---	0	0
	Total for section	210	210	---	1,635	210
62.9	Getty Oil	10,400	8,682	12,000	10,000	35,075
to	Trib	345	345	---	345	345
60.9	Swo	0	0	---	0	0
	Total for section	10,745	9,027	12,000	10,445	35,420
60.9	Delaware City	170	500	170	255	750
to	Diamond Shamrock	---	---	---	15	---
59.0	Trib	102	102	---	102	102
	Swo	0	0	---	0	0
	Total for section	272	602	170	372	852
59.0	Salem City	1,890	1,315	1,911	1,650	1,148
to	Trib	2,852	2,852	---	2,852	2,852
56.5	Swo	0	0	---	0	0
	Total for section	4,742	4,167	1,911	4,502	4,000

docks generally contribute to low habitat quality. Deep basins or lagoons often result in stagnant water conditions due to poor water circulation. The presence of wharfs and docks promotes boat usage which also lowers water quality by introducing toxic motor by-products into the waterway.

3. Use of adjacent land. Shallows existing adjacent to areas in which the natural vegetation has been removed or disturbed may be of lower quality than shallows existing next to undisturbed upland areas. This is due to the greater amount of material carried into the waterway by run-off. Pine barrens in New Jersey, for example, have been found to contribute approximately 4-14 metric tons of sediment per square kilometer per year ($T/km^2/yr$) to adjacent waterways, while urbanized areas along the Delaware contribute 9 to 35 $T/km^2/yr$ and industrialized areas as much as 175 $T/km^2/yr$ (Anderson and McCall, 1968). Farmlands were not evaluated but their contributions of sediment can be high if the land is mismanaged. In addition, farmlands contribute nutrients, herbicides and pesticides which adversely impact the waterway. Urban and industrial areas contribute toxic materials.

Shallows adjacent to naturally vegetated uplands would be of higher quality than those adjacent to urbanized areas and farms. All would be of higher quality than those adjacent to industrialized areas.

The presence of dredged material disposal sites has a similar effect on the quality of shallow habitat. They were generally placed on wetlands or intertidal areas and in as much as they are, represent direct loss of these habitats. In addition, some of the dredged materials may erode into the waterway. Areas near such disposal sites may exhibit lower habitat quality than areas not associated with disposal sites.

WATER QUALITY

Most shallow water habitats within the study area exhibit water quality problems. This is due primarily to the extensive industrialization and urbanization of the surrounding region. There are, thus, no areas with excellent water quality, only those with moderately or extremely poor conditions. How poor would depend on which parameters were exceeding EPA or DRBC standards, how much they were exceeding them and how consistently. The large number of possible combinations of these factors precludes examination and evaluation of the relative effects of each one on habitat quality. It can generally be said, however, that all other conditions being equal, habitat quality declines as the number of parameters exceeding safe levels, the degree to which they exceed them, or the consistency with which they exceed them, increases.

Several other factors need to be mentioned. First, it should be noted that most water quality problems within the study area deal primarily with the creation and maintenance of low levels of dissolved oxygen. As this is a critical parameter, it should probably be the first examined in evaluating habitat quality. Those areas having the lowest dissolved oxygen levels, for whatever reasons, would represent the poorest habitat. In addition, special considerations are needed for situations in which one or more parameters exceed the lethal tolerance limits of common estuarine or aquatic species. For example, an area in which the concentration of three heavy metals slightly exceeds recommended safe levels would be a more suitable habitat than one in which the concentration of even one metal exceeds lethal levels of resident fish species. Given similar DO levels and absence of lethal concentrations of any parameter, there are other conditions of primary importance in indicating relative habitat value. One of particular concern is the presence of heavy metals in areas with elevated temperatures and low DO and pH. Toxicity of heavy metals is increased under these conditions. The presence of even small amounts can prove especially damaging to an area's flora and fauna.

It should be stressed that these considerations are useful in separating the shallows only into large areas of similar condition. This is due to the lack of data on the study area and to the lack of ability within the scientific community to accurately interpret water quality characteristics.

APPLICATION

As an example of the manner in which an evaluation might be undertaken, the criteria are applied to data available on river miles 115-120. These data are found in the shallows description section on pages 208-234. The process basically involves summarizing the data according to each of the criteria. These summaries are then presented in list form from which general habitat characteristics and relative habitat values can be extracted.

Habitat Evaluation - River Miles 115-120

1. Trophic structure. There is demonstrated use of the area by many species of zooplankton, phytoplankton, ichthyoplankton, benthic invertebrates and fish. Well established macrophytic associations also exist in the area. Such trophic complexity is characteristic of a stable system.

2. Dominance and diversity. Values of these indices can be calculated with data generated during two surveys of the fish population of this area. As shown in Table 8, values of S/N and S-1/log N are relatively high while those of S_{10}/S_T are relatively low. The fish population, therefore, appears to be relatively stable and healthy.

3. Indicator organisms. The fact that fish such as the blueback herring, which require well oxygenated water, and the spottail shiner, which requires fairly clean water, are common in the population indicate that water quality is relatively good. This contention is also supported by the fact that only approximately 35% of the common phytoplankton species are considered pollution tolerant forms. In addition, none of these forms dominated the population. Data on benthic invertebrates is somewhat inconclusive. The benthic population is one of the most diverse noted in the study area. It is, however, dominated by species of tubifex worms which are tolerant of organic pollution.

4. Spawning and nursery areas. Fish eggs and larvae of sixteen different species and juveniles of ten species have been taken from this river section. This indicates that the shallows are used as spawning and nursery areas.

5. Use by endangered species. No endangered species are known to utilize this area. Several shortnosed sturgeon have, however, been taken from areas immediately upstream of this section.

6. Size. The shallows comprise a substantial portion of the waterway between river miles 115 and 117 and around Burlington Island. Some sections within this reach do, however, have small or no shallow water areas.

7. Cross-channel location. All shallows exist adjacent to emergent land.

8. Shoreline features.

a. Creeks. Creeks are located on the western shoreline at river mile 115.5 and on both shorelines near river mile 119.

b. Marshes. Marshes exist throughout the area but particularly between river miles 116 and 118 and along the periphery of Burlington Island. Although widespread, the vegetated zone is generally narrow.

c. Bulkheads. The majority of the shoreline is unbulkheaded.

d. Intertidal flats. Intertidal flats exist in the shorezone areas of the entire section.

These characteristics are indicative of moderately good habitats.

9. Stability and depositional characteristics. Sediment loads within this section of the river are relatively low and generally would not pose serious problems for most organisms.

10. Point source dischargers. Three municipal treatment plants, one power plant and four other dischargers are located within this five mile stretch. This is a relatively low number of dischargers.

11. Shoreline modifications. The shoreline is mostly unbulkheaded. Few piers, wharfs or boat basins exist.

12. Land use. Several small communities and some industrial complexes exist on surrounding ground. The area is not as highly modified as those within the middle sub-area, but it does exhibit a considerable amount of development. There is also a large dredged material disposal area located on Burlington Island. These characteristics tend to degrade the habitat quality of the area.

13. Water quality. Generally high dissolved oxygen levels and low oxygen demand and coliform levels characterize this section. These conditions indicate that there is little problem with organic pollutants in this area. Water temperatures and pH also exhibit no deviations from natural levels. Concentrations of several toxic metals, however, have been found to occasionally be above recommended safe levels. Such levels indicate a problem with industrial pollutants, although, at present, these metals appear to have had only minor adverse impacts on the biota.

After examining all of the above factors, shallows in this zone would be considered of relatively good quality. They are used by numerous types of organisms, exhibit many physical characteristics needed for good habitat, are affected by few dischargers and generally exhibit few problems of water quality. In determining whether a project should be undertaken within this area, it would also be important to note that while vegetated wetlands are common, the vegetated zone at any location is relatively narrow. The destruction of such areas would degrade adjacent shallows.

This is the type of analysis that can be undertaken. Although the evaluation are not particularly detailed, it identifies those data which may have bearing on the process of the permit review.

There are several problems inherent in using the criteria and the data which should be mentioned. These problems can be illustrated by examining additional data in greater detail.

Certain data generated during several fish surveys undertaken throughout the study area are presented in Table 8. Values of the two diversity indices discussed earlier, S_T/N and S_T-1/log N, and of the distribution index S_{10}/S_T have been calculated for these data and are included in the table. The percentages of the catch represented by the single most common species collected in each study, the study dates and number of collections involved are also included. Not all of the studies available on each site have been included in the table due to insufficient or non-comparable data. In addition, for some of the studies in which several seining sites were involved, the indices presented in Table 8 represent the means of those calculated for each site. The problems associated with manipulating data in this manner will be discussed later.

The first statement that can be made concerning Table 8, is that the relative importance of each area in maintaining the fish population of the estuary varies depending on which parameters, values and studies are utilized. Some studies in all areas have produced similar numbers of species and specimens. In this regard, all areas appear of equal value. Given that water quality in the middle sub-area is generally poorer than that in the upper and lower areas, this pattern is not expected. If additional data and indices presented in the table are considered, however, the biological evaluations of each sub-area appear in keeping with their water quality characteristics. The dominance of the major species collected in the studies between river miles 70-75 and 83-88 is greater than the dominance of major species collected from river miles 60-63 or 115-120. This is shown in both the higher values of P_C and S_{10}/S_T, and in the generally lower values of S_T/N and S-1/Log N. Diversity and distributional evenness appear to decrease as one moves from the upper and lower sub-areas into the middle sub-area. These changes are considered indicative of lowering habitat quality.

Such trends and data must, however, be interpreted cautiously. It can be seen in Table 8 that the studies were conducted in different years and seasons. There is a large disparity in the sampling effort involved in each study as shown by the

Table 8. Data generated during several fish surveys in study area and calculated indices. N = total number of individuals caught; S_T = total number of species; S_{10} = number of species containing 10% of the individuals caught; P_c = percentage of total catch represented by the most common species.

River Miles	Collection or Study Dates	No. of Collections	N	S_T	S_{10}	P_c	S/N	S-1/Log N	S_{10}/S_T
61-63	01/72-01/73	55	2,919	31	5	26.9	.011	8.65	.16
70-75	06/74-11/74	114	1,291	17	15	57.9	.013	5.14	.88
	12/74-08/75	214	2,519	25	21	34.2	.009	7.06	.87
82-88	06/71-10/71	113	13,638	25	21	48.1	.002	5.80	.84
	01/72-12/72	118	4,743	32	29	59.4	.007	4.81	.90
	01/73-12/73	181	7,484	36	33	43.0	.005	5.86	.91
	01/74-12/74	55	3,708	23	21	62.7	.006	6.16	.91
115-120	06/72-12/72	238	10,731	33	26	25.1	.011	7.94	.71
	01/73-06/73	45	1,098	21	15	27.9	.019	6.66	.71

different number of collections made. Increasing or decreasing sampling effort, or sampling in different seasons or years, can affect the results of studies such as these. The data, diversity values, and quality evaluations reflect not only habitat variation but variation in these factors.

In addition to being sensitive to differences in the specifics of each study, indices can be shown to be sensitive to the way in which data are manipulated. Data generated during the studies of Potter and Harmon (1973) on river miles 82-88 have been manipulated to generate the values of S-1/log N given in Table 9. There were seven seining sites used in the study, each of which proved to be of different habitat quality. This was reflected in the number of species and specimens collected at each site and in the values of the diversity index calculated from them. The site at river mile 84.8 was particularly poor while that at river mile 87.5 particularly good. The latter site, which was on Little Tinicum Island and not actually within the river, harbored several species which were not found at any of the other sites. It was felt that the variety of habitats on the island (small pools, channels, etc.) was responsible for this diversity.

When using diversity indices to characterize the study area, different quality evaluations result from different treatments of the data. If the stations are considered separately, diversity values range from 3.81 to 7.62. If the stations are combined, the values range from 4.81 to 8.43. The value of 4.81 is generated by averaging the diversity indices calculated for each station. The value of 8.43 is generated by first combining all the data collected and then calculating the index. The difference is due to the varying influence the species found at river mile 87.5 have on the index. Given that this site is different from the others, there is reason to exclude it from the calculations. Doing so results in lowering the mean value to 4.33 and the combined value to 5.38.

Depending on the manner in which the data are handled, this section of the river exhibits either the highest or the lowest diversity of estuarine fish. It appears that the sites should be considered

Table 9. Data generated during fish survey of river miles 82-88, 1972 (Potter and Harmon, 1973). S_T and N are described in Table 9. M7 and M6 index values calculated from averaged valued of each station. C7 and C6 index values calculated from combined totals of all species and individuals collected. M7 and C7 based on data from all stations. M6 and C6 based on all stations except river mile 87.5.

	River Miles										
	82.0	83.7	84.8	85.4	85.6	87.4	87.5	M-7	C-7	M-6	C-6
S	11	13	12	9	14	13	25	-	-	-	-
N	104	385	1,237	128	329	1,147	1,413	-	-	-	-
S_T-1/Log N	4.97	4.64	3.52	3.81	5.16	3.92	7.62	4.81	8.43	4.33	5.76

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SHALLOWS OF THE DELAWARE RIVER-TRENTON, NEW JERSEY TO REEDY POI--ETC(U)
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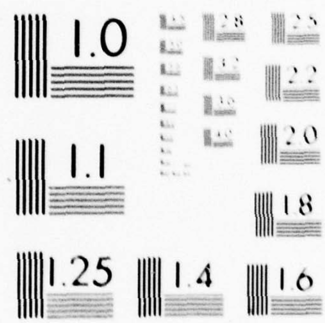


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

individually and only the individual diversity values, or that calculated as the mean of the seven sites, be used in any comparisons with other shallows. Data from other studies are not always presented by site and only indices on combined data can be calculated. Where a homogeneous area was sampled, the results of such calculations may be representative of the data. Where a heterogeneous area was sampled, such as between river miles 82-88, the results could be non-representative. Comparisons involving studies for which such specifics cannot be determined should be made cautiously.

These data can also be used to demonstrate other problems. Many of the criteria deal with the physical characteristics of the habitat. Those areas with marshes, creeks, tidal flats and natural shorelines are considered of higher value than those areas lacking these features. If the maps on river miles 70-75 and 82-88 are examined, it can be seen that based on physical habitat, shallows in the latter area should be more productive. The diversity indices generated for these two areas do not support this contention, however. Further within river miles 82-88, the area most likely to be the best habitat would be at river mile 85 near Monde Island. There is a creek present, well developed marshes composed of a variety of macrophytes, tidal flats and natural shoreline. In several years of study there, it was found that not only did the site not have the best fish diversity of the seven sites sampled, it often had the worst.

The reason for both the similarities in fish diversity of river miles 70-75 and 82-88, and the low diversity noted at site 85.4 is not necessarily due to invalid criteria. It is more likely due to the effect of poor water quality. Water quality within the middle sub-area is poor enough to negate any affects physical characteristics may have on habitat quality. Shallows between river miles 70-75 and 82-88 appear as habitats of similar quality when, in fact, the latter area is potentially of higher value. Specific water quality problems at river mile 85.4 may be the reason for the generally low utilization of this habitat in comparison to others within this portion of the river. There is a known chemical discharger within the area that appears to be affecting this location more so than other nearby sites (Potter and Harmon, 1973). The potential for high utilization of this habitat is not realized due to problems of water quality.

A similar kind of pattern is displayed in data collected between river miles 80 and 81. In two studies done in this river stretch, sites along the eastern shore were generally more productive than sites along the western shore (Potter et al., 1974a; Didun and Harmon, unpublished). As can be seen in the shallows map for river miles 74-83, the eastern shore along this area is relatively undeveloped. A large creek with some naturally vegetated borders enters the river along the eastern shore at river mile 80. In contrast, the western shore is highly developed. There are no marshes, little natural shoreline and only a small creek that flows through a highly industrialized and urbanized area. Differences in the productivity of the two shores was determined to be due partially to these habitat variations.

CONCLUSIONS

Decisions concerning the utilization of shallows based on the criteria and data presented in this study should be made cautiously. Biological productivity and habitat quality are too complex to be adequately evaluated by applying general criteria to a limited amount of data. Additional data on the biological, chemical and physical characteristics on the shallows should be collected. The relationships existing between these parameters and habitat quality should be clarified. In addition, more information on the effects of varying types and amounts of development on productivity and habitat quality needs to be generated.

Within the confines of the present study, however, the data and the criteria presented are of importance in the administration of the regulatory functions of the Philadelphia District, U.S. Army Corps of Engineers. The data are the best available, and the criteria concern factors known to reflect or influence habitat quality. With some modification they would be the same criteria as those created were our understanding of habitat quality and biological productivity more complete.

SHALLOW AREA DESCRIPTIONS

SHALLOW AREA DESCRIPTIONS

INTRODUCTION

In describing shallow water areas, emphasis has been placed on determining their past and present location and size, biological structure, water quality characteristics, shoreline characteristics and impacts. These data have been taken from a large number of studies conducted within the upper Delaware estuary over the past several decades. The studies will be identified as data generated in them is introduced.

In presenting the data, the study area has been divided into three sub-areas. The lower sub-area extends from Reedy Point (river mile 58) to Wilmington (river mile 73), the middle sub-area from Wilmington to Philadelphia (river mile 106), and the upper sub-area from Philadelphia to Trenton (river mile 133). The locations of the shallow water areas within these sub-areas are depicted in several maps accompanying each section. Individual maps depict several miles of the river and, in addition to the shallows, include the locations of the intertidal zone, vegetated marsh lands, main river channels, disposal areas and municipal and industrial point source dischargers. The biological data, since they are so numerous, are summarized according to the exact river miles to which they apply. Data on water quality, land use and impacts, are summarized at the beginning of each sub-area section.

DETERMINATION OF SHALLOW WATER AREAS

The initial steps in describing the shallow water resources of the study area involved determining the past and present locations of the shallows. This was accomplished using data generated primarily by the Corps of Engineers during several river surveys undertaken in 1909, 1932, 1946, 1954, 1960, and 1965 (U. S. Army Corps of Engineers, 1909, 1932, 1960, 1965). As the intent of most of this work was to survey the position and depths of the major channels and ship basins, some shore zone sections within the study area were not adequately surveyed to permit delineation of the shallows. In most cases, however, the river was completely surveyed from mean low water line to mean low water line in ten foot depth intervals.

The results of these investigations are the maps which appear in the remainder of the text, and Tables 10 and 11. Table 10 summarizes the past and present amounts of shallows existing from river miles 58 to 133.4. Table 11 identifies the major dredging projects undertaken within the Delaware and the amounts of material removed during these operations.

In interpreting these data, several factors must be kept in mind. First, it should be noted that "recent" studies vary in age from 15 to 33 years old and the "historical" from 47 to 70. In neither case were the data used in each category generated during the same stage of river development. As shown in Table 11, large amounts of dredging occurred both between 1946 and 1965 and between 1909 and 1932 as, no doubt, did large amounts of other river modifications. Further, "recent" conditions are not completely indicative of present conditions nor are "historical" conditions indicative of primitive ones. Much development of the river has occurred within the last several years, and some of this development has resulted in changes within shallow water areas. Similarly, as the dredging record indicates, modifications in the river were made prior to 1909 and many within the period from 1909 to 1932. Thus, while much less developed than today, the river was already a highly used system by the time

Table 10. Summary of Delaware River shallows (MLW to a depth of 10 feet) from Reedy Point, Delaware to Trenton, New Jersey (river mile 58.6 to 133.4) from 1909 to 1965.

River Mile	"Historic Survey" Year	"Historic Survey" Acres	"Present Day Survey" Year	"Present Day Survey" Acres	Gain or Loss Acres	Gain or Loss %
58.6-63.4	1909	4,372	1946	4,477	+105	+ 2
63.4-68.2	1909	1,083	1956	1,130	+ 47	+ 4
68.2-73.2	1909	987	1954	1,093	+106	+11
73.2-79.5	1909	1,173	1954	1,226	+ 53	+ 5
79.5-84.5	1909	637	1954	1,059	+422	+66
84.6-87.3	1909	450	1956	563	+113	+25
87.3-91.9	1909	1,080	1958	566	-514	-48
91.9-96.2	1909	613	1960	325	-288	-47
96.2-100.9	1909	267	1960	145	-122	-46
100.9-102.9	1909	16	1960	30	+ 14	+88
58.6-102.9	1909	10,678	1946-1960	10,614	- 64	- 1
102.9-105.8	1932	340	1965	143	-197	-58
105.8-108.6	1932	325	1965	137	-188	-58
108.6-111.6	1932	269	1965	191	- 78	-29
111.6-114.2	1932	267	1965	266	- 1	- 0
114.2-117.1	1932	217	1965	211	- 6	- 3
117.1-119.6	1932	114	1965	106	- 8	- 7
119.6-123.2	1932	135	1965	111	- 24	-18
123.2-125.4	1932	123	1965	84	- 39	-31
125.4-128.2	1932	136	1965	91	- 45	-33
128.2-130.8	1932	239	1965	136	-103	-43
130.8-133.4	1932	111	1965	103	- 8	- 7
102.9-133.4	1932	2,276	1965	1,579	-697	-31
58.6-133.4	--	12,954	--	12,193	-761	- 6

Table 11. Dredge projects, date authorized, year dredged and quantity of materials removed from the Delaware River and Bay 1874 to 1967. (Source: U.S. Corps of Engineers, 1969)

Acts	Work Authorized	Documents
6/25/10	Channel 35 feet from Allegheny Avenue, Phila., Pa. to Delaware Bay	H. Doc. 733, 61st Cong., 2d Sess.
7/03/30	Anchorages 35 feet deep at Port Richmond and Mantua Creek, a 30-ft. anchorage at Gloucester, N.J. and extending 1,000-ft. channel in Philadelphia Harbor at Horseshoe Bend	H. Doc. 304, 71st Cong., 2d Sess.[1]
8/30/35[2]	An anchorage 35 feet deep at Marcus Hook, Pa.	Rivers and Harbors Committee Doc. 5, 73d Cong., 1st Sess.
6/20/38[3]	A channel 37 feet deep from Philadelphia-Camden Bridge to Navy Yard, thence 40 feet deep to deepwater in Delaware Bay	S. Doc. 159, 75th Cong., 3d Sess.[1]
3/02/45[4]	A 37-ft. depth in channel from Allegheny Ave., Phila., Pa. to Philadelphia-Camden Bridge and to anchorage to Port Richmond	H. Doc. 580, 76th Cong., 3d Sess.[1]
Do...	A 37-ft. depth in and enlargement of anchorages near Mantua Creek and Marcus Hook	H. Doc. 340, 77th Cong., 1st Sess.[1]
Do...	Maintenance of enlarged channel opposite Philadelphia Navy Yard	Specified in Act.
9/03/54	A channel from Allegheny Ave. to Naval Base 40 feet deep, 400 feet wide along west side of channel through Phila. Harbor and 500 feet wide through Horseshoe Bend	H. Doc. 358, 83d Cong., 2d Sess.[1]
7/03/58	Anchorages at Reedy Point, Deepwater Point, Marcus Hook, and Mantua Creek. 40 feet deep and 2,300 feet wide with mean lengths of 8,000, 5,200, 13,650 and 11,500 feet, respectively	H. Doc. 185, 85th Cong., 1st Sess.

1. Contains latest published maps. 2. Also Public Works Admin., 9/6/33.
3. Channel 37 ft deep and 600 ft wide from Naval Base to Phila-Camden Bridge, deferred for restudy. 4. Channel 37 ft deep and 600 ft wide from Phila-Camden Bridge to Allegheny Ave., deferred for restudy.

these surveys were made. Finally, it must be noted that in no survey of a system this large, is every point along the river studied. Although this has no bearing on identifying large scale changes occurring in the system, small scale changes are often not uncovered. These may not be important on an individual basis. Their combined effects, however, may have significant influences on the shallows and the estuary.

As shown in Table 10, there are now approximately 12,193 acres of shallows within the study area. Of this amount, 6,700 acres exist within the lower 15 miles from river miles 58.3 to 73.2 (Reedy Point to Wilmington). Four thousand fifty-seven (4,057) acres are found within the next 32 miles, from river miles 73.2 to 106 (Wilmington to Philadelphia). The remaining 1,430 acres appear within the upper 30 miles from river miles 107 to 133 (Philadelphia to Trenton). On an acre/mile basis, these figures become 447 ac/mile, 127 ac/mile and 48 ac/mile, respectively in the three zones.

WATER QUALITY

Determinations of water quality involve the interpretation of physical and chemical water parameters in light of an intended water use. All water masses exhibit specific physical and chemical conditions which have no inherent value or quality. High or low dissolved oxygen (DO) levels or hydrogen ion concentration (pH) mean little to the integrity or stability of the water mass. The quality evaluation of these and other parameters develops because these conditions affect the uses for which water may be suitable, and these uses each have been given particular values.

The division between waters of high or low quality is generally made on the basis of whether or not the water is suitable for use by aquatic and estuarine organisms, and by man in domestic water supplies or for primary contact recreation. These uses require that water have characteristics which fall within a relatively narrow range. Waters exhibiting such characteristics are considered of high quality. Waters not exhibiting these characteristics are considered of lower quality and suitable only for industrial or commercial purposes, or for secondary contact recreation such as boating.

The distinction is not based totally on the water requirements of each of these uses. Some industrial processes, for example, need pure water which may not be present in the waterway. Since the industry can treat water, however, any water which can be treated economically is considered of sufficient quality for that use. Similarly, water considered suitable for domestic supplies does not necessarily mean that the water is of high enough quality to be used directly from the waterway. A reasonable amount of treatment may be necessary to render it potable. Only in the case of water use by estuarine and aquatic organisms, or of the consumption of these organisms by man, does the quality designation reflect direct water use at ambient conditions.

There are numerous parameters which affect water use and which could serve as water quality criteria. Regulatory agencies such as the U.S. Environmental Protection Agency (EPA) and the Delaware River Basin Commission (DRBC) generally define water quality in terms of 20 or 30 major parameters. These are water temperature, dissolved oxygen (DO), fecal coliform, turbidity and suspended solids, salinity and dissolved solids, biological oxygen demand (BOD), alkalinity, water hardness, pH, oil and grease, nitrate, nitrite, ammonia, phosphate, phenol, cyanide and concentrations of the heavy metals zinc, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury and nickel. The criteria established by the EPA and DRBC for most of these parameters are listed in Appendices A and B, respectively. Some of these parameters, particularly temperature, DO, BOD, salinity, turbidity and fecal coliform are established parameters which have been used in making water quality determinations. The others have become prominent within the last ten to twenty years as their affects on water use have been substantiated and quantified.

The process by which allowable limits of these parameters are determined is complex. The reasons for this are:

(1) These parameters do not act independently of each other. The effects of heavy metals on estuarine organisms cannot be determined unless conditions of temperature, salinity, pH, water hardness, and others, are known. Given the wide variety of parameters, the possibility of innumerable antagonistic and synergistic effects occurring among them exists.

(2) Each parameter affects different organisms or different life stages of the same organisms in different ways. Few permissable parameter levels protect all organisms or water uses equally.

(3) The long term effects of exposure to small amounts of many of these substances, particularly the heavy metals, cannot presently be determined. Allowable concentration of many parameters while not directly affecting aquatic organisms, may be affectig the long term survival of the population. Due to these and other problems, setting meaningful water quality standards is a difficult task.

Problems also arise in utilizing standards effectively in all systems. While parameters such as turbidity, DO, salinity and temperature are easily and routinely measured, others are not. Tests for these latter parameters often involve complicated chemical procedures for which special equipment or personnel are needed. While these parameters are known to be important in evaluating water quality, they often are not adequately investigated.

These problems are present in monitoring the quality of the study area. Several studies have been undertaken in which parameters in many areas have been investigated: Kiry (1974), U.S. Geological Survey (1974a,b,c), and DRBC (1976b,c,d,e). Other studies are available in which only certain parameters or areas have been examined: Ackerman and Sawyer (1972), ANSP (1958), Delaware Water and Air Resources Commission (1973), and others. While these studies are important in elucidating conditions and problems within the basin it must be noted that they describe only gross water quality trends in the Trenton to Reedy Point area. More subtle differences between smaller areas cannot be distinguished until additional data are available.

The most useful parameters in describing water quality within the study area include salinity, dissolved oxygen, biological oxygen demand, ultimate oxygen demand, nitrogenous oxygen demand, fecal coliform level, water temperature and pH, and concentrations of the heavy metals. Some of the data concerning these parameters are presented in Figures 9 through 12 and Tables 7, 12 and 13. Examination of these data indicate that water quality within the upper sub-area is generally good while that in the middle sub-area is generally poor. Water quality in the lower sub-area is not as poor as that in the middle sub-area but is still of only moderate quality. These trends are discussed in more detail in each of the sub-area summaries.

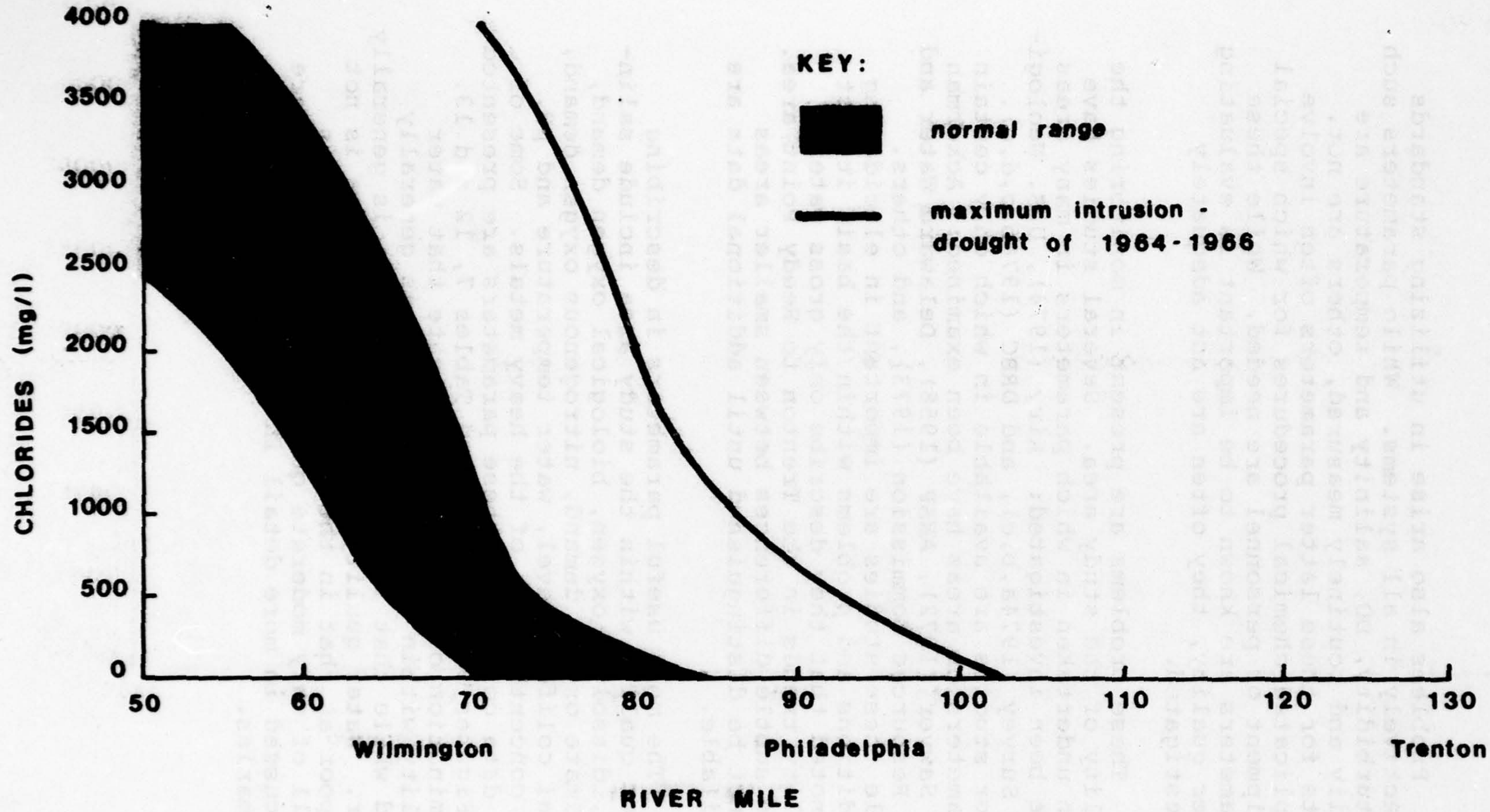


Figure 9. Saltwater intrusion into the Delaware Estuary showing the expected range and maximum intrusion during the drought of 1964-1966. (After: Thomann, 1972)

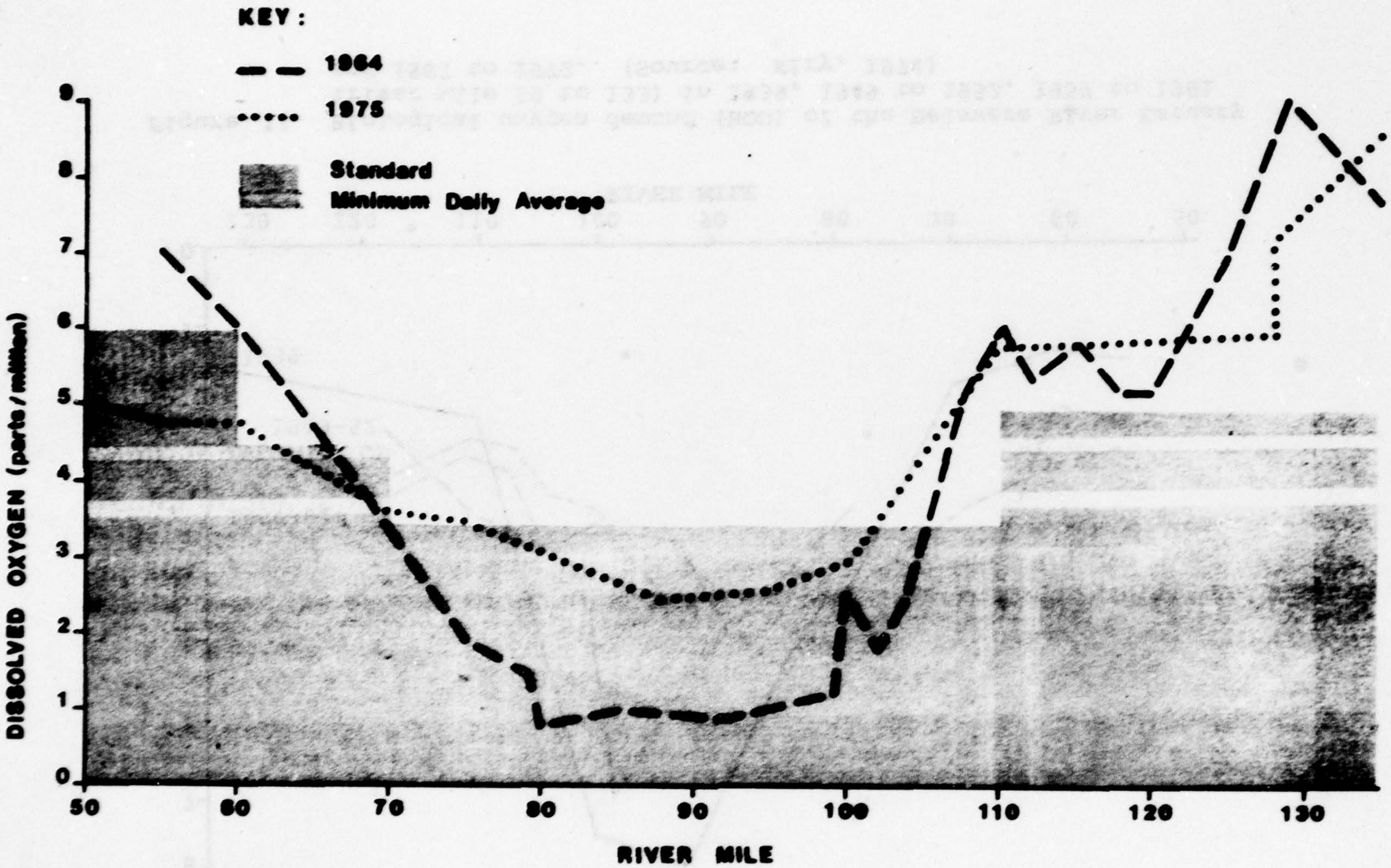


Figure 10. Trend of improved dissolved oxygen in pollution problem reach of the Delaware from 1964 to 1975. (After: DRBC, 1976.) Standard Minimum Daily Average is that level which DRBC hopes to achieve (see Appendix A).

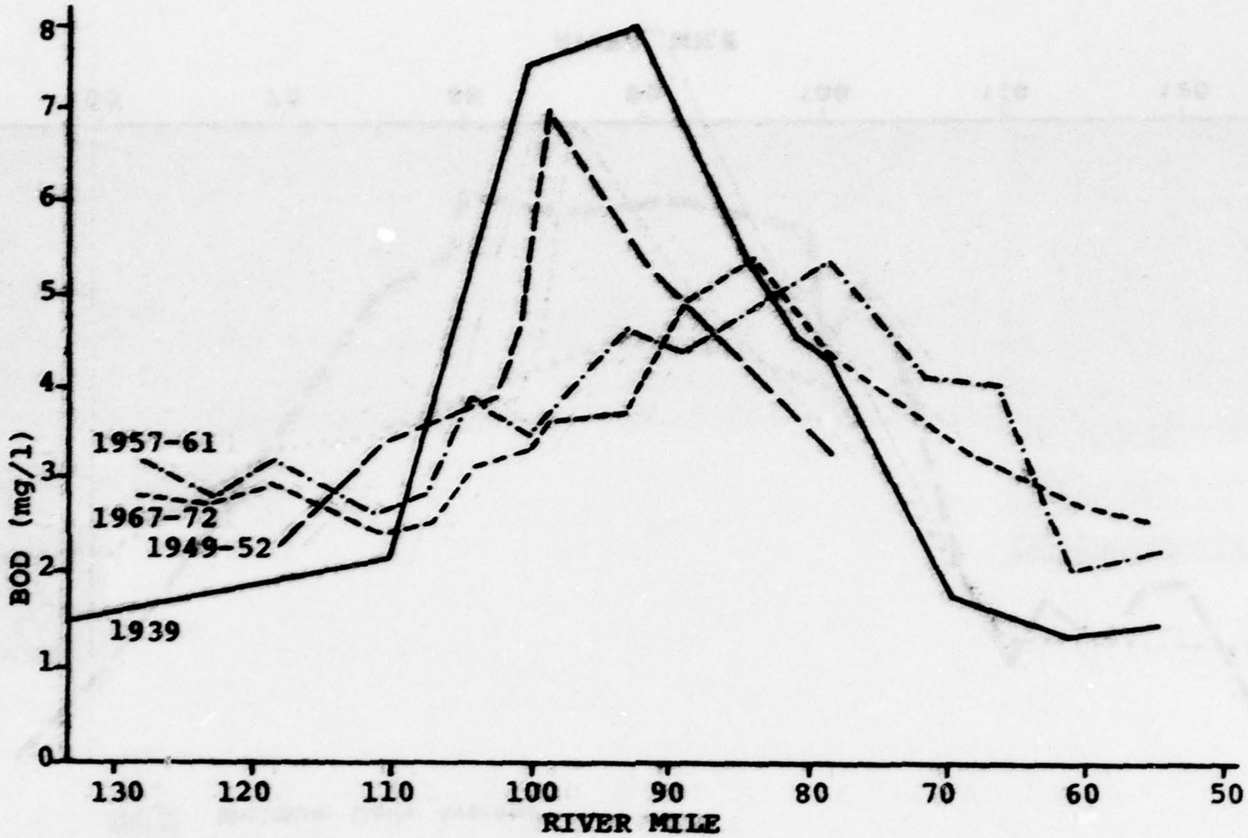


Figure 11 Biological oxygen demand (BOD) of the Delaware River Estuary (river mile 50 to 133) in 1939, 1949 to 1952, 1957 to 1961 and 1967 to 1972. (Source: Kiry, 1974)

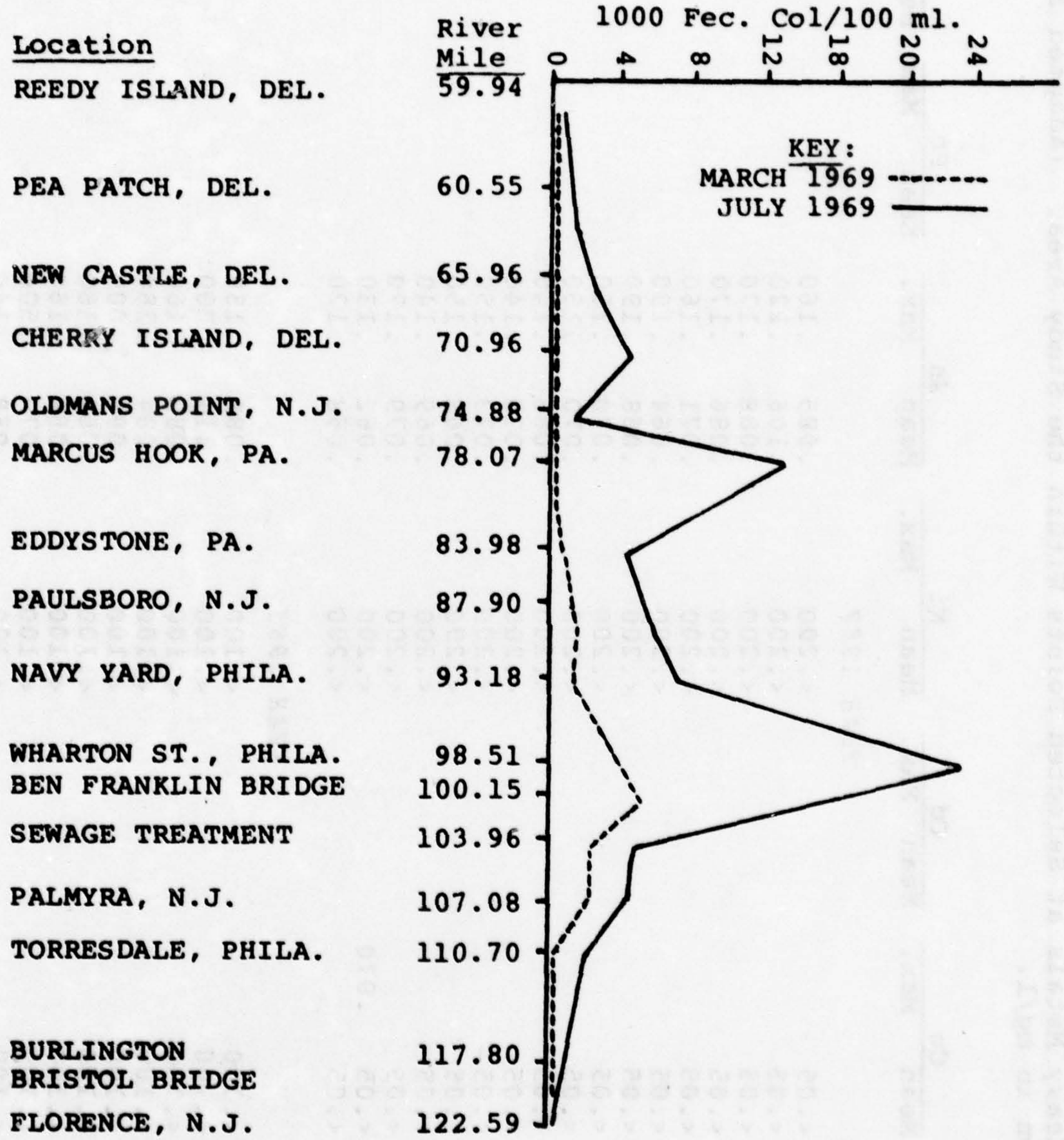


Figure 12. Mean average fecal coliforms in the Delaware River (river mile 59.95 to 122.59) during March and July 1969. (After: Neiheisel, 1973)

Table 12.

Concentrations of Heavy Metals at Selected Points Within the Study Area. (Adapted from Kiry, 1974). Values shown in mg/l.

Mile	Cr		Cu		Cd		Ni		Zn		Pb		Hg	
Point	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.
YEAR 1967														
54.9	<.100		<.05				<.200		.085	.160				
60.6	<.100		<.05				<.200		.106	.220				
66.0	<.100		<.05				<.200		.088	.170				
71.0	<.100		<.05				<.200		.086	.170				
74.9	<.100		<.05				<.200		.071	.160				
78.1	<.100		<.05				<.200		.064	.190				
84.0	<.100		<.05				<.200		.068	.190				
87.9	<.100		<.05				<.200		.070	.150				
93.2	<.100		<.05				<.200		.070	.150				
98.5	<.100		<.05				<.200		.065	.140				
100.2	<.100	.130	<.05				<.200		.070	.140				
104.0	<.100		<.05				<.200		.073	.150				
107.1	<.100		<.05				<.200		.068	.150				
110.7	<.100		<.05				<.200		.069	.140				
117.8	<.100		<.05				<.200		.079	.170				
122.5	<.100		<.05	.070			<.200		.062	.130				
127.5	<.100		<.05				<.200		.068	.120				
YEAR 1968														
59.4	<.100		<.100				<.100		.088	.150				
60.6	<.100		<.100				<.100		.111	.200				
66.0	<.100		<.100				<.100		.083	.160				
71.0	<.100		<.100				<.100		.084	.280				
74.9	<.100		<.100				<.100		.091	1.000				
78.1	<.100		<.100				<.100		.064	.160				
84.0	<.100		<.100				<.100		.058	.160				
87.9	<.100		<.100				<.100		.079	.500				
93.2	<.100		<.100				<.100		.058	.140				

Mile	Cr		Cu		Cd		Ni		Zn		Pb		Hg	
Point	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.
							YEAR 1968 (cont'd.)							
98.5	<.100		<.100				<.100		.057	.180				
100.2	<.100		<.100				<.100		.058	.150				
104.0	<.100		<.100				<.100		.065	.150				
107.1	<.100		<.100				<.100		.055	.150				
110.7	<.100		<.100				<.100		.056	.150				
117.8	<.100		<.100				<.100		.074	.420				
122.5	<.100		<.100				<.100		.063	.350				
127.5	<.100		<.100				<.100		.049	.150				
							YEAR 1969							
54.9	<.100		<.100				<.100		.123	.170				
60.6	<.100		<.100				<.100		.117	.250				
66.0	<.100		<.100				<.100		.145	.570				
71.0	<.100		<.100				<.100		.132	.220				
74.9	<.100		<.100				<.100		<.100	.200				
78.1	<.100		<.100				<.100		<.100	.180				
84.0	<.100		<.100				<.100		<.100	.170				
87.9	<.100		<.100				<.100		<.100	.170				
93.2	<.100		<.100				<.100		<.100	.160				
98.5	<.100		<.100				<.100		<.100	.180				
100.2	<.100		<.100				<.100		<.100	.230				
104.0	<.100		<.100				<.100		<.100	.190				
107.1	<.100	.150	<.100				<.100		<.100	.160				
110.7	<.100	.130	<.100				<.100	.140	<.100	.180				
117.8	<.100		<.100				<.100		<.100	.220				
122.5	<.100		<.100				<.100		<.100	.220				
127.5	<.100		<.100				<.100		<.100	.180				

Mile Point	Cr Mean	Cr Max.	Cu Mean	Cu Max.	Cd Mean	Cd Max.	Ni Mean	Ni Max.	Zn Mean	Zn Max.	Pb Mean	Pb Max.	Hg Mean	Hg Max.
YEAR 1970														
54.9	<.100		<.100				<.100		.133	.210			<.0005	.0008
60.6	<.100		<.100				<.100		.135	.210			<.0005	.0008
66.0	<.100	.140	<.100				<.100		.138	.240			<.0005	.0008
71.0	<.100		<.100				<.100		<.100	.210			<.0005	
74.9	<.100		<.100				<.100		<.100	.160			<.0005	.0007
78.1	<.100	.150	<.100				<.100		<.100	.290			<.0005	.0008
84.0	<.100	.110	<.100				<.100		<.100	.170			<.0005	.0033
87.9	<.100		<.100				<.100		<.100	.190			<.0005	.0007
93.2	<.100		<.100				<.100		<.100	.380			<.0005	
98.5	<.100		<.100				<.100		<.100	.150			<.0005	.0006
100.2	<.100		<.100				<.100		<.100	.150			<.0005	.0007
104.0	<.100	.110	<.100				<.100		<.100	.150			<.0005	.0008
107.1	<.100	.110	<.100				<.100		<.100	.130			<.0005	.0012
110.7	<.100	.140	<.100				<.100		<.100	.340			<.0005	
117.8	<.100	.140	<.100				<.100		<.100	.610			<.0005	.0012
122.5	<.100	.120	<.100				<.100		<.100	.130			<.0005	.0008
127.5	<.100	.160	<.100				<.100		<.100	.160			<.0005	
YEAR 1971														
54.9	<.100		<.100		.017	.040	<.100		<.100		.140	.170	<.005	
60.6	<.100		<.100		.010	.030	<.100		<.100		.060	.120	.002	
66.0	<.100	.300	<.100		<.005		<.100		<.100		.060	.060	<.005	
71.0	<.100		<.100		.005	.010	<.100		<.100		.120	.140	<.005	
74.9	<.100		<.100		.015	.030	<.100		<.100		.105	.130	<.005	
78.1	<.100		<.100		.010	.010	<.100		<.100		.070	.140	<.005	
84.0	<.100		<.100		.010	.010	<.100	5.100	<.100		.110	.140	<.005	
87.9	<.100		<.100		.005	.010	<.100	5.100	<.100		.125	.190	<.005	
93.2	<.100		<.100		<.005		<.100		<.100		.080	.110	<.005	
98.5	<.100		<.100		<.005		<.100		<.100		<.050		<.005	
100.2	<.100		<.100		.010	.010	<.100		<.100		.100	.150	<.005	
104.0	<.100		<.100				<.100		<.100					
107.1	<.100		<.100		<.005		<.100		<.100		<.050		<.005	

Mile Point	Cr Mean	Cr Max.	Cu Mean	Cu Max.	Cd Mean	Cd Max.	Ni Mean	Ni Max.	Zn Mean	Zn Max.	Pb Mean	Pb Max.	Hg Mean	Hg Max.
YEAR 1971 (cont'd.)														
110.7	<.100		<.100		.010	.010	<.100		<.100		.080	.080	<.005	
117.8	<.100		<.100		.010	.010	<.100		<.100		.085	.120	<.005	
122.5	<.100		<.100		<.005		<.100		<.100		.050		<.005	
127.5	<.100		<.100		.005	.010	<.100		<.100		.085	.150	<.005	
YEAR 1972														
54.0	.046	.140	<.100	.220	.013	.050	<.100	.110	<.100	.140	.131	.250	<.005	
60.6	.045	.130	<.100	.140	.008	.030	<.100		<.100	.160	.083	.250	<.005	
66.0	.040	.100	<.100		.007	.030	<.100	.120	<.100	.150	.090	.250	<.005	
71.0	.022	.080	<.100		.007	.020	<.100		<.100	.150	.053	.220	<.005	
74.9	.036	.110	<.100		.005	.020	<.100	.120	<.100	.150	.062	.150	<.005	
78.1	.029	.090	<.100		.006	.040	<.100		<.100	.160	.084	.240	<.005	
84.0	.028	.090	<.100		.009	.040	<.100	5.100	<.100	.130	.065	.280	<.005	.0075
87.9	.034	.110	<.100		.005	.020	<.100	.110	<.100	.130	.104	.460	<.005	
93.2	.027	.120	<.100		.005	.030	<.100		<.100	.130	.073	.240	<.005	
100.2	.024	.120	<.100		.005	.020	<.100		<.100	.110	.074	.160	<.005	
104.0	<.100		<.100				<.100		<.100					
110.7	.023	.110	<.100	5.100	.005	.020	<.100		<.100	.120	.059	.260	<.005	
117.8	.036	.120	<.100		.004	.020	<.100		<.100	.160	.084	.230	<.005	.100
122.5	<.100		<.100		<.100		<.100		<.100	.110			<.005	
127.5	.032	.120	<.100		.006	.020	<.100		<.100	5.100	.060	.180	<.005	

Table 13.

Concentrations of Heavy Metals (mg/l) at Selected Points Within the Study Area. (Adapted from Kiry, 1974)

Mile Point	Zn Mean	Zn Max.	Mg Mean	Mg Max.	Fe Mean	Fe Max.	Mn Mean	Mn Max.	Pb Mean	Pb Max.	Al Mean	Al Max.	Ni* Max.	Cd Max.	Cu Max.	Cr Max.	Hg Max.
*YEAR 1968***																	
87.9	.33	.63	9	14	1.17	2.09	.22	.36						.002	.04	.08	
98.7	.27	1.13	7	11	1.23	2.69	.18	.48						.006	.05	0	
102.9	.28	.89	7	10	1.02	2.01	.13	.18						.003	.03	0	
110.4	.29	.87	7	11	.80	1.38	.10	.20						.002	0	.05	
*YEAR 1969***																	
87.9	.11	.51	8	20	2.53	18.30	.30	.62	.045	.075			0	.003	.13	.06	
98.7	.12	.55	6	14	1.29	5.73	.21	.45	.034	.048			.30	.010	.05	.07	
102.9	.13	.70	5	9	1.26	3.25	.20	.49	.033	.043			.23	.006	.08	.22	
105.1	.13	.71	6	16	1.60	3.79	.18	.32	.043	.095			0	.010	.07	.06	
107.1	.14	.21	5	8	1.49	3.25	.18	.31					0	.003	.08	.02	
110.4	.18	.54	5	15	1.64	12.20	.20	.79	.023	.068			.09	.009	.09	.11	
114.1	.21	.62	6	15	.92	10.90	.19	.50	.020	.032			.20	.002	.09	.16	
117.8	.28	.86	6	16	1.85	14.20	.22	.91	.061	.080			0	.004	.13	.05	
126.0	.21	.87	6	16	.89	9.60	.27	2.72	.014	.020			.12	.005	.31	.95	
*YEAR 1970***																	
87.9	.12	.28	7	9	2.88	5.52	.28	.42	.038	.070	.35	.84		.004	.08	.03	
87.9	.09	.19	9	13	.97	2.20	.23	.40	.017	.035	.41	.73		.002	.03	.03	
98.7	.12	.20	5	9	1.23	2.23	.20	.26	.036	.058	.19	.38		.002	.07	.01	
98.7	.09	.18	7	9	.79	1.64	.15	.25	.017	.033	.37	.95		.002	.05	.01	
102.9	.13	.22	5	7	.92	1.51	.21	.27	.028	.052	.16	.28		.005	.09	.01	
102.9	.09	.15	6	8	.68	1.90	.13	.24	.017	.038	.35	.68		.002	.11	.01	
105.1	.12	.24	5	7	1.19	2.78	.22	.42	.034	.081	.18	.29		.002	.08	.10	
105.1	.09	.17	8	7	.77	2.04	.12	.23	.017	.038	.38	.89		.002	.08	.10	
107.1	.08	.12	5	5	1.20	2.10	.17	.23	.023	.034	.14	.64		.002	.05	.02	
107.1	.09	.17	6	7	.74	2.22	.10	.24	.016	.030	.39	.97		.002	.16	.02	
110.4	.21	.49	5	7	1.09	3.00	.17	.30	.027	.058	.21	.75		.002	.07	.01	

Mile Point	Zn Mean	Zn Max.	Mg Mean	Mg Max.	Fe Mean	Fe Max.	Mn Mean	Mn Max.	Pb Mean	Pb Max.	Al Mean	Al Max.	Ni* Max.	Cd Max.	Cu Max.	Cr Max.	Hg Max.
*YEAR 1970** (cont'd.)*																	
110.4	.10	.20	6	9	.84	2.48	.11	.20	.019	.020	.47	1.13		.002	.05	.01	
114.1	.22	.47	5	7	1.13	4.05	.20	.35	.021	.035	.21	.50		.002	.08		
114.1	.11	.19	6	10	.74	1.81	.12	.23	.017	.033	.40	.83		.002	.04		
117.8	.42	.90	6	7	3.67	15.50	.29	.78	.044	.130	.48	1.96		.012	.16	.01	
117.8	.11	.24	6	9	.73	1.68	.13	.26	.017	.042	.41	.97		.002	.05	.01	
126.0	.35	.85	5	7	3.12	14.40	.36	1.55	.027	.121	.41	1.69		.011	.08	.02	
126.0	.08	.17	6	14	.66	1.63	.12	.21	.016	.033	.35	.91		.002	.10	.02	
134.3	.17	.34	5	6	1.29	5.50	.19	.56	.023	.035	.28	.73		.004	.03	.03	
134.3	.07	.17	6	8	.45	3.32	.13	.39	.016	.037	.41	2.80		.003	.40	.03	
*YEAR 1971***																	
87.9	.11	.23	6	10	1.04	2.87	.17	.45	.021	.120	.74	2.60		.003	.03	.04	.0009
98.7	.12	.70	5	8	.89	3.35	.14	.26	.022	.120	.72	2.90		.015	.03	.04	0
102.9	.10	.19	5	7	.83	2.72	.14	.27	.021	.101	.67	2.90		.003	.02	.02	0
105.1	.10	.23	5	7	1.03	5.59	.13	.29	.023	.052	.78	2.65	.05	.008	.03	.04	0
107.1	.10	.19	6	7	.98	2.67	.12	.25	.021	.099	.63	2.04		.004	.02	.03	0
110.4	.10	.20	5	7	.95	3.22	.13	.25	.023	.095	.73	2.63		.006	.02	.02	.0004
114.1	.10	.23	5	8	.89	3.21	.13	.22	.025	.110	.66	2.04		.005	.04	.04	.0006
117.8	.10	.29	5	8	.92	3.53	.13	.30	.025	.100	.84	3.50		.012	.03	.03	.0008
126.0	.08	.19	5	8	.72	2.37	.12	.27	.019	.107	.49	1.48		.007	.02	.02	.0005
134.3	.08	.23	5	8	.57	2.17	.13	.28	.022	.200	.79	2.63		.003	.10	.01	.0008

* - values on 8/13/69, Pennsylvania shore.
** - 1968 - sample from center channel.
1969 - samples from Pennsylvania shore.
1970 - top numbers - Pennsylvania shore sample.
1970 - lower numbers - center channel sample.
1971 - samples from center channel

IMPACTS AND LAND USE

Data within this category concern the characteristics of the shorelines and the number, type and location of the major point source dischargers within each river section. These data are important in determining the degree to which each portion of the river has been developed. Although these data are qualitative in nature, they provide additional insight into the potential quality of each portion of the river.

The data on shoreline characteristics are presented in Table 14. These have been taken primarily from surveys of the U.S. Army Corps of Engineers. The data on the number and types of point source dischargers in each sub-area are summarized in Table 15. These are presented in more detail preceeding the maps depicting each river section. The locations of the dischargers and dredged materials disposal areas are also indicated on these maps. In examining these data it can be seen that the middle sub-area is the most highly developed. The upper sub-area has undergone significant development. The lower sub-area has experienced the least modifications. These trends are discussed in more detail in the sub-area summaries.

Table 14. Characteristics of the banks of the Delaware River Estuary (river mile 58 to 134). (After: U.S. Corps of Engineers, 1969.)

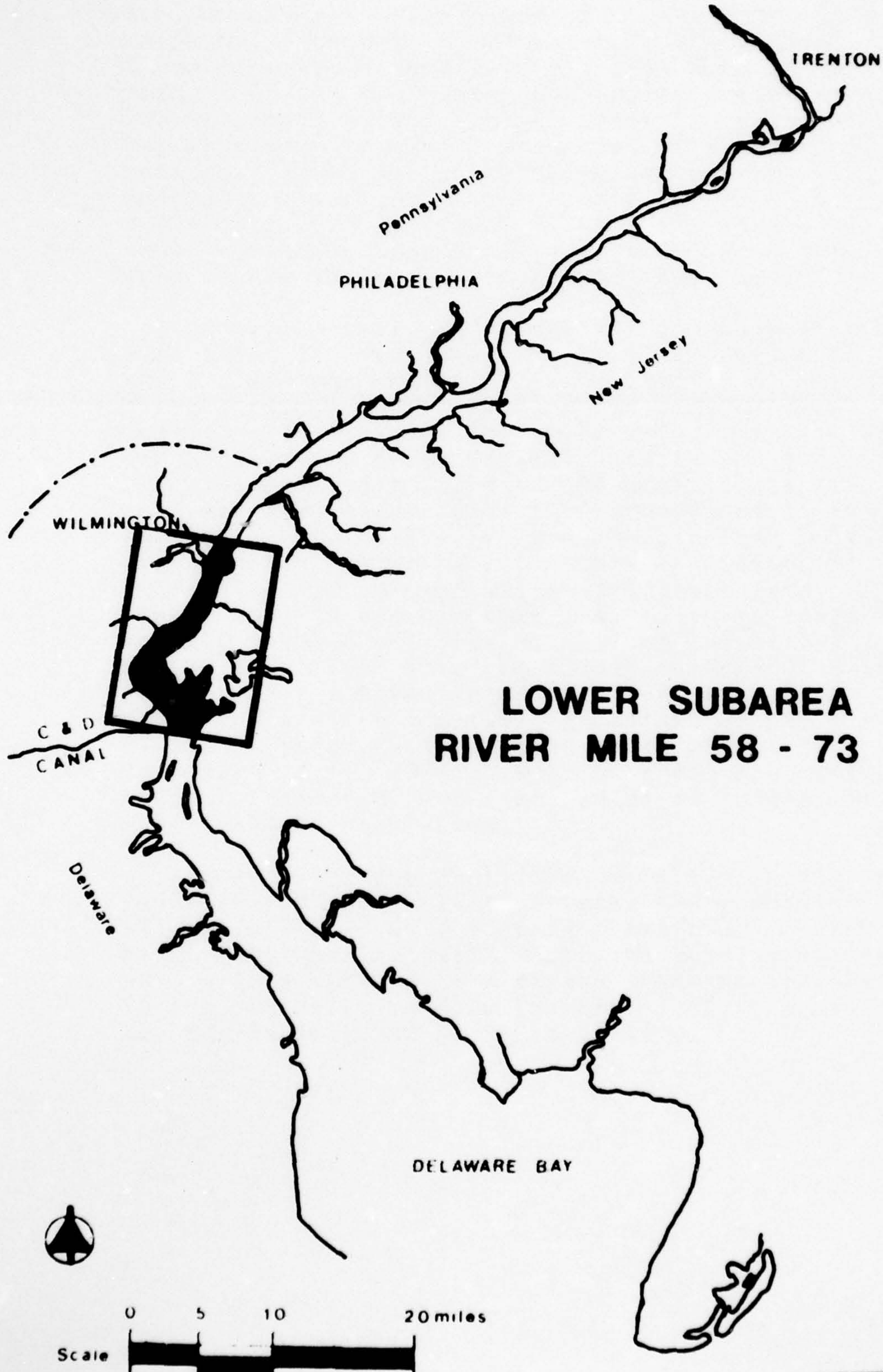
Reach	West Shoreline	East Shoreline
Mile 58 to Mile 62	Mostly protected shoreline, dredge disposal areas, large oil refinery; Unprotected Pea Patch Island west of main channel.	Mostly natural condition; tidal marsh up to mile wide.
Mile 62 to Mile 67	Mostly natural; narrow belt of marsh; small town.	Mostly protected dredge disposal areas and small river communities.
Mile 67 to Mile 70	Mostly protected; dredge disposal areas; small town.	Mostly protected high ground; highly industrialized.
Mile 70 to Mile 74	Protected dredge disposal areas.	About 50% protected, mostly high ground.
Mile 74 to Mile 79	Mostly unprotected high ground; fall line from Mile 74 to Mile 134 sometimes close to shoreline.	Natural or filled ground; little marshlands; mostly unprotected.
Mile 79 to Mile 86	Mostly protected high ground; highly industrialized; large communities of Marcus Hook and Chester.	Many dredge disposal areas, banks generally unprotected; unprotected Chester and Monds Islands east of main channel.
Mile 86 to Mile 89	Mostly bulkheaded; small town; industries; unprotected Tinicum Island west of main channel.	Mostly bulkheaded; filled ground; many industries.
Mile 89 to Mile 94	Piers and bulkheads.	Mostly unprotected filled ground.
Mile 94 to Mile 102	Naval Base and City of Philadelphia; piers and bulkheads; mostly high ground.	City of Camden; mostly bulkheaded, about 1/3 filled ground, remainder high; piers and industry.
Mile 102 to Mile 108	City of Philadelphia, piers and bulkheads, high ground, industry.	About 50% bulkheaded; much high ground some fills; Petty Island, east of main channel, mostly bulkheaded fill; industry.
Mile 108 to Mile 112	City of Philadelphia;	About 50% natural high ground

Mile 89 to Mile 94	Piers and bulkheads.	Mostly unprotected filled ground.
Mile 94 to Mile 102	Naval Base and City of Philadelphia; piers and bulkheads; mostly high ground.	City of Camden; mostly bulk-headed, about 1/3 filled ground, remainder high; piers and industry.
Mile 102 to Mile 108	City of Philadelphia, piers and bulkheads, high ground, industry.	About 50% bulkheaded; much high ground some fills; Petty Island, east of main channel, mostly bulkheaded fill; industry.
Mile 108 to Mile 112	City of Philadelphia; mostly bulkheaded high ground; industry.	About 50% natural high ground remainder filled marsh, little protection; several residential communities.
Mile 112 to Mile 119	Mostly natural high ground, largely unprotected. Dredge disposal areas, unprotected banks. Unprotected marshy Mud Island west of main channel.	Mostly high ground, about 50% protected. Several residential communities and industry.
Mile 119 to Mile 122	Town of Bristol; high ground, mostly protected.	Town of Burlington; mostly high ground, protected. Unprotected Burlington Island with dredged material fill east of main channel.
Mile 122 to Mile 126	Natural shoreline, little protection. About 50% high ground, remainder marsh.	Unprotected bluffs; industry. Small town.
Mile 126 to Mile 128	Heavy industry; protected filled ground.	Natural unprotected shoreline, high ground. Unprotected Newbold Island east of main channel.
Mile 128 to Mile 134	Mostly unprotected natural high ground. Small town.	Mostly unprotected natural high ground. City of Trenton.

2

Table 15. Numbers of Point Source Dischargers and Major Dredged Material Disposal Sites Located Within the Three Sub-Areas.

Sub-Area	Municipal Treatment Plants	Power Plants	Other Dischargers	Disposal Sites
Lower	8	3	12	4
Middle	20	6	44	7
Upper	17	2	16	6



LOWER SUBAREA
RIVER MILE 58 - 73

LOWER SUBAREA

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LOWER SUB-AREA

RIVER MILES 58 TO 73

The lower sub-area extends from Reedy Point (river mile 58.9) to Wilmington (river mile 73). Approximately 6,700 acres of shallows now exist within this reach, an increase of 4% over the 6,442 acres which existed in 1909 (Table 10).

IMPACTS AND LAND USE

Eight municipal treatment plants, three power plants and twelve other point source dischargers are located in this section (Table 15). This represents 18% of those found in the entire study area. Four dredge disposal areas are also located within the lower sub-area. With several small communities and part of the larger city of Wilmington, a large oil refinery, and several large disposal sites existing within this reach, much of the shoreline has been highly modified (Table 14). There are, however, important naturally vegetated sections between river miles 58 and 72 on the eastern shoreline, river miles 60 to 62 on the western shoreline, and river miles 60 to 61 on Pea Patch Island.

WATER QUALITY

The northern limit of the lower sub-area corresponds with the normal limit of salt water intrusion (Figure 8). This limit varies greatly, however, and in conditions of extreme drought, has been located above river mile 100. Much of the water quality of this section is determined by its position downstream of the highly urbanized and industrialized middle sub-area. Mean dissolved oxygen levels are characteristically 4-5 mg/l, which is higher than those common to the middle sub-area (Figure 9) but lower than the standard minimum daily average proposed by the DRBC (1976). There has also been a reduction in the general dissolved oxygen levels within this area in the last 10-15 years. Biological oxygen demand (Figure 10), ultimate oxygen demand (Table 7), nitrogenous oxygen demand (Table 7) and fecal coliform concentration (Figure 11) follow similar patterns with increases occurring as the middle sub-area is approached. These trends reflect the impact of sewage effluent discharged into the middle sub-area on the water quality of the lower area.

Some problems with heavy metal contaminations also exist in this area. As shown in Tables 12 and 13, maximum measured concentrations of chromium, nickel, copper, mercury, zinc and cadmium have ocassionally exceeded the recommended safe limits established for these constituents by the EPA and DRBC (Appendices A and B). The mean levels of lead are also higher than the recommended limits, indicating the existence of a chronic lead pollution problem. Since a relatively low number of industries are located within the lower area (Table 15), it appears that most of these industrially related problems arise from industrial wastes discharged into the middle sub-area. This is partially substantiated by noting that mean water temperature generally increases as the middle sub-area is approached while pH level decreases (Kiry, 1974). Both of these are indicative of increased use of the water in industrial processing or discharge.

Due to the somewhat reduced oxygen levels and moderately high levels of several heavy metals, water quality in this zone is considered marginal. Many organisms can exist under the conditions present within this section though somewhat stressed. If the pollution loading increases, these conditions may become critical to their survival.

LEGEND

Intertidal zone

Municipal treatment plant

Shallows 0'-10'

Other point-source discharge

Disposal area

Power plant

North

River mile

VEGETATION CODE

Arrow arum & Spatterdock

Reed Grass

Wild Rice

Cordgrass

MIXED COMMUNITIES

Mixed communities contain two or more species in significant quantities with no apparent single dominant.

Mixed Freshwater: Wild rice, Arrow arum, Spatterdock, etc. See dominant species and/or species of more limited occurrence such as; Pickerelweed, Cattail, Loosestrife, Waterhemp, Smartweed, Touch-me-not and Arrowhead.

Mixed Saltwater: Cordgrass, Salt hay, Spikegrass, Reedgrass, etc., and/or additional species such as; Black grass, Three-square bulrush and Glasswort.

RIVER MILE 58 to 65

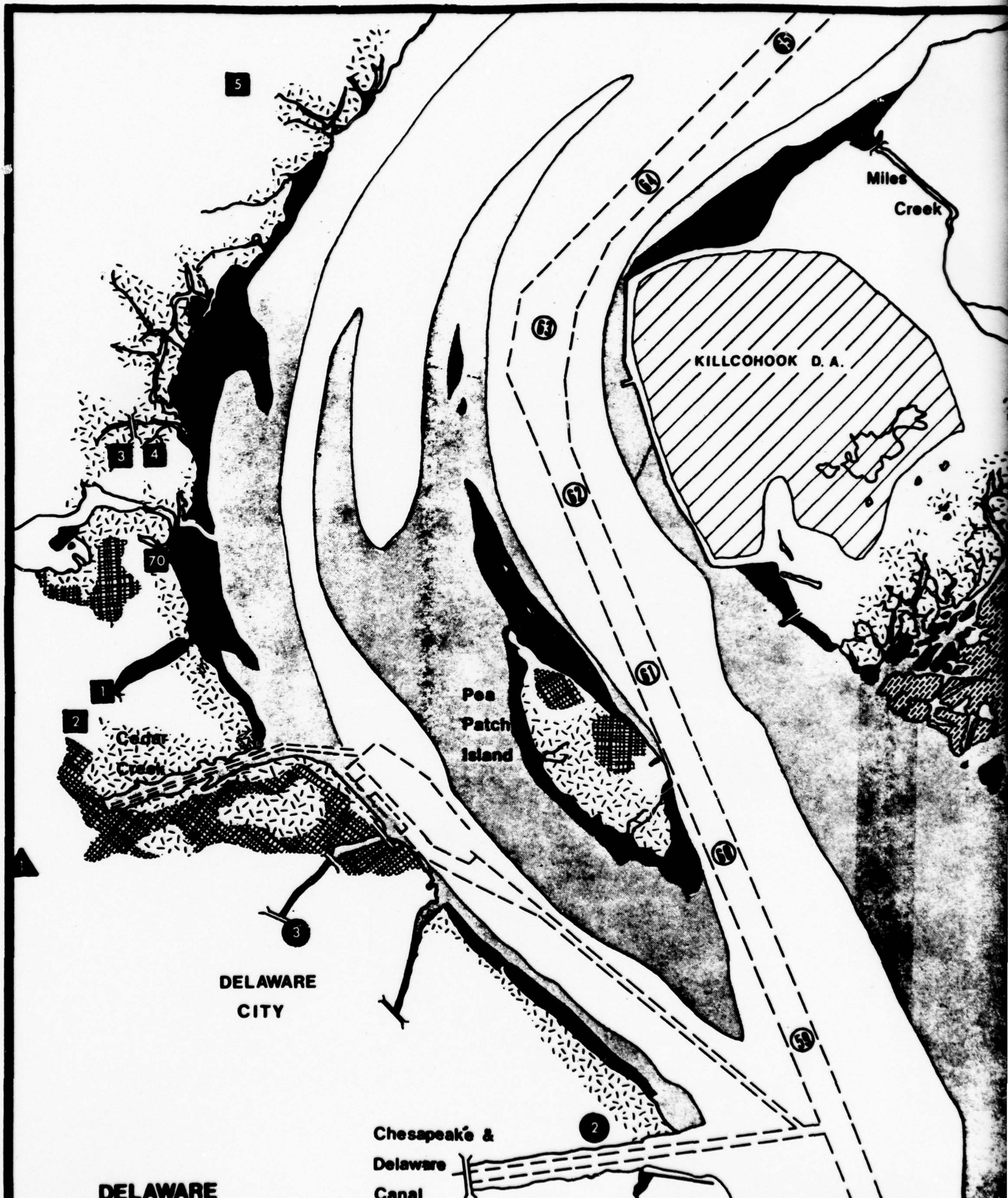
Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
1	Salem City	5	NJ 0024856
2	Port Penn Sanitary District	5	DE 0021539
3	Delaware City	5	DE 0021555
	Power Plant		
1	Delmarva Power and Light, Delaware City	5	
■	Other Point Source Discharge		
1	Getty Oil Company	5	DE 0000256
2	Stauffer Chemical Co.	5	DE 0000272
70	Stauffer Chemical Co.	5	PA 0022004
3	Standard Chlorine	5	DE 0020001
4	Diamond Shamrock Chemical Company	5	DE 0000647
5	Amoco Chemicals Corp., Polymer Plant	5	DE 0000493

ICHTHYOPLANKTON

River Mile 61 to 63 (May 1972 to April 1973)

One hundred twenty-four plankton collections were made from May 1972 through April 1973 in the Delaware River (river mile 61 to 63) (Kernehan, 1973). These collections yielded 2,911 specimens representing 13 taxa of larvae and three taxa of eggs (Appendix Table 1).


5
Miles
Creek
KILLCOHOOK D. A.
3
4
70
1
2
Cedar
Creek
Pea
Patch
Island
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DELAWARE
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2
Chesapeake &
Delaware
Canal
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62
61
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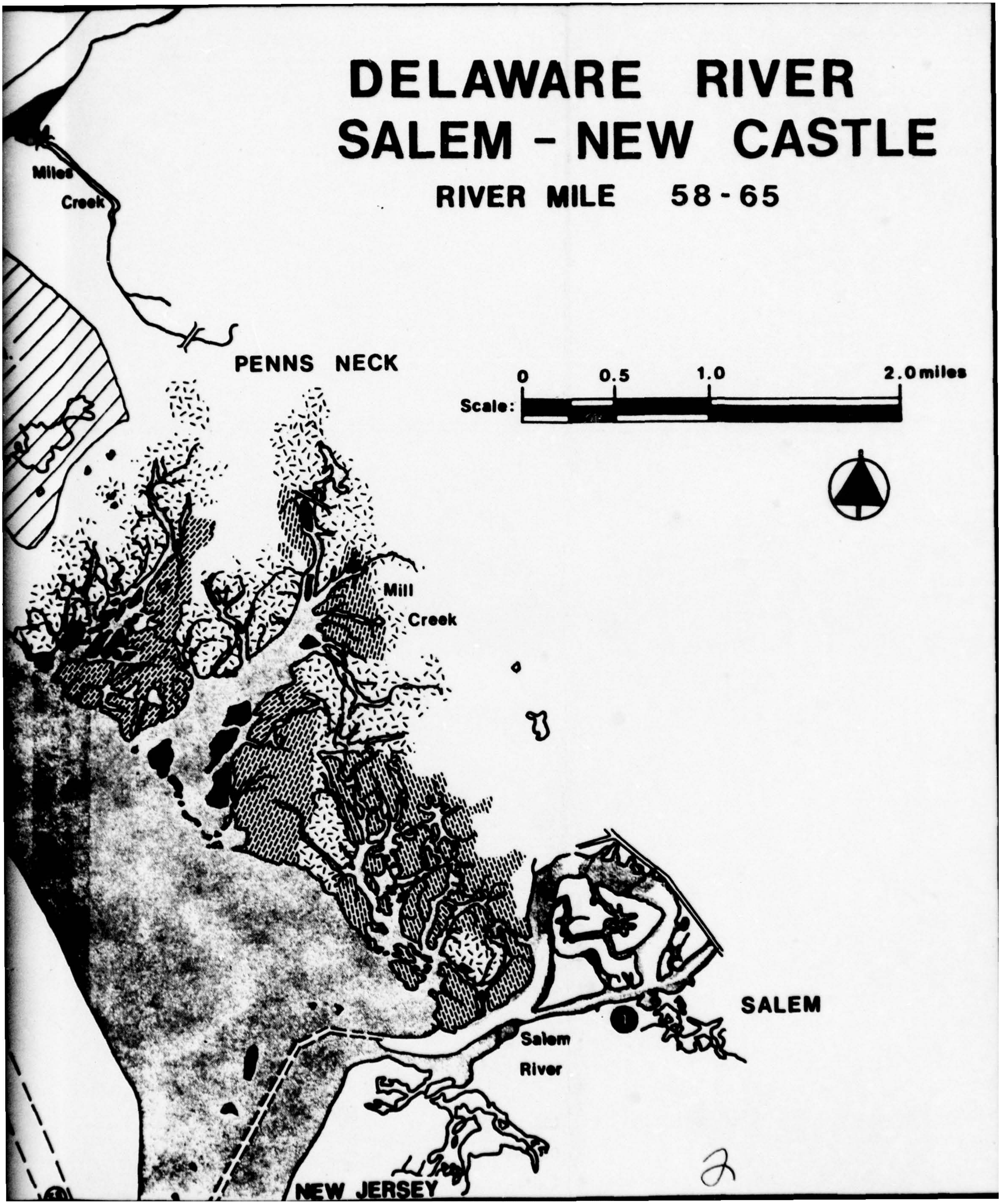

DELAWARE RIVER
SALEM - NEW CASTLE
RIVER MILE 58 - 65
Miles Creek
PENNS NECK
0
0.5
1.0
2.0 miles
Scale:
Mill Creek
SALEM
Salem River
NEW JERSEY

The 397 eggs collected in May, 1972, included striped bass (97.7%), white perch (1.5%) and river herrings (0.8%) (Kernehan, 1973). Ten striped bass eggs collected on April 4, 1973, were the only other eggs taken.

The five most abundant fishes comprised 95.7% of the larvae and included bay anchovy (50.0%), *Lepomis* sp. (32.2%), white perch (8.7%), river herrings (3.2%) and striped bass (1.6%). *Lepomis* sp., white perch and bay anchovy dominated the catch in May, June and July, while bay anchovy accounted for 99.8% of the larvae collected in August, September and October. American eel was the dominant species (78.6%) taken in November through April.

The largest catches were made in May (n/T = 64.3), July (137.8) and August (76.6). The large number of *Lepomis* sp. collected may have been washed into the area by floods in early summer (Kernehan, 1973).

OTHER FISHES

River Mile 61.2-63.0 (1972 and 1973)

On the west shore of the Delaware River (river miles 61.2 and 63.0), 55 seine collections yielded 2,919 fish of 31 species (Bason et al., 1973). Seining was most productive in August when eight collections yielded 945 specimens of 19 fishes. Warm weather seine collections yielded the fewest fish in May. Sampling during the colder months was generally unproductive.

The most abundant species taken by seine, bay anchovy (786 specimens, 26.9% of the total catch), occurred only in May, August, September and October, and ranked first in August (589 specimens, 62.2%) and September (118 specimens, 45.6%). Mummichog ranked second (676 specimens, 23.2% of the total catch), dominated the October catch (536 specimens, 73.4%), but was not taken after November. Atlantic silverside (325 specimens), white perch (291), brown bullhead (147) and silvery minnow (157) accounted for 31.5% of the total catch. White perch was the most abundant species taken by seine in May (63 specimens, 26.0%), June (104 specimens, 41.6%) and March (8 specimens, 66.7%). The brown bullhead was the most abundant species taken in July (106 specimens, 25.9%). Gizzard shad (73 specimens), pumpkinseed (87), bluegill (27) and black crappie (19) constituted a minor, but consistent, part of the monthly catch.

BIRDS

River Mile 61.2

The north end of Pea Patch Island (river mile 61.2) supports a heron rookery (personal communication, Norman J. Morrisson, III).

River Mile 58.2 and 61.6 (1976, 1977)

Two osprey nests were located in the lower subarea. One nest near Delaware City (river mile 61.6) had two fledglings in 1976 and two fledglings in 1977 (Hardin, 1977, 1978). The second nest was located near the mouth of the Salem River (river mile 58.2). Two eggs were recorded in 1976, but no young were observed. In 1977, no eggs or young were observed in the second nest.

RIVER MILE 65 TO 73

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
4	Pennsville Sewerage Authority	5	NJ 0021598
5	Upper Penns Neck Township	5	NJ 0021601
6	South Christiana Temporary Treatment Plant	5	DE 0020231
7	City of Wilmington	5	DE 0020320
8	Penns Grove Sewerage Authority	5	NJ 0024023
▲ Power Plant			
2	Atlantic City Electric, Deepwater	5	NJ 0005363
3	Delaware Power and Light, Edge Moor	5	--
■ Other Point Source Discharge			
6	ICI America	5	DE 0000621
7	E.I. duPont de Nemours & Co., Chambers Works	5	NJ 0005100
8	E.I. duPont de Nemours & Co., Carneys Point	5	NJ 0004201
9	Ludlow Corporation	5	DE 0000507
10	Wilmington Finishing Company	5	DE 0000213
11	E.I. duPont de Nemours & Co., Edge Moor	5	DE 0000051

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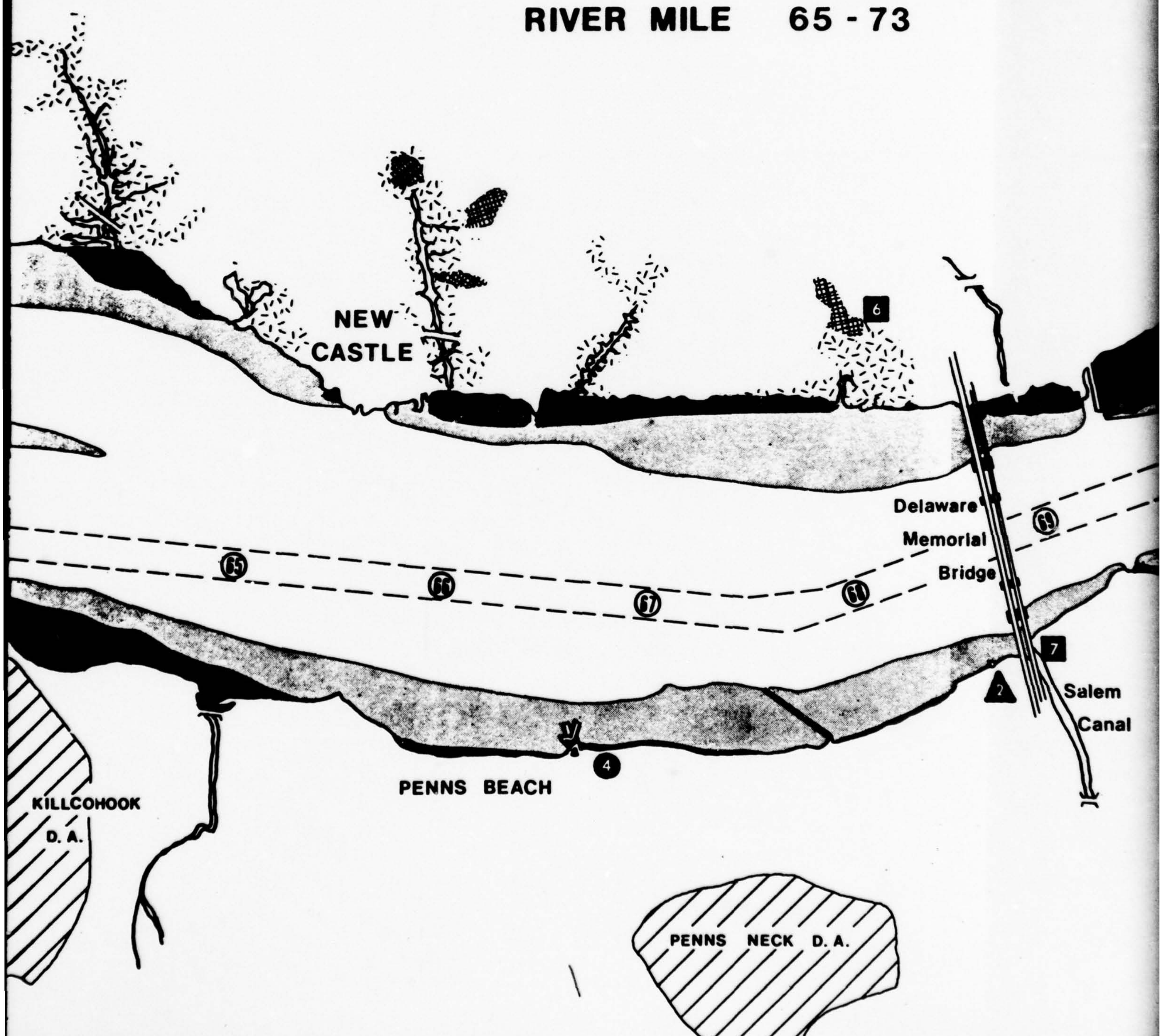
DELAWARE RIVER
NEW CASTLE - WILMINGTON
RIVER MILE 65 - 73



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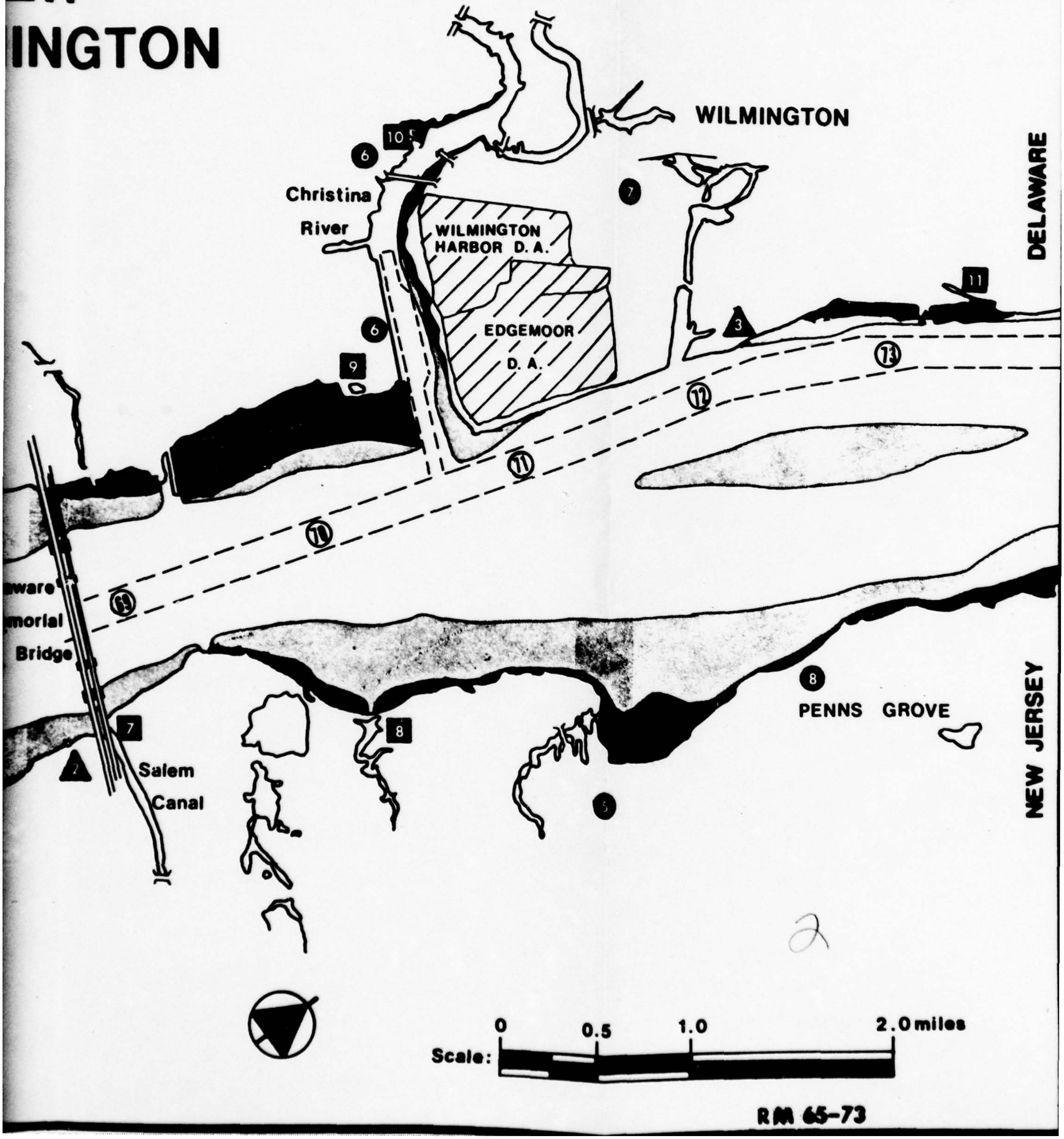


RM 65-73

PHYTOPLANKTON

River Mile 72.0 to 73.0 (May to December 1973)

Unruh (1974a) studied the phytoplankton population from river mile 72.0 to 72.5 from May to December, 1973. Genera of algae commonly collected are listed in Appendix Table 2.

The concentration of total chlorophyll a in May was 7.56 mg/m^3 (Unruh, 1974a). It subsequently increased to peak levels in July and August of 61.88 mg/m^3 and 51.97 mg/m^3, respectively. The concentration decreased steadily thereafter, reaching a low of 3.53 mg/m^3 in December. The levels of active and total chlorophyll a at the surface and at the 2-meter depth were similar. Phaeopigment concentrations were inversely related to active chlorophyll a concentrations. Increases in the phaeopigment/chlorophyll a ratio suggest increased breakdown of algal cells.

River Mile 70.6 to 73.0 (January to May 1974)

Phytoplankton studies were conducted from January through May 1974; 11 stations were sampled (Unruh and Krout, 1974). A list of the phytoplankton taken from the Delaware River (river mile 70.6 to 73.0) is included in Appendix Table 3.

The mean chlorophyll a levels changed little (0.83 mg/m^3 to 1.63 mg/m^3) during January, February and March, and increased in April and May, 3.32 mg/m^3 and 21.2 mg/m^3, respectively (Unruh and Krout, 1974). Phaeopigment concentration showed a similar trend; means varied from 3.97 mg/m^3 to 7.13 mg/m^3 for January through March and increased from 8.39 mg/m^3 to 18.1 mg/m^3 in April to May, respectively. Diatoms (particularly *Melosira* and *Navicula*) were dominant from January through May; *Oscillatoria* (a blue-green algae) was a codominant genus in March. Increasing numbers of green and blue-green algae genera were found in April and May.

River Mile 72.0 to 72.5 (September, November 1974)

Samples were taken at six stations from river mile 72.0 to 72.5 in September and November 1974 (Unruh and Krout, 1975).

In September, mean level of chlorophyll a ranged from 12.8 to 36.5 mg/m^3 and phaeopigment varied from 9.4 to 33.0 mg/m^3 (Unruh and Krout, 1975). In November, chlorophyll a ranged from 2.5 to 11.2 mg/m^3 and phaeopigment ranged from 9.2 to 18.4 mg/m^3. Forty phytoplankton genera were collected (Appendix Table 4). Diatoms (Bacillariophyta) accounted for more than 50% of the total phytoplankton population in September and about 75% in November.

River Mile 72.0 to 72.5 (January to September 1975)

Samples were taken at six stations near river mile 72 in the Delaware River from January through September 1975 (Unruh and Krout, 1976a). Chlorophyll a concentration was highest on 17 July (range 12.7 to 28.0 mg/m^3) and lowest on 21 March (range 2.7 to 6.6 mg/m^3). Phaeopigment level was highest on 17 July (range 12.4 to 24.2 mg/m^3) and lowest on 5 September (range 1.1 to 6.9 mg/m^3). Fifty-three phytoplankton genera were collected (Appendix Table 5). Diatoms accounted for more than 55% of the total phytoplankton population. Green algae and blue-green algae were more abundant during the summer.

ZOOPLANKTON

River Mile 70.5 to 73.5 (January to May 1974)

Zooplankton samples were taken at five sampling stations in the Delaware River and one sampling station near the mouth of the Christina River from river mile 70.5 to 73.5 from January to May 1974 (Brewster, 1974). A total of 87 taxa were identified in 108 collections (Appendix Table 6). No collections were taken from the shallows. Total density of zooplankton was generally lowest in the Christina River. Dominant forms throughout the sampling period were rotifers and copepod nauplii. A total of 132 macroinvertebrate specimens was found in 96 surface and bottom plankton samples; most were leeches and dipteran larvae. Zooplankton density was lowest in January and greatest in May.

A 24-hour study conducted on 20 and 21 May at three sampling stations showed rotifers to have the highest density at flood slack tides and the lowest density at ebb slack tides (Brewster, 1974). No other taxa showed a significant variation with tide.

River Mile 70.5 to 73.5 (June to November 1974)

Zooplankton samples were taken at five sampling stations in the Delaware River and one in the Christina River from June through November 1974 (Brewster, 1975). A total of 85 zooplankton taxa was collected in 168 monthly samples, and in several 24-hour studies (Appendix Table 7). Total density was greatest in samples taken on 7 June and 13 August; total density at most stations was lowest on 29 July. Rotifers were generally found in highest densities in the Christina River; greatest numbers were taken on 7 June. Cladocerans were most numerous on 7 June. Copepod densities generally were lowest in the Christina River. Greatest density within that system was observed on 13 August.

River Mile 70.5 to 71.5 (December 1974 to September 1975)

Zooplankton samples were collected at five sampling stations in the Delaware River and one in the Christina River from December 1974 through September 1975 (Crecco and Matarese, 1976). A total of 77 zooplankton taxa was identified in 312 samples (Appendix Table 8). Total density was greatest at most stations on 23 June and was least at most stations on 10 April. Rotifera, Cladocera and Copepoda were found in greatest densities at most stations on 28 May, 23 June and 27 August, respectively. Density of Rotifera and Cladocera collected in August and September decreased with increasing salinity. Density of Rotifera, Cladocera and Copepoda increased with higher water temperature.

BENTHOS

River Mile 71.0 to 73.7 (October 1973 to September 1975)

Samples were taken from October 1973 to September 1975 with a Ponar grab sampler. The shallows were not sampled.

The dominant organisms, collected at nine stations in October 1973 were the Amphipod, Gammarus daiberi (density from $90/m^2$ to $8040/m^2$), and several Oligochaetes (from $50/m^2$ to $15,000/m^2$) (Orris, 1974a). A total of 14 taxa was identified with the number of taxa per station ranging from 2 to 8.

Sixteen taxa were recorded in the study area, from January through May, 1974 (Orris, 1974b). Oligochaetes were the dominant organisms at this time, and were widely distributed and abundant. Cyathura polita, leeches and insect larvae were widely distributed, but were not abundant. Gammarus daiberi which was abundant in October 1973, was scarce from January through May 1974. Species composition was similar at all stations.

Twelve taxa of benthic macroinvertebrates were taken at nine stations in the Delaware River in July, September and November 1974 (Browell, 1975). The mean biomass from all stations was greatest in September and least in November. Gammarus spp. comprised the largest part of the total biomass and was taken in all months and at all but one station. Crab traps which were fished for 19 days at river mile 72.2 caught 12 blue crab.

Seventeen taxa of benthic macroinvertebrates were taken at nine stations from January through September 1975 (Browell, 1976). Number of taxa varied from four to eight per station. The highest mean biomass per month, 1.62 g/m^2, was taken in January and the lowest, 0.46 g/m^2, in March. Most taxa (11) were taken in May and the fewest (7) in January and July. Biomass was dominated by Oligochaeta during the entire period.

Benthic macroinvertebrates collected near Wilmington from October 1973 to September 1975 are listed in Appendix Table 9.

ICHTHYOPLANKTON

River Mile 70 to 74 (1973)

Wik (1974) reported a total of 42 specimens (14 larvae and 28 young) representing four species was taken from October through December, 1973, in 60 samples from the Delaware River near Edge Moor. No eggs were collected. The catch included larvae and young of the bay anchovy (66.6% of total), larvae of the Atlantic croaker (28.6%), young of the naked goby (2.4%) and young of the hogchoker (2.4%). The greatest monthly catch (85.7%) occurred in October.

River Mile 70.5 to 73.8 (January to May 1974)

Wik and Morrisson (1974) collected a total of 638 eggs, 532 larvae and 31 young of five taxa in 108 samples in the Delaware River near Edge Moor from January through May, 1974 (Appendix Table 10). Striped bass eggs made up 95% of the eggs taken. River herrings and minnows comprised most of the larval catch. All eggs and larvae were taken in April and May. Young of American eel were taken on all sampling dates. During a 24-hour sampling period larvae and eggs were more abundant at flood slack than at ebb slack tide.

River Mile 70.5 to 73.8 (June to November 1974)

Morrisson (1975) reported that two eggs and 1,445 larvae and young of 12 taxa were taken from June through November, 1974, from the Delaware and Christina rivers near Edge Moor. The five most abundant taxa (98.0% of the total catch) are discussed below.

Minnows, probably silvery minnow, were present in the study area from May to 27 June (Wik and Morrisson, 1974; Mirrosson, 1975). The greatest mean density (130/100 m^3) was recorded on 7 June (Appendix Table 11). Minnows made up 49.6% of the total catch from June to November 1974.

One infertile bay anchovy egg was taken on 22 July. Larvae and young (35.9% of total catch) were first taken on 22 July, and subsequently on all sample dates in August and October. Greatest mean density was 30/100 m^3 taken on 22 July. In 24-hour collections, mean density at flood tide was about five times greater than that taken at ebb tide (Morrisson, 1975).

River herrings were collected through 10 July in the Delaware River and 13 August near the mouth of the Christina River (Morrisson, 1975). They comprised 7.1% of the total catch. Greatest density was usually recorded in the Christina River.

Naked goby comprised 3.9% of the total catch and occurred in samples from 22 July through 10 October. Greatest mean density (2.9/100 m^3) was observed during flood tides on 22-23 July.

Juveniles of hogchoker comprised 1.5% of the total catch; they were taken from 22 July through 11-12 September (Appendix Table 11). Greatest mean density (1.3/100 m^3) was observed during the 24-hour study of 13-14 August.

River Mile 70.5 to 73.8 (1975)

Morrisson (1976) collected ichthyoplankton with plankton nets (0.5-mm mesh) from December, 1974, through September, 1975. A total of 14 fish taxa was collected in 619 samples from December 1974 through September 1975. Minnows (probably larvae of silvery minnow), gizzard shad, river herrings and American eel (elver) comprised 70.1%, 10.2%, 9.1% and 4.0%, respectively, of the total number of fish taken in semi-monthly collections (Appendix Table 12). The highest mean density per day (186.6/100 m^3) occurred on 24 June. Striped bass spawned near Edge Moor. Greatest observed mean density of striped bass eggs was 628/100 m^3. Maximum spawning apparently occurred at a water temperature of 55 to 57½F from April through 2 May.

OTHER FISHES

River Mile 71.6 to 74.9 (October to December 1973)

A total of 34 specimens of 11 fishes was taken in 15 collections along the west shore of the Delaware River from river mile 71.6 to 74.9. The mummichog and the silvery minnow were the dominant species and together comprised 64.7% of the total catch. The mummichog was taken only at river mile 74.6 and 74.9; the silvery minnow was taken only at river mile 71.9 and 74.9. Catch in November was larger than in December. No fishes were collected at river mile 72.2 or 73.2 (Preddice, 1974b).

River Mile 71.6 to 74.9 (January to May 1974)

Fishes were collected by seine from the west shore of the Delaware River (river mile 71.6 to 74.9) from January through May 1974 (Preddice and Molin, 1974). The collections yielded 150 specimens of seven species. Fishes collected were mummichog (91.0%), silvery minnow (6.0%), American eel (1.3%), tidewater silverside (0.7%), white perch (0.7%), gizzard shad (0.7%) and banded killifish (0.7%). Fish were taken in all months, but were least abundant in January and February.

At river mile 74.9 (the mouth of Stoney Creek) ten collections yielded 136 specimens (91% of the total catch) of four species. Mummichog (93% of the station catch) was most abundant. At river mile 74.6 no specimens were collected. One gizzard shad was taken in ten collections at river mile 73.2. Eight specimens of four fishes were produced in ten collections at river mile 72.2 One silvery minnow, collected in May, was the only fish taken in ten collections at river mile 71.9. Three mummichog were collected in May and one silvery minnow was taken in January at river mile 71.6 in ten collections.

River Mile 71.6 to 74.9 (June to November 1974)

A total of 1,291 specimens of 17 fishes was taken in 114 day and night seine collections made along the west shore of the Delaware River (river mile 71.6 to 74.9) from June to November 1974 (Molzahn, 1975) (Appendix Table 13).

By station, most specimens per collection (16.6) were taken at river mile 71.9 and most species (10) were captured at river mile 72.2. Fewest specimens per collection (0.9) were found at river mile 71.6.

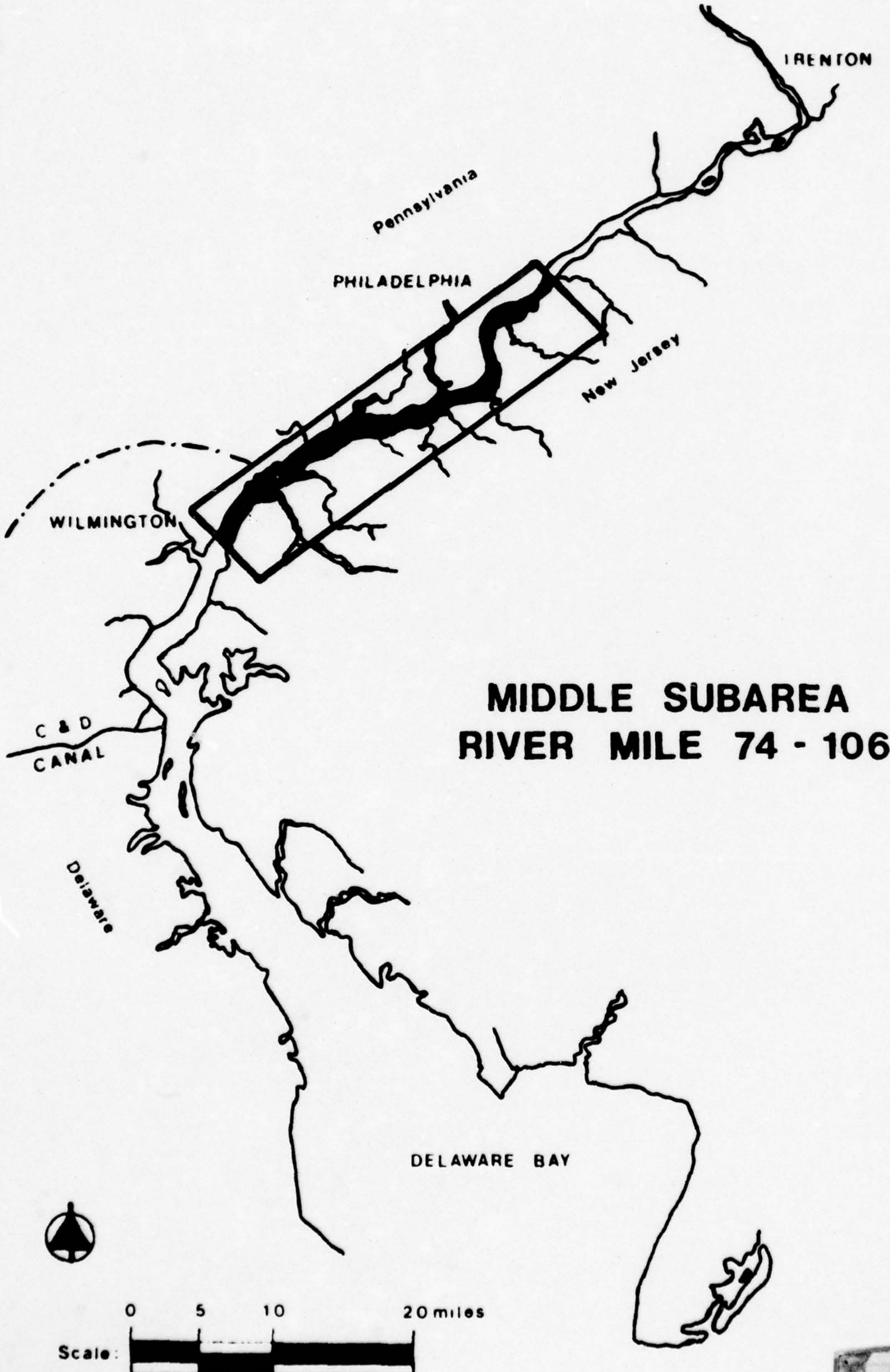
By month, most specimens per collection (29.0) were taken in September and most species (10) were caught in July. Fewest specimens per collection (29) were taken in August and fewest species (5) were captured in June. Of the total catch, mummichog comprised 57.9%, bay anchovy 25.0%, and silvery minnow 10.6% of the total. Only mummichog and silvery minnow were collected every month. Mummichog was the most abundant species taken at river mile 71.9, 73.2, 74.6 and 74.9. Bay anchovy was the most abundant species taken at river mile 71.6 and 72.2 Only at river mile 74.6 did the number of specimens taken in day collections consistently exceed those taken in night collections.

River Mile 71.6 to 74.9 (December 1974 to September 1975)

In 214 day and night seine collections, 2,519 specimens of 25 fishes were taken from the west shore of the Delaware River (river mile 71.6 to 74.9) from December 1974 to September 1974 (Herrig, 1976) (Appendix Table 14). Three fishes comprised 81% of the total seine catch, mummichog (34.2%), silvery minnow (33.3%) and bay anchovy (13.5%). These species occurred at each seine site. Most specimens per seine collection were found at river mile 74.9 while the most fishes were captured at river mile 71.9. Most specimens per seine collection were taken in June while most fishes were caught in July. No species was taken in every month of the sampling period.

River Mile 72

The tidal Delaware near Penns Grove, New Jersey (river mile 72) was sampled by deSylva, et al. (1962). A total of 273 specimens of 15 fishes was taken. Five species comprised 92% of the total catch. These were, in order of decreasing abundance, white perch, bay anchovy, striped bass, mummichog and silvery minnow. Most fishes were taken in August, July and October.



MIDDLE SUBAREA
RIVER MILE 74 - 106

MIDDLE SUBAREA

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MIDDLE SUB-AREA

RIVER MILES 74 TO 106

The middle sub-area extends from Wilmington (river mile 74) to Frankford Creek in Philadelphia (river mile 106). From examining the 1954, 1956, 1958, 1960 and 1965 river surveys, it is estimated that 4,057 acres exist within this 32 mile stretch (Table 10). While this represents a net loss of 519 acres (11%) from the 4,576 estimated with the 1909 and 1932 surveys, there have been gains within the sub-area. These have occurred between river miles 73.2 and 87.3 with an estimated 588 acres created. These gains are negated by a loss of 1,107 acres bewteen river miles 87.3 and 105.8.

IMPACTS AND LAND USE

Twenty municipal treatment plants, six power plants and 44 other point source dischargers are located within the middle sub-area (Table 15). This represents approximately 55% of all dischargers within the entire study area. Due to these facilities, and others associated with the cities of Philadelphia, Camden, Chester, Marcus Hook, Paulsboro, and Palmyra, this river section is the most highly impacted within the study area. Much of the adjacent land areas has been filled and many structures such as piers, wharfs, bulkheads and docks are present. Along the shorelines little naturally vegetated area remains (Table 14). Small but important wetlands exist, however, on the eastern shoreline at river miles 83 to 86, 102, 103, and 106. Additional small patches exist along the upstream sections of small creeks found in this sub-area.

WATER QUALITY

As has been indicated, water quality within this section is poor. This area has DO levels consistently below those considered suitable for most organisms (Figure 9). While these conditions have improved in recent years, a serious dissolved oxygen problem still exists within this area. The area is characterized by very high oxygen demands (Figure 10; Table 7), high coliform concentrations (Figure 11) and reduced pH (Kiry, 1974). Temperatures in this reach are also generally on the order of 2°F higher than in the other sub-areas during all seasons. Concentrations of phenols, cadmium, nickel, iron, zinc, lead, aluminum and mercury often have been found to be above recommended safe levels (Tables 12 and 13). These levels are of special importance since the lower pH and DO, and high temperatures characteristic of this study area increase the toxicities of most of these metals.

RIVER MILE 74 TO 83

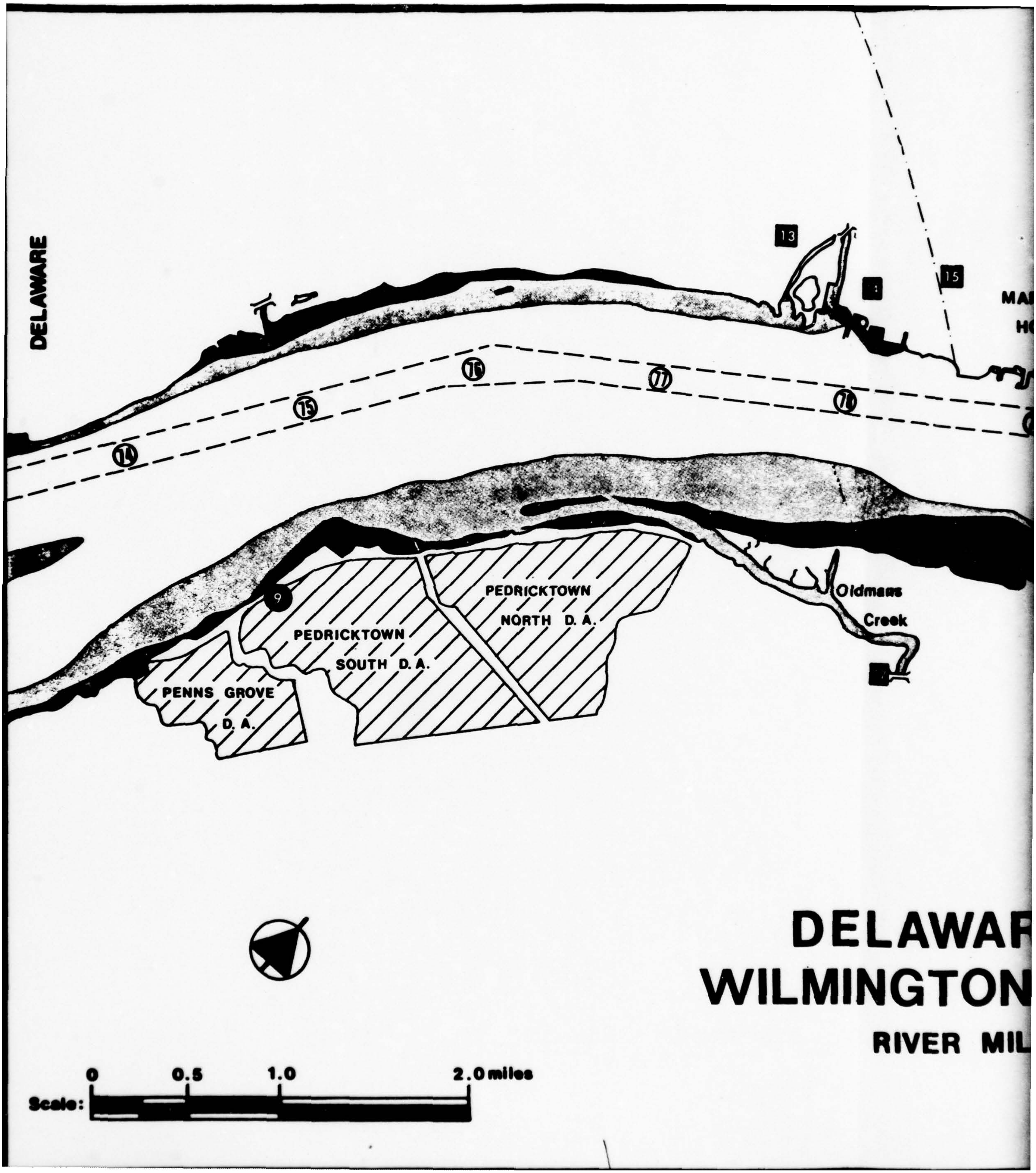
Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
9	Pedricktown Support Facility	5	NJ 0024635
10	Marcus Hook Borough	5	PA 0023884
11	City of Chester	4	--
▲	Power Plant		
4	Philadelphia Electric, Chester	4	PA 0011614
■	Other Point Source Discharge		
12	B. F. Goodrich, Oldmans Township	5	--
13	Phoenix Steel Corp.	5	DE 0000264
14	Allied Chemical Corp., Delaware	5	DE 0000655
15	Sun Oil Co., Sunolin	5	PA 0011096
16	Monsanto Chemical	4	NJ 0005045
17	FMC Corporation	4	PA 0011126
18	B.P. Oil Corporation	4	PA 0012637
19	Philadelphia Quartz	4	PA 0013021
20	Chester Processing	4	--
21	Reynolds Metals	4	PA 0012564

PHYTOPLANKTON

River Mile 81 (1968 and 1969)

Phytoplankton studies were conducted in 1968 and 1969 at river mile 81 (Patrick, 1973). The



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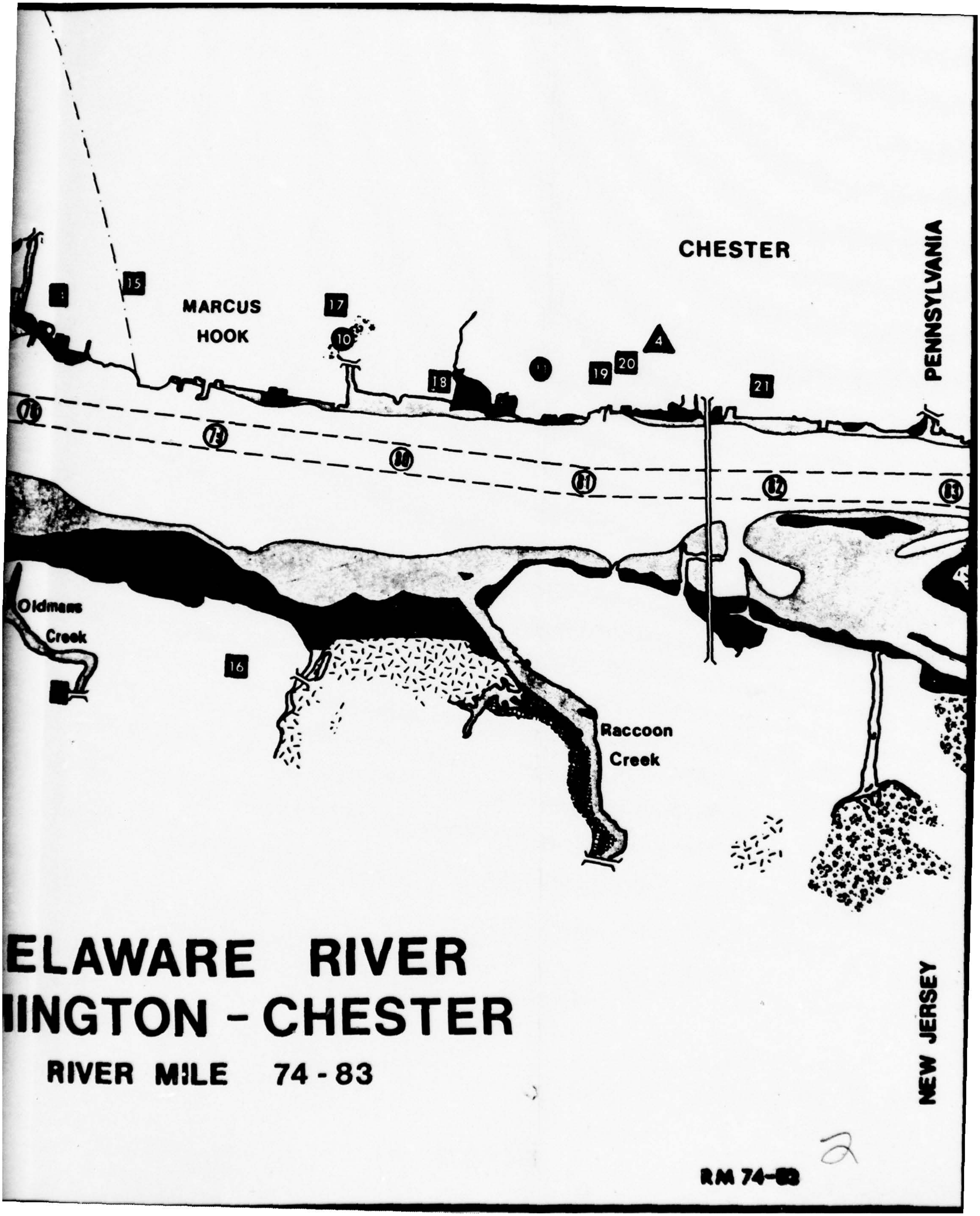
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Raccoon
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NEW JERSEY
ELAWARE RIVER
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RIVER MILE 74 - 83
RM 74-83
2

algae population was found to be extremely variable with more than 150 species present. Total population density varied from less than 10,000 to more than one million organisms per liter. Highest concentrations occurred in the late summer and early fall and again during early to late spring. Diatoms dominated phytoplankton counts, with green algae being the next most common group. The diatom flora was in itself dominated by a few species, which in nearly all cases represented more than 50 percent of the total diatom count. These species were Melosira ambigua, M. angustissima, M. distans and M. granulata.

ZOOPLANKTON

River Mile 81.2 (1976)

Rotatoria was the most abundant component (57.5%) of the zooplankton collected in pump samples at river mile 81.2 in 1976 with a mean annual density of 95,835/m^3 (PECo, 1977a). Rotifers ranked first in all four seasons and dominated the catch on 19 of 25 dates sampled. A total of 73 rotifer taxa was identified (Appendix Table 15). Three major peaks of rotifers occurred, the largest (601,400/m^3) occurred on 27 April. The second peak (180,000/m^3) was recorded on 12 July and the third peak (136,000/m^3) occurred on 20 September. Filinia longiseta was the most abundant rotifer collected in 1976 (26,071/m^3 mean annual density).

Eleven copepod taxa identified in 1976 comprised the second most abundant zooplankton component (PECo, 1977a) (25.3%). They exhibited a mean annual density of 42,125/m^3. Copepods dominated zooplankton samples on 4 of 25 collection dates, and ranked second in abundance in all seasons except winter. Combined copepod density reached two major peaks in 1976. The largest (149,400/m^3) occurred on 26 May. The second occurred on 12 July (131,000/m^3).

Cladocera was the third most abundant component (16.5%) with a mean annual density of 27,242/m^3 (PECo, 1977a). Twenty cladocera taxa were identified. Cladocerans dominated the catch on only two of 25 sampling days. Cladocerans ranked third in spring, summer and fall and last in winter. Combined cladoceran density reached two major peaks in 1976. The first peak (124,100/m^3) occurred on 7 June and the second (198,088/m^3) occurred on 12 July. Both were dominated by Bosmina longirostris.

Tychoplankton (macroinvertebrate drift) was the least abundant component (0.7%) of zooplankton, with a mean annual density of 1,264/m^3 (PECo, 1977a). It never dominated zooplankton samples, ranking third in winter and last in spring, summer and fall. Density varied and never exhibited a well defined peak. The greatest number (2,887/m^3) was recorded on 13 April. Nematodes were the most abundant component (mean annual density of 950/m^3).

BENTHOS

River Mile 80.5 to 81.2 (March to December 1973)

Potter et al. (1974a) reported that 26 species of benthic invertebrates plus 10 genera of midge larvae were collected in 1973 near Raccoon Island. These organisms are listed in taxonomic order in Appendix Table 16. Sludge worms (Tubificidae), leeches (Hirudinae), midge larvae (Chironomidae) and fingernail clams (Sphaeriidae) were the most numerous organisms taken at three stations throughout the year. The greatest taxonomic diversity was found in the family Tubificidae with 10 different species identified. Ten genera of midge larvae and five species of leeches were collected. The number of species collected at all stations varied greatly from April through August. Diversity peaked in September followed by a reduction in the number of species in October and November. At two stations, the highest number of species occurred in September and at the third in April. Limnodrilus hoffmeisteri, L. cervic and Aulodrilus limnobius were present in most samples. Helobdella stagnalis and Mooreobdella fervida were the only leeches that were numerous. Midge larvae showed no seasonal or spatial distribution patterns in 1973.

River Mile 81.2 (1976)

Three hundred thirty-one (331) blue crabs were taken on industrial screens at river mile 81.2 during 1976 (PECo, 1977a). Those caught during the summer represented 51% of the total.

ICHTHYOPLANKTON

River Mile 80.3 to 81.3 (1973)

Potter et al. (1974a) collected 143 specimens of larval fish between river miles 80.3 and 81.3 from 14 June to 17 July. Herrings, minnows, temperate basses and sunfishes were the only families collected. Most specimens (n=92) were captured on 3 July.

River Mile 81 (1976)

Fish eggs were collected only on 28 May 1976 and fish were collected in ichthyoplankton samples from 13 April through 27 July (PECo, 1977a). River herring larvae were collected from 5 May through 14 July. Larvae of temperate basses were collected from 13 May through 27 July. Young American eel were collected from 13 April through 14 July. Minnows were collected from 13 May through 15 June. One carp was taken on 28 May and one goldfish on 5 May. Combined density of all species was greatest from 5 May through 15 June. Estimated density of larval and young fishes by month were 2.23/100 m^3 for April, 24.87/m^3 for May, 10,19/100 m^3 for June, 0.86/100 m^3 for July and 0.00/100 m^3 for August.

Relationships between ichthyoplankton density and enviornmental factors were tested. Collection density was positively correlated with mean dissolved oxygen content of the water (PECo, 1977a).

River Mile 82.0 to 86.0 (1973)

Potter et al. (1974b) sampled the Delaware River near Eddystone from March through August,

1973. No eggs were taken. Specimens were collected from 16 May through 17 July. Herrings were the most common fishes taken and accounted for 60.3% (266 specimens) of the total collected. Members of four other families; temperate basses (29.9%, 132 specimens), minnows and carp (7.9%, 35 specimens), sunfishes (1.4%, 6 specimens) and killifishes (0.5%, 2 specimens) were also collected. Most herrings and temperate basses were taken on 3 July.

River Mile 82.0 to 86.0 (1974)

Harmon and Smith (1975) reported that larval fish were taken from late April through mid-July and were most numerous in May. Herrings, the most abundant fishes taken, accounted for 80.9% (2,236 specimens) of the total. Minnows and carp (17.8%) were the second most numerous. Collection results are given in Appendix Table 17.

OTHER FISHES

River Mile 80.4 to 80.9 (March to December 1973)

A total of 1,995 specimens of 27 fishes was taken in 60 collections at three Delaware River (river mile 80.4 to 80.9) seine stations from March to December, 1973 (Potter et al., 1974a). The silvery minnow (49.8% of the total catch) was the most abundant species. Other frequently captured fishes included mummichog (21.7%), banded killifish (8.5%), blueback herring (7.9%), tidewater silverside (2.6%) and satinfin shiner (2.6%). These six fishes accounted for 93.2% of the total catch.

Collections along the New Jersey shore at river mile 80.9 yielded 279 specimens of 15 fishes. The silvery minnow, blueback herring (young) and mummichog were about equal in abundance and composed 80.6% of the catch. Young blueback herring, alewife, white perch, bluegill, large-mouth bass and white crappie were taken in July and August. One young striped bass was taken in August.

A total of 643 specimens of 15 fishes was taken along the New Jersey shore at river mile 80.4. This was the most productive seine station. The silvery minnow (50.1% of the catch), the mummichog (21.6%), banded killifish (13.4%) and blueback herring (4.8%) were most common. Young of blueback herring, alewife, white perch, largemouth bass, white crappie and black crappie were taken in July and August. One young striped bass was taken in early July.

At river mile 80.9 in Pennsylvania a total of 440 specimens of 14 fishes was taken. The silvery minnow (62.3% of the catch), mummichog (20.5%), American eel (6.6%) and banded killifish (5.5%) were most common. Fish were taken throughout the sampling period, but most were collected in August.

River Mile 80.4 to 80.9 (1974)

Forty-four collections from the Delaware River (river mile 80.4 to 80.9) yielded 2,401 specimens of 14 fishes (Didun and Harmon, unpublished). Clupeids (1,250 specimens, 52.1% of the seine catch), blueback herring (667, 27.8%), silvery minnow (201, 8.4%), cyprinids (100, 4.2%), mummichog (83, 3.5%) and banded killifish (68, 2.8%) were the most abundant fishes and comprised 98.7% of the seine catch. Most fish were collected in summer; this peak corresponded with the occurrence of young.

Seine sites along the New Jersey shore at river mile 80.4 and 80.9 yielded the greatest number of specimens, whereas the site at river mile 80.9 along the Pennsylvania shore yielded the least number of specimens. However, the seine sites were not comparable on the basis of habitat (Didun and Harmon, unpublished).

Fishes taken in 1973 and 1974 from this study area are listed in Appendix Table 18.

River Mile 81.2 (1976)

At river mile 81.2 a total of 14,325 fish representing 30 species, one genus and one minnow hybrid was collected on industrial screens in 1976 (Appendix Table 19) (PECo, 1977a). Silvery minnow (4,278 specimens), spot (4,020), white perch (3,534), alewife (868), gizzard shad (511), blueback herring (468) and *Alosa* species (176) ranked first through seventh, respectively, in numerical abundance and together comprised 97% of the total number and 89% of the total weight.

The number of fish collected in the winter of 1976 was low. Silvery minnow (231), gizzard shad (76) and white perch (71) dominated the catch and together accounted for 92% of the number and 80% of the biomass collected in winter.

In spring, silvery minnow (1,241) ranked first in numerical abundance, accounted for 80% of the total number and 76% of the total weight. White perch (109), alewife (60), blueback herring (44) and brown bullhead (17) represented an additional 15% of the catch. The number of fish collected increased from 307 on 27 April to 917 on 11 May and dropped to 109 on 27 May. This peak reflected an increase in silvery minnow that may be the result of spawning migrations due to suitable water temperature (Raney, 1939).

In summer, spot (1,243) ranked first in numerical abundance, accounting for 53% of the total number and 39% by weight. Alewife (335 specimens), white perch (262), blueback herring (81), brown bullhead (80) and Atlantic menhaden (49) made up an additional 36% of the fish collected. On 13 September, 770 spot were collected. Only 11 spot were collected for the entire month of August.

In fall 1976, white perch ranked first in numerical abundance (2,994) and represented 30% of the total catch. Spot (2,777) and silvery minnow (2,759) made up an additional 55% of the catch. Migratory fish made up 70% of the fish collected. Two American shad, one bluefish, three striped bass and one Atlantic croaker were also collected in the fall. On 27 September, the largest number of specimens (2,053) for the year was collected; spot (1,489) made up the major portion of the catch.

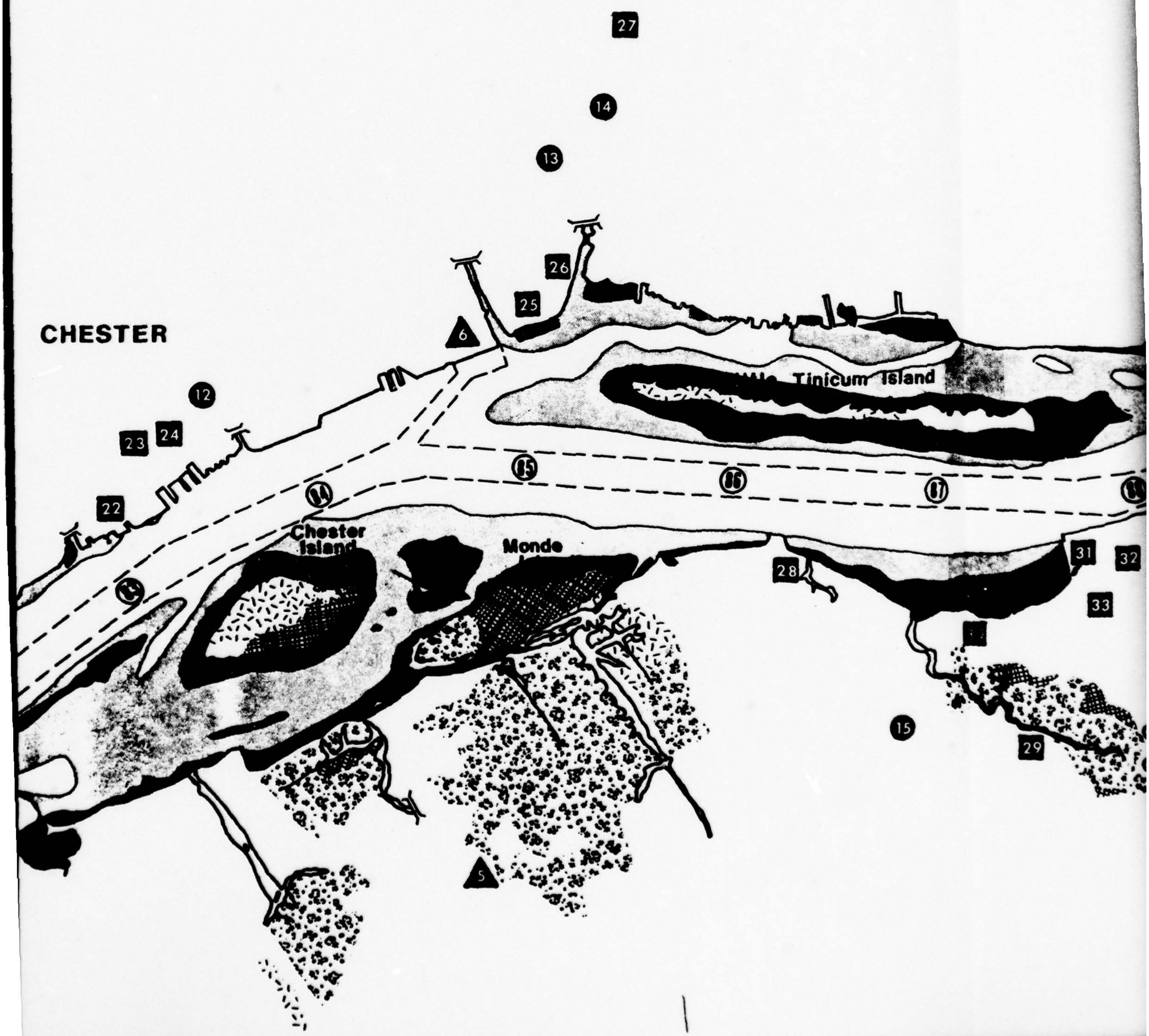
RIVER MILE 83 TO 92

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
12	Eddystone Borough	4	PA 0028355
13	Central Delaware Sewerage Authority	4	PA 0025925
14	Tinicum Township	4	PA 0028380
15	Gibbstown, Greenwich Township	4	--
16	Gloucester County Sewerage Authority	4	NJ 0024686
17	Philadelphia Southwest Water Pollution Control Plant	4	PA 0026671
18	Philadelphia Water Dept., Old Fort Mifflin Sewage Plant	4	--
19	Fort Mifflin	4	--
20	Gulf Oil Co., Sanitary Waste	4	PA 0011533
▲	Power Plant		
5	Atlantic City Electric, Greenwich	4	--
6	Philadelphia Electric, Eddystone	4	--
■	Other Point Source Discharge		
22	Scott Paper Co., Chester	4	PA 0013081
23	Scott Paper Co. (Foam Division)	4	PA 0013137
24	Sun Shipbuilding	4	PA 0012939
25	General Steel Indus.	4	--
26	Union Carbide	4	PA 0013556
27	Westinghouse	4	PA 0012734
28	E.I. duPont de Nemours & Co., Repauno Works	4	NJ 0004219

DELAWARE RIVE
CHESTER - PHILADEL

RIVER MILE 83-92



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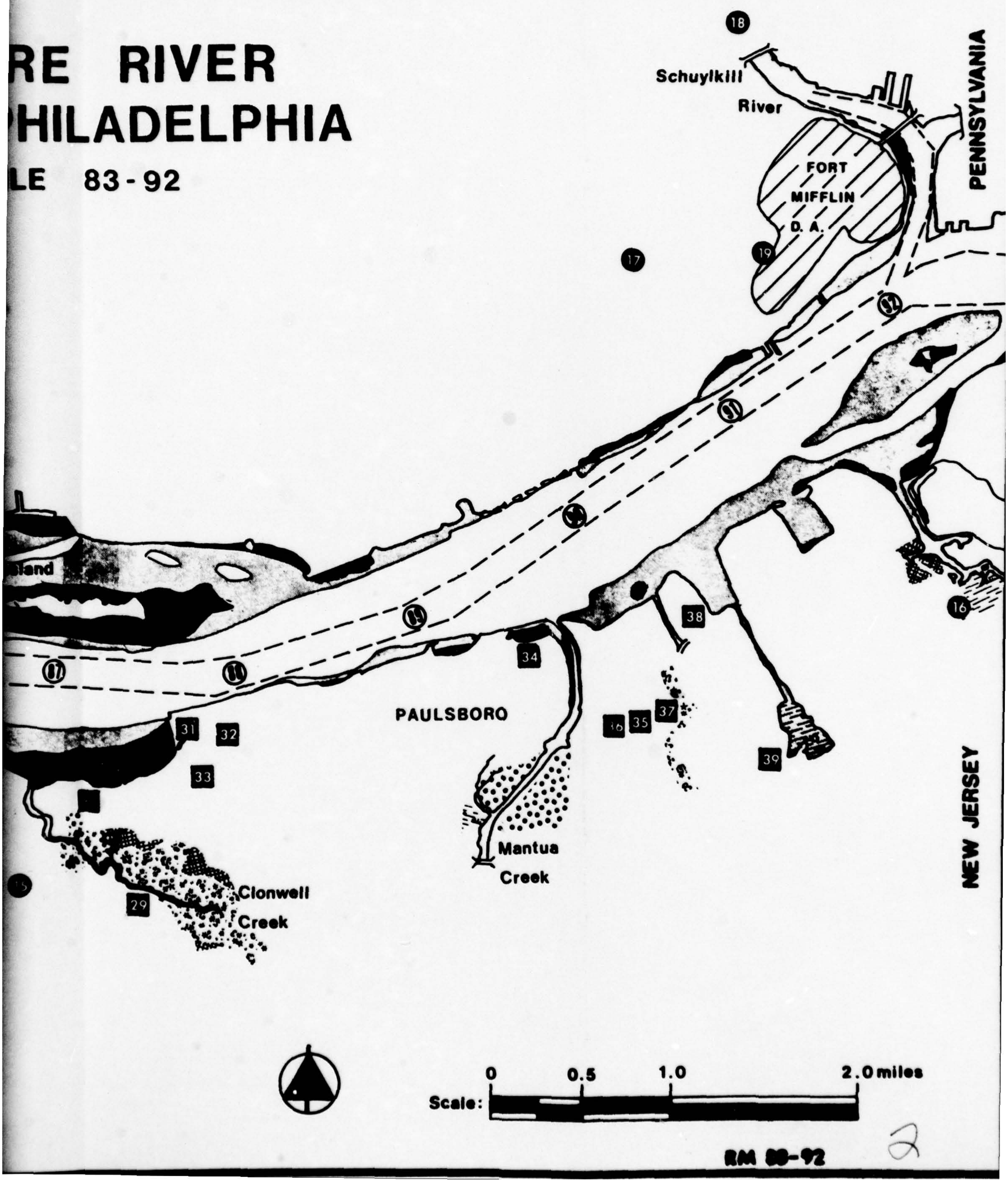


RIVER MILE 83 TO 92

Point Source Impacts

(Cont'd.)

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
■ Other Point Source Discharge (continued)			
29	Air Products and Chemical Company	4	NJ 0004278
30	Hercules, Inc., Gibbstown	4	NJ 0005134
31	Exxon Company	4	NJ 0004197
32	Essex Chemical Corp.	4	NJ 0005355
33	Mobil Oil Corp.	4	NJ 0005029
34	B.P. Oil, Paulsboro	4	NJ 0005584
35	Olin	4	NJ 0005088
36	Paulsboro Products		--
37	Shell Chemical Co.	4	NJ 0000400
38	Pennwalt, W. Deptford	4	NJ 0005185
39	ARCO, W. Deptford	4	NJ 0023230

Phytoplankton

River Mile 83.7 to 85.2 (1973)

Fifty-nine genera of algae were recorded from four sampling stations in the Delaware River (river mile 83.7 to 85.2) in 1973 (Potter et al., 1974b). High numbers of algal genera were observed more commonly during the summer than throughout the remainder of the year. Green algae of the families Volvocales and Chlorococcales were found more commonly during the summer and early fall than during the rest of the year. Algae of the phylum Euglenophyta were more common during the warmest months.

The filamentous diatom Melosira was the alga most commonly found in the plankton samples (Potter et al., 1974b). The three centric diatoms Melosira, Coscinodiscus and Cyclotella were found in all except one of the plankton samples taken in 1973. The green alga Pediastrum was common in the October and November samples, and Staurastrum was common in July. Asterionella was abundant in the May and December samples, but was not observed at all in August, September and October. The diatom Fragilaria was common in July samples. Microcystis was the only blue-green alga to appear as a major part of the plankton and was common in the August samples.

River Mile 83.8 to 84.8 (1974)

Fifty-eight genera of phytoplankton were recorded from two sampling stations (river mile 83.8 to 84.8) in 1974 (Harmon and Smith, 1975). Phytoplankton was dominated by Chrysophyta (diatoms), Chlorophyta (green algae) and Cyanophyta (blue-green algae), with the diatoms being the most abundant. The diatoms encountered in large numbers were the true planktonic forms: Melosira, Cyclotella, Stephanodiscus and Asterionella. Benthic diatoms occurred in relatively small numbers. Melosira varians was the most common taxa. It was present in the Delaware River year-round and was particularly abundant in May. Asterionella formosa was common from February through May. It reappeared in large numbers in October and was common through December. Chlorophyta was the second most abundant group and was particularly abundant from May through November. Common genera included Ankistrodesmus, Selenastrum, Scenedesmus, Pediastrum and Microspora. Microspora was very abundant in September and October, but less numerous in the winter. Oscillatoria and Anabaena were the only abundant blue-green algae collected. They were common only during the summer.

Schuylkill River (June 1975 to September 1976)

Data are available for the tidal Schuylkill River (river mile 92.5, 6.5) from June 1975 through September 1976 (PECo, 1977e).

ZOOPLANKTON

River Mile 83.7 to 85.2 (1973)

Rotifers dominated the zooplankton community at four sampling stations in the Delaware River (river mile 83.7 to 85.2) and were most abundant during the summer months (Potter et al., 1974b). Seven genera of rotifers were observed during 1973, with Keratella and Brachionus the most common. Cyclopoid copepods and the cladoceran Bosmina were found in most samples.

River Mile 83.8 to 84.8 (1974)

Fifteen genera of zooplankton were identified from two sampling stations (river mile 83.8 to 84.8) in 1974 (Harmon and Smith, 1975). Rotifers were the dominant zooplankters. Seven genera of rotifers were identified; Brachionus and Keratella were most abundant. Cyclopoid copepods and the cladoceran Bosmina were also found in a majority of the samples.

Schuylkill River

Data are available for the tidal Schuylkill River (river mile 92.5, 6.5) from July 1975 through September 1976 and from September 1975 through September 1976 (PECo, 1977e, 1977f, respectively).

BENTHOS

River Mile 84 (1972)

A limited study of the benthos near Eddystone was conducted in 1972 (Potter and Harmon, 1973). It was reported that worms (Tubificidae) were abundant in the collections. Few other organisms were taken. A list of organisms observed is given in Appendix Table 20.

Limnodrilus hoffmeisteri, *L. cervix* and *Aulodrilus limnobius* and three species of Tubificidae, were present in most samples throughout the year (Potter et al., 1974b). Of the six species of leeches collected, only two, *Helobdella stagnalis* and *Mooreobdella fervida* were found during most months of the year. Only midge larvae of the genus *Procladius* occurred commonly. The fingernail clam, *Sphaerium straitinum*, was present only at two stations from June through December. Other species of macroinvertebrates were infrequently collected and showed no definite trends in occurrence.

River Mile 83.0 to 85.5 (1973)

Potter et al. (1974b) reported that 21 species of benthic invertebrates plus seven genera of midge larvae were collected from the Delaware River (river mile 83.0 to 85.5). Organisms are listed in taxonomic order in Appendix Table 21. Tubificid worms, leeches, midge larvae and fingernail clams comprised most of the organisms taken at three stations in 1973. The greatest taxonomic diversity was found in the family *Tubificidae*; ten different species were collected and identified. Midge larvae (Chironomidae) were represented by seven genera and leeches (Hirudinae) by six species. Little variation occurred in the number of species collected from March through May.

Based on ten months of sampling data, the species diversity of the benthos in the study area appeared to be quite low. The low species diversity of the benthic community was probably due to the rather high degree of organic and industrial pollution in this portion of the river (Potter et al., 1974b).

River Mile 83.0 to 85.5 (1974)

At river mile 83.0 to 85.0 the benthic fauna was characterized by few taxa, large numbers of Oligochaeta and Hirundinea relative to other taxa and a paucity of insect life (Harmon and Smith, 1975). Twenty-three taxa were collected at three sampling stations in 1974 (Appendix Table 22). Slightly over 50% of the taxa were Oligochaeta (primarily Tubificidae) and Hirudinea; only five taxa of Insecta were taken. The number of taxa collected at each sampling station ranged from 10 to 12. Only three species were common to all stations: Limnodrilus cervix, L. hoffmeisteri and Erpobdella punctata.

ICHTHYOPLANKTON

See above, RIVER MILE 74 TO 83, for a summary of ichthyoplankton from river mile 82.0 to 86.0 in 1973 and 1974.

Schuylkill River

Data are available for the tidal Schuylkill River (river mile 92.5, 6.5) from September 1975 through August 1976 (PECo, 1977e).

OTHER FISHES

River Mile 82.0 to 87.5 (June to October 1971)

Bason (1971b) reported 25 fishes were taken in 113 seine collections at seven sites in the Delaware River (river mile 82.0 to 87.5) from June to October 1971. Mummichog (48.1), pumpkinseed (14.4%), blueback herring (8.3%), brown bullhead (8.2%), banded killifish (8.1%) and silvery minnow (6.4%) together comprised 93.5% of the total catch (Appendix Table 23). Mummichog was common at all seine stations; adults and young were taken. Most pumpkinseed (90.7%) were taken at the eastern end of Little Tinicum Island at river mile 87.5. Spawning "nests" were observed at this site. All blueback herring taken were juveniles. They were often found in large concentrations during July and September in the ponds on Little Tinicum Island (river mile 87.5). Over 99% of the brown bullhead captured were taken on Little Tinicum Island; of these, about 90% were from several "schools" of young observed in early July. About 89% of the banded killifish were taken from the island (river mile 87.4 and 87.5). Young and adult silvery minnow were taken.

River Mile 82.0 to 87.5 (1972)

A total of 4,743 specimens of 31 fishes and a Lepomis hybrid was taken in 118 collections at the seven seine stations (river mile 82.0 to 87.5) from January through December 1972 (Potter and Harmon, 1973) (Appencix Table 24). The mummichog (59.4% of the total catch), banded killifish (18.3%), pumpkinseed (9.1%) and silvery minnow (7.8%) accounted for 94.6% of the total catch. These species were taken at all river seine stations and were the most common fishes at most stations. The white perch (0.6% of the catch) was the only other species taken at all sites.

A total of 385 specimens of 13 species was taken at river mile 83.7 on Chester Island. The mummichog (55.1% of the catch at this station) was the most abundant species; it was taken in every collection from April through November. The silvery minnow (27.8%) and banded killifish (9.4%) were commonly found except in late summer when few fish were taken.

Collections at the mouth of Crum Creek in Pennsylvania (river mile 84.8) yielded 1,237 specimens of 12 fishes. This was the second most productive site in number of specimens, but a single species, the mummichog, represented 93.2% of the catch. Few or no fish were taken in collections from July to October.

A total of 329 specimens of 14 fishes was taken on Little Tinicum Island (river mile 85.6). Mummichog (78.7% of the catch), silvery minnow (10.9%) and banded killifish (3.3%) were the most common species. The mummichog was taken in every collection but one.

On Little Tinicum Island at river mile 87.4, 1,147 specimens of 13 fishes were collected. The three most abundant species were the mummichog (49.8% of the catch), banded killifish (37.8%) and silvery minnow (7.2%). The mummichog was taken in every collection, and the banded killifish in all but one collection.

A total of 1,413 specimens of 25 fishes, the greatest diversity found at any station, was taken on Little Tinicum Island (river mile 87.5). Greater numbers of species and specimens per collection were generally taken here than at other seine sites. The mummichog (35.8%), banded killifish (26.0%), pumpkinseed (23.7%) and silvery minnow (5.8%) were most common. The tidal pools apparently provided a more suitable year-round habitat for fishes, particularly for dissolved oxygen. Several sunfish nests were observed, and more young of the silvery minnow, brown bullhead, mummichog, pumpkinseed, bluegill and largemouth bass were taken at this site than at any other (Potter and Harmon, 1973).

A total of 128 specimens of nine fishes was collected at Monde Island (river mile 85.4). Eight collections yielded no fish and over half of the specimens captured at this station were taken in one collection. Fishes were taken infrequently and were scarce throughout most of the year. Mummichog (68.8%), silvery minnow (12.5%) and banded killifish (9.4%) were the most abundant. The low catch may be due to the affects of a chemical effluent that is discharged near the seine station (Potter and Harmon, 1973).

Seine collections in New Jersey at river mile 82.0 yielded 104 specimens of 11 fishes. The silvery minnow, alewife (young) and mummichog were nearly equal in abundance and represented 87.5% of the total catch. Few species and specimens were taken throughout most of the year and no fishes were taken in four of the six collections made from September through November.

River Mile 82.0 to 87.5 (1973)

A total of 7,484 specimens of 36 fishes was taken in 181 collections at the seven river seine sites (river mile 82.0 to 87.5) from January through December 1973 (Potter et al., 1974b). The mummichog (43.0% of the total catch) was the most abundant species captured at every site (Appendix Table 25). Other species taken at every site were banded killifish (21.3% of the total catch), silvery minnow (20.4%), spottail shiner (0.5%) and white perch (0.4%). Pumpkinseed was fourth in total abundance (6.6%), but most specimens came from Little Tinicum Island (river mile 87.5).

A total of 947 specimens of 18 fishes was taken at Chester Island (river mile 83.7). The silvery minnow (45.8% of the catch) and mummichog (34.3%) were the most abundant fishes and were taken regularly from April through September. Few specimens were taken prior to April, and the most fishes and specimens were collected in August.

Collections at the mouth of Crum Creek yielded 1,036 specimens of 16 fishes. The mummichog accounted for 91.8% of the catch and was taken regularly from March through December.

A total of 1,156 specimens representing 19 fishes was taken on Little Tinicum Island (river mile 85.6). The mummichog (60.3% of the catch), banded killifish (23.6%) and silvery minnow (11.8%) were the most abundant. Fishes were most common from June through August.

On Little Tinicum Island (river mile 87.4) 1,338 specimens representing 17 fishes were collected. The mummichog (48.2% of the catch) was the most abundant species and was taken regularly from March through December. Banded killifish (32.5%) and silvery minnow (12.3%) were common.

A total of 2,125 specimens of 27 fishes, the greatest diversity found at any station, was taken on Little Tinicum Island (river mile 87.5). The greatest numbers of species and specimens taken at any seine site were usually taken here. The banded killifish (33.7% of the catch), pumpkinseed (22.3%), mummichog (18.0%) and silvery minnow (13.6%) were the most common species.

A few sunfish "nests" were observed during the summer months; more young fish were captured here than at any other station.

A seine site located on Monde Island (river mile 85.4) was the least productive station sampled; 249 specimens of 15 fishes were collected. The mummichog (71.5% of the catch), silvery minnow (10.4%) and banded killifish (5.6%) were the most numerous fishes. Most specimens were captured from May through July; few fish were captured during the remainder of the sampling period. A nearby chemical discharge may have caused fishes to avoid this area (Potter et al., 1974b).

A total of 633 specimens of 18 fishes was taken at river mile 82.0 in New Jersey. The silvery minnow (71.9% of the catch) was the most abundant species. The mummichog (6.5%) and banded killifish (3.5%) were frequently taken. Young herrings (65 blueback herrings and 17 alewife) were more common at this site than at any other.

River Mile 83.7 to 87.5 (1974)

Twenty-three fishes and 3,708 specimens were taken in 55 seine collections at five sites in the Delaware River (river mile 83.7 to 87.5) in 1974 (Harmon and Smith, 1975). The mummichog (62.7% of the total catch) and banded killifish (23.6%) were the most abundant fishes and were taken at every seine site (Appendix Table 26).

The site on Little Tinicum Island at river miles 87.5 had the most diverse ichthyofauna. Goldfish, carp, swallow-tail shiner, brown bullhead, green sunfish, bluegill, large-mouth bass and black crappie were taken only at this site. The fewest fishes (4) were collected on Little Tinicum Island at river mile 87.4, but only eight collections were made here due to thick silt which at times made seining nearly impossible. The 11 or 12 collections made at other stations yielded six to ten fishes. The average number of specimens per collection was lowest (27.5) on Chester Island (river mile 83.7). The values in the mouth of Crum Creek (52.3), west end of Tinicum Island (57.5) and east end of Tinicum Island at river mile 87.4 (63.0) agreed well. The site on Tinicum Island at river mile 87.5 yielded an average of 141.45 specimens per collection.

Seasonal variation in seine catch was reported; few specimens were taken in winter and the catch increased from spring through fall. Seine catch per collection increased greatly in the fall when young fishes entered the seine catch.

Schuylkill River

The fishes of the Schuylkill River (near river mile 92.5, 6.5) were studied by Ichthyological Assocites, Inc., from 1971 to 1976 (PECo, 1977e, 1977f).

Schuylkill River, Fairmount Dam

Until construction of dams in the early 19th century, American shad annually migrated in the spring from the Atlantic Ocean through the Delaware Estuary as far as Pottsville, Pennsylvania, on the Schuylkill River, 120 miles from its confluence with the Delaware River (Hobbs and Mulfinger, 1978). The Pennsylvania Fish Commission initiated a four year study of the feasibility of restoring shad to the Schuylkill. This study, completed in 1976, revealed that American shad and other fishes were present below the Fairmount Dam nine miles above the Delaware Rvier. Water quality evaluations indicated that no adverse effect on restoration could be expected as far upriver as the Felix Dam (river mile 92.5, 79) and possibly to the New Kernsville Dam (river mile 92.5, 100). As a result of the study, the commission requested the City of Philadelphia, owner of the Fairmount Dam, to construct a fish passage facility in compliance with Pennsylvania law. In 1976 and 1977, the project was designed and plans and specifications prepared for a vertical slot fishway designed to pass up to 200,000 American shad seasonally.

The City of Philadelphia began construction of the fishway in November 1977. Construction is being performed by public contract administered by the city and is expected to be completed and in operation in the spring of 1979.

BIRDS

River Mile 82 to 86

Potter and Harmon (1973) noted that herring gulls were common throughout the year near river mile 85. Canada goose, scaup and other ducks were common during the fall.

Bason (1971b) noted that herring gulls were observed during the summer and fall and were most abundant near the New Jersey shore at river mile 82. Large flocks of sandpiper sighted in late summer and early fall were most common on Tinicum Island. Black duck and mallard were observed on Tinicum Island. Large rafts of scaup occurred on the flats along the New Jersey shore during the fall.

River Mile 85.2

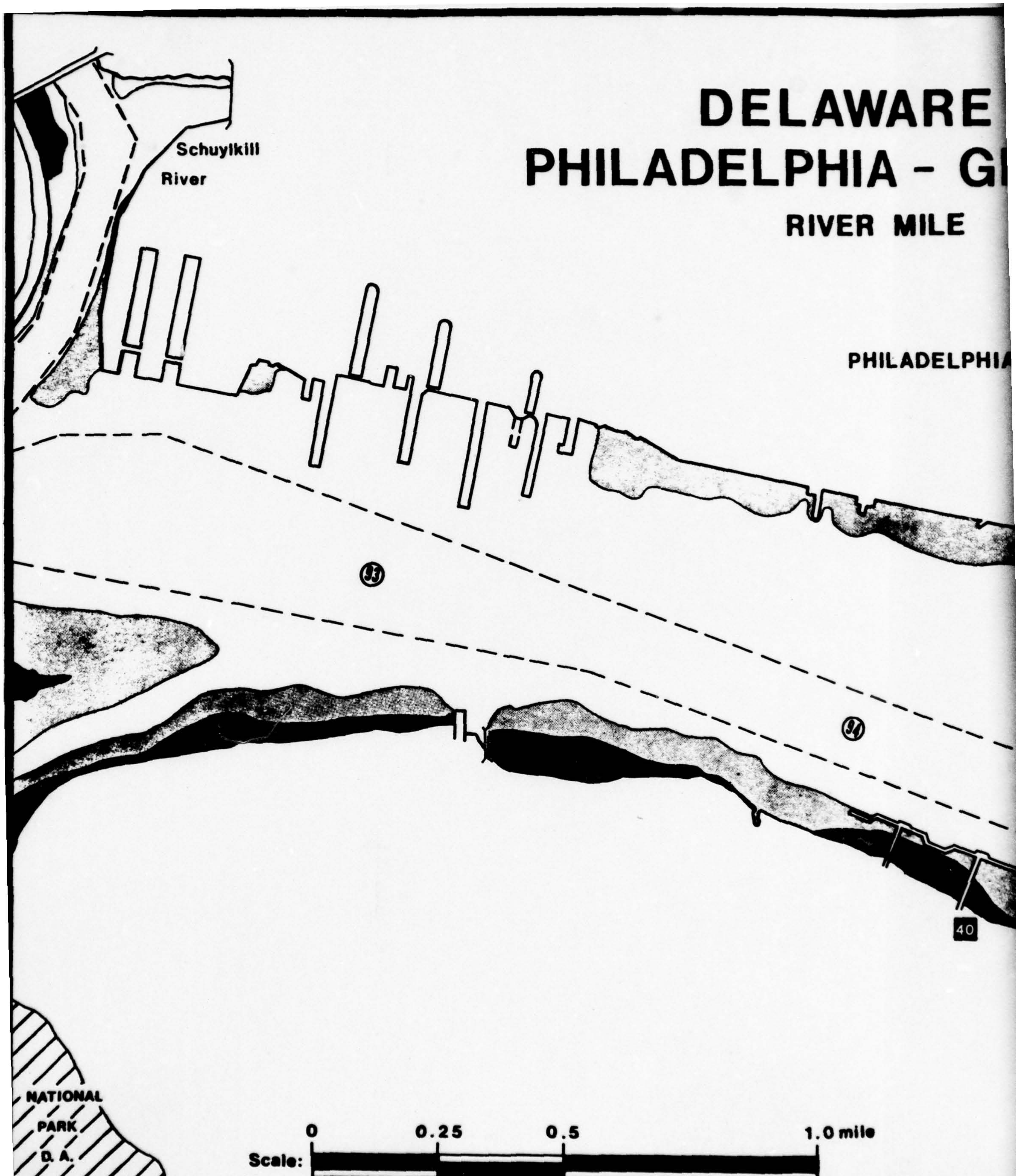
At Tinicum Marsh (river mile 85.2), a total of 296 species of birds have been identified, 119 species of which are waterfowl and shorebirds (McCormick, 1970). The Delaware River Valley is an important migratory route for various birds which pass through the area in spring and fall. The most numerous migratory ducks include teal, merganser and scaup. Mallard and black duck are year-round residents. The area also supports a variety of herons, sandpipers and related birds. Birds which are common nesters in the vicinity include mallard, black duck, green heron and black-crowned night heron. Several species of hawks pass through during migration.

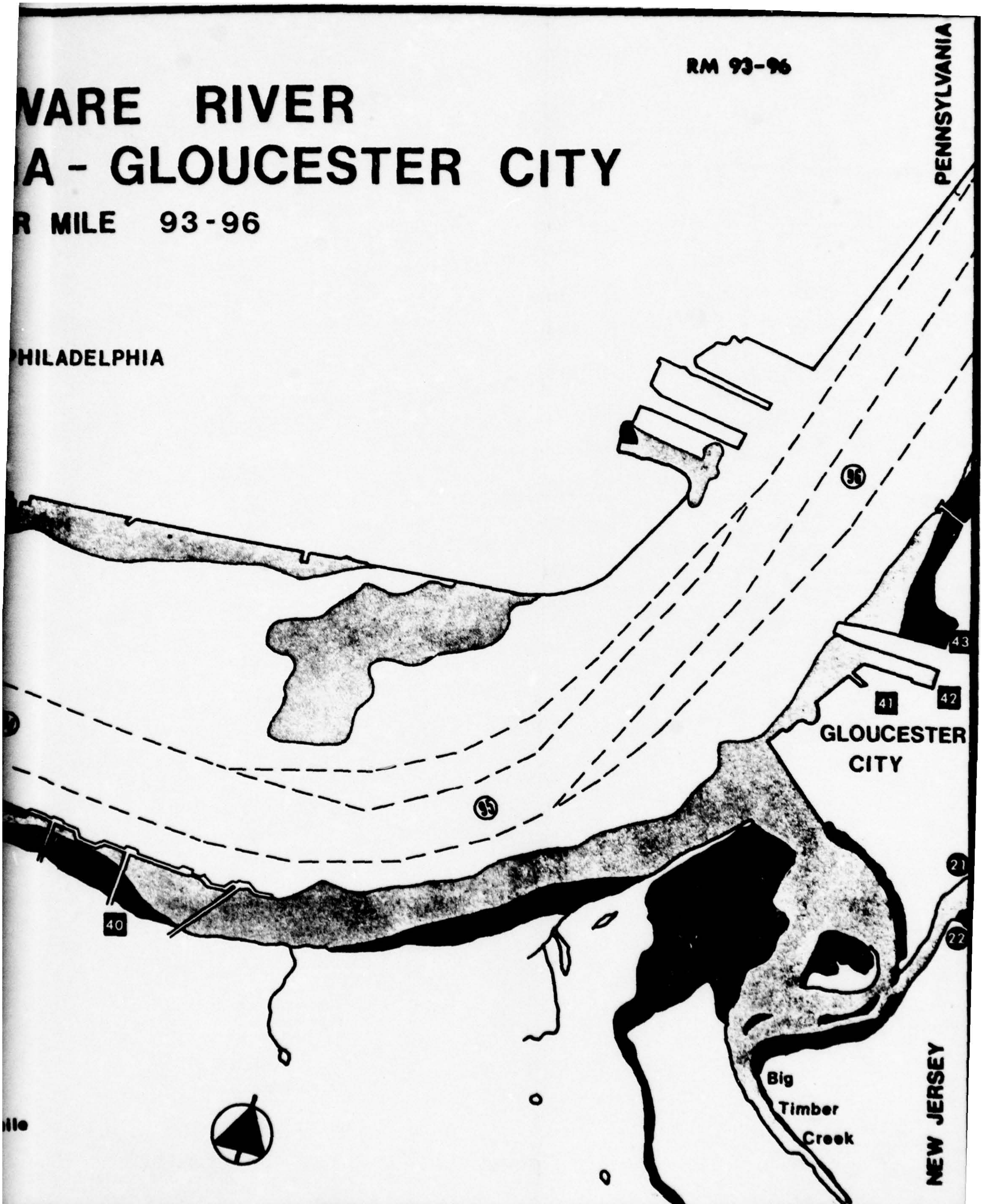
OTHER VERTEBRATES

Sixteen species of mammals have been identified in the region of Tinicum Marsh with more than half of them being rodents (McCormick, 1970). Bason (1971b) recorded bullfrog tadpoles, muskrat and raccoon on Little Tinicum Island. He also observed one garter snake swimming in the river near Chester Island and deer tracks on the Chester Island beach.

RIVER MILE 93 TO 96
Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
21	Brooklawn Borough	3	NJ 0022748
22	Gloucester City	3	NJ 0026620
■	Other Point Source Discharge		
40	Texaco, Inc.	4	NJ 0005401
41	New Jersey Zinc	3	NJ 005061
42	Harshaw Chemical	4	NJ 005495
43	GAF Corporation	3	NJ 0005371


DELAWARE
PHILADELPHIA - G
RIVER MILE
Schuylkill
River
PHILADELPHIA
93
94
40
NATIONAL
PARK
D. A.
0
0.25
0.5
1.0 mile
Scale:


RM 93-96
WARE RIVER
A - GLOUCESTER CITY
R MILE 93-96
PENNSYLVANIA
PHILADELPHIA
95
95
40
41
42
43
21
22
GLOUCESTER CITY
Big Timber Creek
ille
NEW JERSEY

RIVER MILE 97 TO 99

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
23	Phila. Southeast Water Pollution Control Plant	3	PA 0026662
24	City of Camden, Main Plant	3	NJ 0026132
▲	Power Plant		
7	Philadelphia Electric, Southwark	3	--
■	Other Point Source Discharge		
44	Publicker Industries, Incorporated	3	PA 0013315
45	New York Shipbuilding		
46	MacAndrews & Forbes Co.	3	NJ 0004090
47	Amstar Corporation	3	PA 0011509

ZOOPLANKTON

River Mile 97.5 (1976)

Rotatoria was the most abundant component (64.6%) of the zooplankton with a mean annual density of 112,128/m^3 (PECo, 1977b). Rotifers ranked first in all four seasons. Rotifer density reached two major peaks in 1976. The first (284,650/m^3) occurred on 3 May and the second and largest peak (405,500/m^3) was recorded 14 June.

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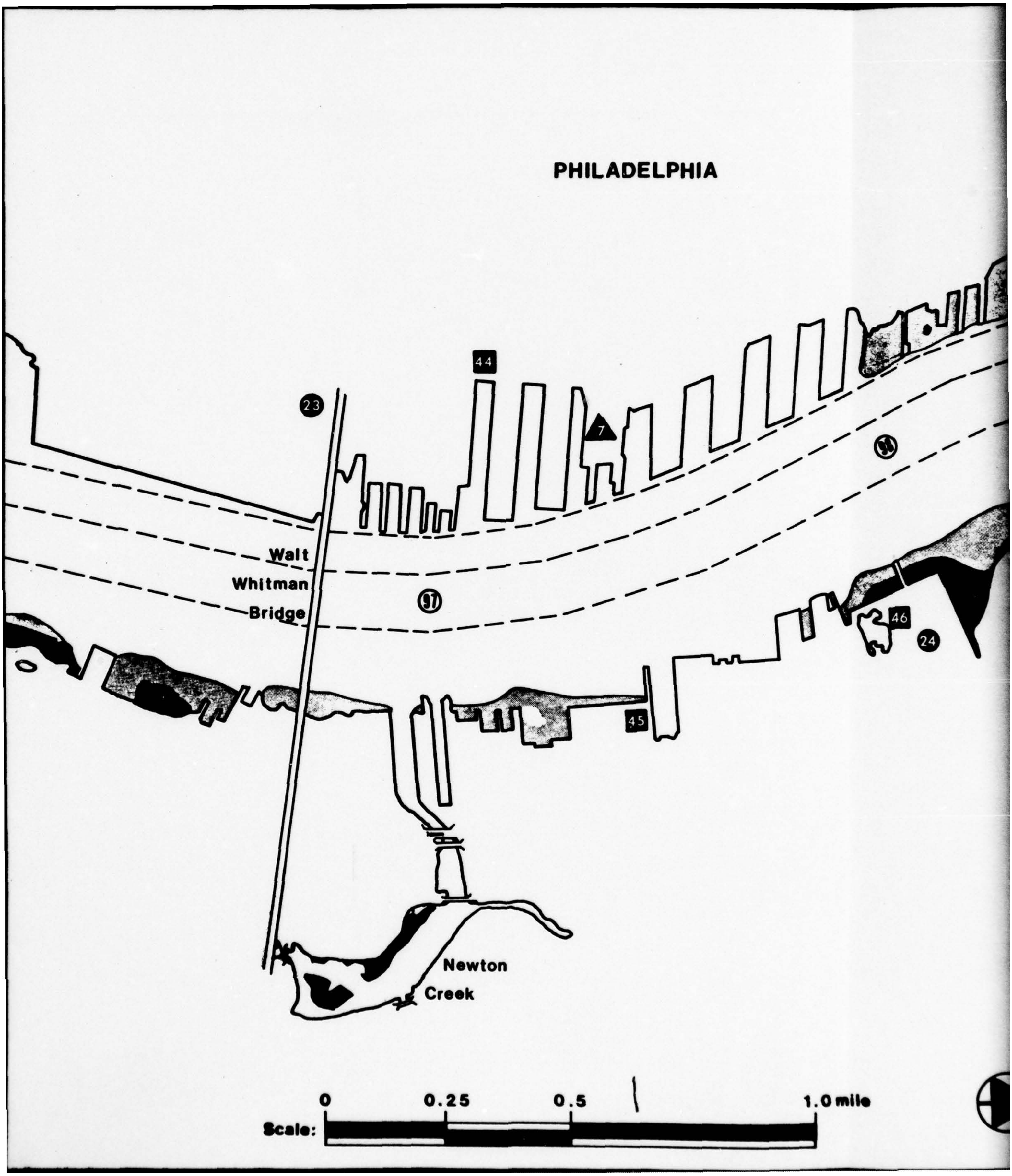
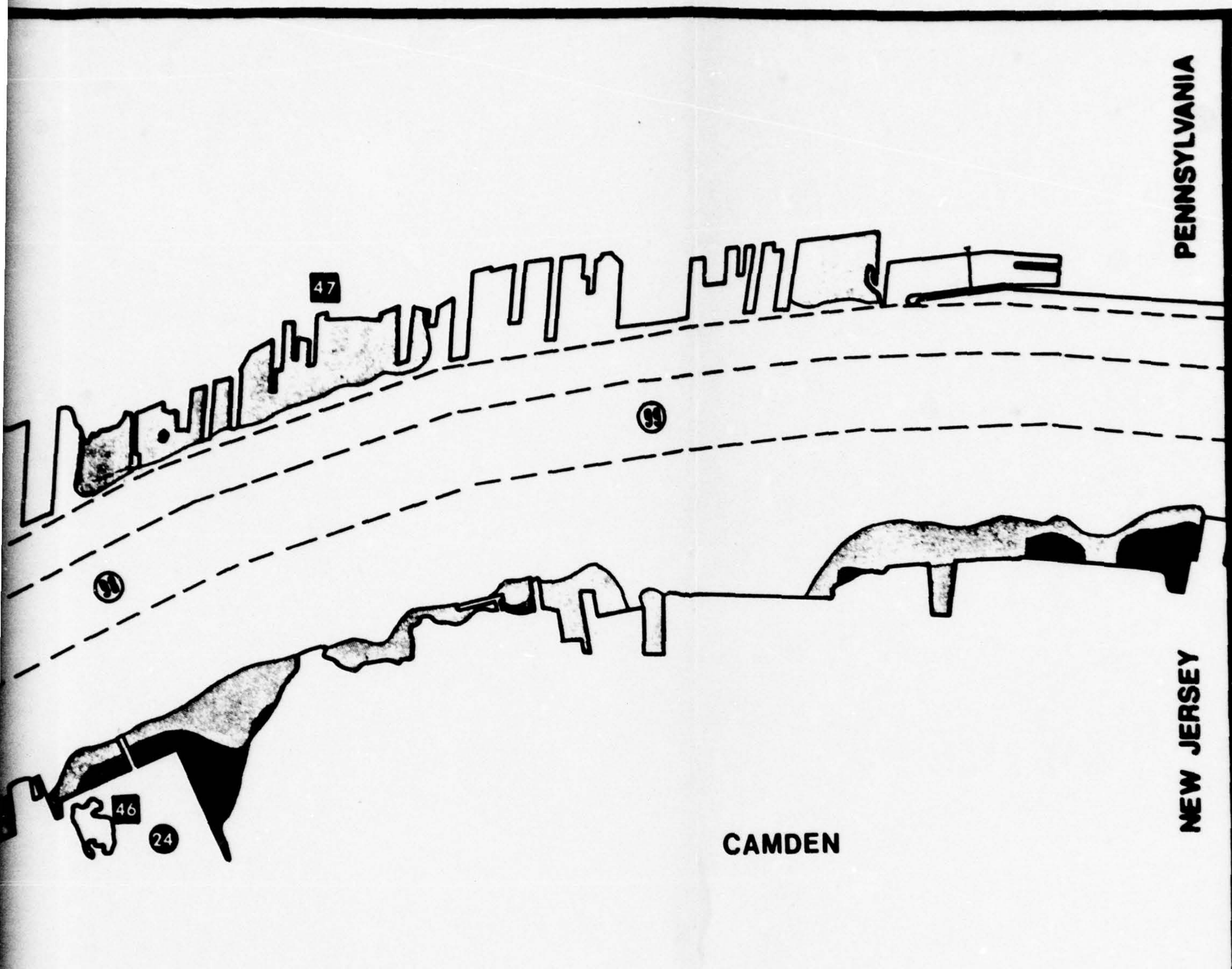


PHILADELPHIA
44
23
7
96
Walt
Whitman
Bridge
97
46
24
45
Newton
Creek
0
0.25
0.5
1.0 mile
Scale:



DELAWARE RIVER
PHILADELPHIA - CAMDEN
RIVER MILE 97-99

2

Cladocera was second in abundance (20.4%), with a mean annual density of 35,494/m^3 (PECo, 1977b). Nineteen cladoceran taxa were identified (Appendix Table 15). It ranked second in spring, third in summer and last in winter and fall. Combined cladoceran density reached two major peaks. The largest (524,500/m^3) occurred on 2 June and the smaller peak (51,500/m^3) was recorded on 31 August.

Copepoda was third in abundance (13.8%), with a mean annual density of 23,194/m^3 (PECo, 1977b). Fifteen copepod taxa were identified (Appendix Table 15). Copepoda never dominated zooplankton samples. It ranked second in summer and fall and third in winter and spring. Combined copepoda density reached one major peak (182,327/m^3) on 17 May.

Tychoplankton was the least abundant (1.2%) component of zooplankton, with a mean annual density of 2,108/m^3 (PECo, 1977b). Tychoplankton never dominated zooplankton samples. It ranked second in winter, third in fall and last in spring and summer. Density varied and never reached a well-defined peak. The greatest number collected (4,500/m^3) was on 14 June.

ICHTHYOPLANKTON

River Mile 97.5 (1976)

River herring larvae comprised over 68% of all larvae collected in 1976 at river mile 97.5 (PECo, 1977b). Temperate basses (15.6%), American eEl (10.8%), and minnows (5.1%) ranked second, third and fourth, respectively, in overall abundance. River herring larvae were collected from 4 May through 28 June. Temperate basses occurred in samples from 4 May to 13 June. Minnow larvae were collected from 4 May through 13 July. American eel juveniles were collected on 13 May, 27 May and 8 July. A single mummichog was collected on 8 June.

Greatest mean density of all larval and young fishes combined was in May 35.62/100 m^3 (PECo, 1977b). Mean density per 100 m^3 was 0.0, April; 12.00, June; 6.69, July and 0.00, August.

Kendall's Tau demonstrated negative correlation between density and mean temperature. Density was positively correlated with mean dissolved oxygen content of the water (PECo, 1977b).

OTHER FISHES

River Mile 97.5 (1976)

Fishes collected on industrial screens were sampled at river mile 97.5 in 1976. White perch, blueback herring, alewife, silvery minnow and gizzard shad were the five most abundant fishes and together comprised 90% of the total number and 89% of the total weight (PECo, 1977b). The next eight species in order of abundance were mummichog, white catfish, American eel, American shad, pumpkinseed, channel catfish and spot. Twenty-five young American shad and three striped bass were collected.

In winter, the number of fish decreased steadily from 6 January through 16 March. White perch (360), silvery minnow (1964) and gizzard shad (110) dominated the catch and accounted for 95% of the number and 90% of the weight collected. Most fish were collected in January or early February. Late February and March was a period of low catch. Most white perch were Age I or Age II.

In spring, blueback herring (280 specimens) ranked first in numerical abundance and accounted for 54% of the total number and 51% by weight. Alewife (59), silvery minnow (48), white perch (35), American eel (26), white catfish (25) and mummichog (25) accounted for an additional 42% of the catch. Blueback herring length-frequency data indicated Age I fish.

In summer, 1976, few fish were taken. Alewife (41 specimens) ranked first in numerical abundance and accounted for 48% of the total. Blueback herring (13) and mummichog (12) made up an additional 29% of the catch.

Most fish were collected in fall. Blueback herring (1,379 specimens) and white perch (1,273) ranked first and second in numerical abundance, represented 67% of the total catch and both were collected in more than 50% of the collections. Alewife (822) and herrings (238) made up 27% of the catch. Anadromous, catagromous and other migratory fishes accounted for over 95% of all specimens collected. All 25 American shad (Age 0) collected in 1976 were taken during the fall. Length-frequency data indicated that most blueback herring and alewife were Age 0. Most white perch were Age II or younger.

RIVER MILE 100 TO 103

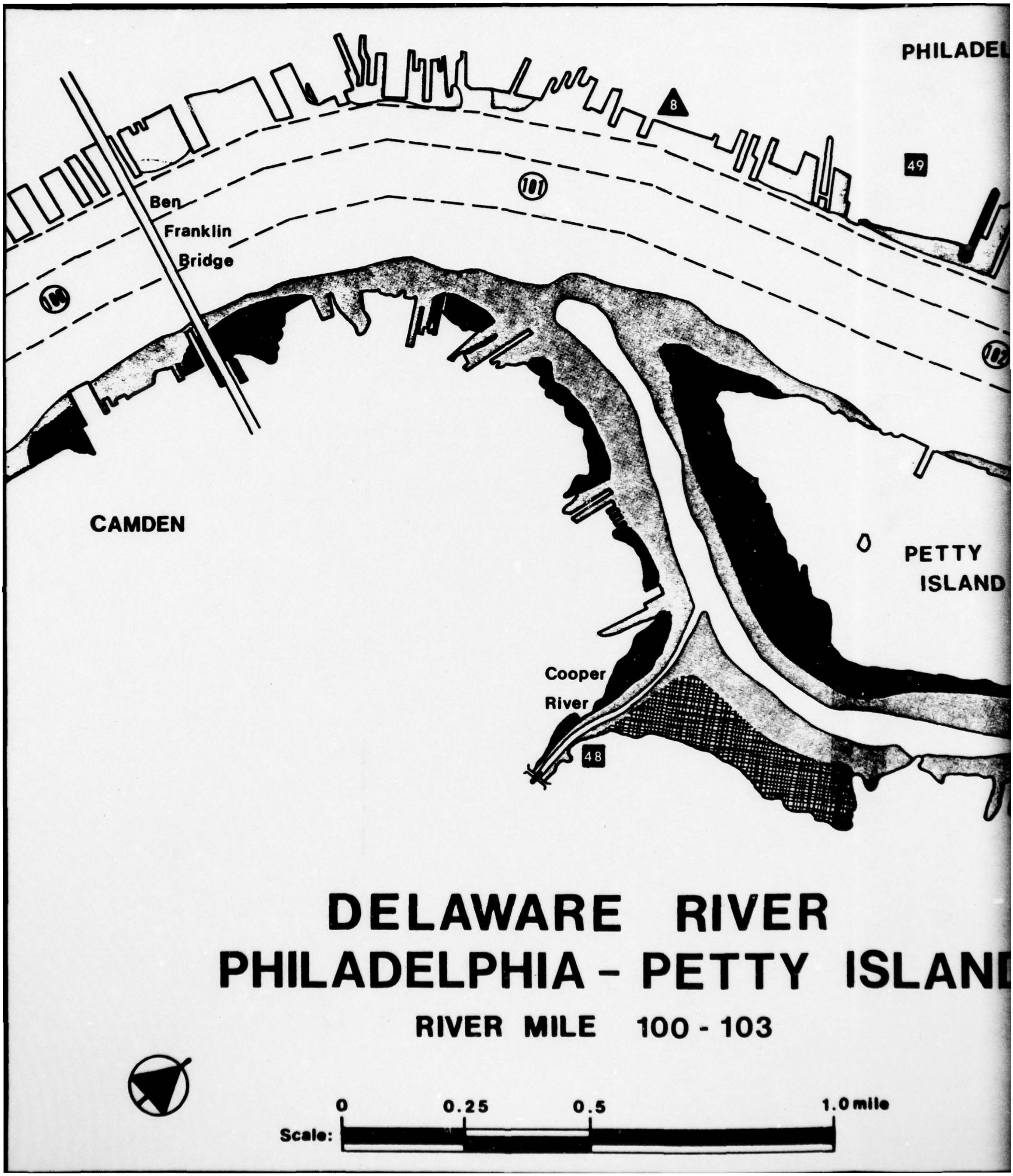
Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
25	N.J. Water Co., Camden	3	NJ 0005215
▲	Power Plant		
8	Philadelphia Electric, Delaware	3	--
■	Other Point Source Discharge		
48	Allied Chemical, Camden	3	--
49	National Sugar Refining Company	3	PA 0012645

ZOOPLANKTON

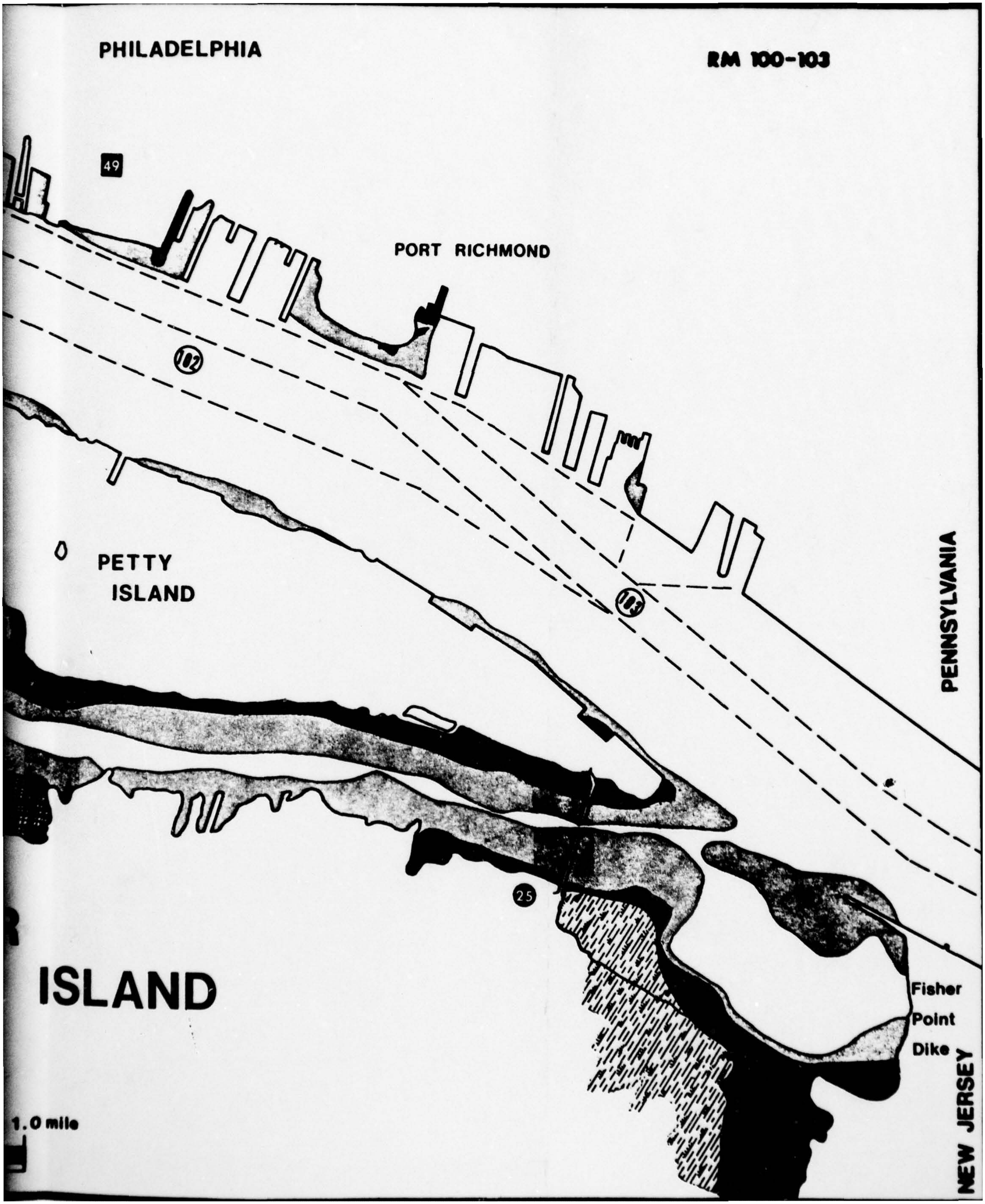
River Mile 101.2 (1976)

At river mile 101.2 Rotatoria was the most abundant component (53.5%) of zooplankton with a mean annual density of 99,264/m^3 (PECo, 1977c). Rotifers ranked first in winter, summer and fall and second in spring. A total of 65 rotifer taxa was identified (Appendix Table 15). Rotifer density reached two major peaks in 1976. The first (182,062/m^3) occurred on 3 May. The second and largest peak (371,685/m^3) was recorded on 30 June. Filinia longiseta was the most abundant rotifer collected.



DELAWARE RIVER
PHILADELPHIA - PETTY ISLAN

RIVER MILE 100 - 103


PHILADELPHIA
RM 100-103
49
PORT RICHMOND
102
PETTY
ISLAND
103
PENNSYLVANIA
25
R
ISLAND
Fisher
Point
Dike
1.0 mile
NEW JERSEY

Cladocera was the second in abundance (33.0%) with a mean annual density of 61,401/m^3 (PECo, 1977c). Eighteen cladoceran taxa were identified (Appendix Table 15). Cladocerans ranked first in spring, third in summer and last in winter and fall. Cladoceran density reached one major peak (1,132,625/m^3) in 1976, which was recorded on 2 June.

Thirteen copepod taxa were identified (Appendix Table 15); it was third in abundance (12.5%) with a mean annual density of 23,117/m^3 (PECo, 1977c). Copepods ranked second in winter, summer and fall and third in spring. Copepod density reached one major peak (148,00/m^3) on 17 May.

Tychoplankton was the least abundant component (1.0%) of zooplankton, with a mean annual density of 1,826/m^3 (PECo, 1977c). Tychoplankton never dominated the zooplankton samples. There was no well defined peak. The greatest number (6,500/m^3) was recorded on 14 June.

ICHTHYOPLANKTON

River Mile 101.2 (1976)

River herring, temperate basses, minnows and American eel were the most abundant ichthyoplankton taxa collected at river mile 101.2 (PECo, 1977c). River herring larvae comprised 82.9% of all specimens collected. Temperate basses (8.9%) and minnows ([illegible].4%) were second and third in overall abundance. American eel juveniles (2.9%) ranked fourth.

Fish were collected in ichthyoplankton samples from 20 April through 22 July (PECo, 1977c). Temperate basses were collected from 4 May through 28 June. A single young white perch was collected on 13 July. American eel juveniles were collected from 20 April through 22 July. Minnows were collected from 27 May through 8 July. One carp was taken on 8 July. One tessellated darter was taken on 27 May. Mean density per 100 m^3 was 1.30, April; 47.12, May; 5.10, June; 1.62 July; and 0.00, August.

Kendall's coefficient of rank correlation demonstrated a negative correlation between collection density and mean water temperature and a positive correlation between collection density and mean dissolved oxygen content (PECo, 1977c).

OTHER FISHES

River Mile 101.2 (1976)

Blueback herring (13,877 specimens), alewife (6,858), river herring (4,508) and white perch (3,222) ranked first through fourth in abundance and together comprised 93% of the total number and 63% of the total weight collected on industrial screens (PECo, 1977c). The next four species in order of abundance were silvery minnow, American eel, gizzard shad and mummichog, which comprised an additional 6% of the total number and 35% of the weight collected.

The number of fish collected in winter 1976 was low in comparison with the other three seasons. Gizzard shad (223), white perch (170) and silvery minnow (88) dominated the catch and together accounted for 91% of the number and 87% of the biomass collected in winter.

In spring, alewife (144) ranked first in numerical abundance, accounted for 23% of the total number and 13% by weight. Blueback herring (136), silvery minnow (116) and white perch (101) represented an additional 57% of the catch. The number of fish collected increased from 16 March to 5 April, which probably signaled the start of the spring run of herring and silvery minnow, then decreased on 1 June.

In summer, alewife (1,675) ranked first in numerical abundance, and accounted for 47% of the total number and 22% of the weight. Blueback herring (949), herrings (525), American eel (243) and white perch (132) made up an additional 52% of the catch by number. The number of fish collected increased from 6 on 19 July to 276 on 2 August and by 31 August it reached a peak of 1,680. Length-frequency data indicated most alewife and blueback herring were Age 0.

Blueback herring (12,792) ranked first in numerical abundance, represented 50% of the total number and 31% of the biomass in the autumn. Alewife (5,039), river herrings (3,984) and white perch (3,743) comprised an additional 46% of the catch by number and 48% by weight. Migratory fish accounted for 98% of the catch. The largest catch of the study was recorded on 14 October, when 10,156 fish were taken. Most blueback herring, alewife and white perch taken were Age 0. Eleven American shad (Age 0) and four striped bass were also taken during the fall.

RIVER MILE 104 TO 106

Point Source Impacts

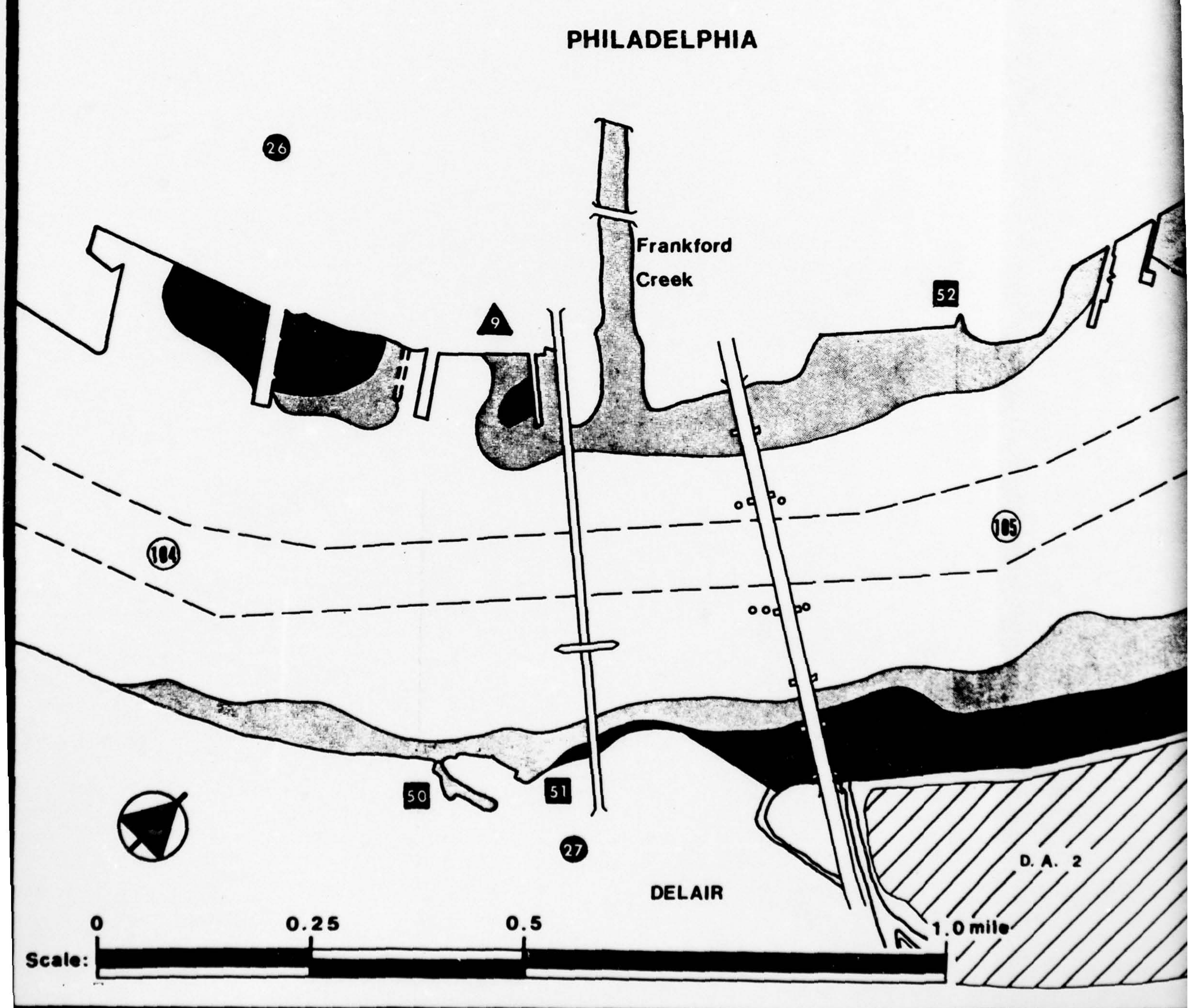
MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
26	Phila. Northeast Water Pollution Control Plant	3	PA 0026689
27	Pennsauken Township Sewerage Authority	3	NJ 0025348
28	Moorestown Township Sewage Treatment Plant	3	NJ 0024996
▲ Power Plant			
9	Philadelphia Electric, Richmond	3	--
■ Other Point Source Discharge			
50	Texaco, Pennsauken	3	NJ 0005436
51	Georgia-Pacific Corp.	3	NJ 0004669
52	A.P. Green Refractories	3	PA 0011703
53	U.S. Steel Products Division, Camden	3	NJ 0005533
71	U.S. Steel, Camden	3	NJ 0005533
54	Rohm and Haas, Phila.	3	--

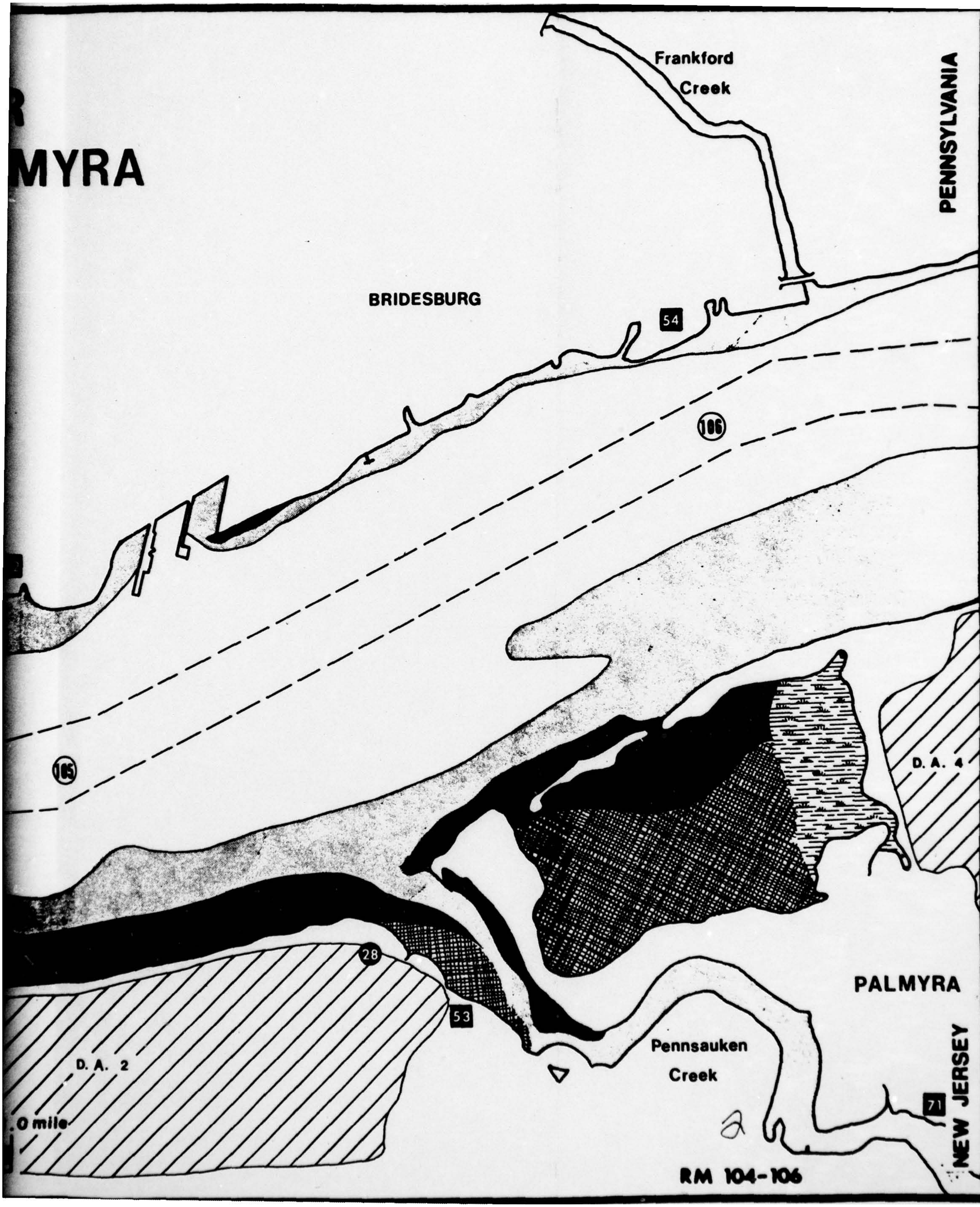
ZOOPLANKTON

River Mile 104.3 (1976)

Rotatoria was the most abundant component (62.6%) of zooplankton, with a mean annual density

DELAWARE RIVER
PHILADELPHIA - PALMYRA
RIVER MILE 104 - 106




R
MYRA
Frankford
Creek
PENNSYLVANIA
BRIDESBURG
54
106
105
D. A. 4
28
53
PALMYRA
D. A. 2
Pennsauken
Creek
NEW JERSEY
71
.0 mile
RM 104-106

of 108,951/m^3 (PECo, 1977d). Rotifers ranked first in abundance during winter, summer and fall and second during spring. Rotifer density reached three major peaks in 1976. The first (101,688/m^3) occurred on 3 May. The second (406,500/m^3) was recorded on 30 June and the third and largest peak (496,000/m^3) was recorded on 16 September.

Cladocera was the second in abundance (22.2%), with a mean annual density of 38,661/m^3 (PECo, 1977d). Fifteen cladoceran taxa were identified (Appendix Table 15). Cladocerans ranked first in spring, third in summer and last in winter and fall. Cladoceran density reached two major peaks in 1976. The largest (723,500/m^3) occurred on 2 June and the second peak (54,962/m^3) occurred on 31 August.

Twelve copepod taxa were identified (Appendix Table 15). Copepoda was third in abundance (13.2%), with a mean annual density of 23,032/m^3 (PECo, 1977d). Copepods ranked second in summer and third in winter, spring and fall. Copepod density reached two major peaks in 1976. The largest (115,083/m^3) occurred on 17 May and the second peak (112,500/m^3) was recorded on 19 July.

Tychoplankton was the least abundant (1.9%) component, with a mean annual density of 3,315/m^3 (PECo, 1977d). Tychoplankton ranked second in winter and fall and last in spring and summer. There was no well-defined peak. The greatest number (12,222/m^3) was observed on 26 October.

ICHTHYOPLANKTON

River Mile 104.3 (1976)

River herring (84%), minnows and carp (8.3%) temperate basses (5.0%) and American eel (1.8%) were the most abundant taxa collected in ichthyoplankton samples at river mile 104.3 (PECo, 1977d). Goldfish, <u>Lepomis</u> species and tessellated darter comprised the remainder. Fish eggs were collected on 12 May, 16 June and 28 June. This indicated that most spawned in early May. White perch prolarvae were collected on 4 and 12 May and a single postlarval white perch was collected on 16 June. This suggests that white perch spawned in May and early June; young were collected on 8 and 13 July. *Lepomis* species were collected on 24 June and 13 June, which suggested a June spawn for these fish. Minnows were collected from 4 May to 13 July. American eel was collectec on 9 June and 8 July.

Mean density (per 100 m^3) for all taxa combined was 0.0, 99.51, 11.35, 2.44 and 0.00 for April, May, June, July and August, respectively (PECo, 1977d).

Kendall's Tau demonstrated negative correlation between density and mean temperature. Density was not correlated with mean dissolved oxygen content of the water (PECo, 1977d).

OTHER FISHES

River Mile 104.3 (1976)

River herring (8.095 specimens), white perch (2,419), blueback herring (1,800), American eel (1,150) and gizzard shad (331) were the five most abundant fishes taken on industrial screens at river mile 104.3 and together comprised 93% of the total number and total weight (PECo, 1977d). The next species in order to decreasing abundance were silvery minnow, channel catfish, mummichog, brown bullhead and banded killifish.

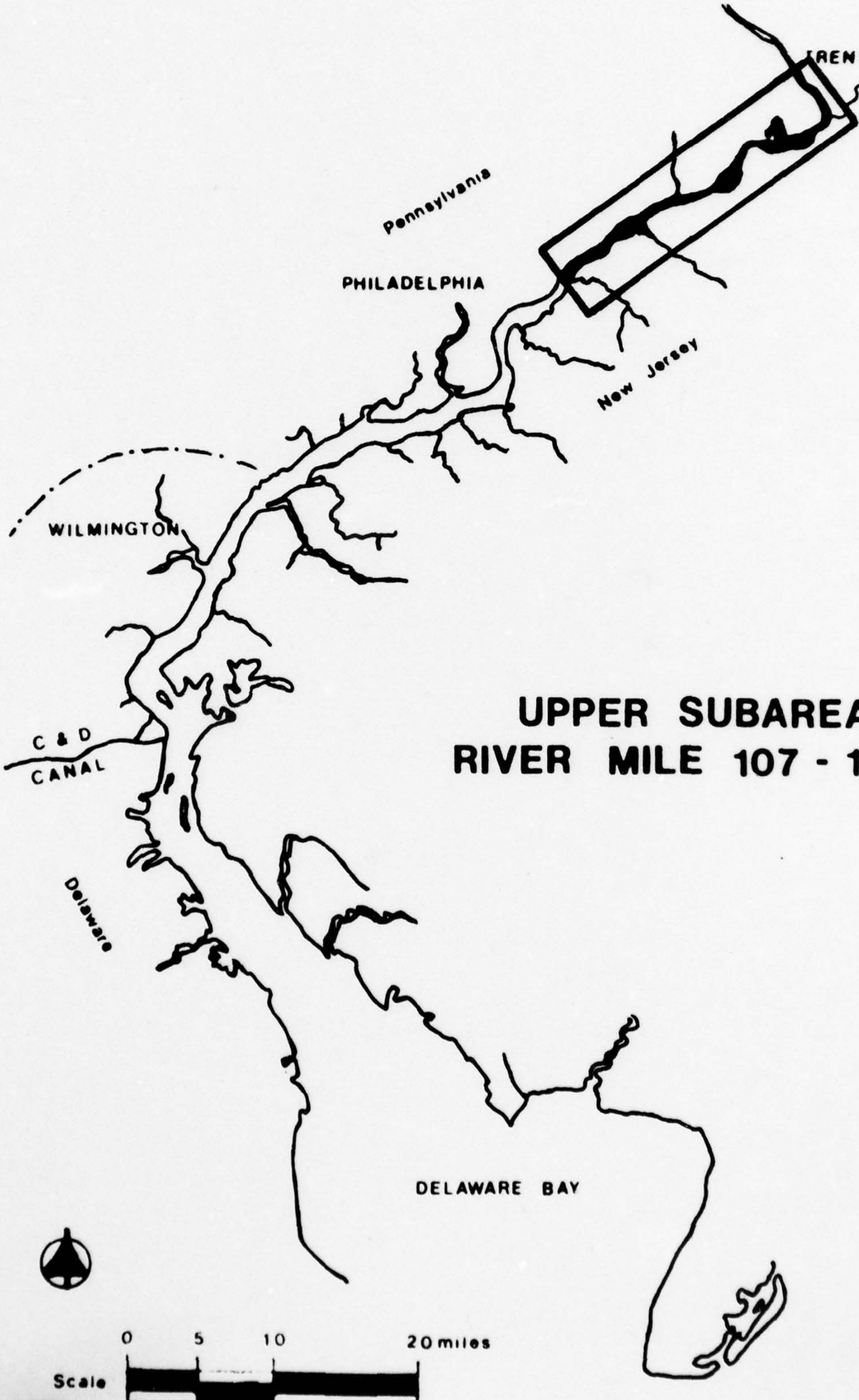
In winter (January through March) gizzard shad (288) and white perch (85) dominated catches and together accounted for 79% of the number collected. Most gizzard shad (91%) collected in winter were taken in January; most were Age I.

In spring, white perch (367) ranked first in numerical abundance and accounted for 36% of the total. Blueback herring (191), alewife (156), silvery minnow (123) and American eel (103) accounted for 57% of the spring catch. From 5 April to 19 April the number of fish tripled reflecting the increased catch of blueback herring. Numbers of alewife and blueback herring sharply increased on 19 April and decreased thereafter, indicating the spring run of herrings took place from middle to late April. Both fishes were primarily Age I specimens. Most white perch were Age I, but Age II and III were also represented.

In summer, alewife (3,294 specimens) ranked first in numerical abundance and accounted for 54% of the total. American eel (891), white perch (877), blueback herring (784) and river herrings (231) made up 46% of the catch. Migratory fishes represented 85% of the total in summer. Most alewife were young (Age 0). Blueback herring were represented by Age 0 and Age I fish.

In autumn, alewife ranked first in numerical abundance (4,635) and represented 64% of the total catch. White perch (1,076 specimens), blueback herring (822) and river herrings (382) made up an additional 32% of the catch. Anadromous and catadromous fish made up 83% of the catch, with herrings being the major component. Nine young American shad were collected in the fall. Both blueback herring and alewife were dominated by Age 0 specimens.

UPPER SUBAREA
RIVER MILE 107 - 133



UPPER SUBAREA

UPPER SUB-AREA

RIVER MILES 107 TO 133

The upper sub-area extends from Philadelphia (river mile 107) to Trenton (river mile 133). It is estimated that only 1,436 acres of shallows existed within this reach at the time of the 1965 survey, and the present figure may be less. An estimated 500 acres were lost between the surveys of 1932 and 1965 (Table 10).

LAND USE AND IMPACTS

Seventeen municipal treatment plants, two power plants and sixteen other point source dischargers are present within this sub-area adjacent to the river (Table 15). These represent 27% of all dischargers located within the entire study area. In addition, six dredge disposal areas are located within this reach.

Due to presence of Philadelphia, Burlington and Trenton within this sub-area, a good portion of the shoreline and adjacent land areas have been modified (Table 14). Much natural shoreline, however, still remains although it is composed mostly of high ground. Pockets of vegetated wetlands exist, however, on Mud Island (river mile 112), around Neshaminy Creek (river miles 115-118), on Burlington Island (river mile 119) and around Bristleton Creek (river mile 120).

WATER QUALITY

Water quality within this sub-area is somewhat difficult to describe. The upper sub-area is characterized by consistently high DO levels (Figure 9), low oxygen demand (Figure 10; Table 7) and low coliform levels (Figure 11). Water temperatures show no artificial elevation, and pH no

AD-A071 484 TYRAWSKI (JOHN M) WILMINGTON DE F/G 8/8
SHALLOWS OF THE DELAWARE RIVER-TRENTON, NEW JERSEY TO REEDY POI--ETC(U)
MAR 79 J M TYRAWSKI DACW61-79-M-0445

UNCLASSIFIED NL

3 OF 6
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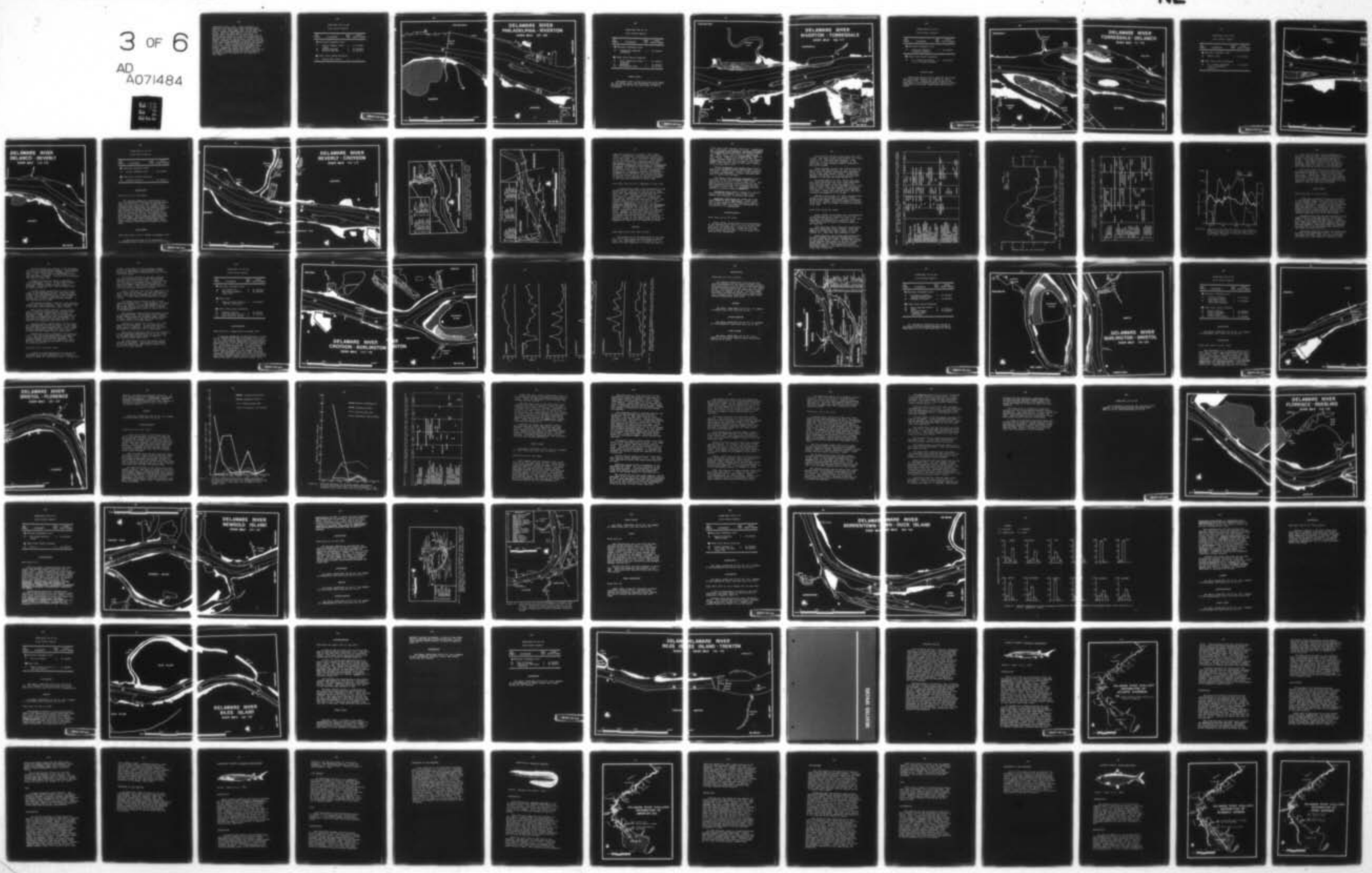
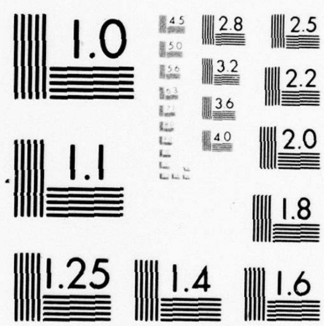
A071484





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

reductions (Kiry, 1974). Water turbidity is generally low within this reach and the photic zone is, thus, much deeper than in the other sub-areas. Based on these charactersitics water quality would be described as very good. In recent years, however, it has been found that of the three sub-areas the highest concentrations of several toxic water constituents, notably cyanide, copper, chromium, manganese, aluminum, mercury and iron, often existed within the upper area (Tables 12 and 13). This is particularly evident near river mile 119-120 around the Burlington-Bristol Bridge. Therefore, while there appears to be little problem from sewage pollution, there may be a problem of industrial pollution which would seriously lower the quality of the shallows in this reach.

RIVER MILE 107 TO 108

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
29	City of Camden, North Plant	3	NJ 0024481
30	Palmyra Borough	3	NJ 0024449
31	Riverton Borough	2	NJ 0021610
■ Other Point Source Discharge			
55	Pennsylvania Forge	2	--

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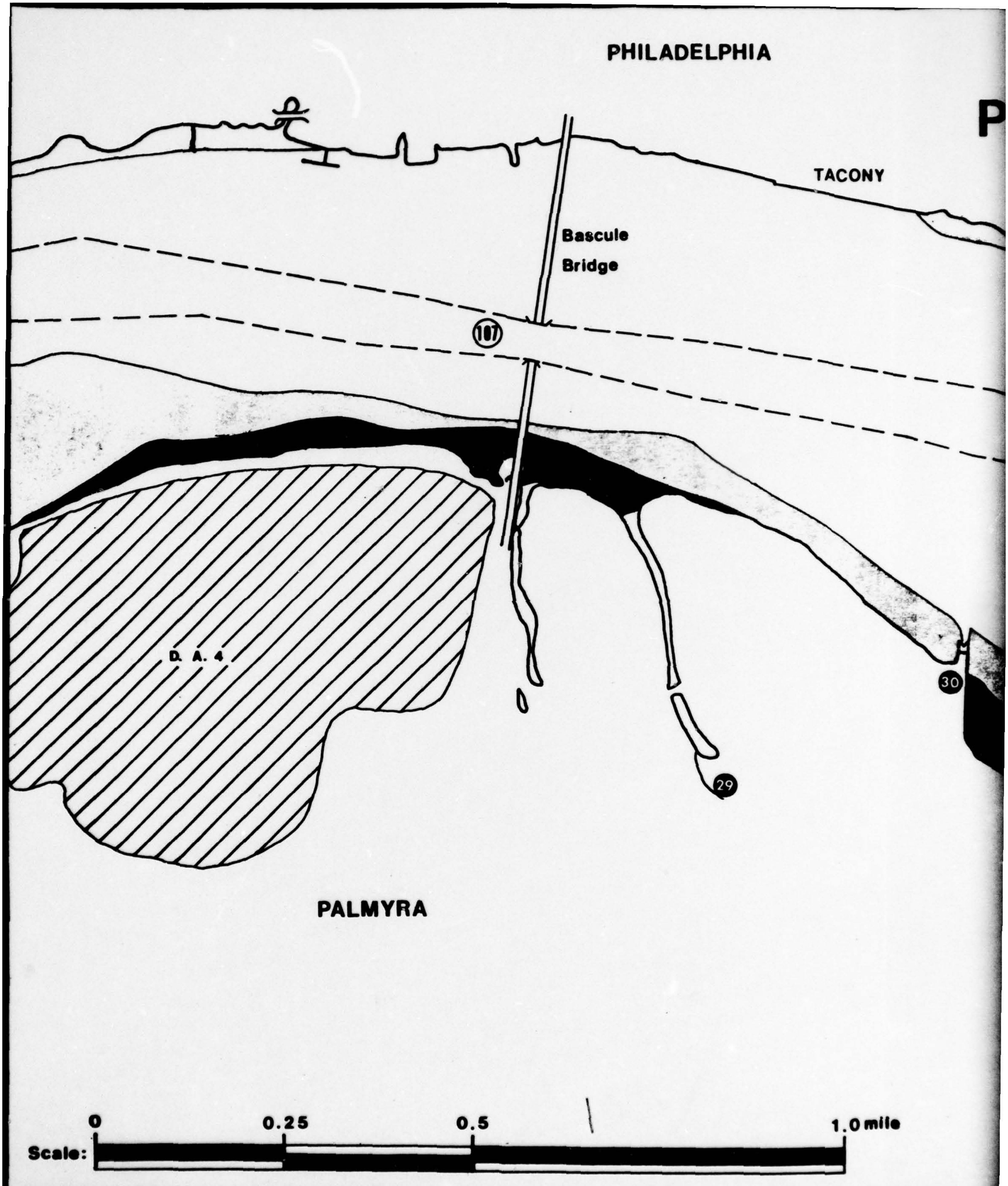
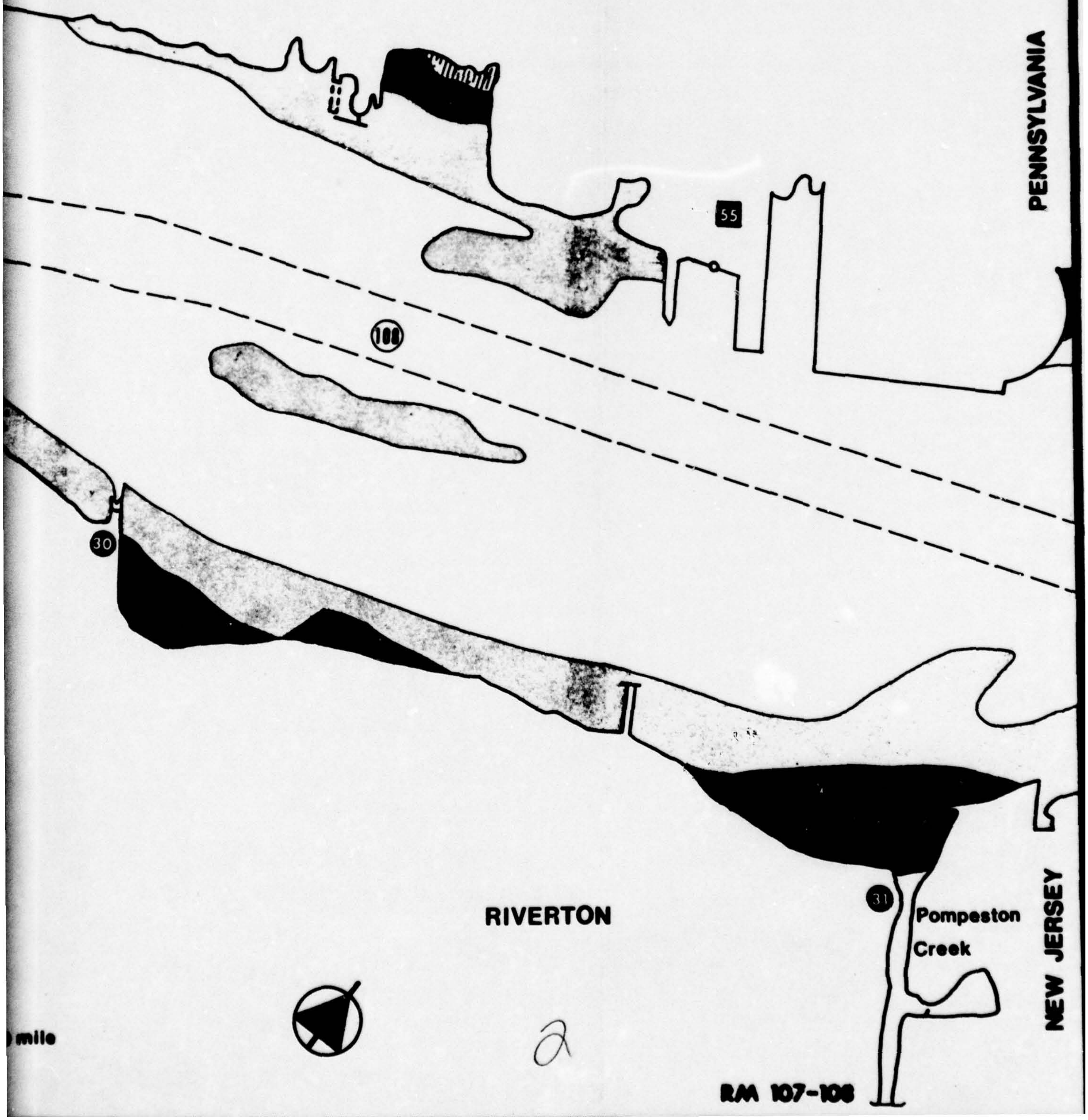

PHILADELPHIA
TACONY
Bascule
Bridge
107
D. A. 4
30
29
PALMYRA
0
0.25
0.5
1.0 mile
Scale:

DELAWARE RIVER
PHILADELPHIA - RIVERTON
RIVER MILE 107 - 108



2

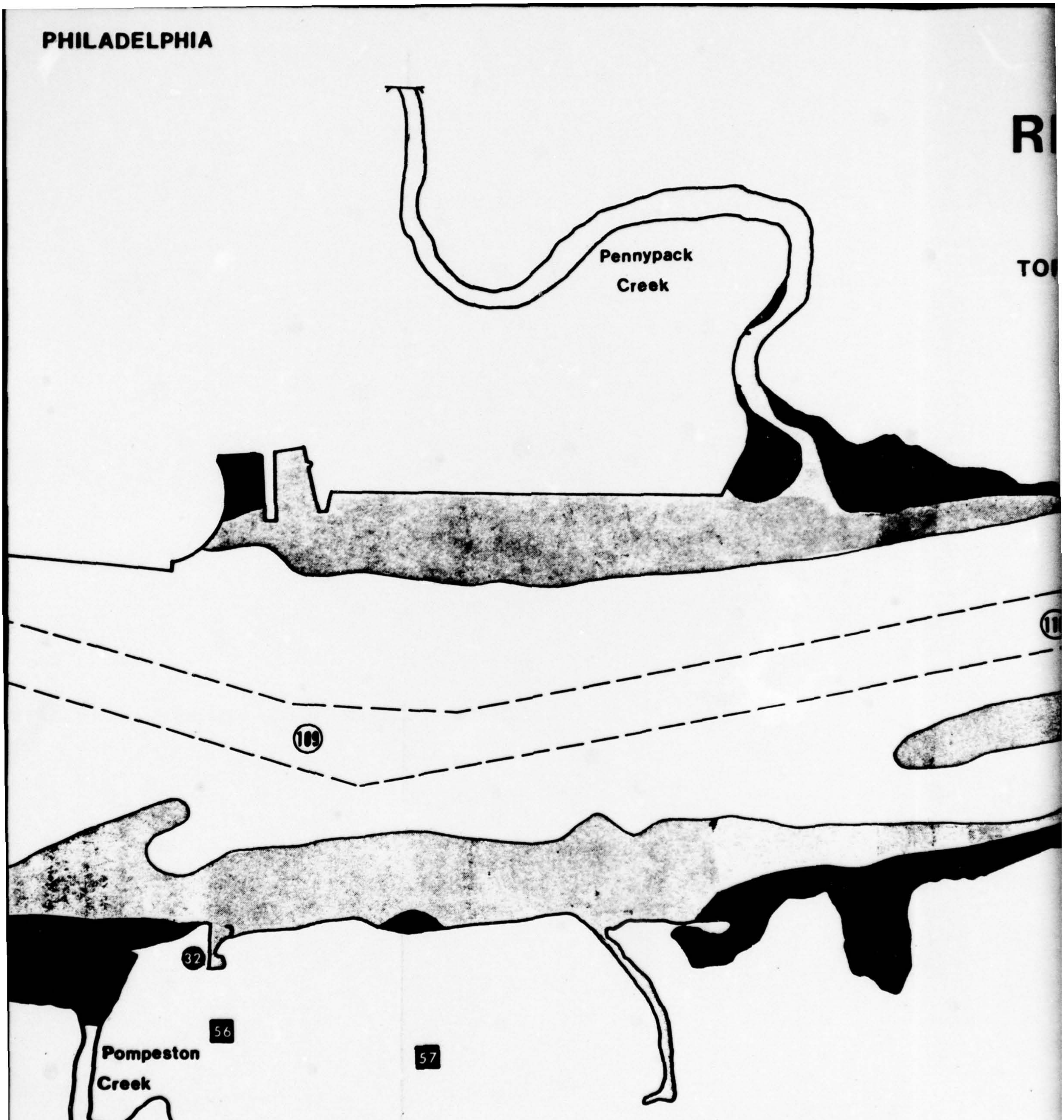
RIVER MILE 109 TO 111

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
32	Cinnaminson Sewerage Authority	3	NJ 0024007
■	Other Point Source Discharge		
56	Airco Industrial Gases, Riverton	2	NJ 0004545
57	Haagonaes	2	NJ 0004375
58	Philadelphia Coke	2	PA 0011401

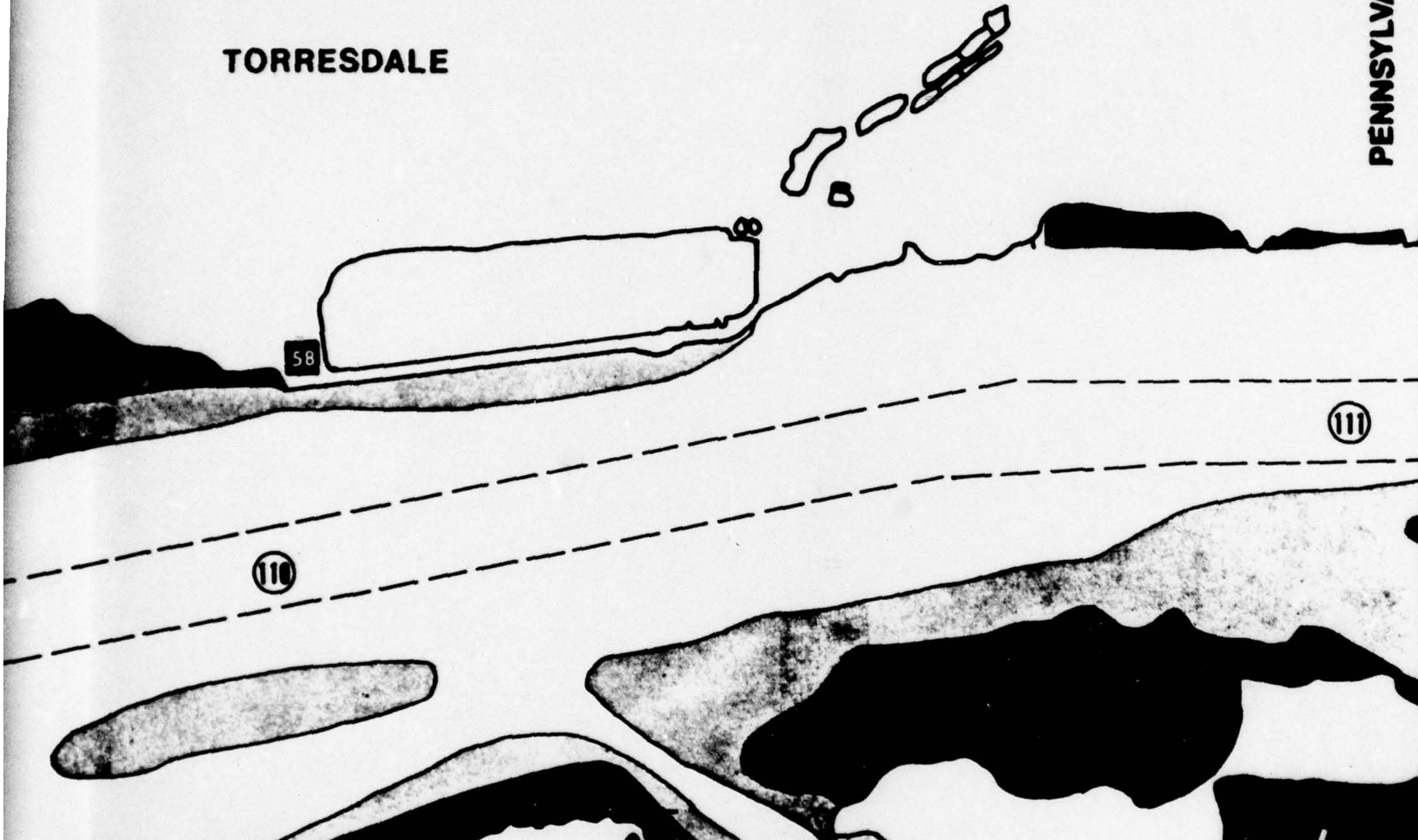
OTHER FISHES

Chittenden (1971) seined more than 9,000 *Alosa* sp. and fairly large, but unrecorded, numbers of white perch during the fall from 1963 to 1965 at Torresdale.



PHILADELPHIA
RI
TO
Pennypack
Creek
109
32
56
57
Pompeston
Creek
0
0.25
0.5
Scale:

DELAWARE RIVER
RIVERTON - TORRESDALE
RIVER MILE 109 - 111



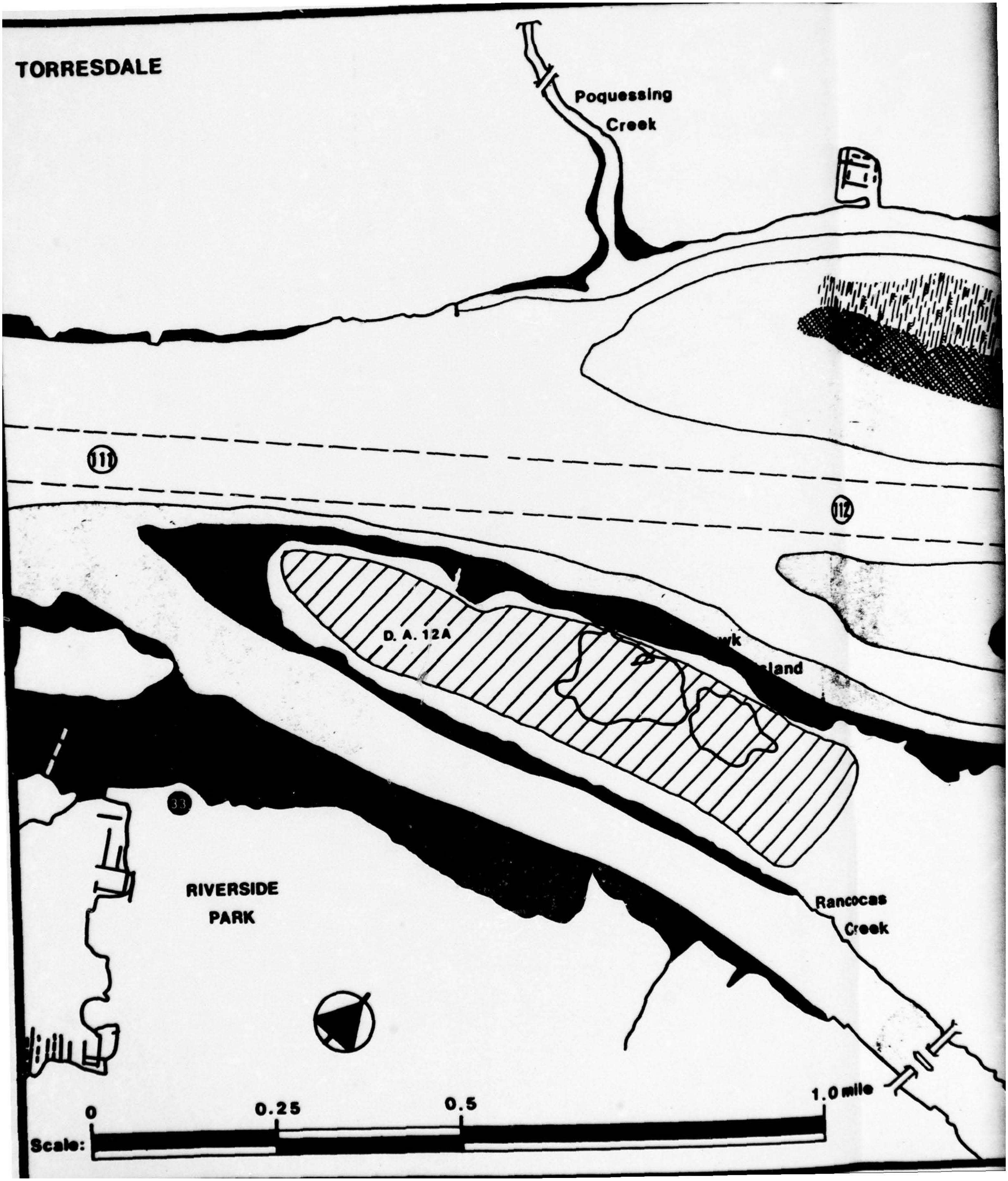
RIVER MILE 111 TO 113

Point Source Impacts

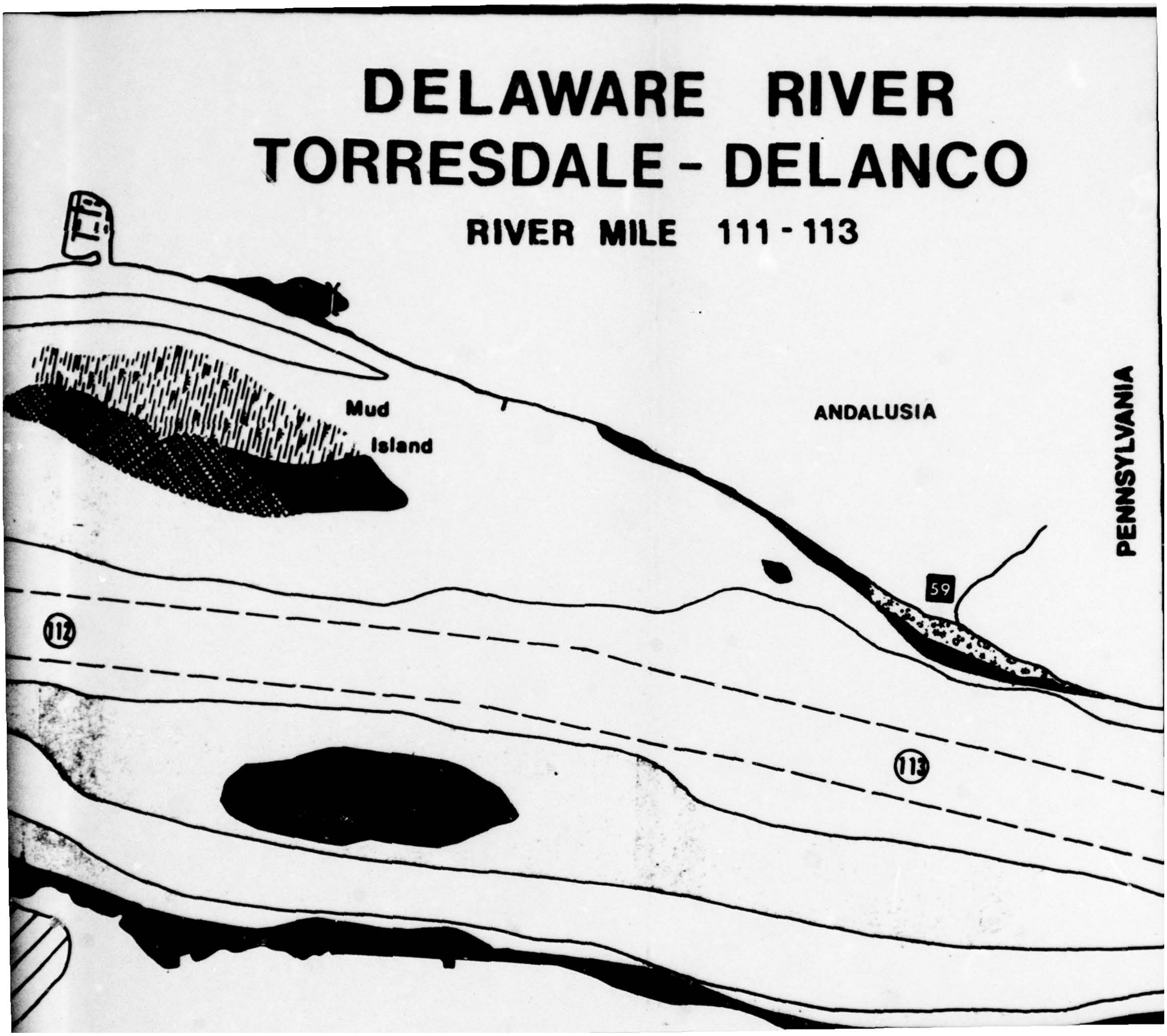
MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
33	Riverside Township Sewerage Authority	2	NJ 0022519
■	Other Point Source Discharge		
59	E.I. duPont de Nemours & Co., Cornwell Heights	2	PA 0011932

OTHER FISHES

Walton and Patrick (1973) reported that trawls near Mud Island collected no fish on 27 and/or 28 August 1972. Trawls near Hawk Island on the same date(s) took blueback herring, spottail shiner, mummichog, white perch, pumpkinseed and satinfin shiner.



TORRESDALE
Poquessing
Creek
111
112
D. A. 12A
wk
sland
33
RIVERSIDE
PARK
Rancocas
Creek
0
0.25
0.5
1.0 mile
Scale:


DELAWARE RIVER
TORRESDALE - DELANCO
RIVER MILE 111 - 113
Mud
Island
ANDALUSIA
PENNSYLVANIA
59
112
113

RIVER MILE 113 TO 115

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
34	Beverly City	2	NJ 0027481
■ Other Point Source Discharge			
59	E.I. duPont de Nemours & Co., Cornwells Heights	2	PA 0011932

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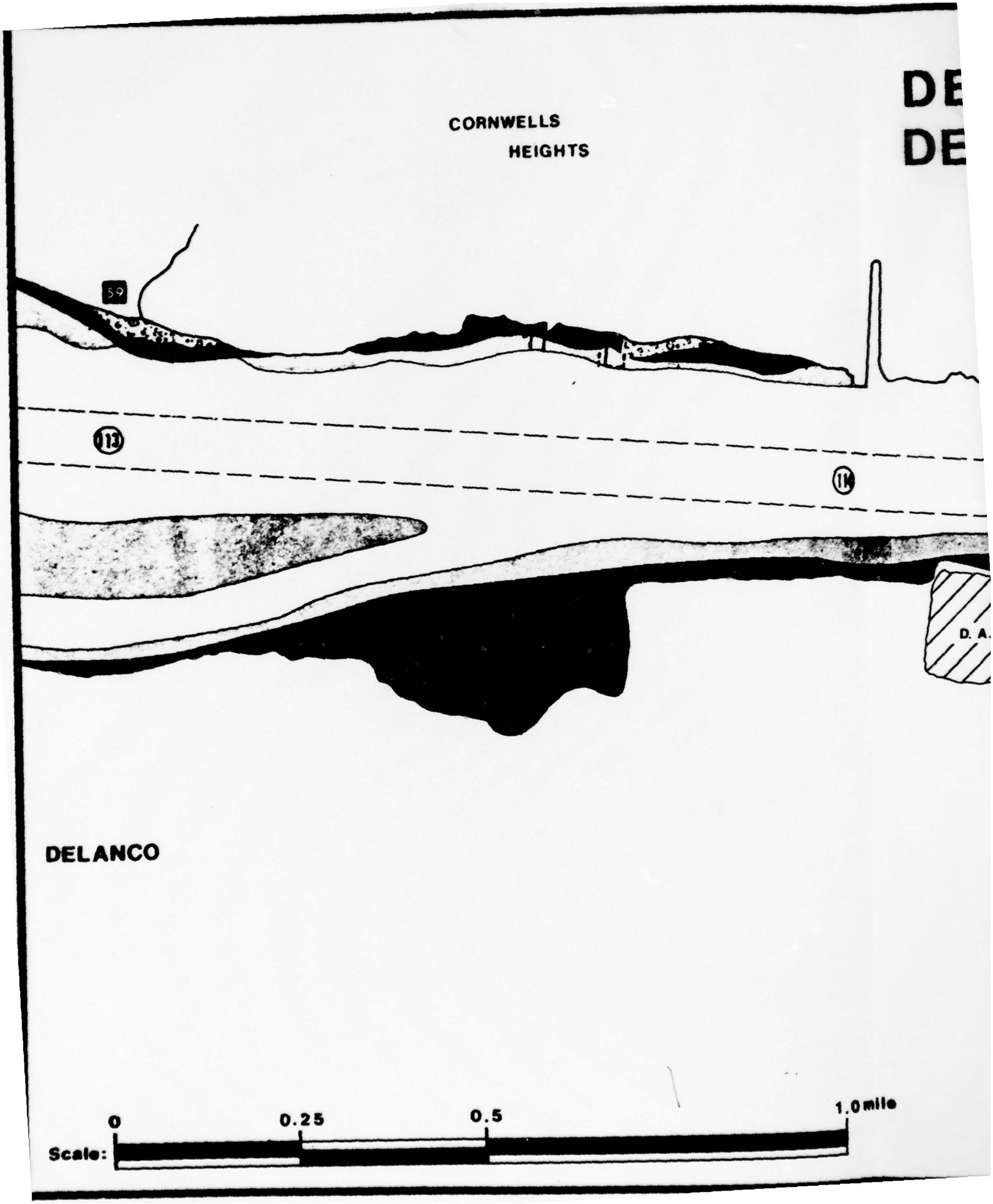
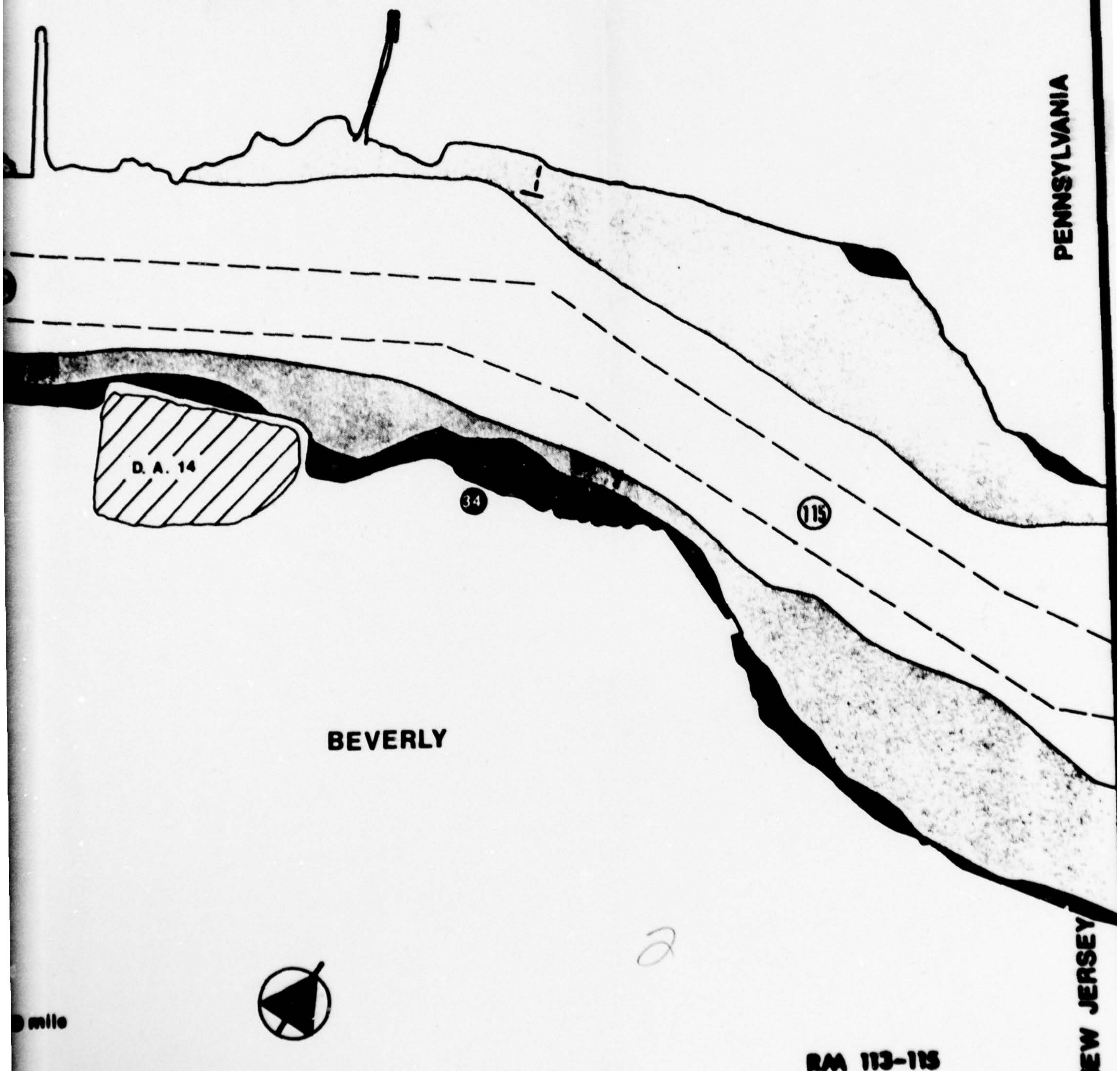


DE
DE
CORNWELLS
HEIGHTS
59
113
DELANCO
D. A.
0
0.25
0.5
1.0 mile
Scale:

DELAWARE RIVER
DELANCO - BEVERLY
RIVER MILE 113 - 115



RIVER MILE 115 TO 117

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
35	Bristol Township Auth.	2	PA 0026450
■	Other Point Source Discharge		
60	Tenneco Plastics	2	NJ 0004391

MACROPHYTES

River Mile 115 to 118 (1972)

The species composition, distribution and relative abundance of the aquatic vascular plants from river mile 115 to 118 were determined by Ichthyological Associates, Inc. (Chase, 1974b). Personnel using small boats followed the shoreline and recorded and mapped the aquatic vegetation. The location of the major beds of plants are shown in Figures 13 and 14. The species within each bed are listed in order of decreasing relative abundance. Some 26 species were identified. The most common and widely distributed plants were: yellow water lily, pickerel weed, three-square bulrush, broad-leaved arrowhead and arrow arum.

ZOOPLANKTON

River Mile 116.8 to 117.7 (March to December 1972)

A quantitative study of the zooplankton in the Delaware River (river mile 116.8 to 117.7) was

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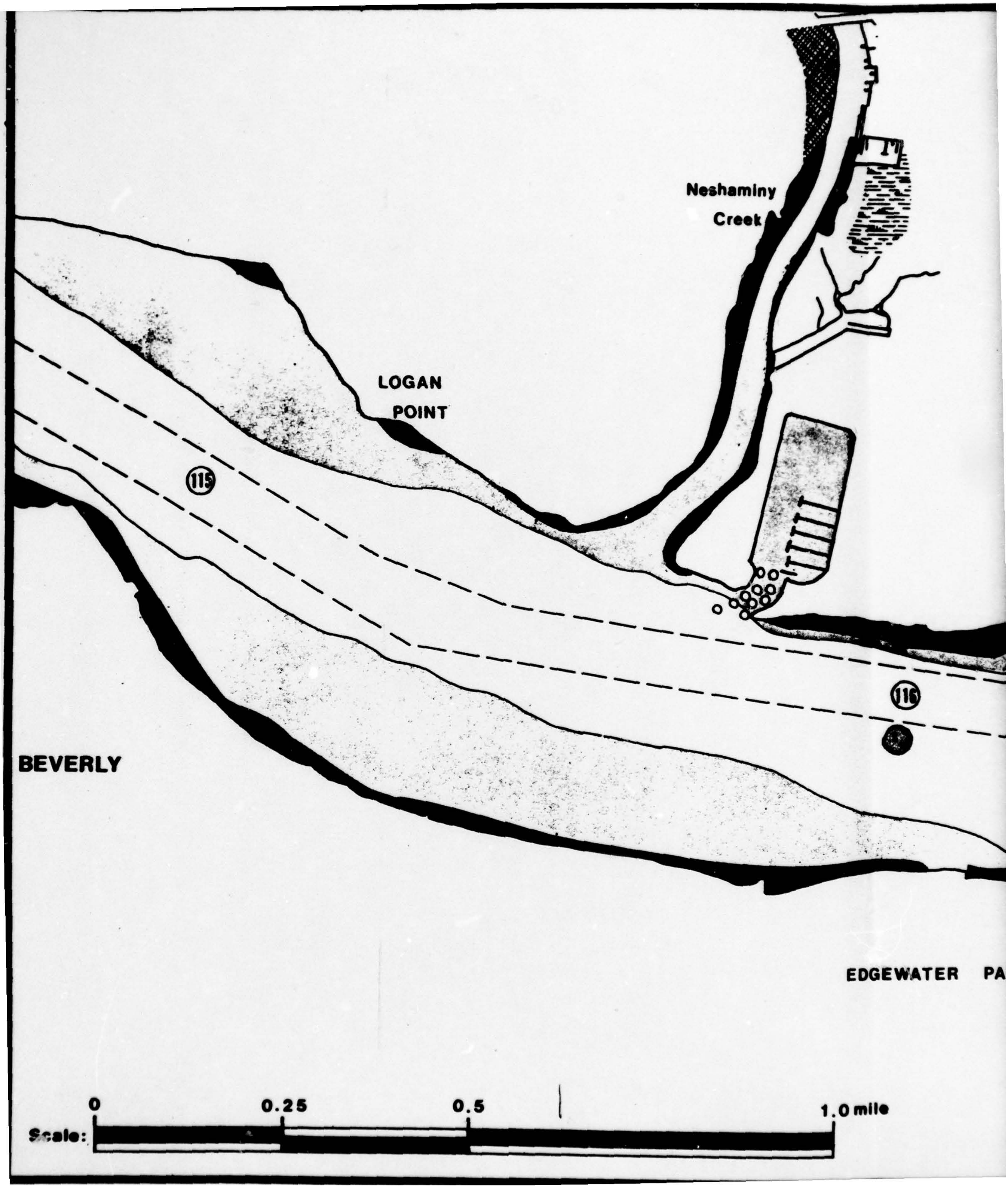
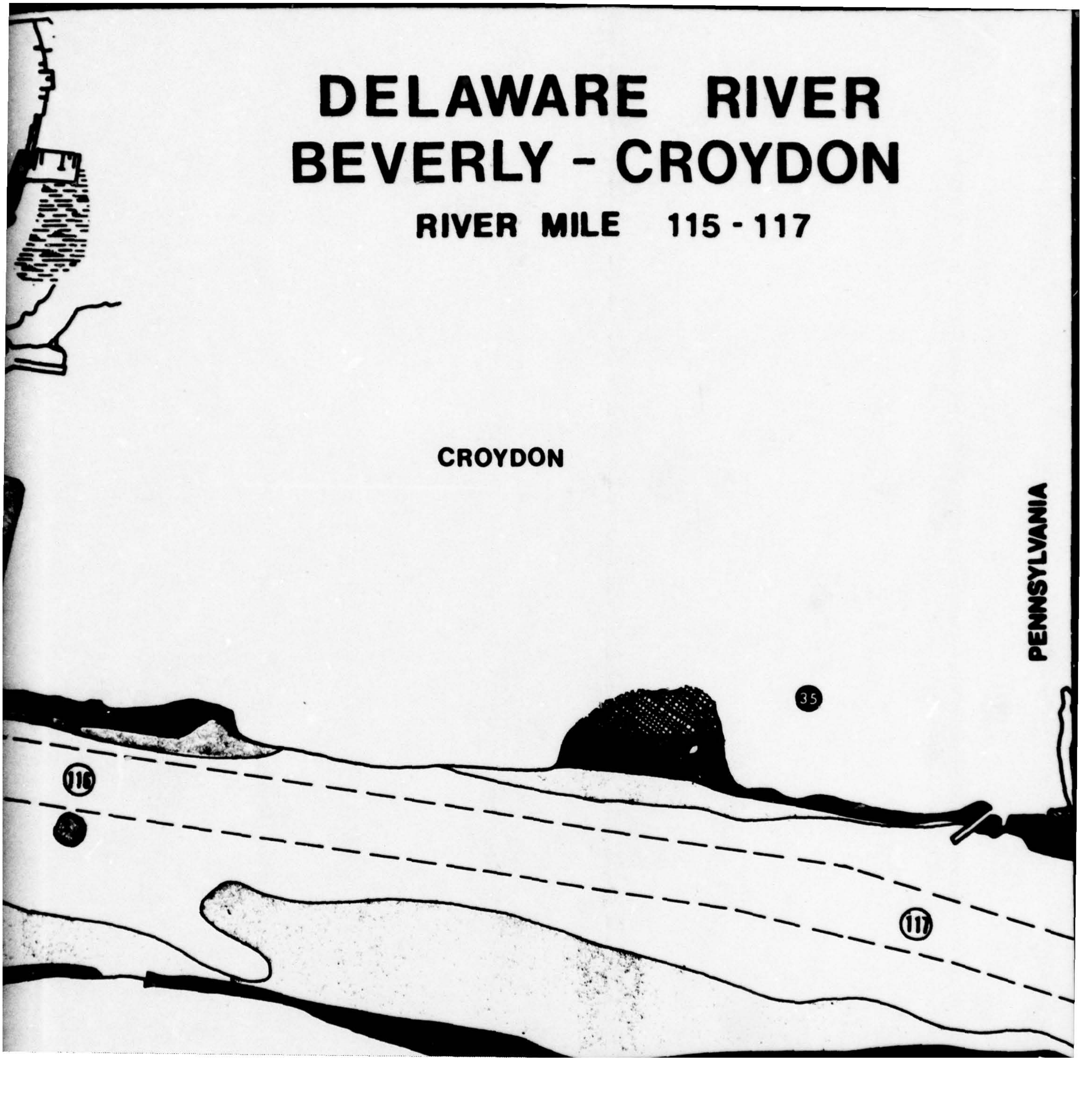

Neshaminy
Creek
LOGAN
POINT
115
116
BEVERLY
EDGEWATER PA
0
0.25
0.5
1.0 mile
Scale:


DELAWARE RIVER
BEVERLY - CROYDON
RIVER MILE 115 - 117
CROYDON
PENNSYLVANIA
35
116
117

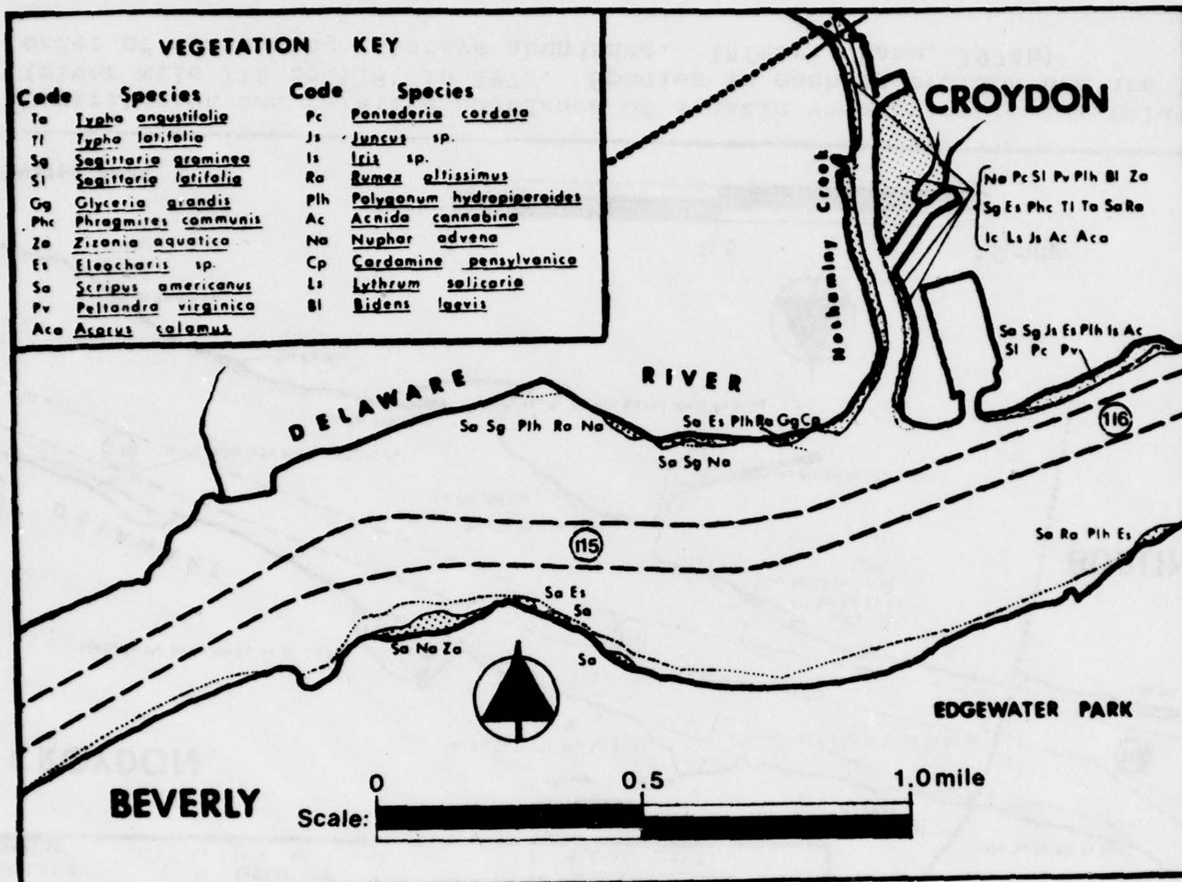


Figure 13. Distribution and relative abundance of aquatic vegetation in the Delaware River (river mile 115 to 116) in 1972. Species in each vegetation bed are listed in order of decreasing relative abundance. (After: Chase, 1974b)

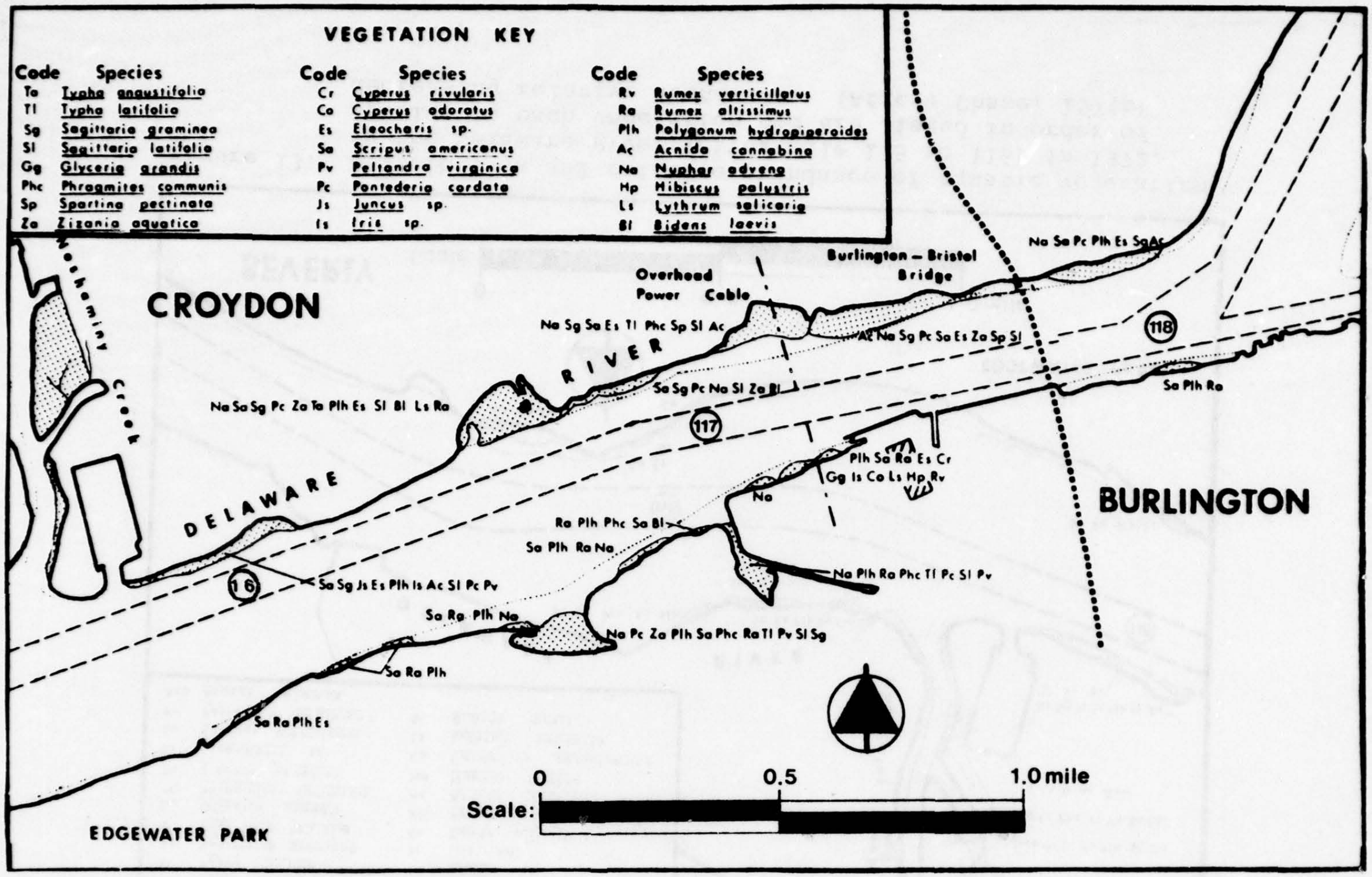


Figure 14. Distribution and relative abundance of aquatic vegetation in the Delaware River (river mile 116 to 118) in 1972. Species in each vegetation bed are listed in order of decreasing relative abundance. (After: Chase, 1974b)

conducted from March to December 1972 (Chase, 1974a). Cladocerans, copepods and rotifers were taken year-round. Total zooplankton density was low in the spring and in the fall. Large numbers of the two cladocerans, Bosmina coregoni and B. longirostris, were taken from June to October. The rotifer Brachionus calyciflorus and Diaphanosoma brachyurum (a cladoceran) were abundant in August. In general, there was no difference in zooplankton distribution with depth. However, Eurytempora affinis and D. brachyurum appeared to concentrate at depths of 10, 20 and 30 feet during daylight and at the surface and at 10 feet during darkness. In general, total zooplankton density increased on ebb tides and decreased on flood tides.

River Mile 116.8 to 117.7 (February to June 1973)

A quantitative study of the zooplankton in the Delaware River (river mile 116.8 to 117.7) near Burlington was conducted by Ichthyological Associates, Inc., from February through June 1973 (Ritson, 1974). Zooplankters collected in 1973 are listed in Appendix Table 27. Cladocerans, copepods and rotifers were the major groups. Zooplankton density was low in the spring. Large numbers of Bosmina spp. were taken in June. Brachionus clayciflorus (a rotifer) and Eurytempora affinis (a calonoid) were the next most abundant species. The density of zooplankton at mid-channel (excluding cladocerans) did not vary with depth. Bosmina in June, was evenly distributed during daylight and densities decreased with increasing depth during darkness. The density of zooplankton did not vary between the shoreline stations, except in June where larger densities of Bosmina were found near the Pennsylvania shore.

BENTHOS

River Mile 116 to 131 (1970 to 1973)

The benthos of the Delaware River (river mile 116 to 131) was studied by Ichthyological Associates, Inc. from August 1970 to October 1973. A total of 97,000 organisms of 70 taxa was taken in

1,085 Ponar grabs (Appendix Table 28). Limnodrilus spp., Procladius culiciformis, Corbicula manilensis and Peloscolex ferox dominated the benthic community (Crumb, 1977). The density of Limnodrilus spp., 90% of which were L. hoffmeisteri, ranged up to 4,552/m^2. Numbers were highest in May and June. Biomass ranged up to 4.79 g/m^2 (dry weight). Limnodrilus spp. were most abundant in mud sediments. Peak numbers occurred when water temperature was from 68 to 77°F.

Larval Procladius culiciformis mean density was as high as 281/m^2 with a mean standing crop of 0.89 g/m^2. Numbers were highest in mud sediments in August and September. Greatest emergence was also in August and September.

The Asiatic clam Corbicula manilensis colonized the Delaware River between Trenton and Burlington in or prior to 1971 (Crumb, 1977). The density of the clam was increasing through 1973. Peak numbers were 67/m^2 with a biomass (without the shell) of 0.52 g/m^2. C. manilensis was most abundant on sand or coarser sediments.

Peloscolex ferox density ranged up to 207/m^2 with a 0.16 g/m^2 standing crop (Crumb, 1977). Numbers were greatest in February and March.

Sphaerium transversum was common until the rapid expansion of C. manilensis. Crumb (1977) said it was probable that interspecific competition between these two clams was responsible for the decline of S. transversum.

ICHTHYOPLANKTON

River Mile 116 to 119 (1972)

Kranz (1974a) investigated the ichthyoplankton of the Delaware River (river mile 116 to 119) from 4 April to 5 October 1972. A total of 420 one-half meter net collections yielded 436 fish eggs, 37,414 larvae and 236 young. Sixteen genera in 10 families were represented.

River herring and white perch eggs were identified. Eggs were present from 26 April to 19 July (Figure 15). They were most abundant in May. Eggs were 30 to 40 times more abundant in the river than in the secondary channel southeast of Burlington Island.

River herrings (alewife and blueback herring), white perch and minnows were the most abundant of the 15 taxa of larvae identified and represented 91.7% of the catch (Kranz, 1974a). Larvae were present from 26 April to 17 August and were most abundant in late May and June (Figure 15).

Decreased numbers of eggs, larvae and young were noted following high river flows associated with Hurricane Agnes, June 1972 (Figure 16). River herrings were the most abundant egg and larva taken in 1972. Eggs were present in collections from 26 April to 12 June, and were most abundant on 10 May. Larvae were captured from 3 May until 8 August and peaked on 23 to 24 May.

Few white perch eggs (13) were collected from 12 May to 12 July (Figure 15) (Kranz, 1974a). Larvae ranked second in abundance and represented 26.4% of all larvae. They were present in collections from 3 May to 8 August and were most abundant on 12 June.

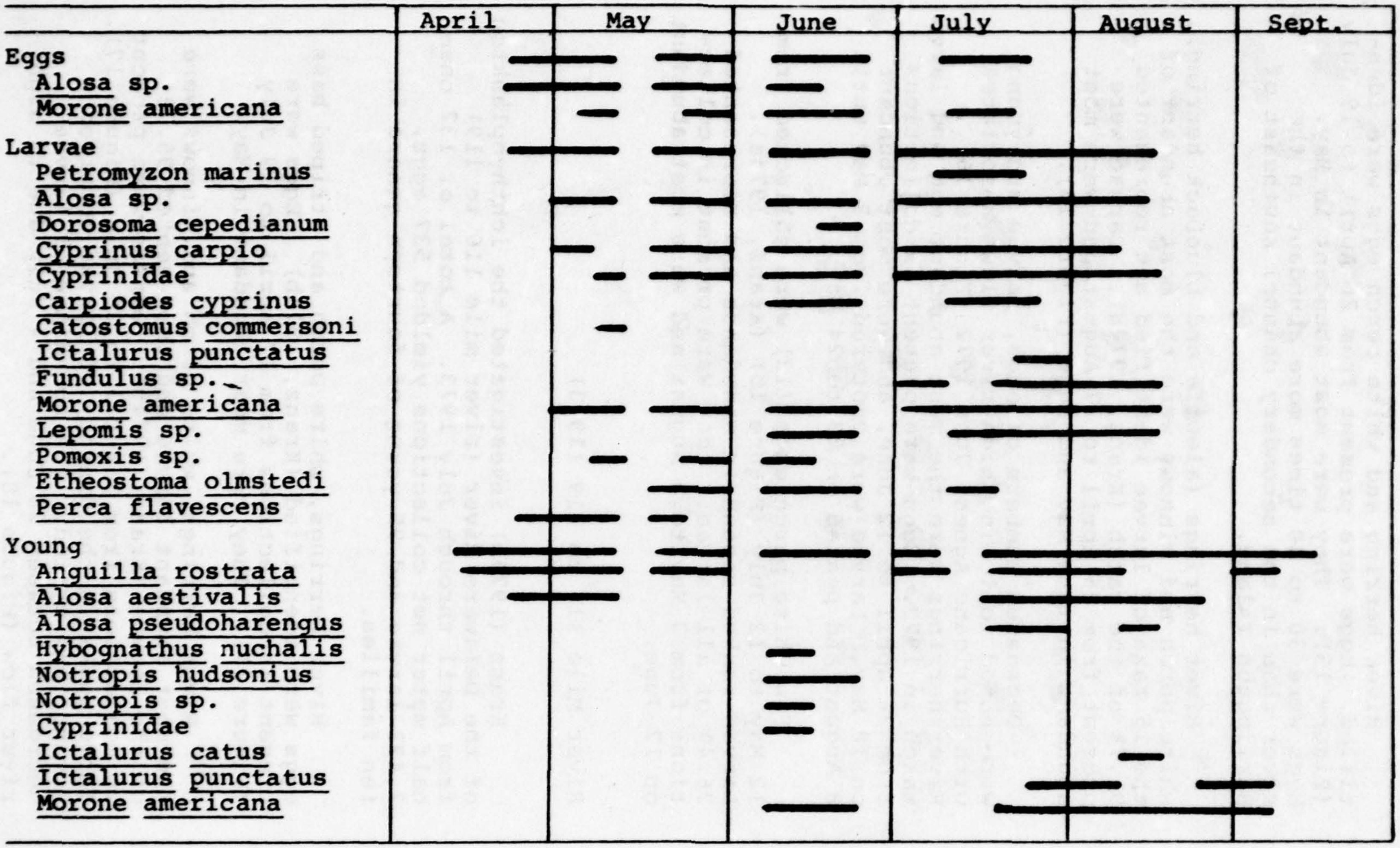
River Mile 116 to 119 (1973)

Kranz (1974b) investigated the ichthyoplankton of the Delaware River (river mile 116 to 119) from April through July 1973. A total of 132 one-half meter net collections yielded 537 eggs, 7,492 larvae and 95 young of fourteen genera in ten families.

River herrings, white perch and striped bass eggs were identified (Kranz, 1974b). Eggs were present in collections from 17 April to 19 July (Figure 17). They were most abundant in May.

River herrings, white perch and minnows were the most abundant larvae and represented 95.7% of the larvae (Kranz, 1974b). Larvae were present in collections from 3 April to 30 July (Figure 17). Three peaks in the density of larvae occurred during this period. The abundance of larvae decreased between 26 June and 4 July due to high river flow (Figure 18).

Figure 15. Occurrence of fish eggs, larvae and young taken with a one-half meter plankton met in the Delaware River (river mile 116 to 119) from April through September 1972. (After: Kranz, 1974a)



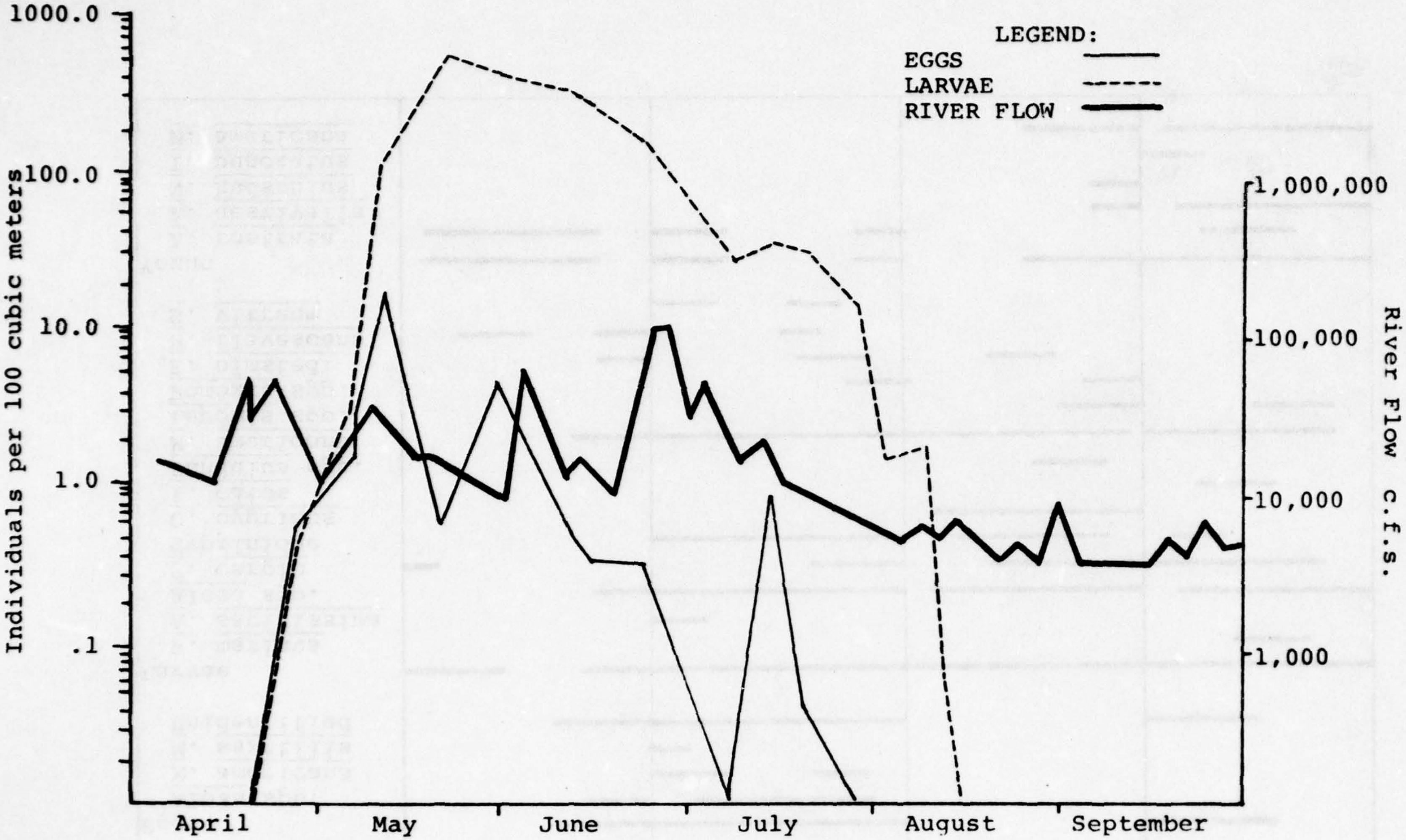
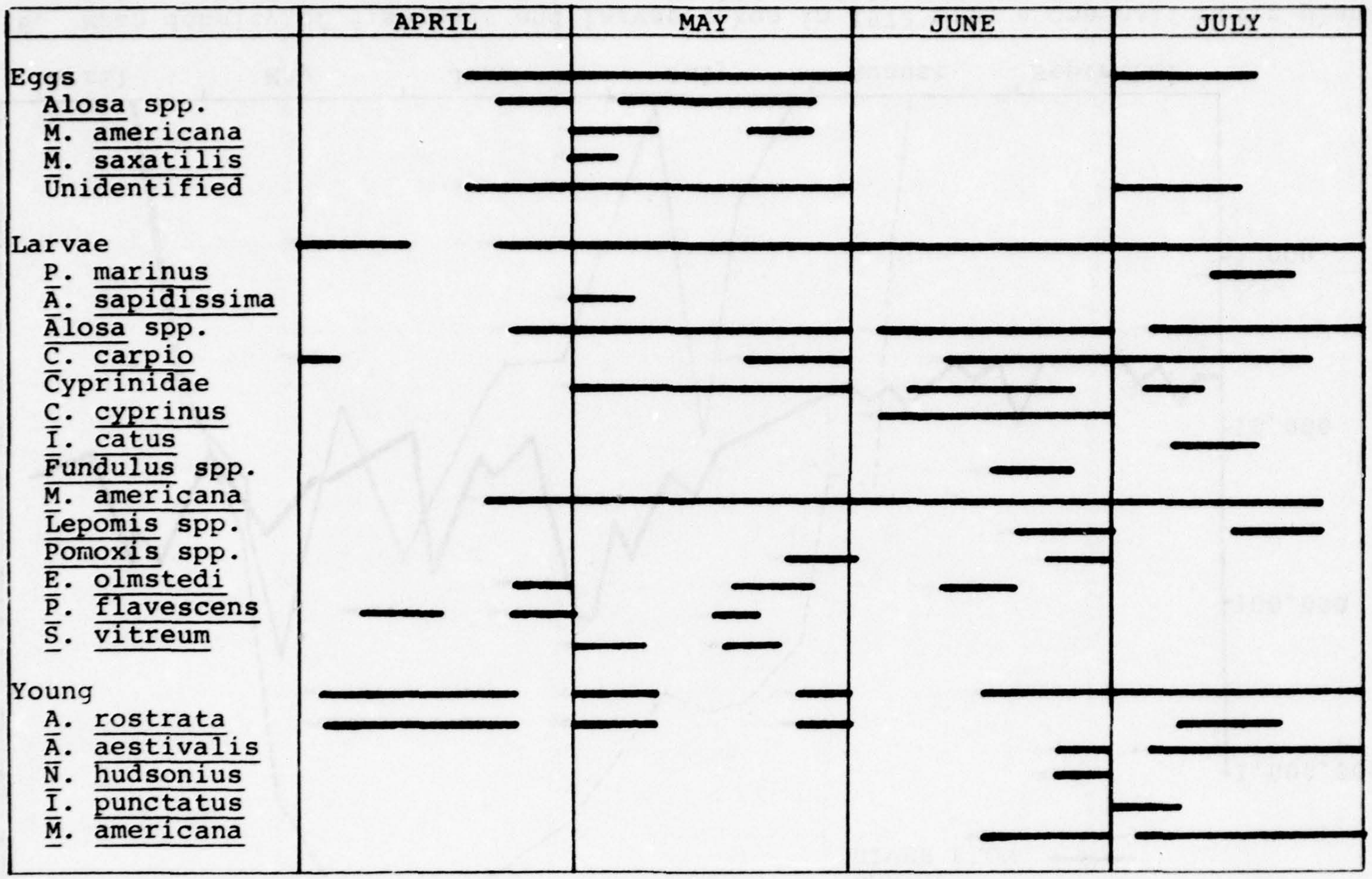


Figure 16. Mean density of fish eggs and larvae taken in 1972 with a one-half meter plankton net in the Delaware River (river mile 116 to 119) and the daily river flow at Trenton, New Jersey from April through September 1972. (After: Kranz, 1974a)

Figure 17. Occurrence of fish eggs, larvae and young taken with a one-half meter plankton net in the Delaware River (river mile 116 to 119) in 1973. (After: Krantz, 1974b)



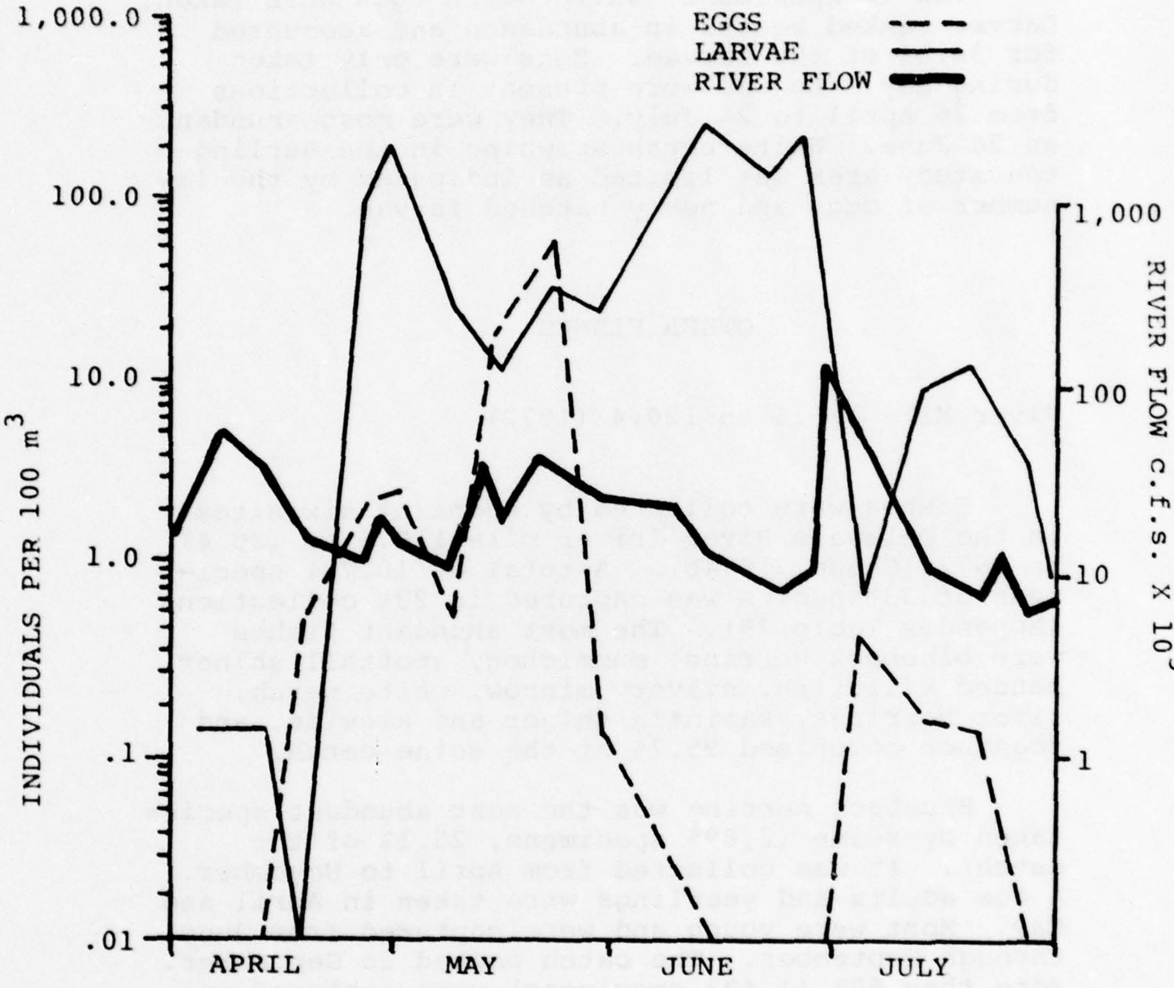


Figure 18. Density of fish eggs and larvae in the Delaware River (river mile 116 to 119) and mean river flow at Trenton, New Jersey from April through July 1973 (Kranz, 1974b).

River herrings were the most abundant egg and larva taken in 1973. Eggs were collected from 26 April to 23 May and were most numerous on 15 May. Larvae were captured from 26 April to 30 July. Two peaks in the density of larvae occurred. The first was on 1 and 2 May and was comprised mainly of prolarvae. The second was on 12 June and was almost entirely postlarvae.

Few (5 specimens) white perch eggs were taken. Larvae ranked second in abundance and accounted for 34.5% of the larvae. Eggs were only taken during May. Larvae were present in collections from 26 April to 26 July. They were most abundant on 26 June. White perch spawning in the Burlington study area was limited as indicated by the low number of eggs and newly hatched larvae.

OTHER FISHES

River Mile 115.5 to 120.4 (1972)

Fishes were collected by seine at six sites in the Delaware River (river mile 115.5 to 120.4) in 1972 (Chase, 1974b). A total of 10,731 specimens of 33 species was captured in 238 collections (Appendix Table 29). The most abundant fishes were blueback herring, mummichog, spottail shiner, banded killifish, silvery minnow, white perch, river herrings, satinfin shiner and alewife, and together comprised 95.7% of the seine catch.

Blueback herring was the most abundant species taken by seine (2,695 specimens, 25.1% of the catch). It was collected from April to November. A few adults and yearlings were taken in April and May. Most were young and were captured from June through September. The catch peaked in September. More than 50% (1,493 specimens) were captured in New Jersey at river mile 117.3.

Mummichog ranked second among the fishes taken by seine (2,186 specimens, 20.4%). It was taken throughout the year. Most were taken in August and primarily in New Jersey at river mile 116.5.

Spottail shiner was captured (1,583 specimens, 14.8%) in all months except January. Large numbers were collected from March to December with the peak in June. Young (Age 0+) were common in collections taken in summer. From 224 to 312 specimens were taken at each site.

Banded killifish was fourth in abundance (1,276 specimens, 11.9%). It was taken in every month but January; almost 25% were taken in September. About 50% were taken in Pennsylvania at river mile 117.7.

Silvery minnow ranked fifth in seine collections (1,156 specimens, 10.8%). Most were taken between April and September with a peak abundance in May. Young (Age 0+) appeared first in June collections, and were common through December. It was captured at all sites.

Postlarvae and young (<25mm FL) river herrings ranked sixth (541 specimens). They comprised 5.0% of the seine catch; most were taken in June.

White perch ranked seventh in seine collections (3.8%); 411 specimens were collected from March to December. Most (45%) were taken in September. Young (Age 0+) were first captured in June and were common from July to December. It was taken at every site, but about 40% were collected in New Jersey at river mile 117.3.

Satinfin shiner ranked eighth with 283 specimens representing 2.6% of the catch. It was taken in every month; peak abundance was in fall. About 80% were collected at river mile 117.3 and 117.7 in New Jersey and Pennsylvania, respectively.

Alewife was ninth in abundance (145 specimens, 1.4%). All but one specimen were young (Age 0+). It was taken from June through September; the greatest number (135, 93%) was captured in July. About 81% of the alewife was taken in New Jersey at river mile 117.3.

River Mile 115.5 to 120.4 (1973)

A total of 1,098 specimens of 21 species was collected in 45 seine collections at six sites (Appendix Table 30) (Holmstrom, 1974). The spottail

A quantitative study of the zooplankton in
the Delaware River (river mile 116.8 to 117.7) was

shiner, young (Age 0+) river herrings, banded killifish, mummichog, satinfin shiner, silvery minnow and white perch accounted for 92.7% of the 1973 seine catch.

The spottail shiner was the most numerous species collected by seine with 307 specimens representing 27.9% of the catch. It was taken at all sites and in all months except February. It was most abundant along the New Jersey shore at river mile 116.5. The largest catch occurred in June and consisted primarily of young.

Young (<25mm FL) river herring comprised 22.4% of the total seine catch. All were collected in June. They were most abundant at river mile 116.5 and 117.7 in New Jersey and Pennsylvania, respectively.

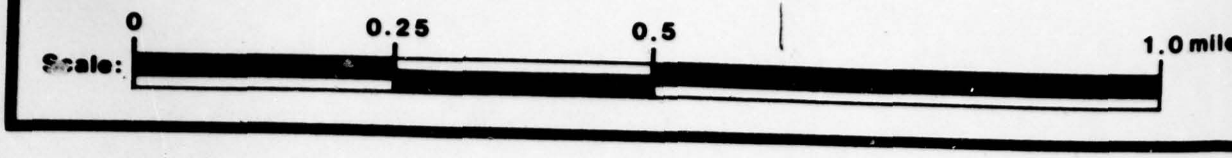
The banded killifish made up 15% of seine catch and ranked third. It was caught at all sites and in all months. It was most abundant in early spring and made up 46.2% of the catch in March. The largest numbers were taken at river mile 115.5 in Pennsylvania.

The mummichog ranked fourth representing 14.8% of the seine catch. It was taken in all months except February with the greatest number captured in June. About 73% of the catch was collected at river mile 116.5 in New Jersey.

The satinfin shiner was fifth in total abundance (5% of the catch). It was taken during every month of sampling. About 51% of the catch was taken at river mile 117.3 in New Jersey.

The silvery minnow was sixth in total abundance with 49 specimens representing 4.5% of the catch. It was taken during every month of sampling. It was found at every seine site.

The white perch (3.1% of the catch) ranked seventh in abundance. Approximately two-thirds of the specimens were taken during June at river mile 117.3 in New Jersey.



RIVER MILE 117 TO 119

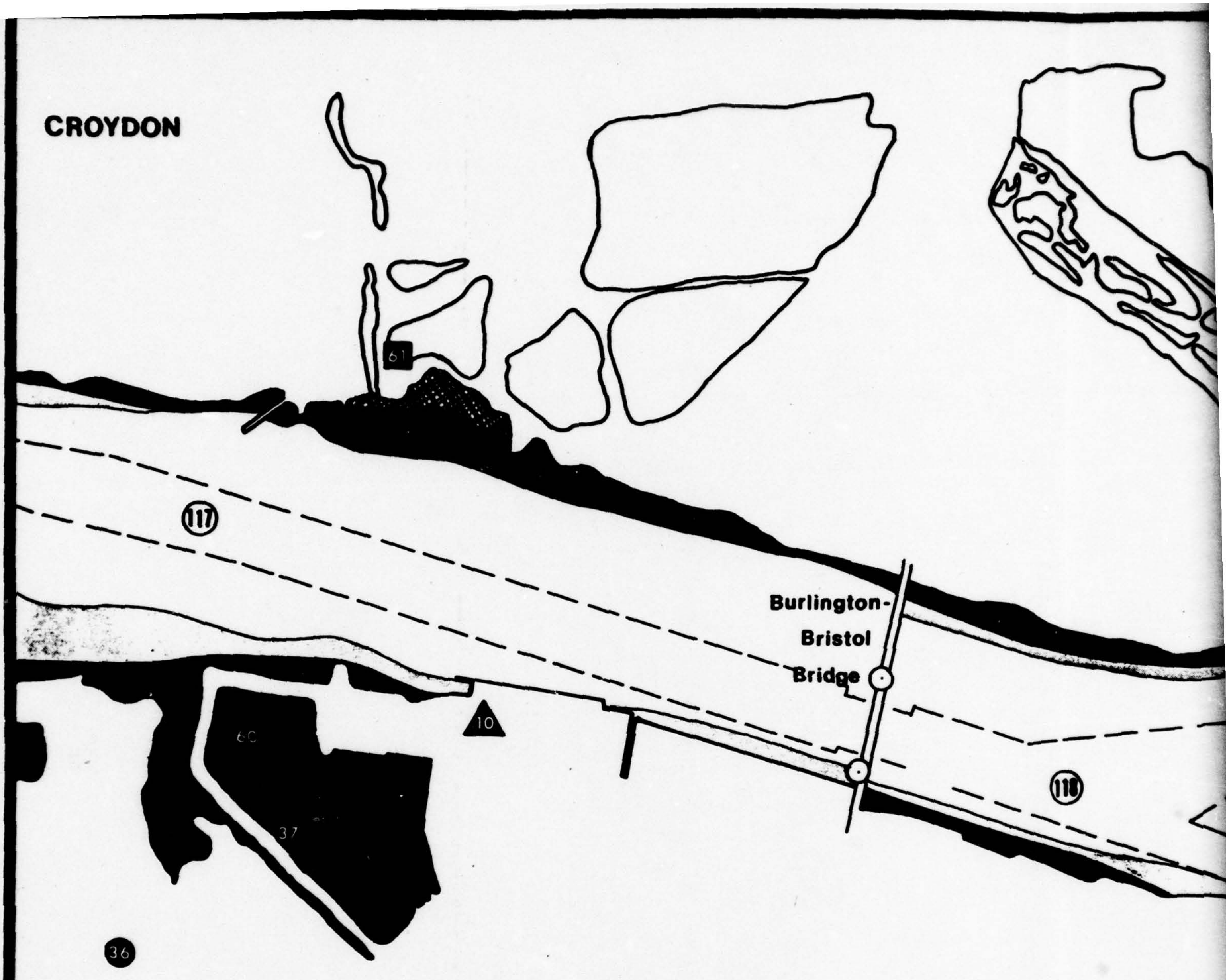
Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
36	Burlington City	2	NJ 0024660
37	Burlington Township Main Plant	2	NJ 0021709
▲	Power Plant		
10	Public Service Electric and Gas, Burlington	2	NJ 0005002
■	Other Point Source Discharge		
60	Tenneco Plastics	2	NJ 004391
61	Rohm and Haas, Bristol	2	PA 0012769
62	Amico Sand and Gravel	2	--

PHYTOPLANKTON

River Mile 117.3 (March 1972 to October 1973)

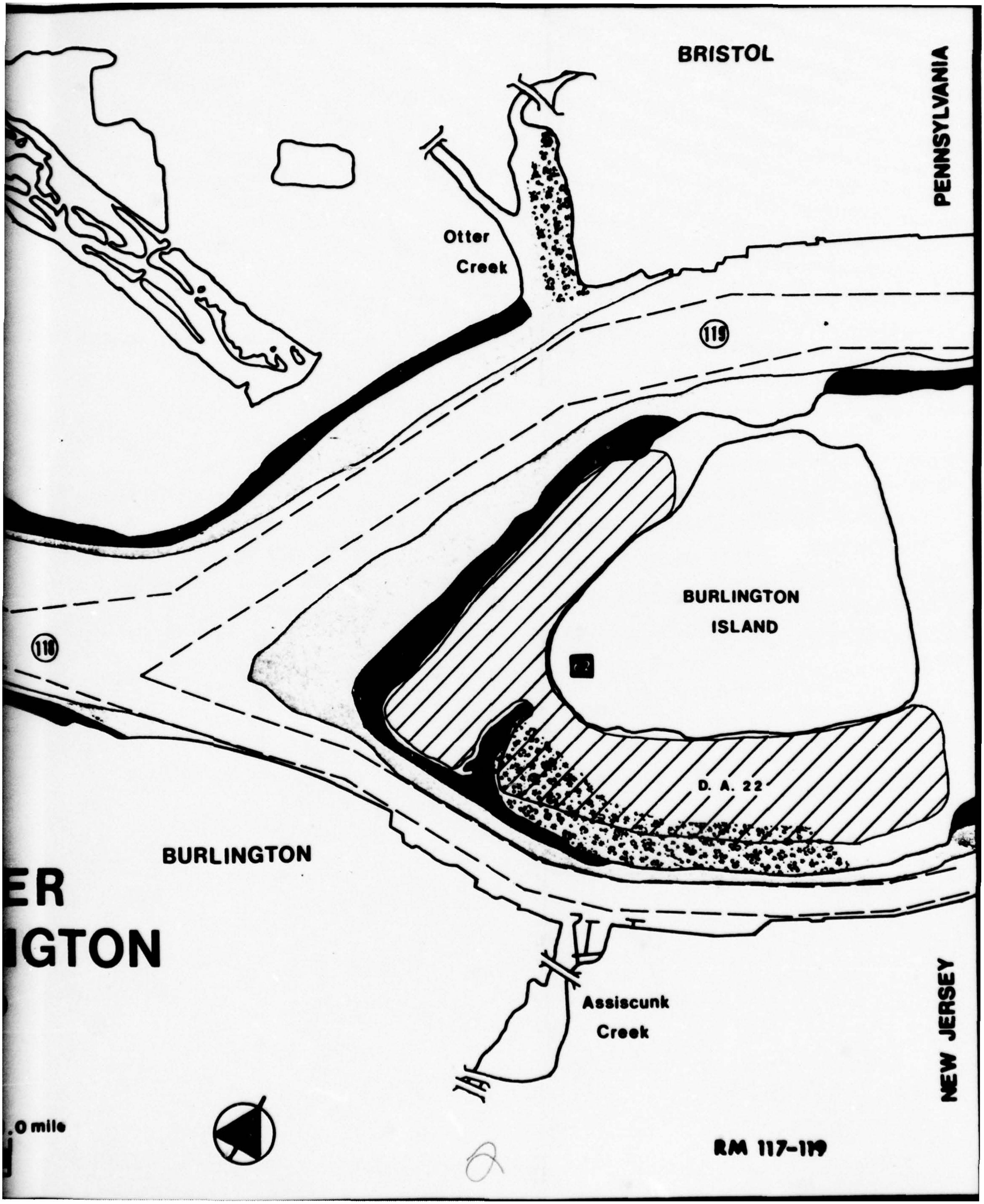
A diverse assemblage of phytoplankton is found in the Delaware River near Burlington (river mile 117.3). More than 60 genera were identified during the ecological studies conducted by Ichthyological Associates, Inc., in 1972 and 1973 (Appendix Table 31). A quantitative analysis of plant pigments was made in 1973 (Figure 19). Blue-green algae were found in every month, and as a group, were proportionally greatest in late summer and early fall. The unpleasant conditions that frequently accompany blue-green algal blooms such as offensive odors and nuisance growth, were not observed during the studies made in 1972 and 1973 (Krout, 1974).



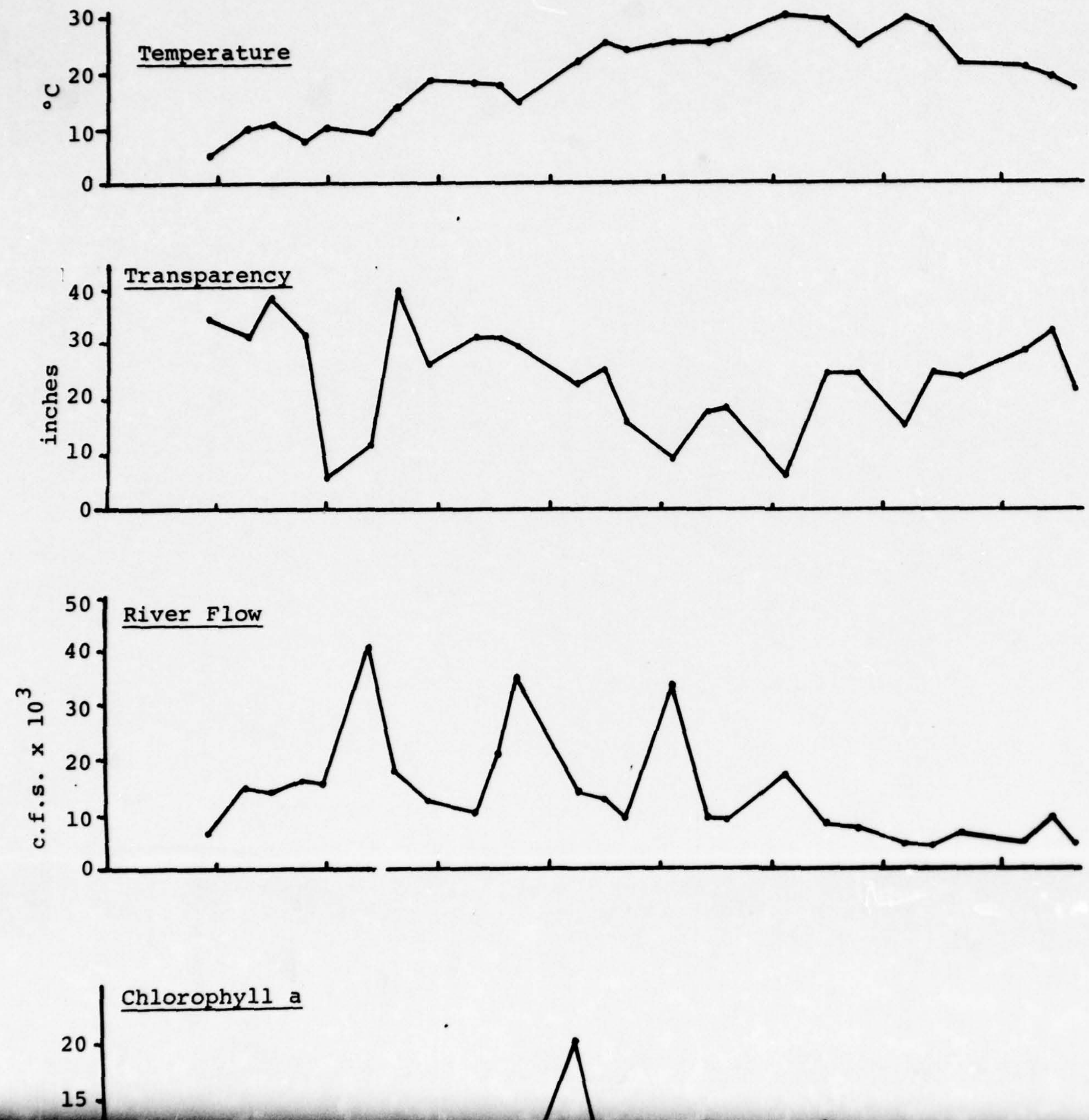
DELAWARE RIVER
CROYDON - BURLINGTON

RIVER MILE 117 - 119

Scale: 0 — 0.25 — 0.5 — 1.0 mile



BRISTOL
PENNSYLVANIA
Otter Creek
119
118
BURLINGTON ISLAND
D. A. 22
BURLINGTON
ER
IGTON
Assiscunk Creek
NEW JERSEY
.0 mile
RM 117-119


Temperature
°C
30
20
10
0
Transparency
inches
40
30
20
10
0
River Flow
c.f.s. x 10^3
50
40
30
20
10
0
Chlorophyll a
20
15

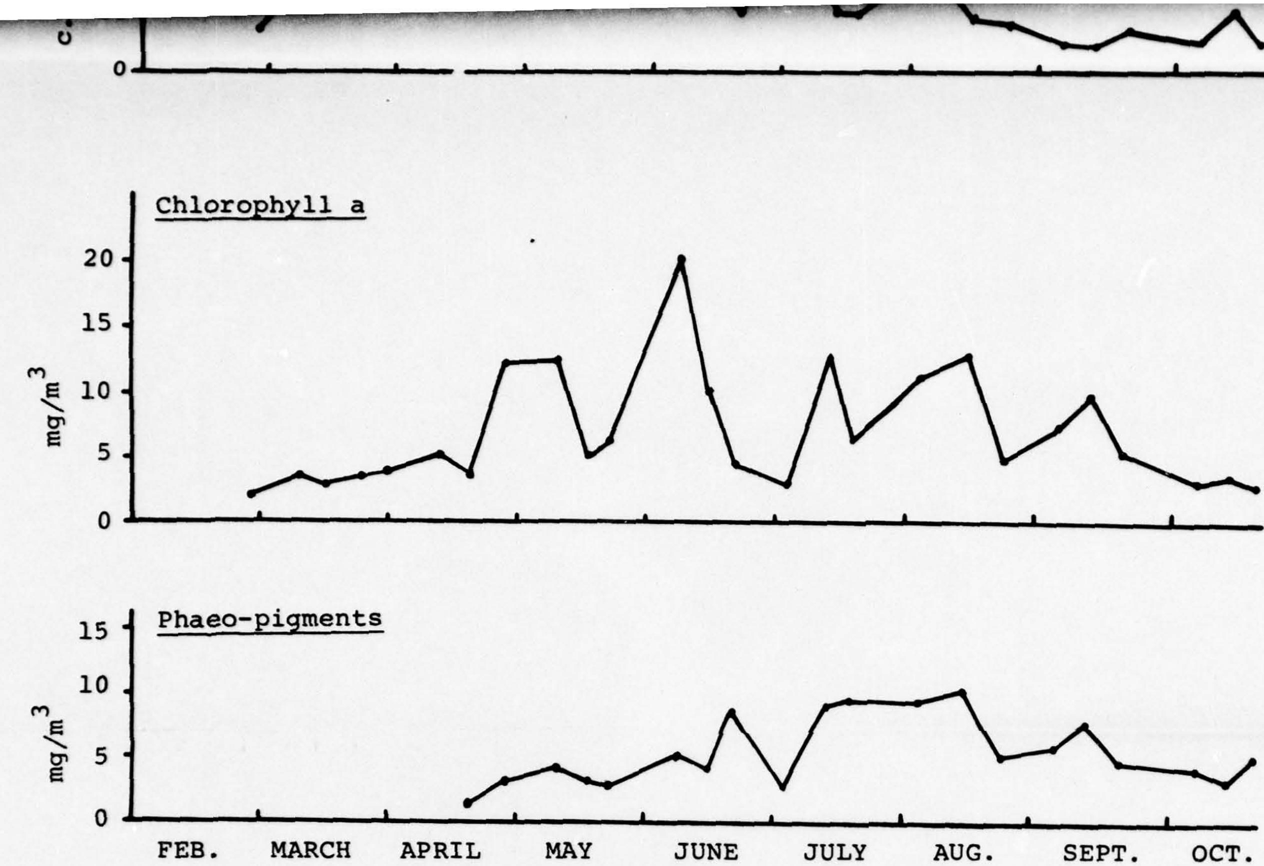


Figure 19. Water temperature and transparency; river flow at Trenton, New Jersey; chlorophyll a and phaeopigment in the Delaware River (river mile 117.3) in 1973 (Kroūt, 1974).

ates, Inc. from August 1970 to October 1973. A total of 97,000 organisms of 70 taxa was taken in

MACROPHYTES

River Mile 117 to 121 (1972)

The species composition, distribution and relative abundance of the aquatic vascular plants from river mile 117 to 121 were recorded and mapped by Ichthyological Associates, Inc., in 1972 (Chase, 1974b). The location of the major beds of plants are shown in Figures 14 and 20. The most common and widely distributed plants were: yellow water lily, pickerel weed, three-square bulrush, broad-leaved arrowhead and arrow arum.

BENTHOS

See above, RIVER MILE 115 TO 117, for summary of benthos from river mile 116 to 131.

ICHTHYOPLANKTON

See above, RIVER MILE 115 TO 117, for studies of ichthyoplankton from river mile 116 to 119.

OTHER FISHES

See above, RIVER MILE 115 TO 117, for a summary of the fishes taken by seine from river mile 115.5 to 120.4.

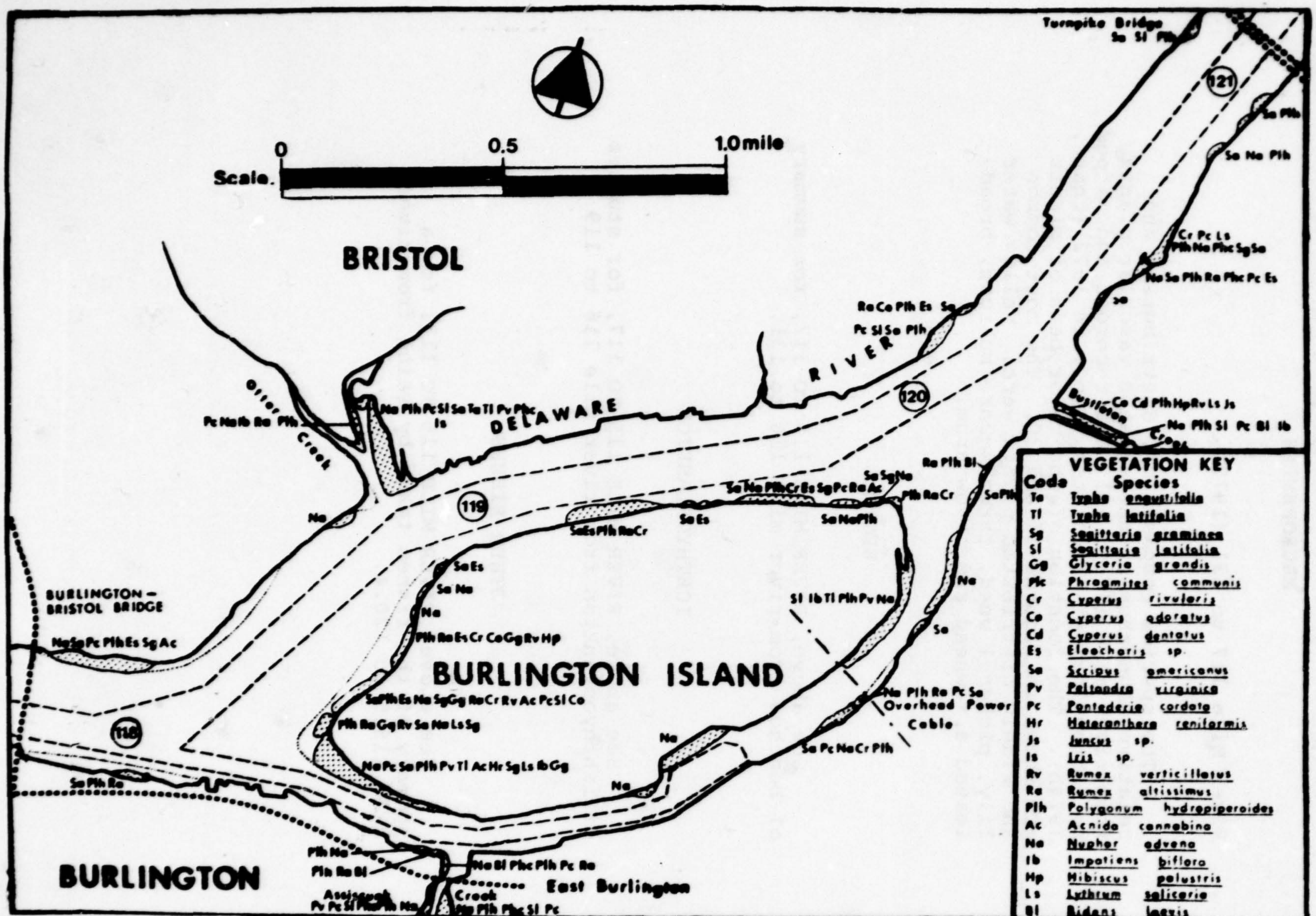


Figure 20. Distribution and relative abundance of aquatic vegetation in the Delaware River (river mile 118 to 121) in 1972. Species in each vegetation bed are listed in order of decreasing relative abundance (Chase, 1974b).

RIVER MILE 119 TO 120

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
39	Burlington Township, LeGorce Square Plant	2	NJ 0021695
40	Borough of Bristol	2	PA 0027294
■ Other Point Source Discharge			
62	Amico Sand and Gravel	2	--
63	Purex	2	PA 0011215
72	Hercules Powder, Organics Dept., Burlington	2	NJ 0005142

For information concerning the ecology of this portion of the Delaware Estuary see above RIVER MILE 115 TO 117 and RIVER MILE 117 TO 119.

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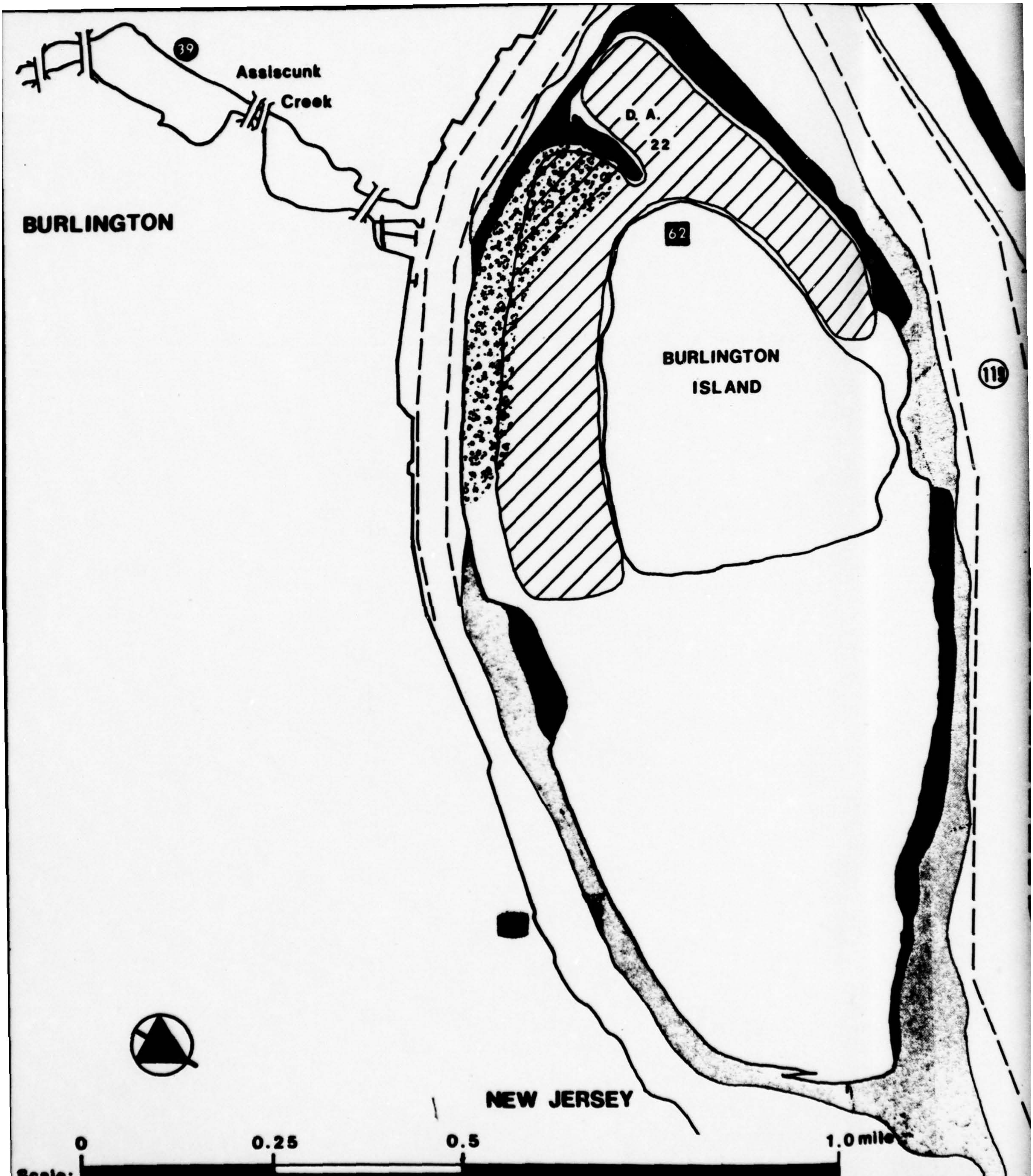
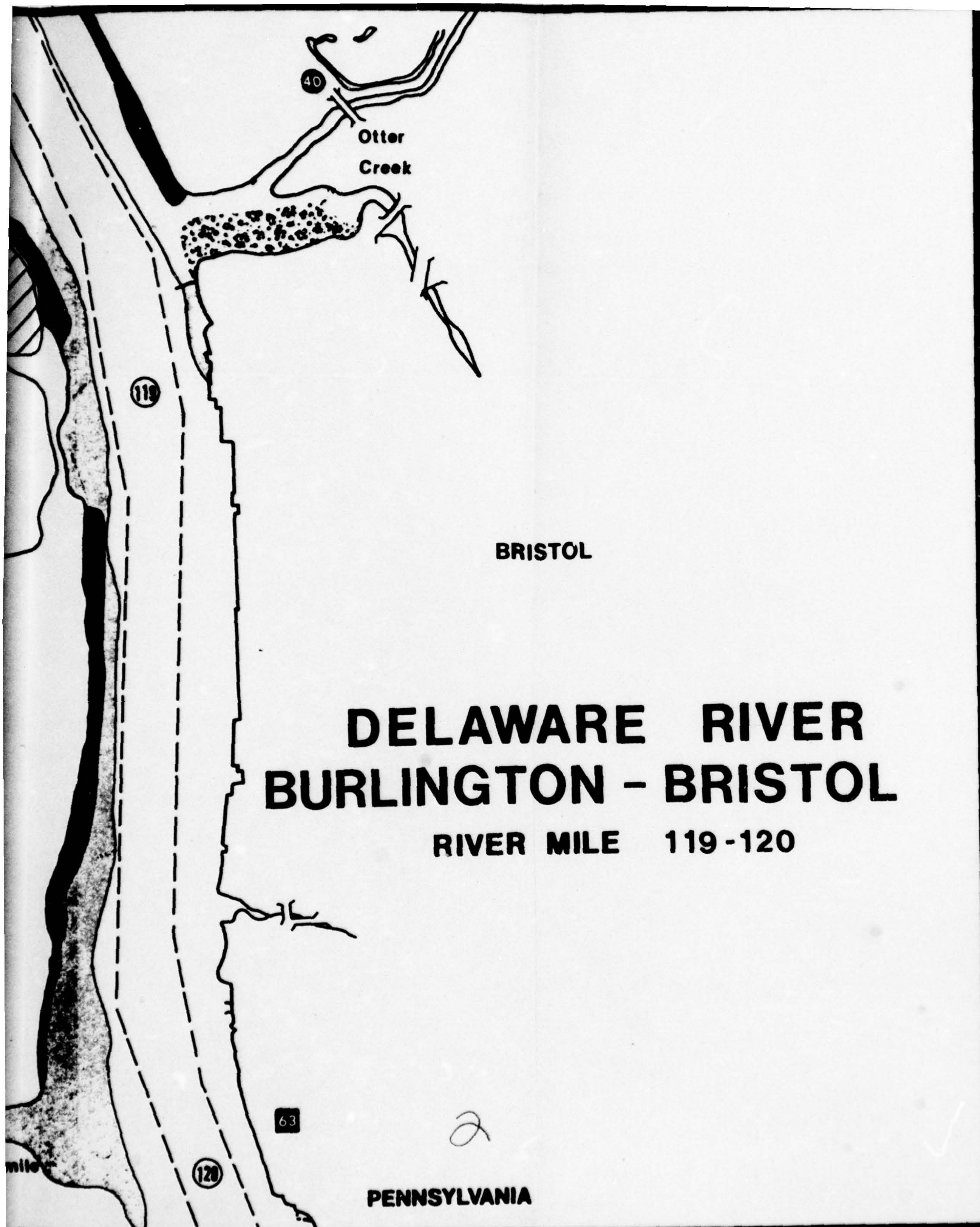


39
Assiscunk
Creek
BURLINGTON
D. A.
22
62
BURLINGTON
ISLAND
119
NEW JERSEY
0
0.25
0.5
1.0 mile
Scale:


40
Otter
Creek
119
BRISTOL
DELAWARE RIVER
BURLINGTON - BRISTOL
RIVER MILE 119-120
63
120
PENNSYLVANIA

RIVER MILE 120 TO 122

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
42	Florence Township, Burlington County	2	NJ 0023701
43	Lower Bucks County Municipal Authority	2	PA 0026468
■ Other Point Source Discharge			
64	Hooker Chemical	2	NJ 0004235
65	Pateron Parchment Paper Company	2	PA 0013307
66	Griffin Pipe Company	2	NJ 0005096

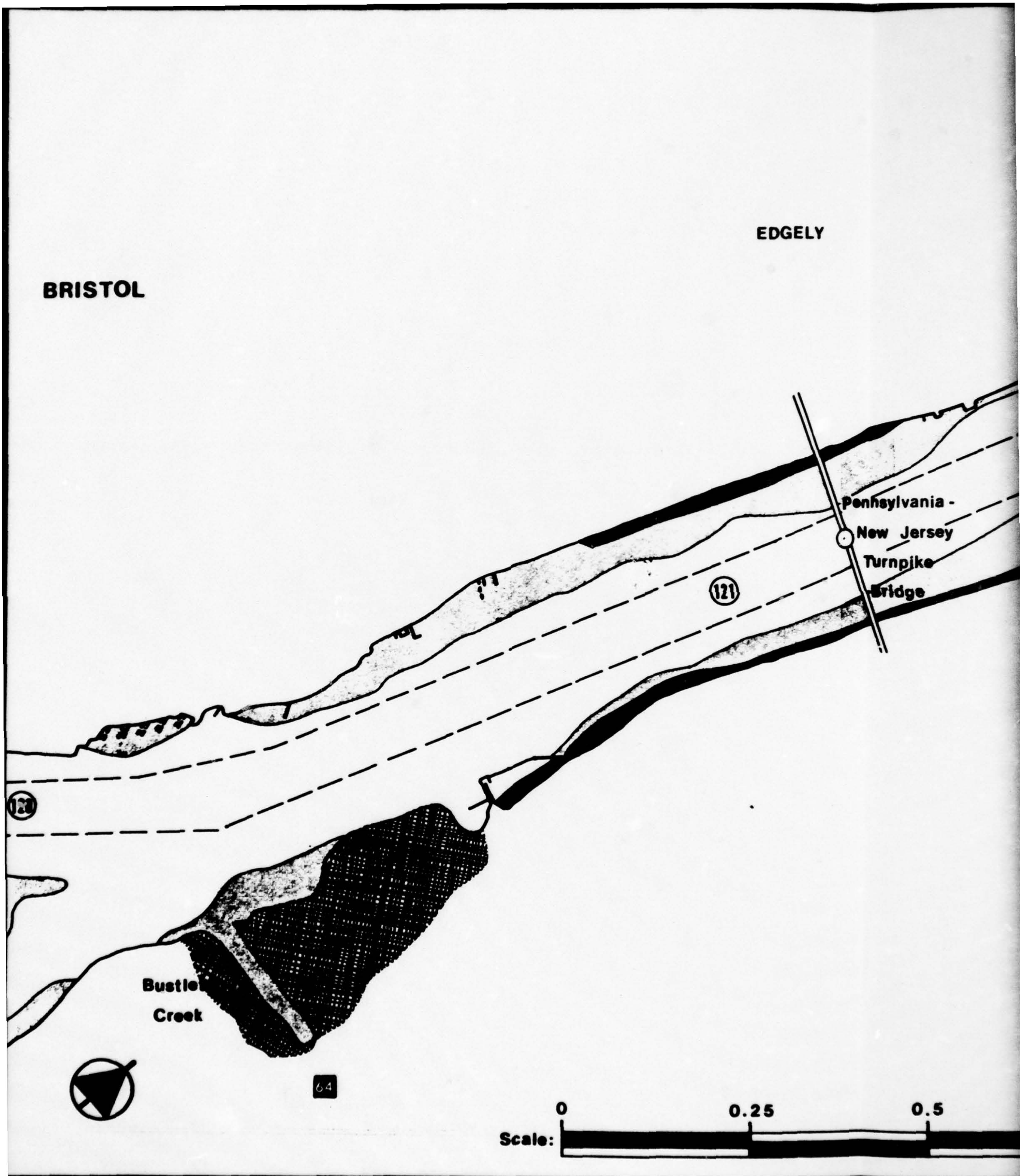
MACROPHYTES

See above, RIVER MILE 115 TO 117, for summary of macrophytes from river mile 117 to 121.

ZOOPLANKTON

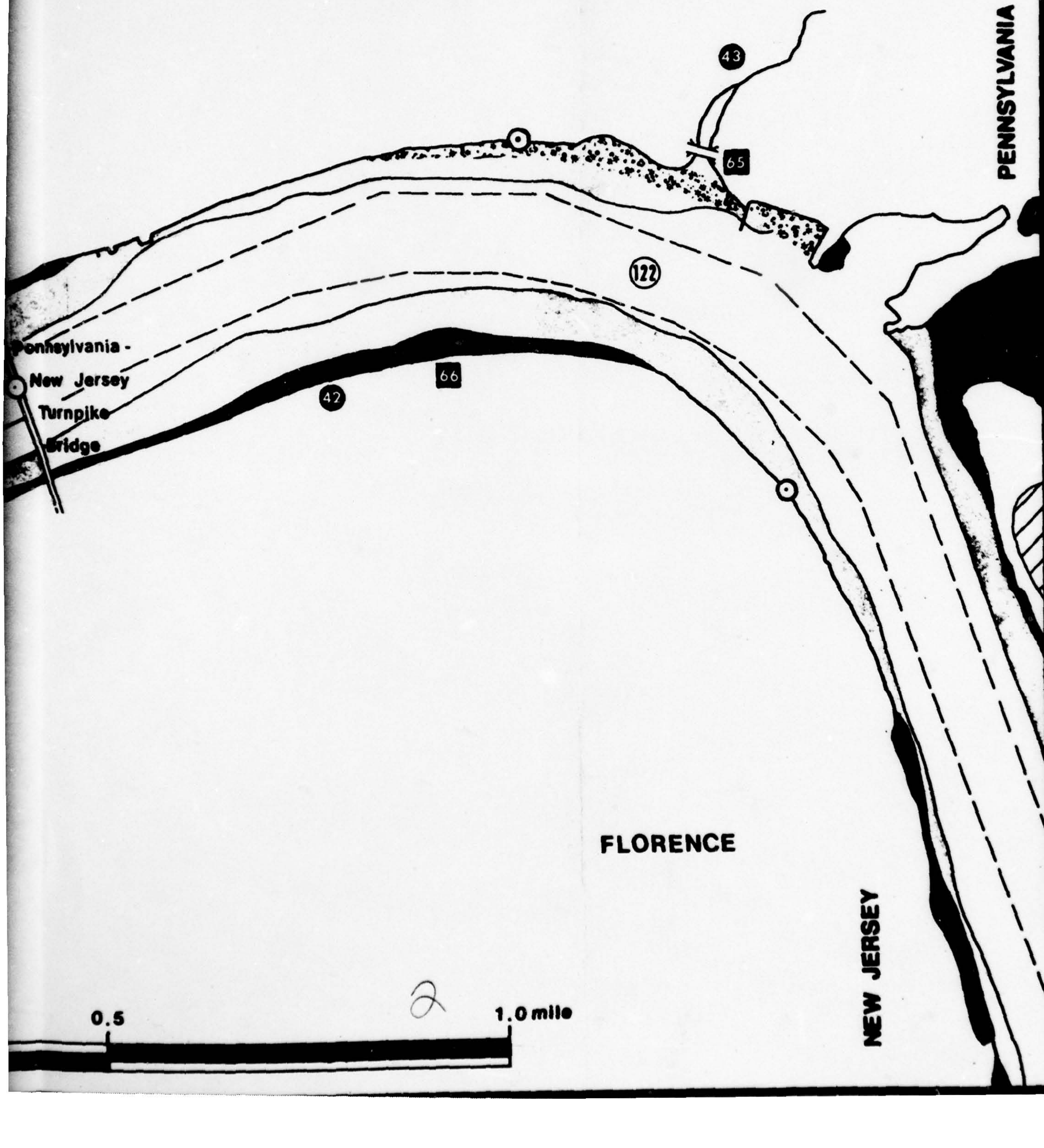
River Mile 120.5 to 130.5 (1971)

The zooplankton in the Delaware River (river mile 120.5 to 130.5) was sampled quantitatively in 1971 (Chase, 1976). More than 60 taxa were identified in 183 samples (Appendix Table 32). Cladocerans were the most diverse and abundant of the zooplankton. The most common species were *Bosmina longirostris* and *Leptodora kindtii*. Copepods were common, but were less numerous as a group than cladocerans. *Macrocyclops ater* was the dominant


EDGELY
BRISTOL
Pennsylvania -
New Jersey
Turnpike
Bridge
121
Bustleton
Creek
64
0
0.25
0.5
Scale:

DELAWARE RIVER
BRISTOL - FLORENCE

RIVER MILE 120 - 122



species. Rotifers were abundant seasonally. The most numerous genera were Asplanchna, Brachionus, Filinia and Keratella. Day and night samples revealed that many organisms were most numerous at the surface during darkness than in daylight (Figures 21 and 22).

BENTHOS

See above, RIVER MILE 115 TO 117, for summary of benthos from river mile 116 to 131.

ICHTHYOPLANKTON

River Mile 120 to 130 (1971)

A total of 97 eggs, 16,476 larvae and 174 young fish representing 12 genera in 9 families was collected in samples taken from 14 April to 30 August 1971 (Young, 1976). The fish eggs collected were river herring, yellow perch and white perch. The most numerous larvae taken were river herring, yellow perch, minnows, white perch and quillback. Blueback herring, spottail shiner, alewife and American eel were the most abundant young fishes captured.

River herrings were the most abundant fishes collected in 1971. Eggs (82.4% of all eggs taken) were found from 21 April to 15 June and were in all stages of embryonic development (Figure 23). Larvae (88.5% of the total larvae catch) were taken from late April through early July. Most, however, were found from late May through mid-June.

The eggs and larvae of the yellow perch were caught in April. Most were collected in the outlet from Crystal Lake, a tributary stream that enters the secondary channel of the Delaware River between river mile 125 and 127. Yellow perch was observed spawning in the outlet in mid-April and four subsequent collections in the area yielded 15 eggs and 1,266 larvae (Young, 1976). Yellow perch was scarce elsewhere.

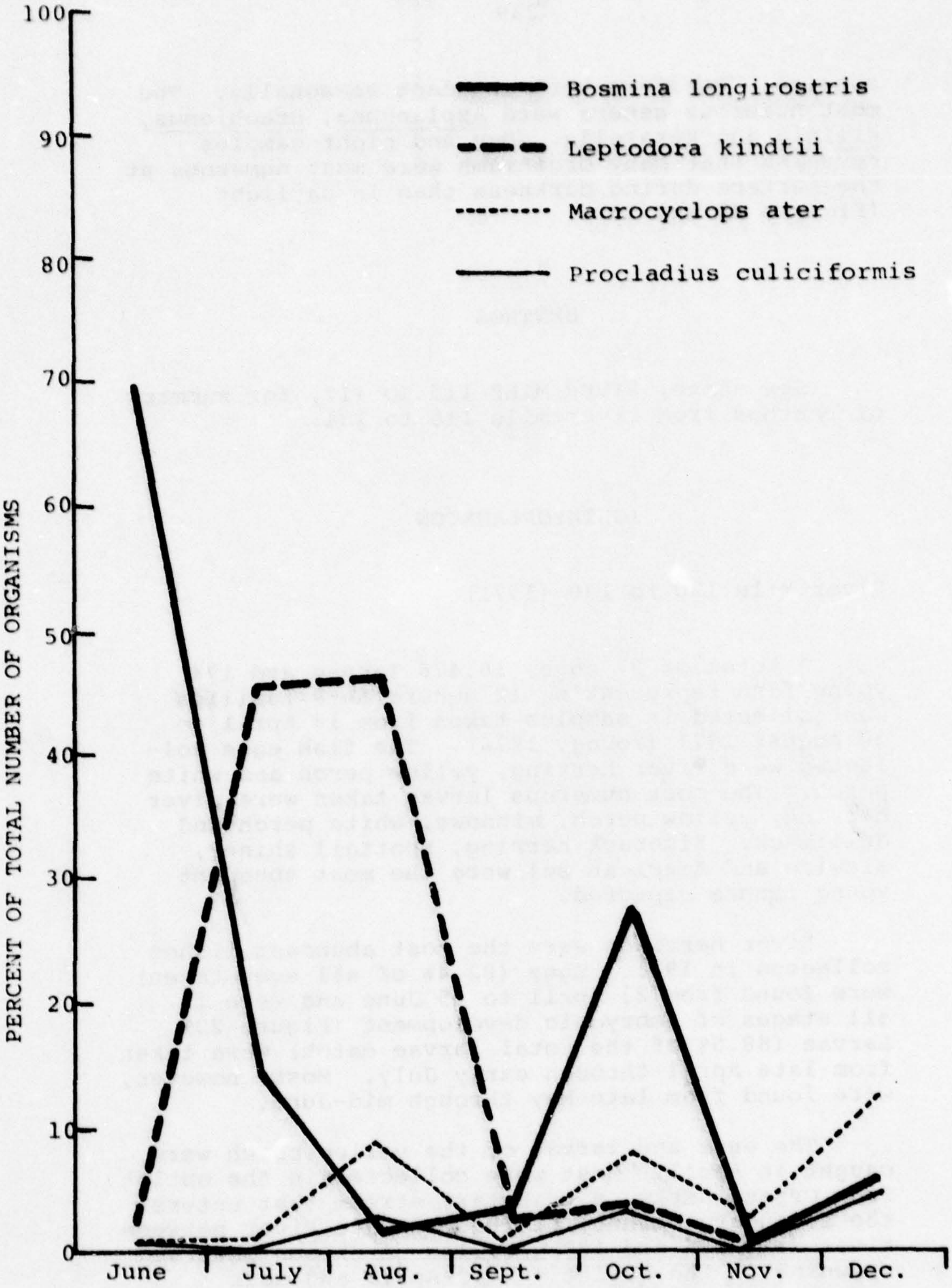


Figure 21 Relative abundance of the most common zooplankters collected by one-half meter net during daylight in the Delaware River (river mile 120.5 to 129.2 in 1971 (Chase, 1976).

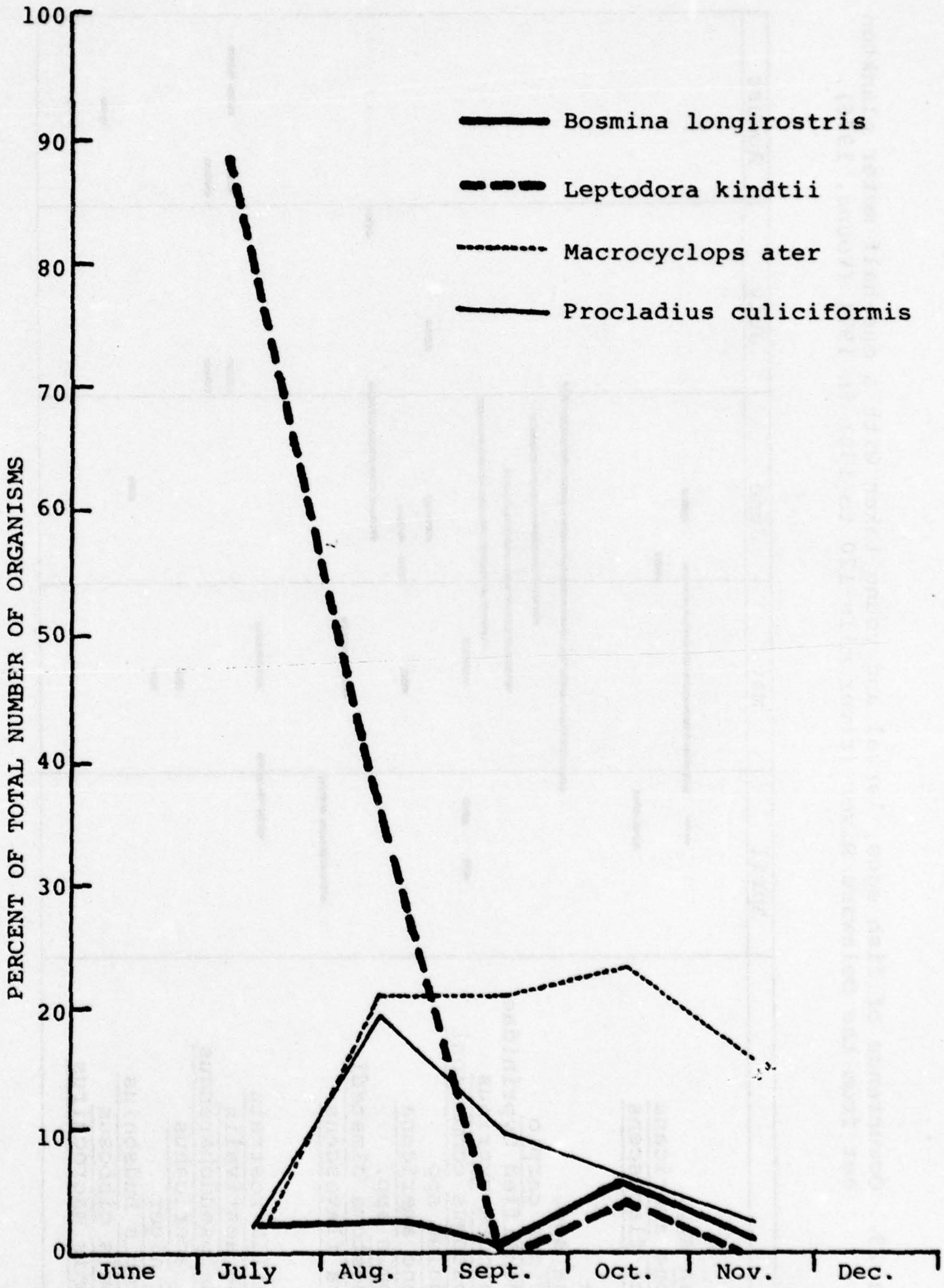
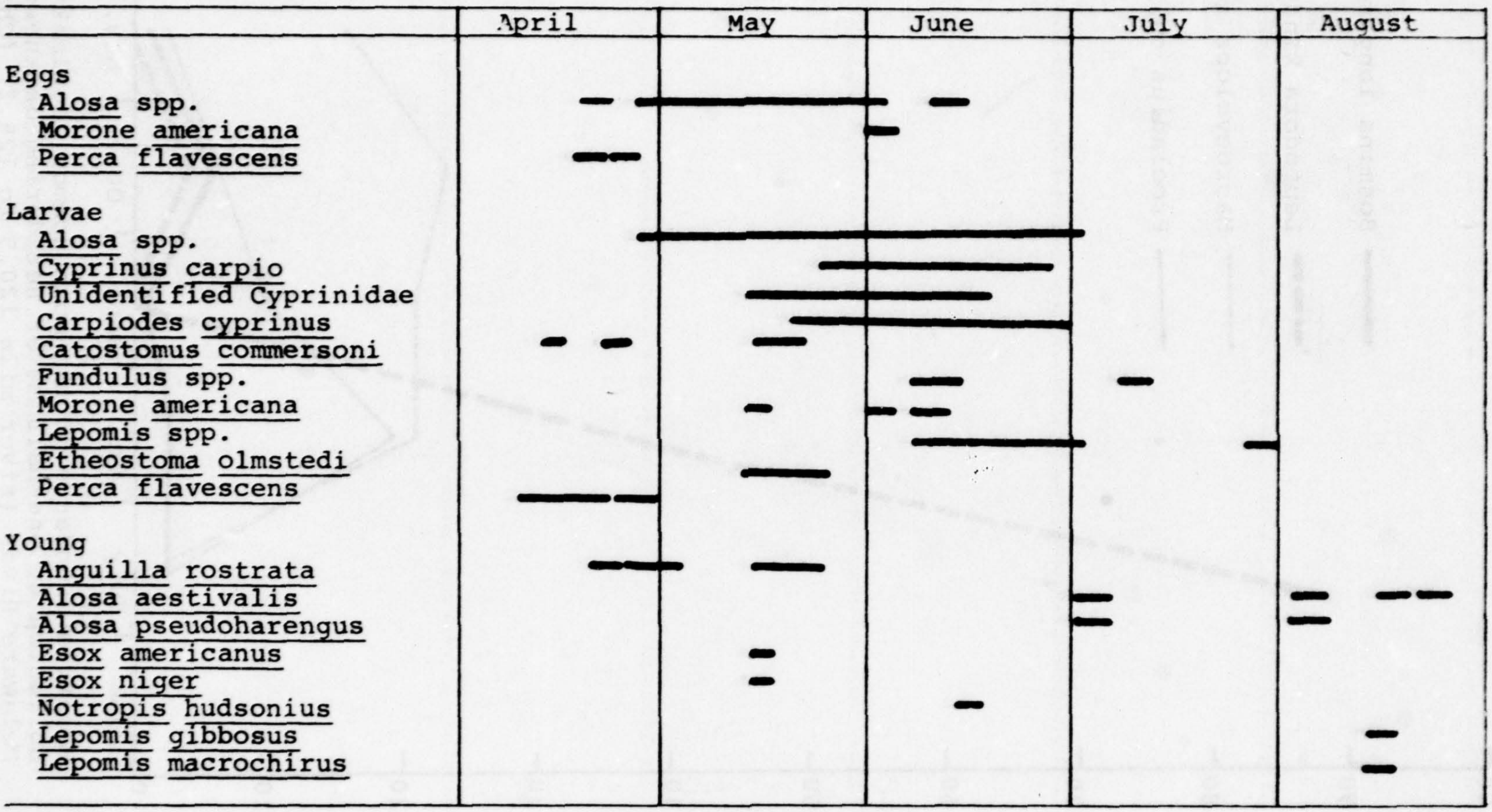


Figure 22. Relative abundance of the most common zooplankters collected by one-half meter net during darkness in the Delaware River (river mile 120.5 to 129.2) (Chase, 1976).

Figure 23. Occurrence of fish eggs, larval and young taken with a one-half meter plankton net from the Delaware River (river mile 120 to 130) in 1971 (Young, 1976).



Other than carp, larval minnows were difficult to distinguish and were grouped as minnows (Young, 1976). These (325 specimens) were collected from mid-May through mid-June.

The eggs and larvae of the white perch were collected on 17 May (2 larvae), 1 June (2 eggs, 9 larvae) and 15 June (120 larvae). Larvae of the quillback (125 specimens) were collected from 24 May to 30 June. Postlarvae of the white sucker (21 specimens) were taken sporadically from 14 April to 24 May. Larvae of the bluegill, pumpkinseed and red breast sunfish (<7mm) were difficult to separate and were grouped as Lepomis spp. (Young, 1976). These larvae (13 specimens) were found from mid-June through July.

American eel elvers were captured during April and May when water temperature was from 56-66°F. Prolarvae of the carp (11 specimens) were collected from 17 May to 15 June when surface water temperature was between 59-79°F. Six postlarvae of the tessellated darter were found in late May. Postlarvae Fundulus spp. were collected from mid-June through early July.

OTHER FISHES

See above, RIVER MILE 115 TO 117, for a summary of fishes from river mile 115.5 to 120.4.

River Mile 122 to 130 (1970)

Seine samples from the Delaware River (river mile 122 to 130) were taken in 1970. Seine collections (208) produced 99,489 specimens of 28 fishes (Appendix Table 33) (Anselmini, 1971). The blueback herring, spottail shiner, silvery minnow, mummichog, alewife, white perch and brown bullhead comprised 99.5% of the seine catch. As measured by gross numbers, all seine sites were productive. Fewer species but greater numbers were collected at downstream sites. The number of specimens taken near the Pennsylvania shore as compared to New Jersey was greater but not significantly so.

The seine site at river mile 127.5 on the Pennsylvania shore was located at the mouth of a small heated outfall (Anselmini, 1971). Water temperature year-round was from 5 to 13°F above river ambient. Large numbers of fishes, particularly blueback herring and mummichog, were seined even in the warmest periods during August. Fishes also tended to concentrate here during November and December.

The anadromous species, blueback herring, was by far the most abundant species collected (Anselmini, 1971). Many were taken by seine (62,312) in the shallow water. Nearly all specimens were young. This area is an important nursery grounds for this species. Young were collected when sampling was initiated in lte June. It was most numerous in August collections when water temperatures were highest and, as the river cooled, their numbers gradually declined. In early November the catch decreased sharply and by the end of the month, when water temperature had fallen below 50°F, it was not taken. The seine sites below and surrounding Newbold Island yielded most specimens.

The spottail shiner ranked second in the seine catch; 16,997 specimens were collected. Most taken by seine were young; most adults were taken by trawl. The spottail shiner was collected from all areas. Young were most numerous in June and July after which the catch decreased. In November and December the spottail shiner was dominant in trawl collections.

Silvery minnow ranked third with 7,590 specimens taken by Seine (Anselmini, 1971). Most young were captured by seine; most adults were captured by trawl.

Mummichog ranked fourth in abundance; 4,703 specimens were taken. All were collected in the shore zone by seine. It was prevalent at seine sites above Newbold Island and was especially common in the heated waters at river mile 127.5.

The alewife was the fifth most numerous (12,392 specimens, 2.4% of the seine catch) species collected by seine; most specimens taken were young (Anselmini, 1971). The catch peaked in August and subsequently declined as the river cooled; it was absent from collections made in water colder than 50°F.

The spatial distribution of the alewife was different from that of the related blueback herring. The greatest numbers of the alewife were collected offshore by trawl. Alewife comprised 25.6% of the trawl catch as compared to 2.4% for the seine. Also, the alewife was the prevalent species in deep water hauls taken in the shipping channel. Sites upstream of Newbold Island yielded most seine specimens.

The white perch was the sixth most common species; 2,106 specimens were collected by seine. Anselmini (1971) concluded it was a resident species since adults and young were taken in all months. The greatest concentration at seine sites was below Newbold Island, moderate numbers were taken adjacent to Newbold Island and the lowest catch was from areas upstream.

Brown bullhead was the most common catfish collected and ranked seventh (1,451 specimens) in seine collections. Most young were collected at seine sites upstream of Newbold Island in late June and early July.

Banded killifish was the eighth most abundant species sampled. It is mostly restricted to the shallows; all but six of the 1,497 specimens were collected by seine. Both young and adults were taken. The banded killifish was the most numerous in the quiet waters of the Newbold Island back-channel.

Abbott (1878) reported that the Newbold Island area, especially Crosswicks Creek, was a spawning place for the striped bass. More recently, Murawski (1969) reported taking striped bass larvae from this region. Sampling in 1970 yielded one striped bass (96mm FL). It was captured across the river from Newbold Island on 5 August by trawl.

Game fish such as the chain pickerel and large-mouth bass were scarce. A number of pan fishes were taken but not in large numbers. These included American eel, white catfish, channel cat-fish, redbreast sunfish, pumpkinseed, bluegill, white crappie, black crappie and yellow perch.

Young American shad on their autumnal seaward migration were collected with a 25-foot trawl rigged to fish at the surface. Some 65 specimens were taken in 68 hauls made between October 27 and November 27. Most were captured in late October and early November when water temperature raned from 50 to 59°F.

River Mile 122 to 130 (1971)

Daylight seine collections (384) were taken weekly at 10 sites throughout the year. The collections yielded 47,073 specimens of 35 fishes (Appendix Table 34). The seine catch varied with season. Relatively few fish were found in winter and early spring. The catch increased markedly in late spring (June) with the recruitment of young (Age 0+). Most fish in the summer and fall seine collections were young. In the cooler months fish were most abundant at river mile 127.4 near an industrial outfall where water temperature was generally 5 to 13°F higher than river ambient. Large catches were also made there in the summer months when water temperature was occasionally as high as 95°F (Anselmini, et al., 1976).

The most abundant fishes (99% of the catch) in the daylight seine collections were blueback herring, spottail shiner, mummichog, alewife, silvery minnow, banded killifish, satinfish shiner, golden shiner and white perch (Anselmini, 1976).

The blueback herring was the most abundant species with 16,578 specimens representing 35.2% of the catch. It was taken from June through November and all specimens were young. It was widely distributed and was found at all sites. The smallest catch was made upstream of Newbold Island and in the secondary channel south of the island.

The spottail shiner was the second most common species with 12,819 specimens representing 27.2% of the catch. It was taken in all months and at all sites. The largest number (7,631, mostly young) was taken in June. Spottail shiner was the most abundant fish in the seine collections made in January and December.

The mummichog made up 13.5% (6,337 specimens) of the daytime catch and ranked third. It was collected at all sites and was found throughout the year. The catch peaked in July and August (3,913, mostly young). The greatest number was found at river mile 127.5.

Alewife ranked fourth with 5,421 specimens representing 11.5% of the catch. It was found from June through August and all specimens were young. Like the blueback herring, it was scarce in the secondary channel.

Silvery minnow (2,085 specimens) accounted for 4.4% of the catch. It was collected from March through December and was found at all sites. About 70% of the specimens were taken in July at river mile 126.0 and 127.5.

The banded killifish was the sixth most abundant fish with 1,906 specimens representing 4% of the catch. It was taken year-round and was found at all sites. The largest number was taken from river mile 126.0 to 127.5.

The satinfin shiner ranked seventh with 577 specimens (1.2%). It was taken from February through December and was found at all sites.

The golden shiner accounted for about 1% of the catch with 497 specimens. Most (453 specimens) were taken in June.

The white perch ranked ninth in abundance (262 specimens) but comprised less than 1% of the catch. It was found at all sites and was taken sporadically from May through November.

Night collections (85) were made from 28 June to 2 September 1971. The most abundant fishes at night were spottail shiner, silvery minnow, mummichog, banded killifish and white perch. The white perch was significantly more abundant at night than in the day. Blueback herring, and to a lesser extent the alewife, were conspicuously less abundant in the night seine collections. Only 66 blueback herring were taken at night.

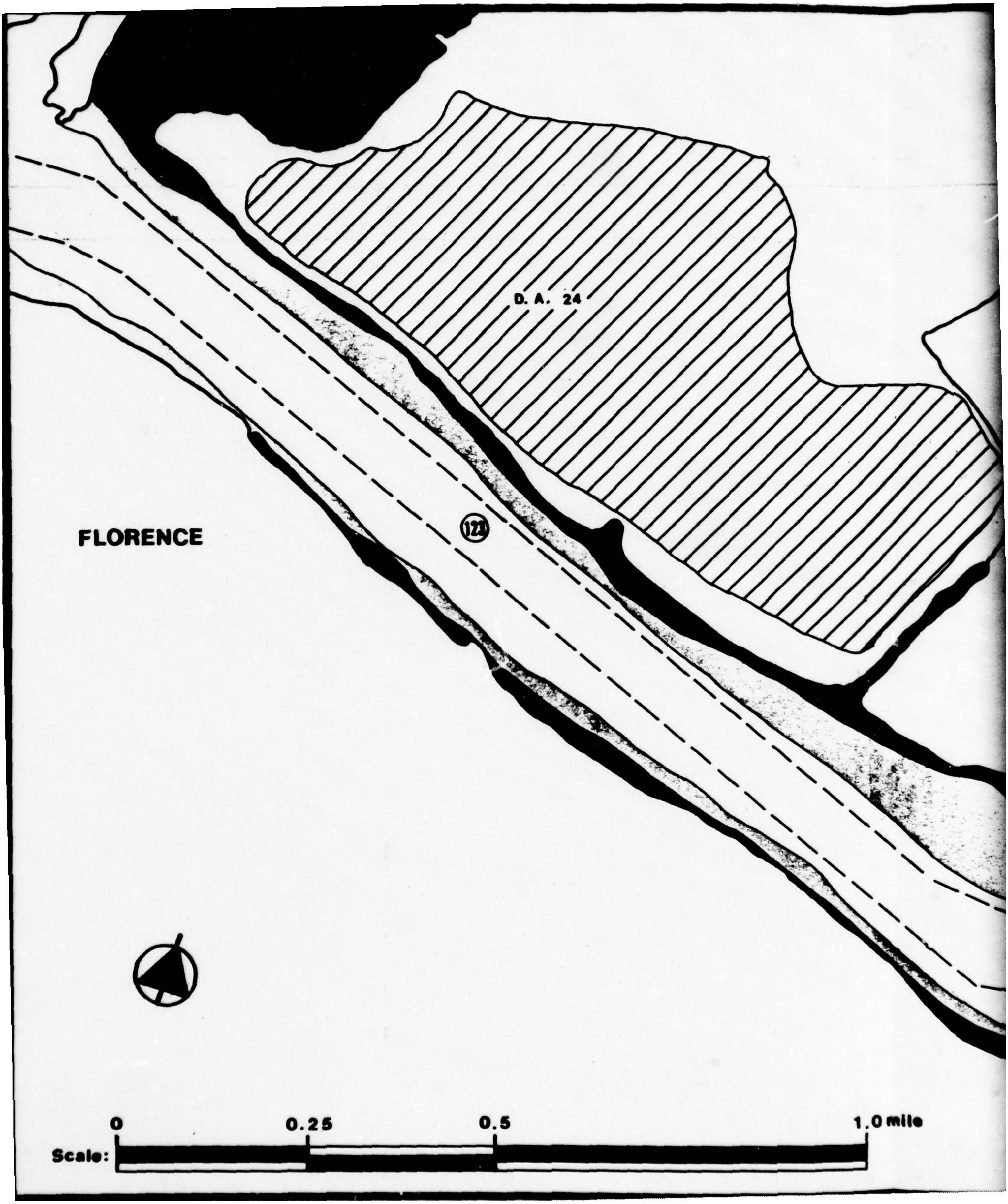
Collections with the 250-foot beach seine were made at nine locations from 30 June to 20 August. A total of 346 specimens representing 22 fishes were taken in 17 samples. White perch, blueback herring, mummichog, pumpkinseed and striped bass were the most common fishes taken. All 28 of the striped bass were captured in a single haul made on 30 June; all were less than 250mm FL.

The study area is a spawning ground and nursery area for the anadromous blueback herring and alewife. The young (Age 0+) of both species were abundant and widely distributed in summer and fall. Game fish such as the striped bass, largemouth bass and chain pickerel were scarce.

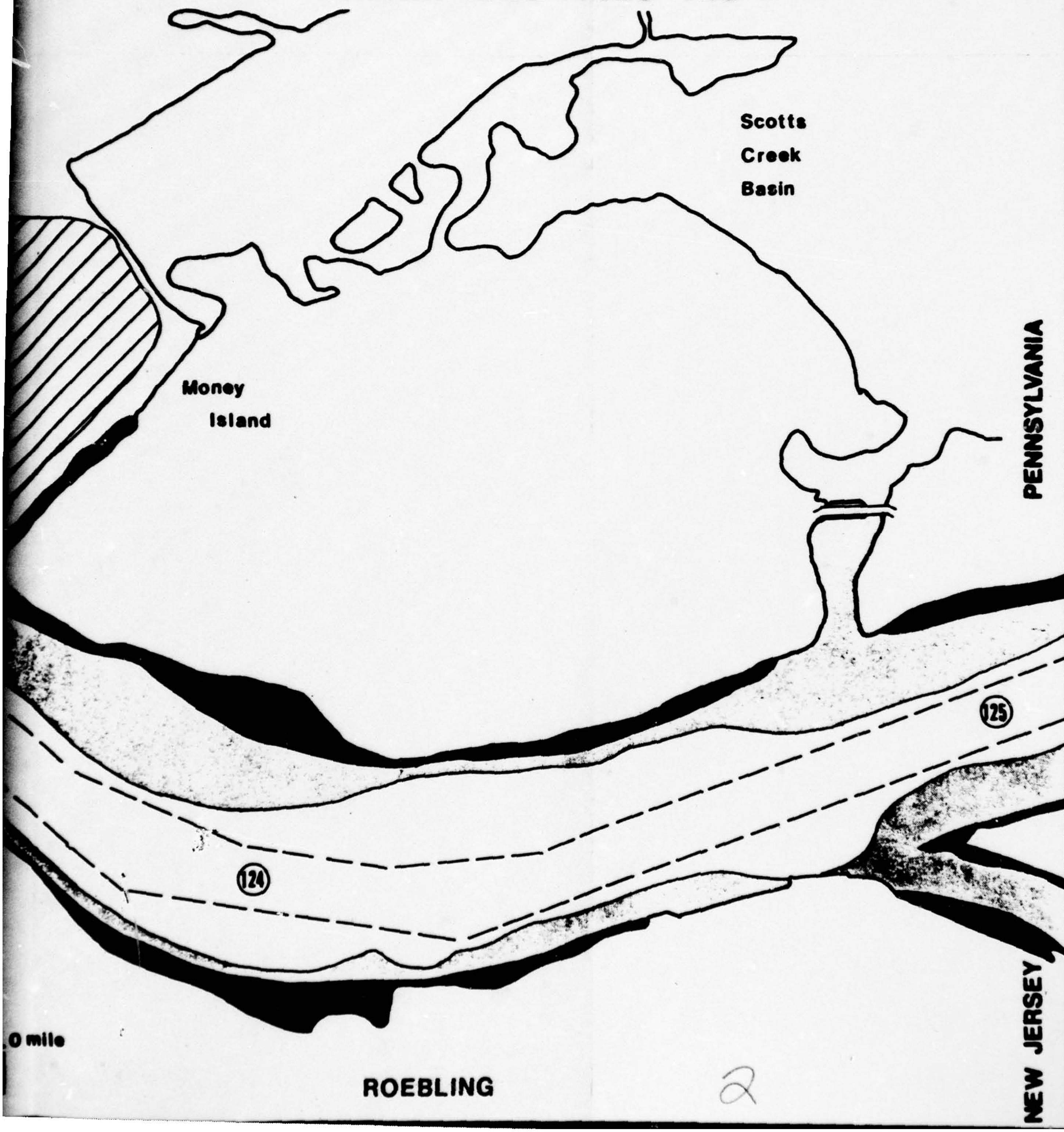
A total of 76 surface collections made with a 25-foot trawl at night in autumn captured 11,763 specimens of 16 species. The most common fishes were blueback herring, alewife, white perch and American shad. Most of the American shad were taken from mid-October to early November.

RIVER MILE 123 TO 125

For information concerning the ecology of this segment of the Delaware Estuary see above RIVER MILE 115 TO 117 and RIVER MILE 120 TO 122.


D. A. 24
123
FLORENCE
0
0.25
0.5
1.0 mile
Scale:

DELAWARE RIVER
FLORENCE - ROEBLING
RIVER MILE 123-125



2

RIVER MILE 125 TO 127

Point Source Impacts

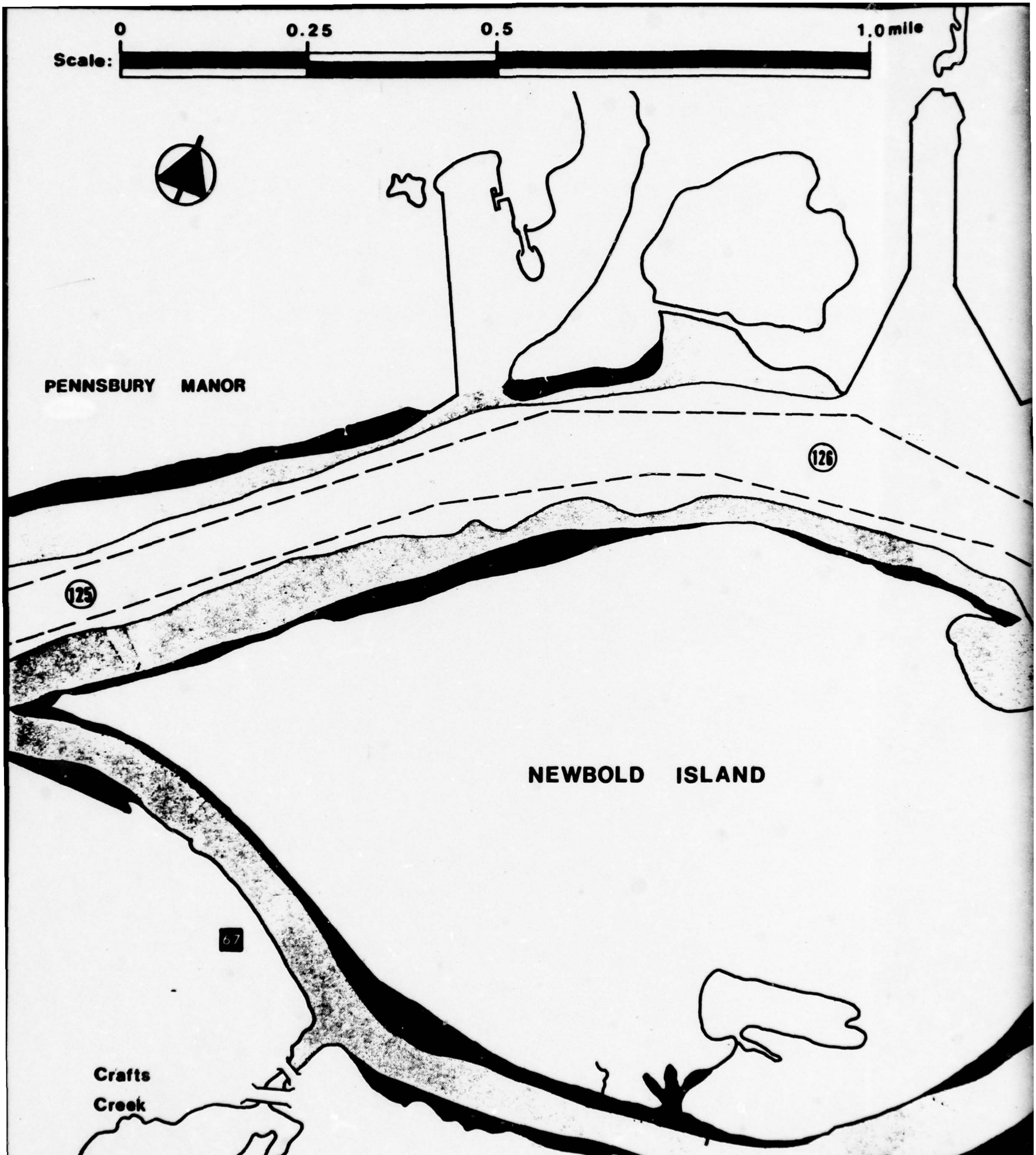
MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
45	U.S. Steel Sanitary Waste	2	PA 0012637
■ Other Point Source Discharge			
67	CF & I	2	NJ 0005274

PHYTOPLANKTON

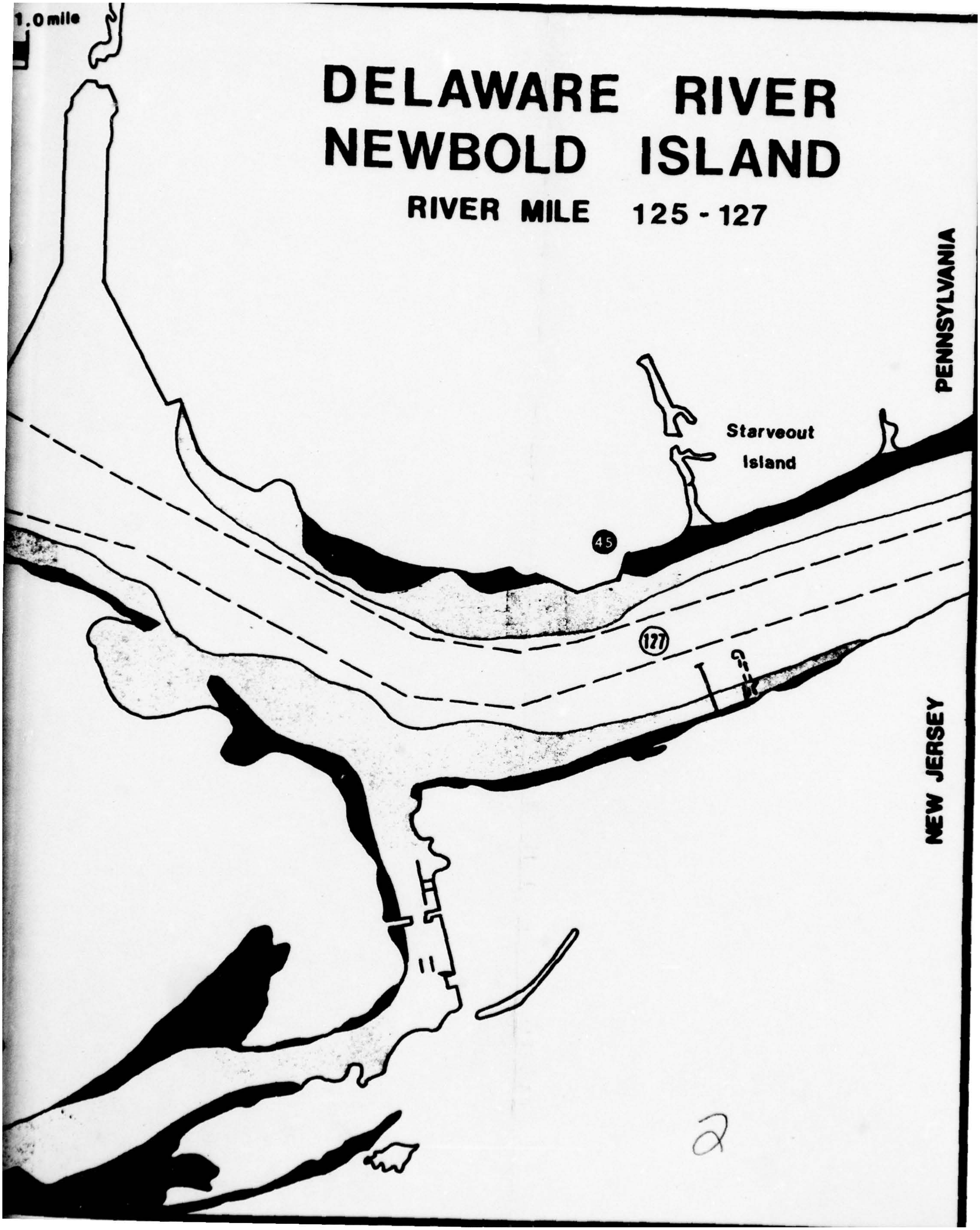
River Mile 125.5

Fifty-six genera of phytoplankton were identified near Newbold Island (river mile 125.5) (PSE&G, 1972). These represented five divisions: green algae, 20 genera; yellow-green algae, composed primarily of diatoms, 19 genera; blue-green algae, five genera; red algae, one genus and yellow-brown algae, including the dinoflagellates, two genera. The 17 most commonly collected genera were: *Amphiprora*, *Asterionella*, *Audouinella*, *Diatoma*, *Fragilaria*, *Lyngbya*, *Melosira*, *Oedogonium*, *Oscillatoria*, *Palmodictyon*, *Pediastrum*, *Scenedesmus*, *Spirogyra*, *Stauroneis*, *Stigeoclonium*, *Tabellaria* and *Volvox*.

Phytoplankton population increases were observed in the Delaware River near Newbold Island with blooms during spring and fall (PSE&G, 1972). Green algae predominated in spring and summar 1971, with *Oedogonium*, *Palmodictyon*, *Spirogyra*, *Stigeoclonium* and *Volvox* being most important from March to May and *Pediastrum*, *Scenedesmus* and *Spirogyra* dominant in June and July. A bloom of



0
0.25
0.5
1.0 mile
Scale:
PENNSBURY MANOR
126
125
NEWBOLD ISLAND
67
Crafts
Creek


DELAWARE RIVER
NEWBOLD ISLAND
RIVER MILE 125 - 127
1.0 mile
PENNSYLVANIA
NEW JERSEY
Starveout
Island
45
127

Oscillatoria occurred in August and early September; this agreed with the Academy of Natural Science Report (Patrick, et al., 1969) that a fall bloom occurs downstream from Newbold Island between 1 August and 15 September. Diatoms (Asterionella, Fragilaria, Melosira, Stauroneis and Tabellaria) were the dominant organisms from October to December.

MACROPHYTES

River Mile 125 to 130 (1972)

The species composition, distribution and relative abundance of the aquatic vascular plants from river mile 125 to 130 were recorded and mapped by Ichthyological Associates, Inc., in 1972 (PSE&G, 1972; Anselmini, 1974b). The location of the major beds of plants are shown in Figures 24 and 25. The most common and widely distributed plants were yellow water lily, pickerel weed, three-square bulrush, broad-leaved arrowhead and arrow arum.

ZOOPLANKTON

See above, RIVER MILE 120 TO 122, for summary of zooplankton from river mile 120.5 to 130.5.

BENTHOS

See above, RIVER MILE 115 TO 117, for summary of the benthos from river mile 116 to 131.

ICHTHYOPLANKTON

See above, RIVER MILE 120 TO 122, for summary of ichthyoplankton from river mile 120 to 130.

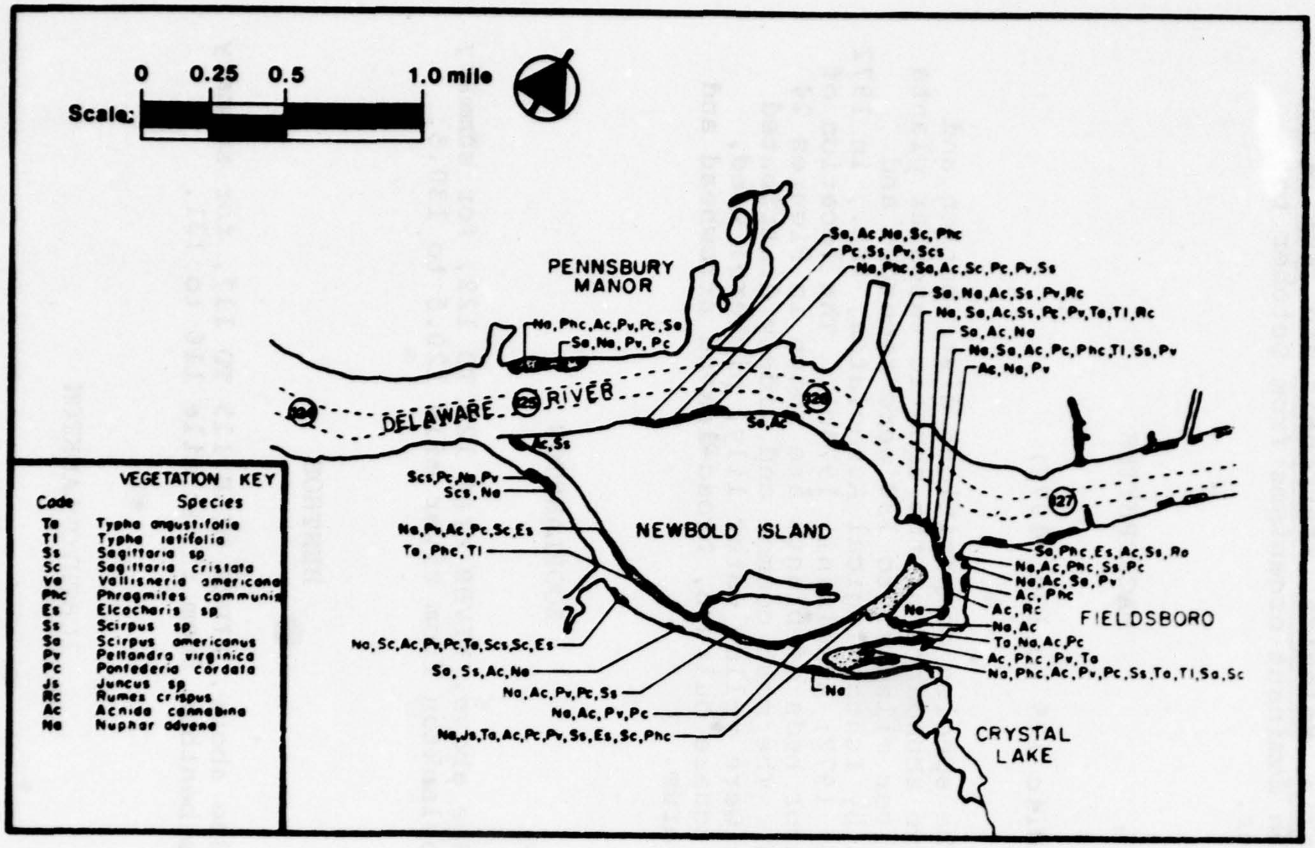


Figure 24. Distribution and relative abundance of aquatic vegetation in the Delaware River (river mile 125 to 127) in 1972. Species in each vegetation bed are listed in order of decreasing relative abundance (PSE&G, 1972).

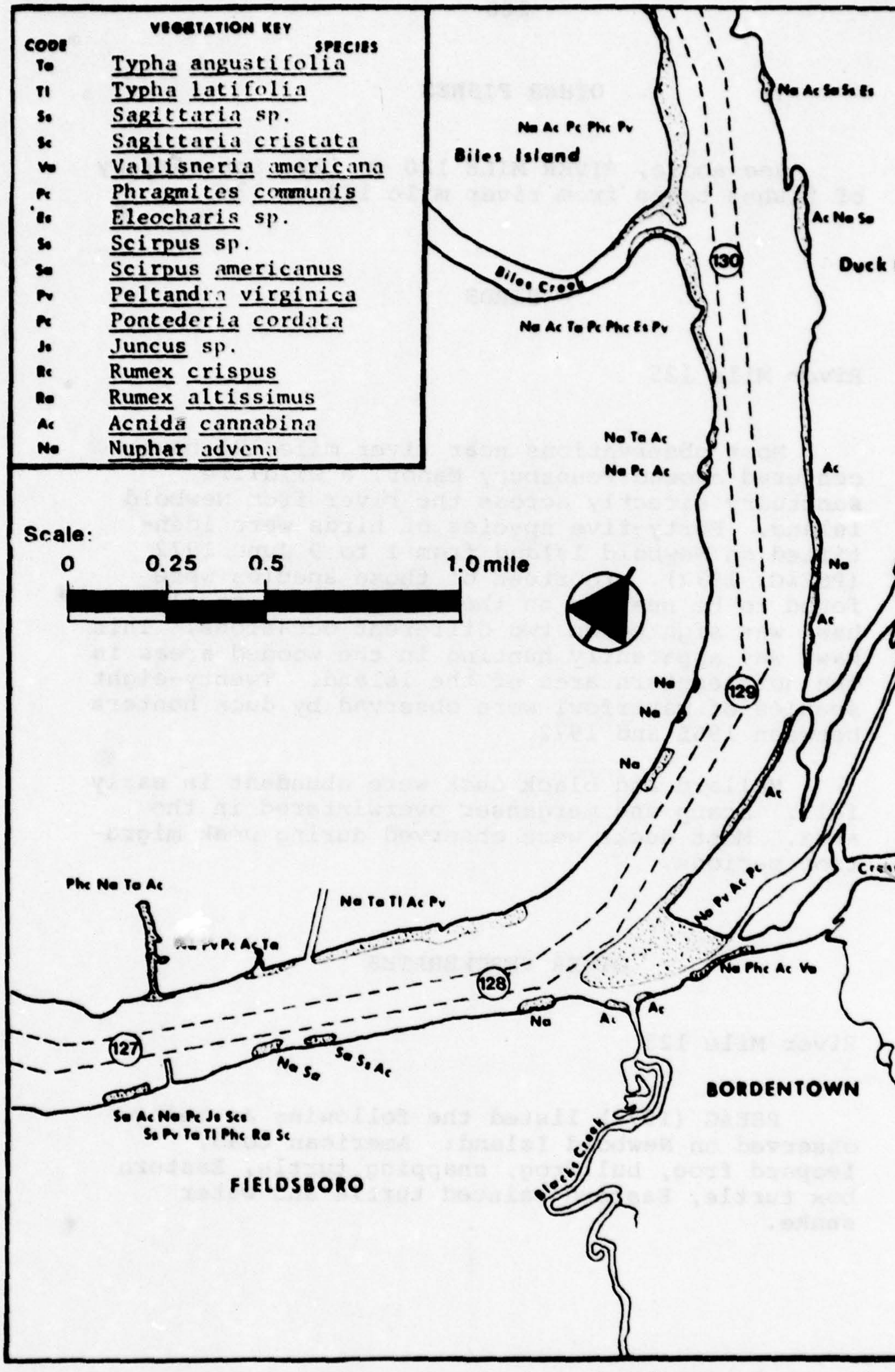


Figure 25. Distribution and relative abundance of aquatic vegetation in the Delaware River (river mile 127 to 130) in 1972. Species in each vegetation bed are listed in order of decreasing relative abundance (Anselmini, 1974b).

OTHER FISHES

See above, RIVER MILE 120 TO 122, for summary of fishes taken from river mile 122 to 130.

BIRDS

River Mile 125

Most observations near river mile 125 have centered around Pennsbury Manor, a wildlife sanctuary directly across the river from Newbold Island. Forty-five species of birds were identified on Newbold Island from 1 to 9 June 1972 (PSE&G, 1972). Fourteen of those species were found to be nesting on the island. A Cooper's hawk was sighted on two different occasions. This hawk was apparently hunting in the wooded areas in the northeastern area of the island. Twenty-eight species of waterfowl were observed by duck hunters between 1965 and 1972.

Mallard and black duck were abundant in early fall. Scaup and merganser overwintered in the area. Most ducks were observed during peak migration periods.

OTHER VERTEBRATES

River Mile 125

PSE&G (1972) listed the following as being observed on Newbold Island: American toad, leopard frog, bullfrog, snapping turtle, Eastern box turtle, Eastern painted turtle and water snake.

RIVER MILE 128 TO 130

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
● Municipal Treatment Plant			
46	Hamilton Township (Main Plant)	2	NJ 0026301
■ Other Point Source Discharge			
68	Stepan Chemical Co.	2	NJ 0005410
69	U.S. Steel, Fairless Works (IW)	2	PA 0013463

MACROPHYTES

See above, RIVER MILE 125 TO 127, for a summary of the macrophytes from river mile 125 to 130.

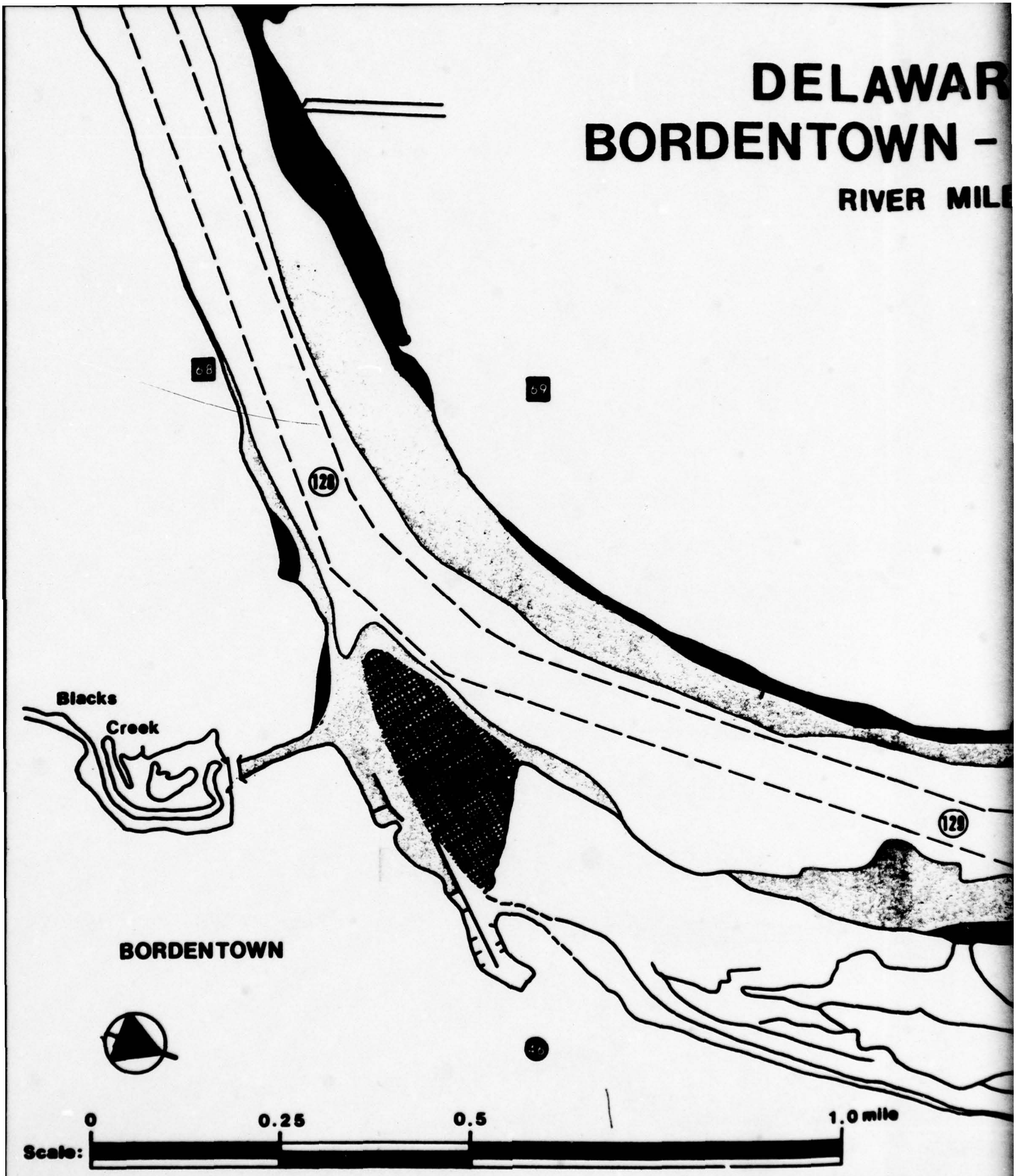
ZOOPLANKTON

See above, RIVER MILE 120 TO 122, for a summary of the zooplankton from river mile 120.5 to 130.5.

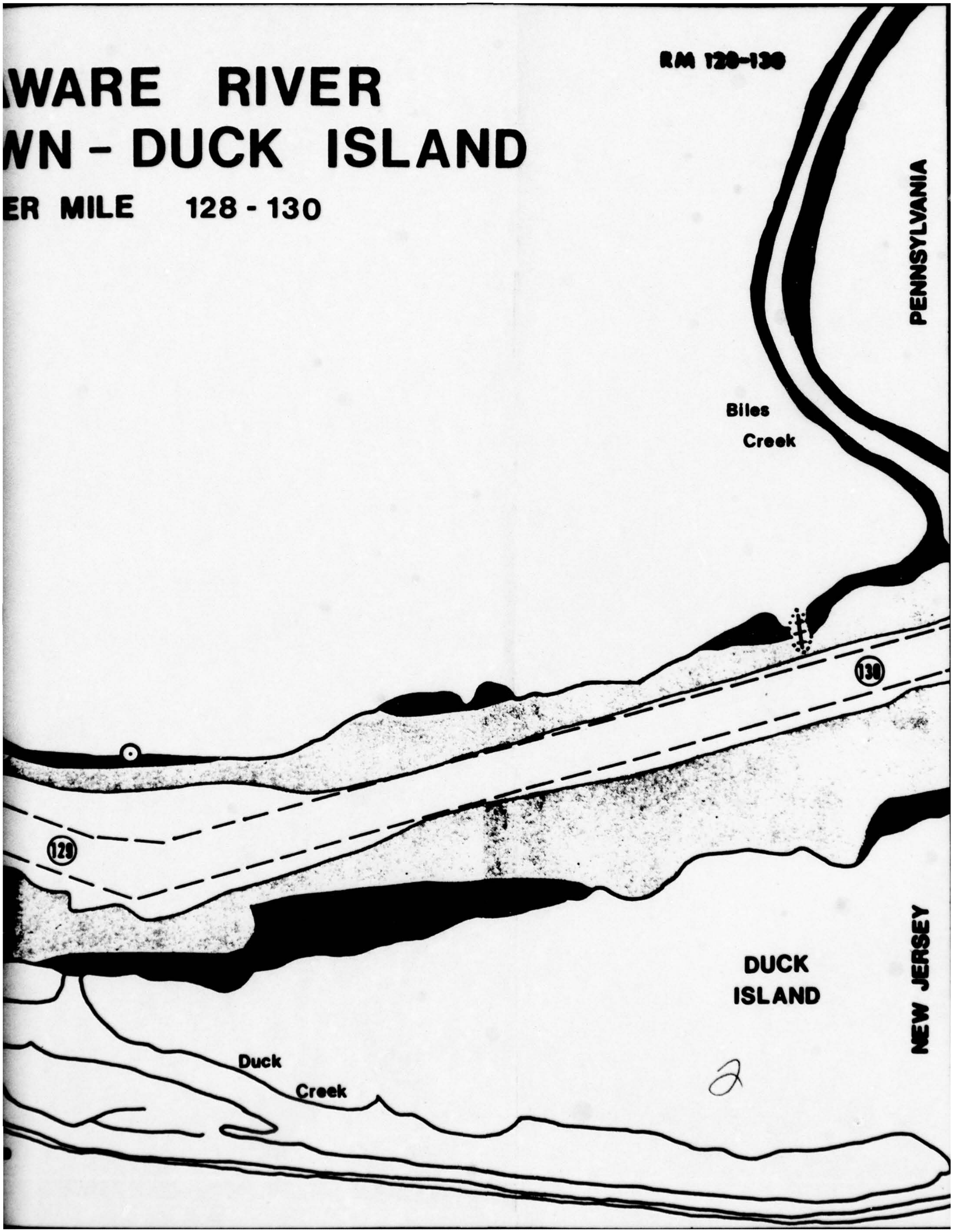
River Mile 129.2 to 130.5 (March 1971 to June 1972)

A list of zooplankters collected in the Delaware River near Duck Island in 1971 and 1972 is presented in Appendix Table 35.

Rotifers were captured year-round (Anselmini, 1947b). The rotifers were proportionately greatest in spring and fall (Figure 26). However, the highest density was found in July and August.



DELAWAR
BORDENTOWN -
RIVER MIL
68
69
128
Blacks
Creek
BORDENTOWN
0
0.25
0.5
1.0 mile
Scale:


RM 128-130
AWARE RIVER
WN - DUCK ISLAND
ER MILE 128 - 130
PENNSYLVANIA
Biles
Creek
130
129
DUCK
ISLAND
NEW JERSEY
Duck
Creek

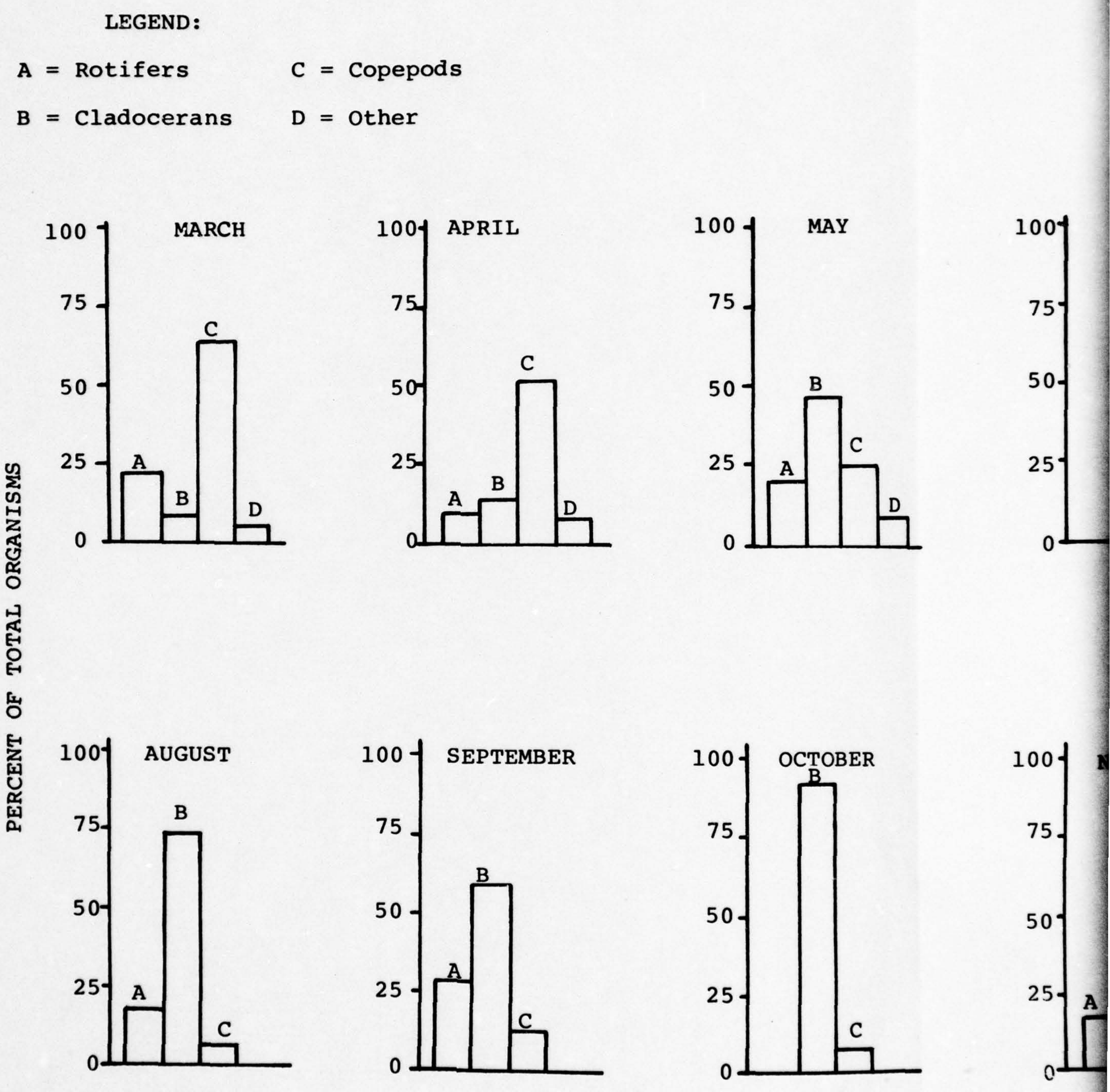
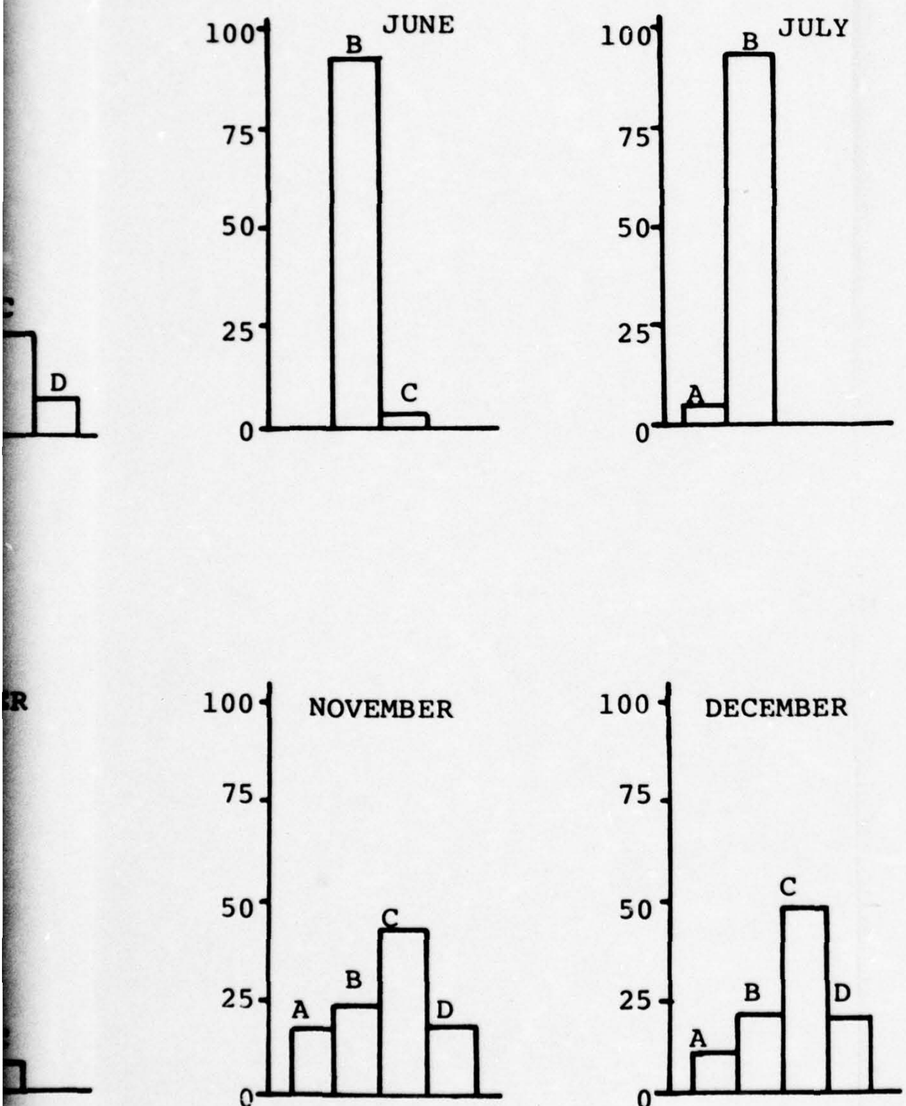


Figure 26. Seasonal composition of the zooplankton collected in the De
130.5) (Anselmini, 1974b).



ollected in the Delaware River (river mile 129.2 to

Brachionus calyciflorus, B. plicatilis and B. quadridentata were the most numerous species in July and August; density was usually between one and ten individuals per liter.

The cladocera were the most diverse and abundant zooplankton collected (Anselmini, 1974b). They were taken year-round and comprised more than 50% of the total plankton from June through October (Figure 26). Bosmina longirostris and to a lesser extent, B. coregoni, were by far the most abundant species. Both species were collected throughout the year and both exhibited a single long population pulse from June to September. B. longirostris reached a maximum density in late August (1,100/l). The maximum density of B. corregoni also occurred in late August (100/l). The density of Bosmina declined sharply in September. However, it remained the predominant cladoceran through December.

Copepods were found year-round and were proportionately greatest from March to May and November and December (Figure 26) (Anselmini, 1974b). Cyclops bicuspidatus and C. vernalis were the principal species in spring. Eurytemora affinis was the most abundant copepod in summer and fall. Nauplii were taken in September and copepodids were found in September and October.

BENTHOS

See above, RIVER MILE 115 TO 117, for a summary of the benthos from river mile 116 to 131.

ICHTHYOPLANKTON

See above, RIVER MILE 120 TO 122, for a summary of the ichthyoplankton from river mile 120 to 130.

OTHER FISHES

See above, RIVER MILE 120 TO 122, for a summary of the fishes from river mile 122 to 130.

VERTEBRATES

River Mile 128 to 146 (19th Century)

Charles C. Abbott, a naturalist whose residence was on Crosswicks Creek near the Delaware River about five miles south of Trenton spent many years observing the wildlife of the area. Abbott (1887) listed 26 species of mammals, 217 species of birds, 22 species of reptiles, 17 species of amphibians (Batrachians) and 57 fishes from Mercer County, New Jersey.

RIVER MILE 130 TO 132

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
47	City of Trenton	2	NJ 0020923
▲	Power Plant		
11	Public Service Electric and Gas, Mercer	2	NJ 0004995

ZOOPLANKTON

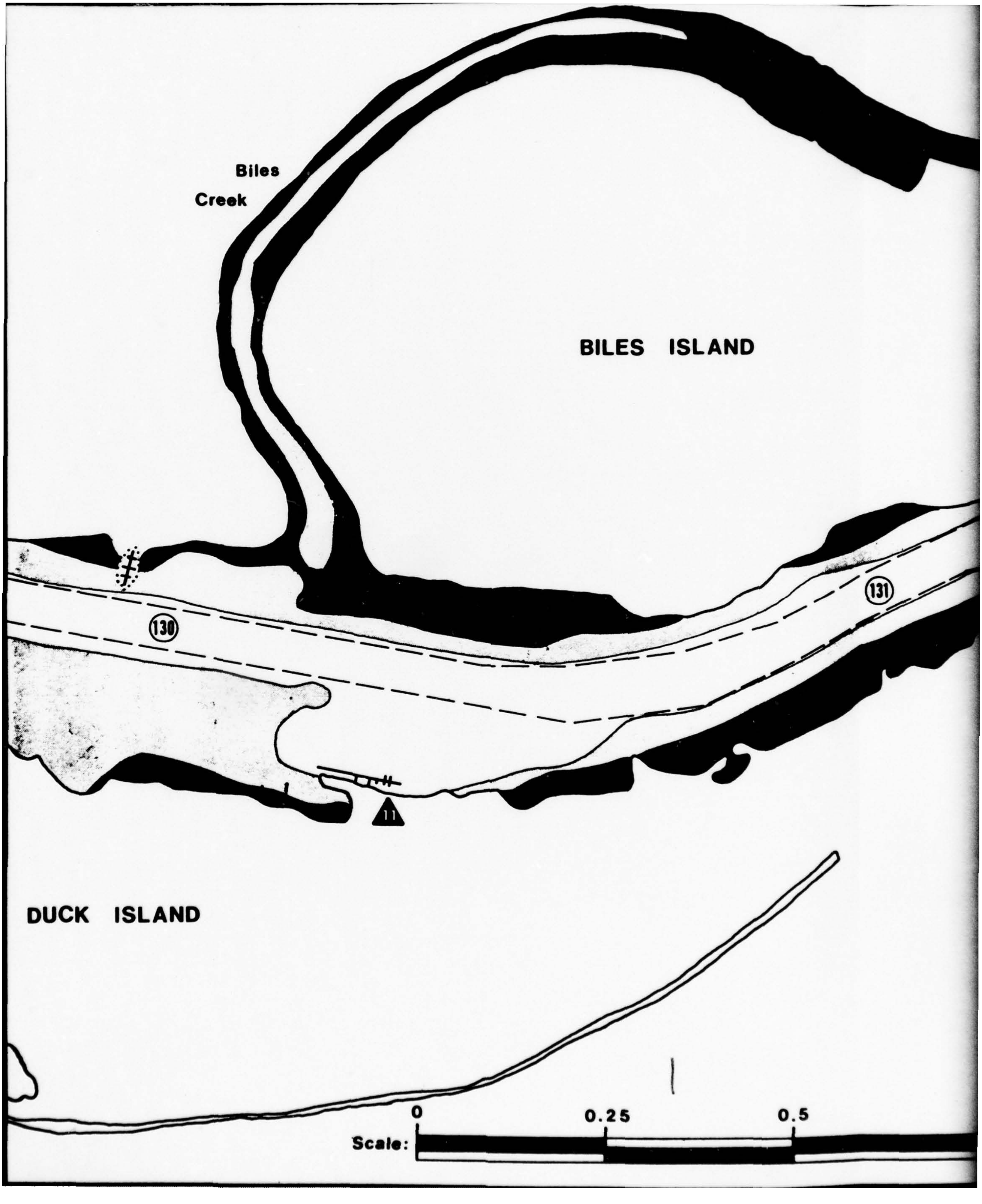
See above, RIVER MILE 120 TO 122 and 128 TO 130, for a summary of the zooplankton from river mile 120.5 to 130.5 and 129.2 to 130.5, respectively.

BENTHOS

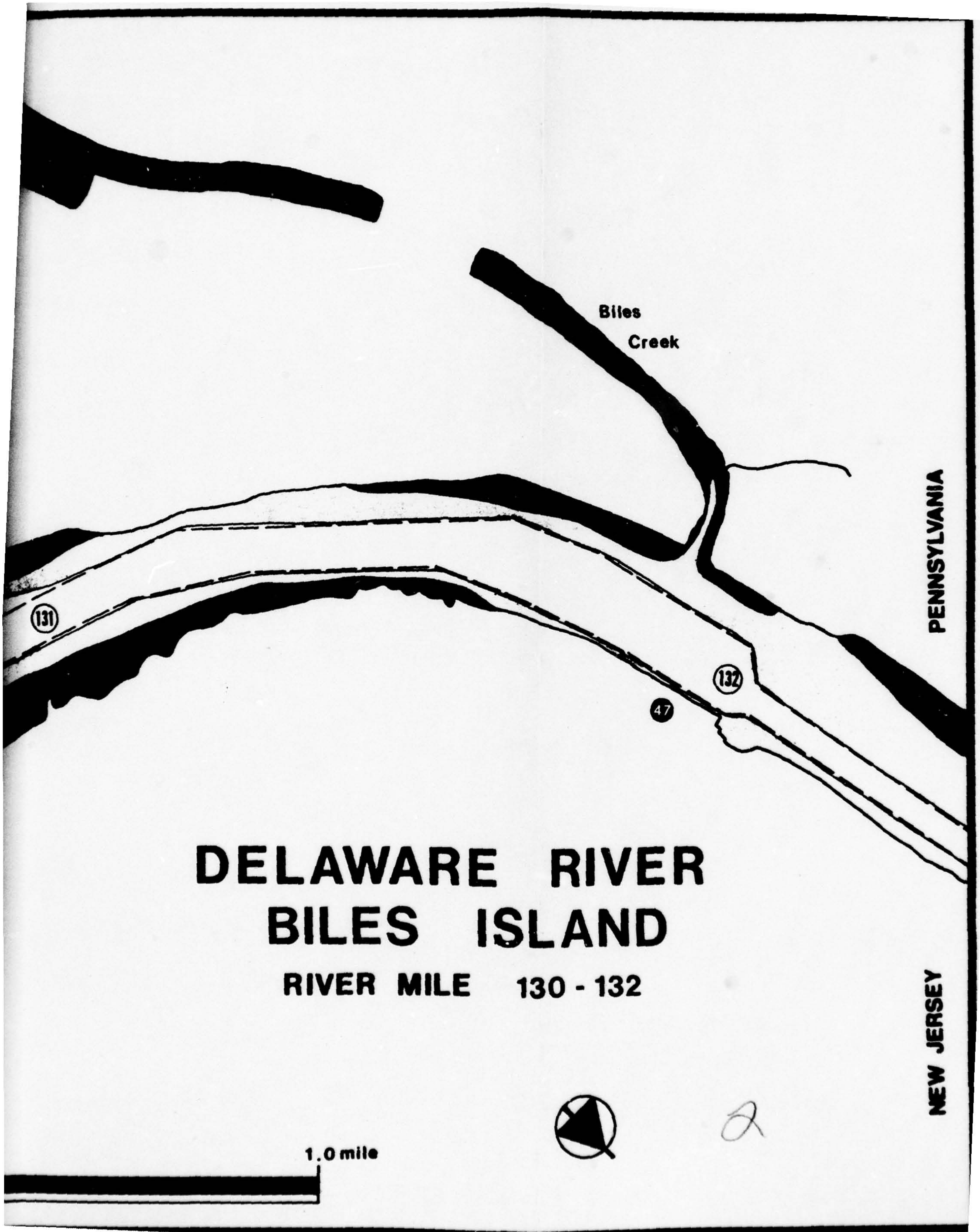
See above, RIVER MILE 115 TO 117, for a summary of the benthos from river mile 116 to 131.

River Mile 130 (1957 to 1959)

The Academy of Natural Sciences Philadelphia (ANSP, 1959) described the benthic fauna near river mile 130 as rich in both diversity and numbers. This report mentioned the presence of a unionid, *Lampsilis cariosa*, which was noted as an indication of the absence of heavy pollution in this area. Insects were common in collections, with several orders represented, but densities were low.



Biles
Creek
BILES ISLAND
130
131
11
DUCK ISLAND
0
0.25
0.5
Scale:



DELAWARE RIVER BILES ISLAND

RIVER MILE 130 - 132

ICHTHYOPLANKTON

River Mile 130 (April 1971 to July 1973)

A total of 286 1/2-meter net collections was made by Ichthyological Associates, Inc., from April 1971 to July 1973 near river mile 130 (Anselmini, 1974b). Fish eggs, larvae and young taken in the collections are listed in Appendix Table 36.

In 1971, 28 collections made from April to August 1971 yielded 30 eggs and 392 larvae (Anselmini, 1974b). All eggs were river herring and all were taken in May. Larvae were collected from April to early July. The larvae of river herring (369 specimens) and minnows (13 specimens) were dominant. Most were captured in late May and early June. Other larvae taken were quillback (3 specimens), carp (2), white perch (2), sunfish (Lepomis sp., 2) and white sucker (1).

The abundance and distribution of the ichthyoplankton was similar in 1972 and 1973 (Anselmini, 1974b). The most numerous eggs were river herrings and white perch. Both were taken from late April to July and were most abundant in May.

The most numerous larvae in collections for both years were river herrings, white perch and minnows and carp (Anselmini, 1974b). River herrings comprised 78.2% of the larvae in 1972 and 82.9% in 1973. They were taken from April through July but were most abundant in late April and early May. The white perch made up 6.5% of the larvae in 1972 and 8.8% in 1973. They were most abundant from late May to mid-June. Most specimens were prolarvae.

OTHER FISHES

Mihursky (1962) in "Fishes of the Middle Lenapewihittuck (Delaware River) Basin" mapped the distribution of fishes of the basin from below Trenton through the Delaware Water Gap. From the data given it is not possible to determine the method or year(s) of capture. A list of the fishes derived from Mihursky's distribution maps, for the tidal Delaware below Trenton, is given in Appendix Table 37.

VERTEBRATES

See above, RIVER MILE 128 TO 130, for a summary of the vertebrates of Mercer County, New Jersey, during the 19th century.

RIVER MILE 132 TO 134

Point Source Impacts

MAP SYMBOL	DISCHARGER	DRBC ZONE	NPDES PERMIT NUMBER
●	Municipal Treatment Plant		
47	City of Trenton	2	NJ 0020923
48	Morrisville Municipal Authority	2	PA 0026701

VERTEBRATES

See above, RIVER MILE 128 TO 130, for a summary of the vertebrates of Mercer County, New Jersey, during the 19th century.

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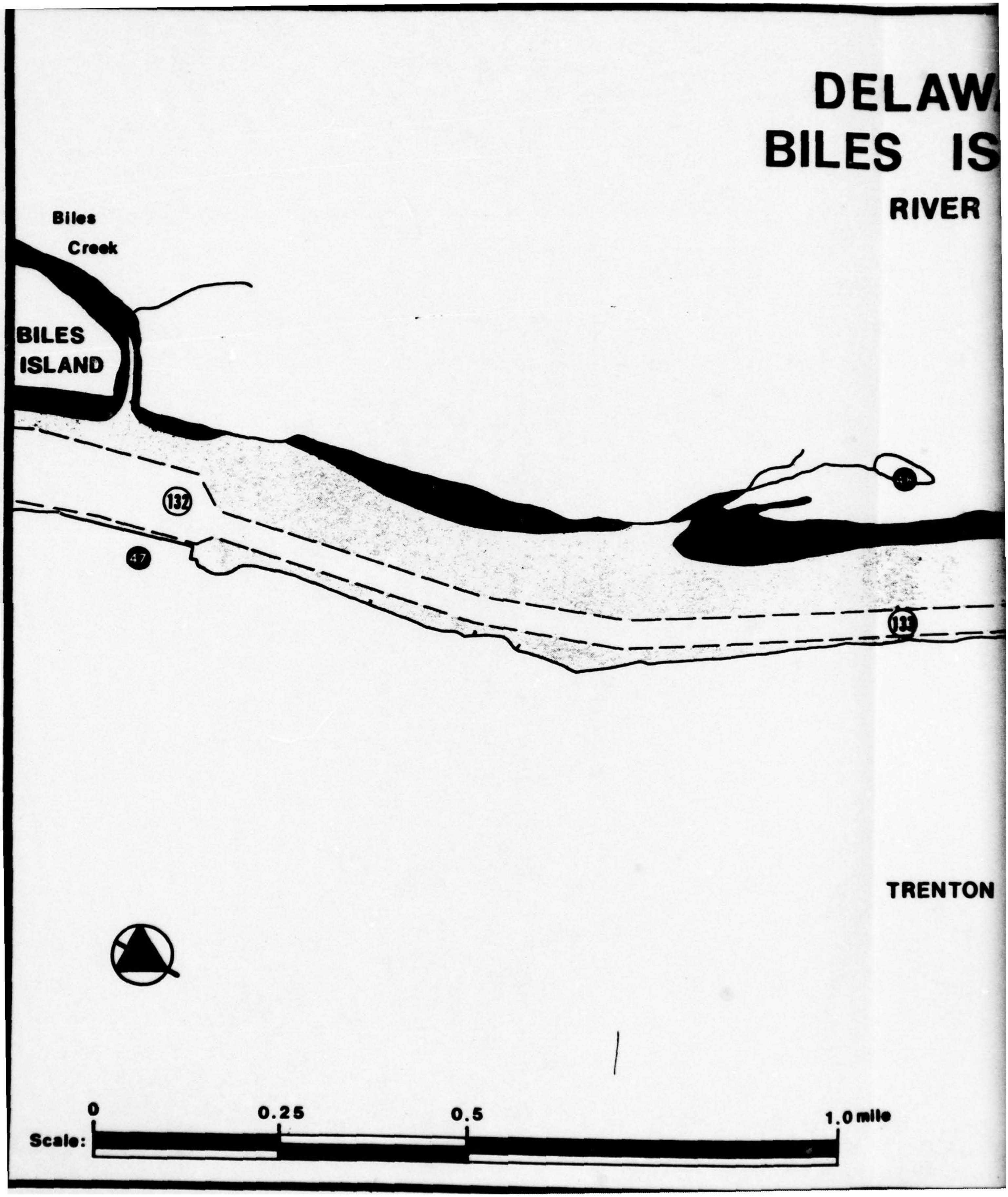
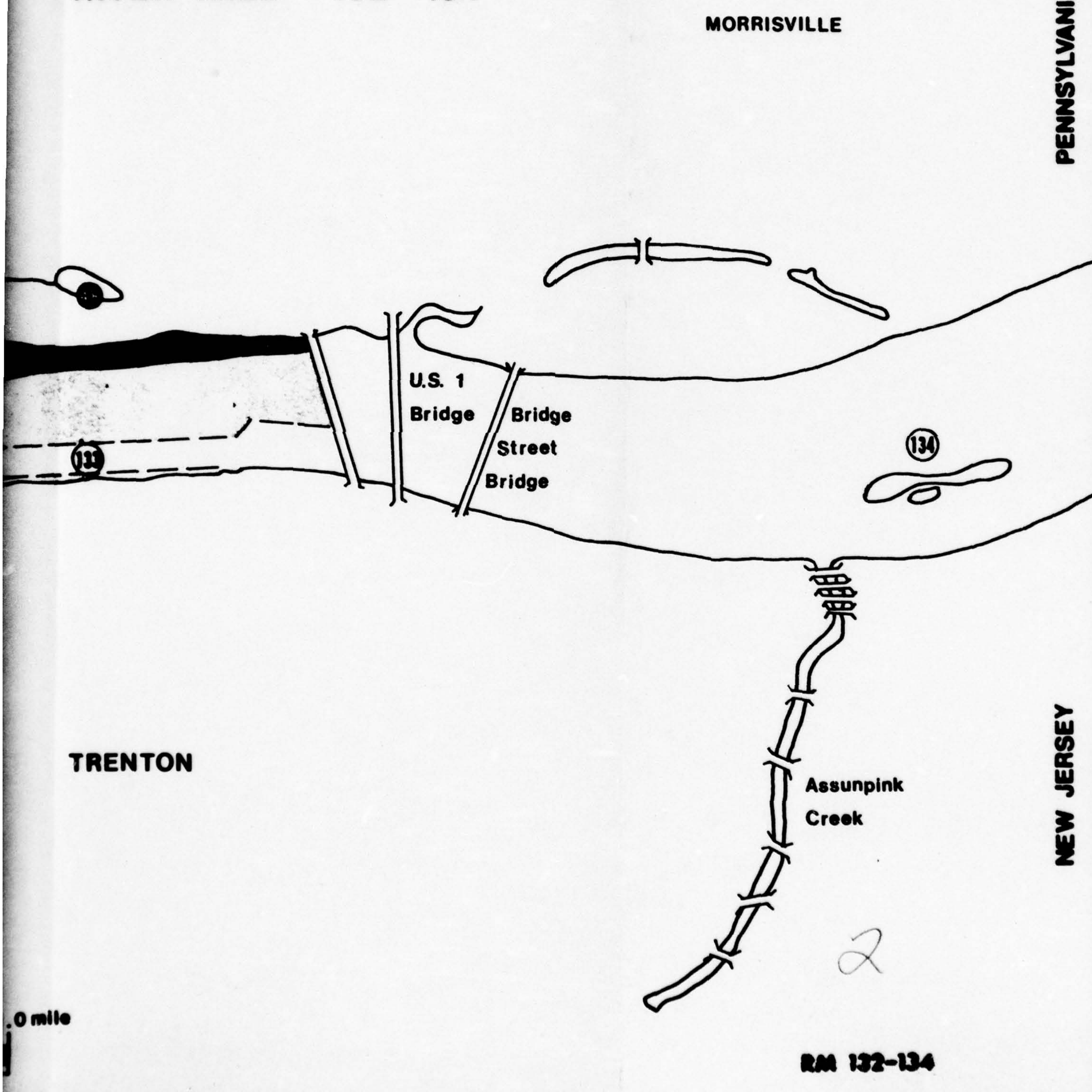

DELAW
BILES IS
RIVER
Biles
Creek
BILES
ISLAND
132
47
133
TRENTON
0
0.25
0.5
1.0 mile
Scale:

DELAWARE RIVER
...ES ISLAND - TRENTON

RIVER MILE 132 - 134



RM 132-134

SELECTED SPECIES

SELECTED SPECIES

The following species of fish are considered important in the study area: Atlantic sturgeon, shortnosed sturgeon, American eel, blueback herring, alewife, American shad, Atlantic menhaden, bay anchovy, spot, white perch, striped bass, mummichog, banded killifish, spottail shiner, satinfin shiner, silvery minnow, carp, white catfish, brown bullhead, channel catfish and white sucker. Several criteria were used to select these species, including: general distribution; commercial, sporting and historical importance; and use of the study area as a migratory route, spawning ground, nursery area or wintering area. The shortnosed sturgeon has also been included because it is listed as an endangered species by the U.S. Department of the Interior and the Pennsylvania Fish Commission. In addition to these fish, blue crab and migratory waterfowl are also discussed.

The description, life history, diet, distribution and use of shallow water areas of each species is discussed. A table summarizing each species' use of the shallows appears at the end of this section. Maps depicting the distribution of each species within the study area have also been prepared. These appear with the discussions of the individual species. It should be noted that the distribution maps accompanying the discussions indicate only those sections of the study area for which use by each species has been substantiated. Since most of the species have not been examined throughout the entire study area, the indicated distributions are incomplete. It is felt that the distributions of most of these species are more extensive than depicted.

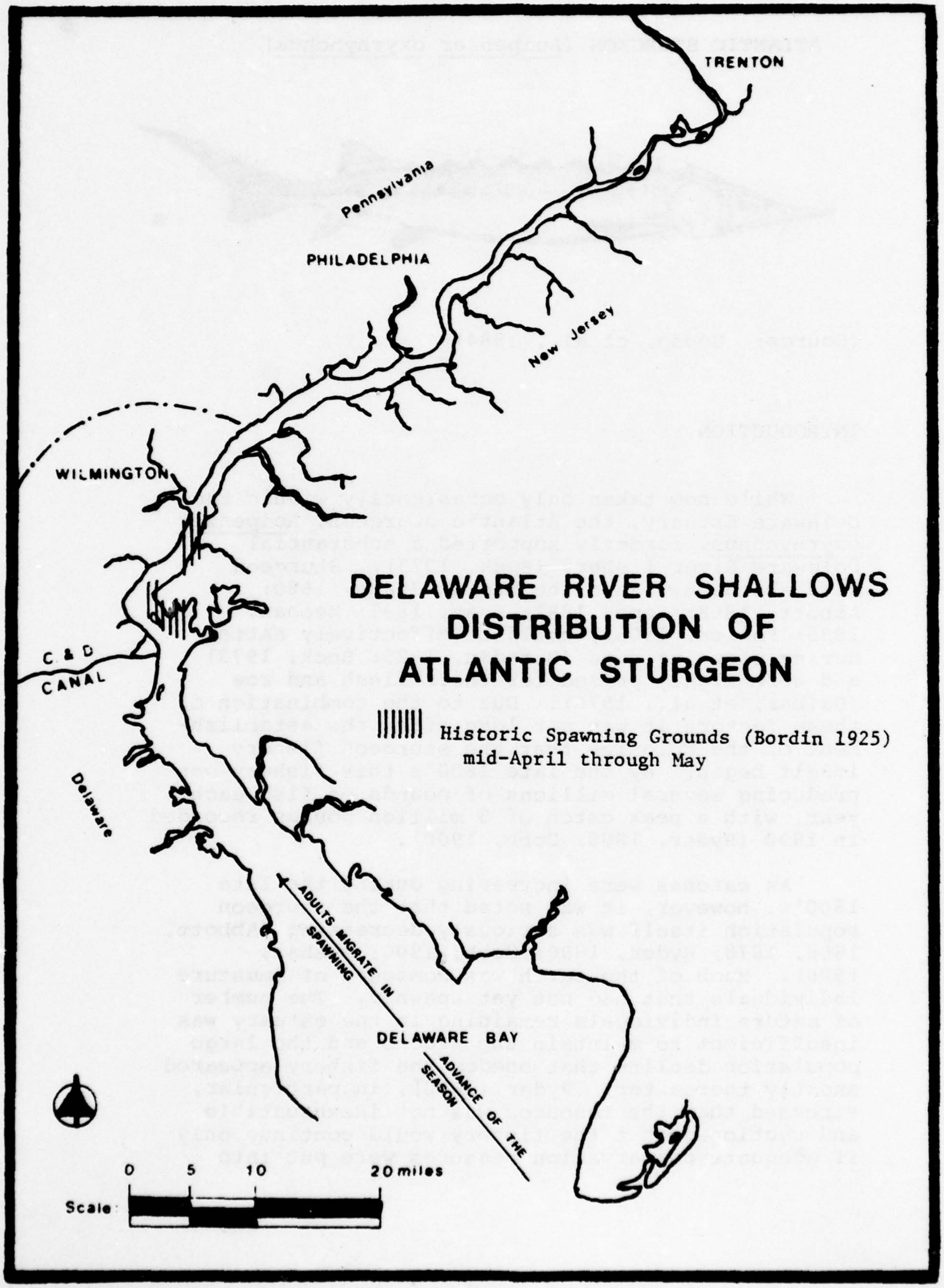
ATLANTIC STURGEON (Acipenser oxyrhynchus)

(Source: Goode, et al., 1884)

INTRODUCTION

While now taken only occasionally within the Delaware Estuary, the Atlantic sturgeon, Acipenser oxyrhynchus, formerly supported a substantial Delaware River fishery (Beck, 1973). Sturgeon were abundant within the basin (Stacy, 1680; Abbott, 1868; Cope, 1881; Bean, 1891; Meehan, 1895; Fowler, 1906), could be effectively netted during spawning runs (Barodin, 1925; Beck, 1973) and were highly prized for their flesh and roe (Daiber, et al., 1976). Due to the combination of these factors it was not long after the establishment of the colonies that the sturgeon fishery itself began. By the late 1800's this fishery was producing several millions of pounds of fish each year, with a peak catch of 5 million pounds recorded in 1890 (Ryder, 1890; Cobb, 1900).

As catches were increasing during the late 1800's, however, it was noted that the sturgeon population itself was seriously decreasing (Abbott, 1868, 1878; Ryder, 1890; Cobb, 1900; Meehan, 1900). Much of the catch was composed of immature individuals that had not yet spawned. The number of mature individuals remaining in the estuary was insufficient to maintain the stocks and the large population decline that eneded the fishery appeared shortly thereafter. Ryder (1890), in particular, stressed that the resource was not inexhaustible and cautioned that the fishery would continue only if adequate conservation measures were put into


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
ATLANTIC STURGEON
Historic Spawning Grounds (Bordin 1925)
mid-April through May
C & D
CANAL
Delaware
ADULTS MIGRATE IN SPAWNING
ADVANCE OF THE SEASON
DELAWARE BAY
0 5 10 20 miles
Scale

affect. These measured would have included limiting the size of the catch, maintaining spawning areas, propagating sturgeon artificially and improving water conditions. None of these measures was effectively undertaken. The result was that by 1897 the commercial catch was reduced to 2.5 million pounds (Cobb, 1900). Such decreases continued through the early part of the twentieth century and by 1940, no commercial landings of sturgeon were recorded in the basin (Daiber, et al., 1976). The few remaining commercial fishermen abandoned the fishery at this time and no commercial fishing of sturgeon has been since undertaken.

Atlantic sturgeon still exist within the basin and some are taken by recreational fishermen each year (deSylva, et al., 1962; Mihursky, 1976). The population has apparently increased to a stable level. It is doubtful that the sturgeon population could presently support a commercial fishery. The effects of improving water conditions and low fishing pressure, however, may lead to future population increases and the re-establishment of the Delaware sturgeon fishery.

DESCRIPTION

The size of the Atlantic sturgeon and the characteristics of its head and skin allow this fish to be easily distinguished from most other species common to the Delaware Estuary. Atlantic sturgeon are generally very large fish, adults in this region averaging 5 to 10 ft in length and 100 to 300 lbs in weight (Ryder, 1890; Bigelow and Schroeder, 1950; Vladykov and Greeley, 1963; Daiber, et al., 1976). Unusually large fish may even reach 14 ft and 800 lbs, although captures of fish this large have been rare. Differences in size are due partially to the age of the fish, but also to its sex. Females are larger than males of the same age.

More characteristic than their size, however, are features of its head and skin. The head of the fish extends into an elongated, flattened snout which projects noticeably beyond the body. On the underside of the snout are found the mouth, and several fleshy projections called barbels. These are sensory organs which aid the sturgeon in locating its food. As the fish swim close to the bottom, the barbels sweep over and through the sediments and come in contact with the prey. The sturgeon then uses its snout to dislodge prey organisms, sucking them into its mouth as it slowly passes by.

The skin of the sturgeon is also unique in that it possesses large bony plates or shields. These plates generally exist in five rows--one along the dorsal (upper) margin and two along each lateral (side) surface of the body. These plates are hard, and often sharp, and give the Atlantic sturgeon the appearance of being armored. Within the Delaware Estuary, only the Atlantic sturgeon and its smaller relative, the shortnosed sturgeon, possess this type of body armor. Because of this, its unique head structure and large size, the Atlantic sturgeon can be easily distinguished from other Delaware fishes.

LIFE HISTORY

The sturgeon is an anadromous species. Mature individuals live in the saltier tidal areas and run up into the fresher river areas to spawn. Spawning runs begin in the Delaware area during April and peak in May (Borodin, 1925). Water temperatures of 56°F to 64°F appear to be optimal for spawning activity. Sturgeon are prolific egg layers, average females producing between 1 to 2.5 million eggs each season (Vladykov and Greeley, 1963). The eggs are demersal, meaning that they sink, and covered by a glutinous membrane that adheres the eggs to the bottom. The eggs apparently scatter over a wide area as there is no evidence of any nest building.

Eggs hatch in approximately one week depending on the water temperature. The larvae grow several inches during the first few months and may or may not remain within the estuary during their first several years. Fishes as small as 5-6 inches in length have been captured leaving the Delaware Bay, while others tens of inches in length and several years old have been taken during all seasons (Bigelow and Schroeder, 1953). Larger fish, however, seem to move out of the basin to spend considerable time in offshore waters.

One of the critical factors of the life history of the sturegon is that they are slow growing and take several years to mature. No ripe females have been found under 150 pounds in weight, a size which these fish do not attain until approximately ten years in age (Daiber, et al., 1976).

DIET

Sturgeon are mainly bottom feeders. They ingest almost anything living in or on the bottom sediments including molluscs, isopods, amphipods, polychaete worms, pelecypods and gastropods (Vladykov and Greeley, 1963; Daiber, et. al., 1976). They have also been known to consume small fish, although these probably account for a much smaller portion of the diet than do benthic invertebrates.

DISTRIBUTION

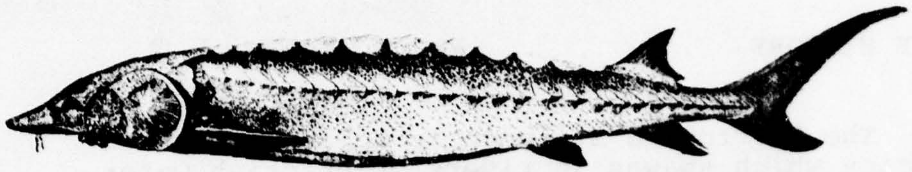
The Atlantic sturgeon is found along the Eastern coast of North America from the St. Lawrence River to the Gulf of Mexico (Bigelow and Shroeder, 1950; Vladykov and Greeley, 1963). Its distribution within this area is dictated primarily by its life habit. It is an anadromous species, the adults of which live in more saline waters and which migrate into fresh water portions of rivers to spawn. Large populations of sturgeons have been associated historically with rivers and estuaries such as the St. John's, Hudson, Potomac, James, St. Mary's (Georgia), Susquehana and importantly the Delaware (Daiber, et al., 1976). Within the Delaware, larger fish seem to prefer the deeper tidal areas and are generally found below Trenton (Bean, 1891; Meehan, 1895). However, sturgeon have been reported as far up river as Easton (Fowler, 1906, 1913) and Port Jervis (New

York) (Abbott, 1868). Preferred spawning areas are those where the bottom consists of clay, rubble, gravel or shell with water depths less than 30 feet (Bigelow and Schroeder, 1953; Vladykov and Greeley, 1963). Historically, these areas were found along the New Jersey shore near Pea Patch Island and below Wilmington, and along both shores near Chester (Borodin, 1925). Smaller sturgeon are distributed throughout the basin, only the largest of the fish restricting their movements to the deeper tidal areas.

IMPORTANCE OF THE SHALLOWS

As large fish, adult sturgeon do not spend considerable time in shallow areas such as small tidal creeks. Shallows, however, offer the conditions attractive to spawning fish. Most important in this regard is bottom composition. Sturgeon seem to prefer areas with coarser sediments, and these are found generally within the nearshore areas. The location of the historically important spawning areas along the shores near Pea Patch Island and Chester attest to this dependence of the Atlantic sturgeon on shallow water areas for its survival.

SHORTNOSED STURGEON (Acipenser brevirostrum)



(Source: Goode, et al., 1884)

INTRODUCTION

While closely resembling the Atlantic sturgeon, the shortnosed sturgeon, Acipenser brevirostrum, has not generated the same amount of interest. It is much smaller in size and has generally been much less common than the Atlantic sturgeon. Vladykov and Greeley (1963) reported only four taken from the Delaware River in 1911 and three in 1913. Anselmini, et al., (1976) took only two from the channel between Bordantown and Trenton in 1971. The fish is presently so scarce that it is listed as an endangered species by the U.S. Fish and Wildlife Service and the Pennsylvania Fish Commission. It is for this reason that the species has been included in this section on important shallow water inhabitants.

DESCRIPTION

In general body design, the shortnosed sturgeon closely resembles the Atlantic sturgeon. It possesses rows of armor-like plates, a small ventrally opening mouth and several sensory barbels. As its name implies the snout of the shortnosed sturgeon is not as elongated as is that of the Atlantic sturgeon. It is approximately 1/10 to 1/12 of the body length in the shortnosed while

1/6 to 1/7 of the body length of the Atlantic sturgeon. The shortnosed sturgeon is also the smallest of all the sturgeons. Maximum length is approximately 3 feet.

LIFE HISTORY

The shortnosed sturgeon is an anadromous species which spawns in rivers or brackish water estuaries. Little else, however, is known about its life history (Vladykov and Greeley, 1963). There is some evidence that it may be more restricted to estuaries than is the Atlantic sturgeon and does not migrate as far from its parent stream (Bigelow and Schroeder, 1953). This habit requires that conditions suitable for its existence be maintained within estuaries if the species is to be saved. Where spawning has been observed, such as in the Hudson River, it appears that the run of the shortnosed sturgeon occurs before the yearly run of American shad.

DIET

Diet and feeding of the shortnosed sturgeon is similar to that described for the Atlantic sturgeon. It is a bottom feeder routing worms, crustaceans, larvae and some plants from the sediments.

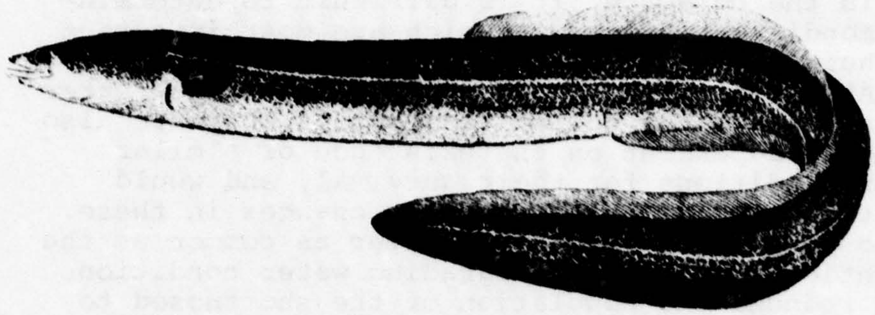
DISTRIBUTION

The shortnosed sturgeon ranges along the Atlantic seaboard of North America from New Brunswick, Canada to Florida. The Connecticut, Hudson, Delaware, Potomac and Charleston Rivers have produced the most specimens (Bigelow and Schroeder, 1953; Vladykov and Greeley, 1963). Within the Delaware, the distribution of the species has not been established. It has not been found above Trenton (Mihursky, 1962), but other than this, areas of concentration have not been identified.

IMPORTANCE OF THE SHALLOWS

Since there are so few shortnosed sturgeons within the Delaware, it is difficult to determine the conditions and areas which are most important to their survival. It can be assumed that, like the Atlantic sturgeon, they spawn in shallow water areas with coarse bottom sediments. They are also probably dependent on the existence of similar water conditions for their survival, and would react in similar manners to any changes in these. Since they most likely were never as common as the Atlantic sturgeon, the degrading water conditions have reduced the population of the shortnosed to periously low levels. Improving these conditions would probably not lead to large enough increases to make the species a numerically important one in the Delaware Estuary. However, such improvements are necessary to ensure the maintenance of the small population that does still exist. If this species is to be saved, it is also necessary to identify and preserve those shallow areas in which it spawns.

AMERICAN EEL (Anguilla rostrata)



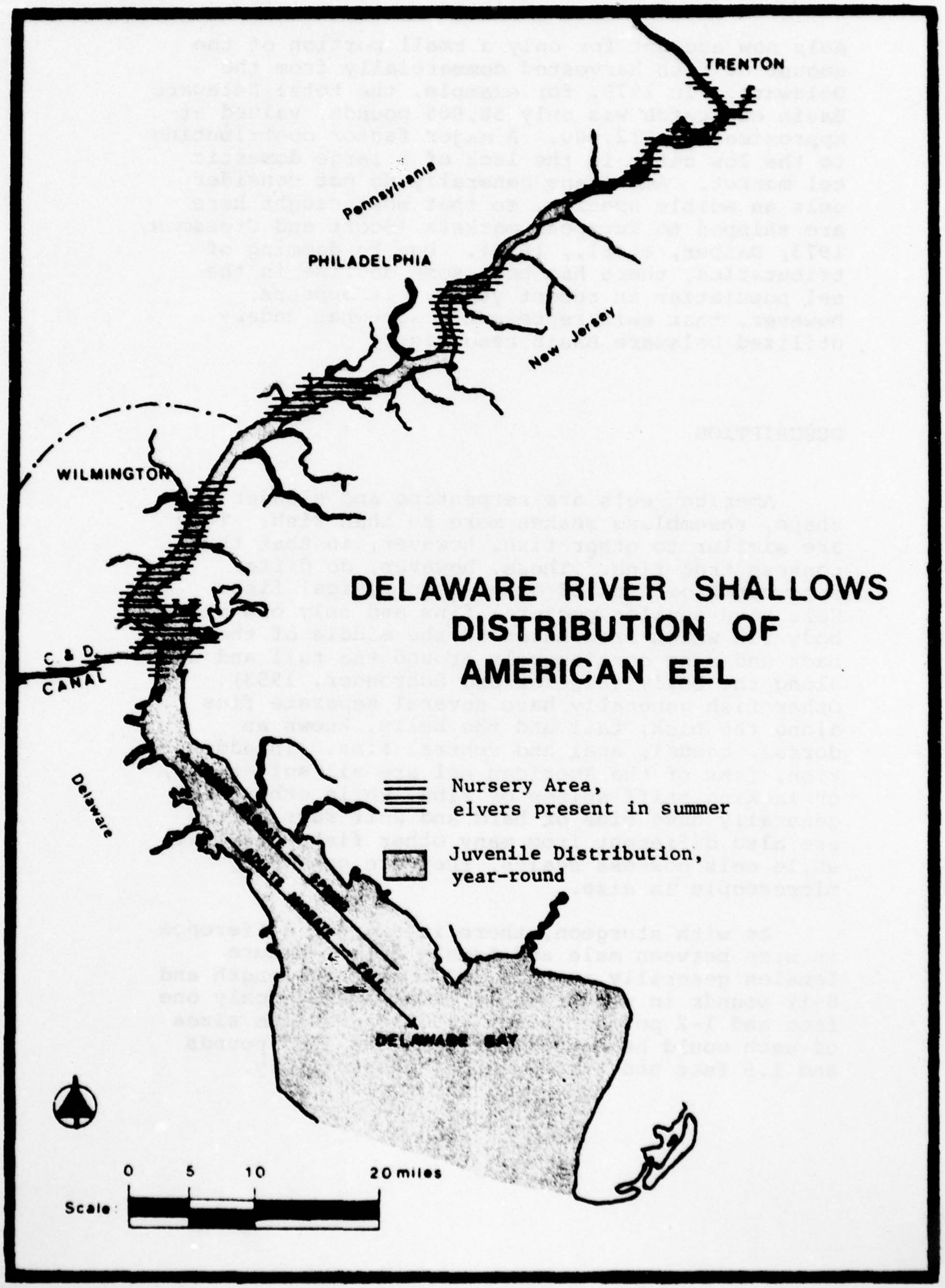
(Source: Evermann and Kendall, 1894)

INTRODUCTION

The American eel, Anguilla rostrata, is one of several catadromous species that utilize the Delaware estuary. The adults of such species live in fresh and brackish waters and migrate to salt water areas to spawn. Larvae and juveniles then return to the fresh water systems to grow and mature.

Eels have been taken from the Delaware for many years. Jackson (1967) has described the writings of early Swedish and English settlers who noted that eels were plentiful and harvested by the colonists. Gay (1892) and Meehan (1897) have indicated that many eels were taken from the Delaware during the late 1800's primarily with the use of weirs. These are enclosures of fencing, brush or netting placed in the waterway along routes used by migrating fish. Similar techniques are used to harvest many of the other migrating species such as shad and herrings.

Weirs are still used to take eels in the Delaware, although many are captured with baited traps and pots (Daiber, et al., 1976). Some are also taken by trawling during the summers, particularly at night when eels migrate through the water column to feed. While they are still plentiful,


DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
AMERICAN EEL
TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE BAY
Nursery Area,
elvers present in summer
Juvenile Distribution,
year-round
0
5
10
20 miles
Scale:

eels now account for only a small portion of the amount of fish harvested commercially from the Delaware. In 1970, for example, the total Delaware Basin eel catch was only 58,000 pounds, valued at approximately $12,000. A major factor contributing to the low catch is the lack of a large domestic eel market. Americans generally do not consider eels an edible species, so that most caught here are shipped to European markets (Scott and Crossman, 1973; Daiber, et al., 1976). Due to damming of tributaries, there has been some decline in the eel population in recent years. It appears, however, that eels represent a somewhat under-utilized Delaware Basin resource.

DESCRIPTION

American eels are serpentine and slender in shape, resembling snakes more so than fish. They are similar to other fish, however, in that they possess true fins. These, however, do differ somewhat from fins of other more typical fish. Eels have smaller pectoral fins and only one other body fin which originates in the middle of the back and runs continuously around the tail and up along the belly (Bigelow and Schroeder, 1953). Other fish generally have several separate fins along the back, tail and the belly, known as dorsal, caudal, anal and ventral fins. In addition, fins of the American eel are all soft-rayed, or lacking stiff spines or ribs, while other fish generally have fins of hard and soft rays. Eels are also different from many other fishes in that while eels possess scales, they are generally microscopic in size.

As with sturgeon, there is a great difference in size between male and female eels. Mature females generally average 2-3.5 feet in length and 8-12 pounds in weight while males average only one foot and 1-2 pounds (Raney, 1959). Maximum sizes of each would be about four feet and 16.5 pounds and 1.5 feet and three pounds, respectively.

LIFE HISTORY

The life cycle of the American eel begins a good distance from the Delaware Estuary. Sexually mature adults migrate from the estuary to at least the Sargasso Sea to reproduce. This fact was unknown until 1922, when a Danish oceanographer, Johannes Schmidt reported taking the eels of the youngest larval stage, called leptocephali, in that area. More recent work by Vladykov (1964) suggests that the principle spawning grounds may be even farther south than the Sargasso Sea. In either case, eels migrate several thousand miles to produce their young.

Migrations from the Delaware begin between August and September and continue through the fall and early winter. Eels involved in the migration have generally spent five to ten years, and possibly as many as 20, within the Delaware Basin growing and maturing (Daiber, et al., 1976). They travel mostly at night, covering the distance from the basin to the spawning area in two to three months. In preparation for migration, eels go through many significant internal and external changes that enable them to move from fresh water to the saline waters of the open ocean. They also cease feeding as the time for migration approaches and apparently do not feed during the migration itself.

The ovaries of the females mature as they reach the spawning area. Eels are one of the more prolific of all fishes (BIgelow and Schroeder, 1953; Raney, 1959). Average females produce five to ten million eggs, and the larger ones possibly as many as 20 million. As with salmon, eels apparently die after spawning although this has not been definitely proven. Eggs of the eel have never been found and hatching times are unknown. The larval stages, however, have been well documented. In the first stage, the larvae, called leptocephali, are ribbon-like and transparent and have small pointed heads and very large teeth. They begin their migrations immediately, but do not reach the mid-Atlantic region until the following December or January. Like the adults, the leptocephali apparently do not feed during the migration.

When they reach the coast, they are approximately 1.5 inches long, and ready for transformation into the next form, the elver stage. Elvers are more adult-like forms, which begin their migration into Delaware Bay in April and May (Daiber, et al., 1976). They will then migrate throughout the estuary and non-tidal upriver portions.

DIET

Eels feed on almost all materials with which they come in contact, both living and dead. They will take fish, insects, snails, worms, shrimps, lobsters, crabs, other crustacea and all kinds of refuse (Bigelow and Schroeder, 1953; Godfrey, 1957). Feeding usually takes place at night as most eels remain buried in mud during the day (Raney, 1959).

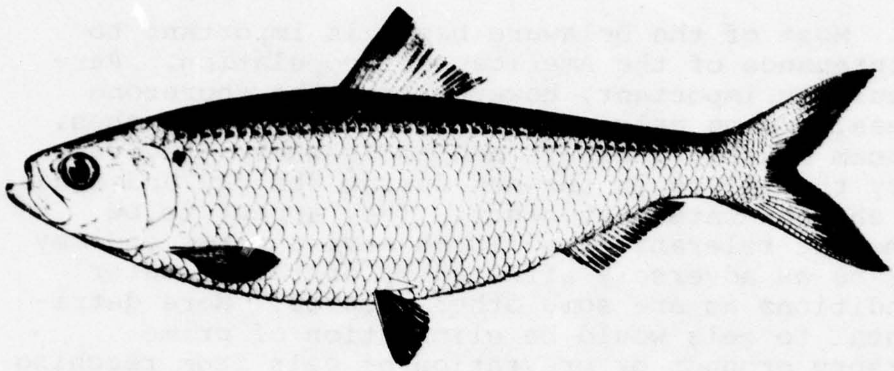
DISTRIBUTION

The American eel can be found all along the North American coast from Greenland to the Gulf of Mexico, occurring in both fresh and salt water (Raney, 1959). Within the Delaware Basin, juveniles are present throughout the year from the bay to the headwaters (Greeley, 1937; Trembley, 1960; Mihursky, 1962; Anselmini, 1971, 1974a; Schuler, et al., 1970; Schuler, 1971; Wurtz, 1973a,b; Rohde and Schuler, 1974a,b,c; Chase, 1974b; Holmstrom, 1974; Krantz, 1974a). Elvers have been shown to concentrate in tidal creek tributaries to the Delaware Bay during February and March, near Artificial Island in April and May, and in the upper estuary between Burlington and Biles Island in May and June. All forms, however, can generally be found throughout most of the system.

IMPORTANCE OF THE SHALLOWS

Most of the Delaware basin is important to maintenance of the American eel population. Particularly important, however, are the shorezone areas. Young eels concentrate along the marshes, stream mouths, channels and pools where they can bury themselves in the mud during the day and feed in shallow waters at night. They appear to be somewhat tolerant of polluted environments and may not be as adversely affected by degrading water conditions as are some other species. More detrimental to eels would be elimination of prime nursery grounds or prevention of eels from reaching these areas by damming tributaries.

BLUEBACK HERRING (Alosa aestivalis)



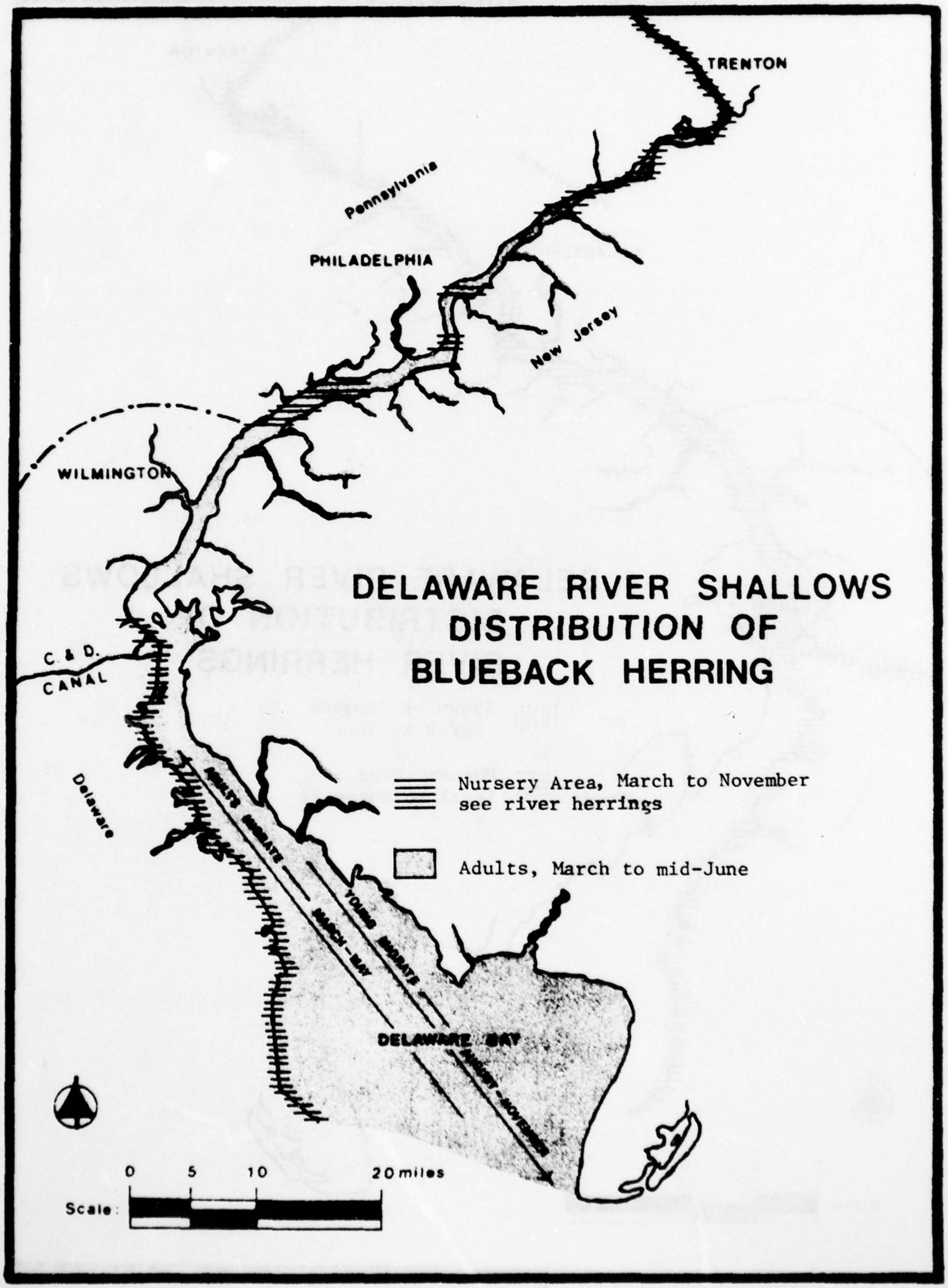
(Source: Goode, et al., 1884)

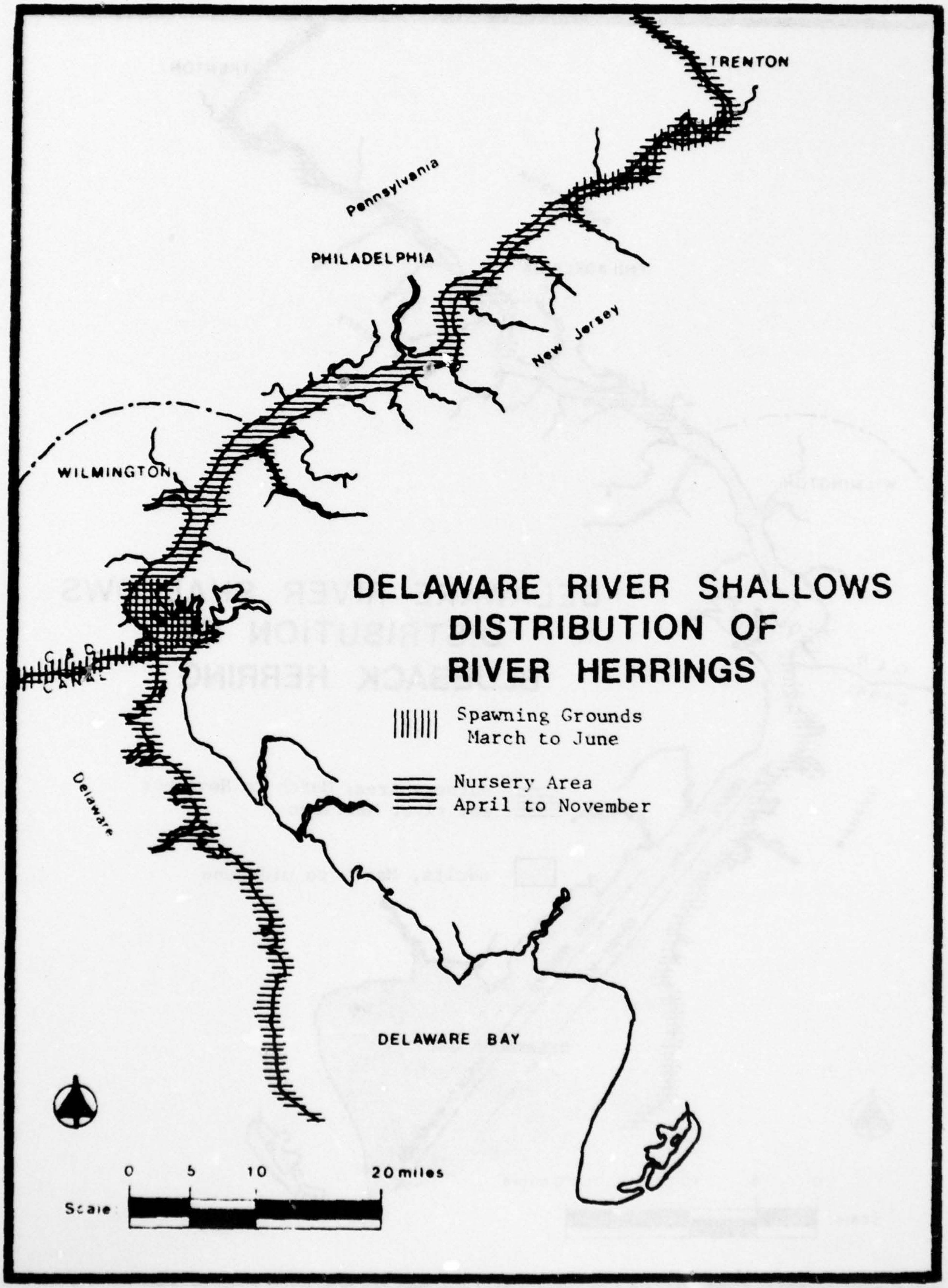
INTRODUCTION

The blueback herring is one of the more common fishes of the Delaware Estuary. With the alewife, it is also one of the most important forage fishes. As a predator of zooplankton, it forms an important link between these smaller forms and the carnivorous fishes which feed upon the blueback, alewife and others. This is also a commercially valuable fish which has been taken from the Delaware Basin for some time. It is still taken commercially from the estuary and processed primarily for pet food, fish meal, or bait.

DESCRIPTION

As with all members of the herring family, the blueback herring has one small dorsal fin, a deeply forked tail, small teeth and very large scales (Bigelow and Schroeder, 1953). They get their name from the fact that the back of the blueback is blue-green in color. This color, however, readily fades when the fish is removed from the water and is not a reliable distinguishing characteristic. It is, in fact, difficult to


DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
BLUEBACK HERRING
TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C. & D.
CANAL
Delaware
DELAWARE BAY
Nursery Area, March to November
see river herrings
Adults, March to mid-June
0
5
10
20 miles
Scale:


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
RIVER HERRINGS
Spawning Grounds
March to June
Nursery Area
April to November
DELAWARE BAY
0
5
10
20 miles
Scale

AD-A071 484 TYRAWSKI (JOHN M) WILMINGTON DE F/G 8/8
SHALLOWS OF THE DELAWARE RIVER-TRENTON, NEW JERSEY TO REEDY POI--ETC(U)
MAR 79 J M TYRAWSKI DACW61-79-M-0445

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4 OF 6

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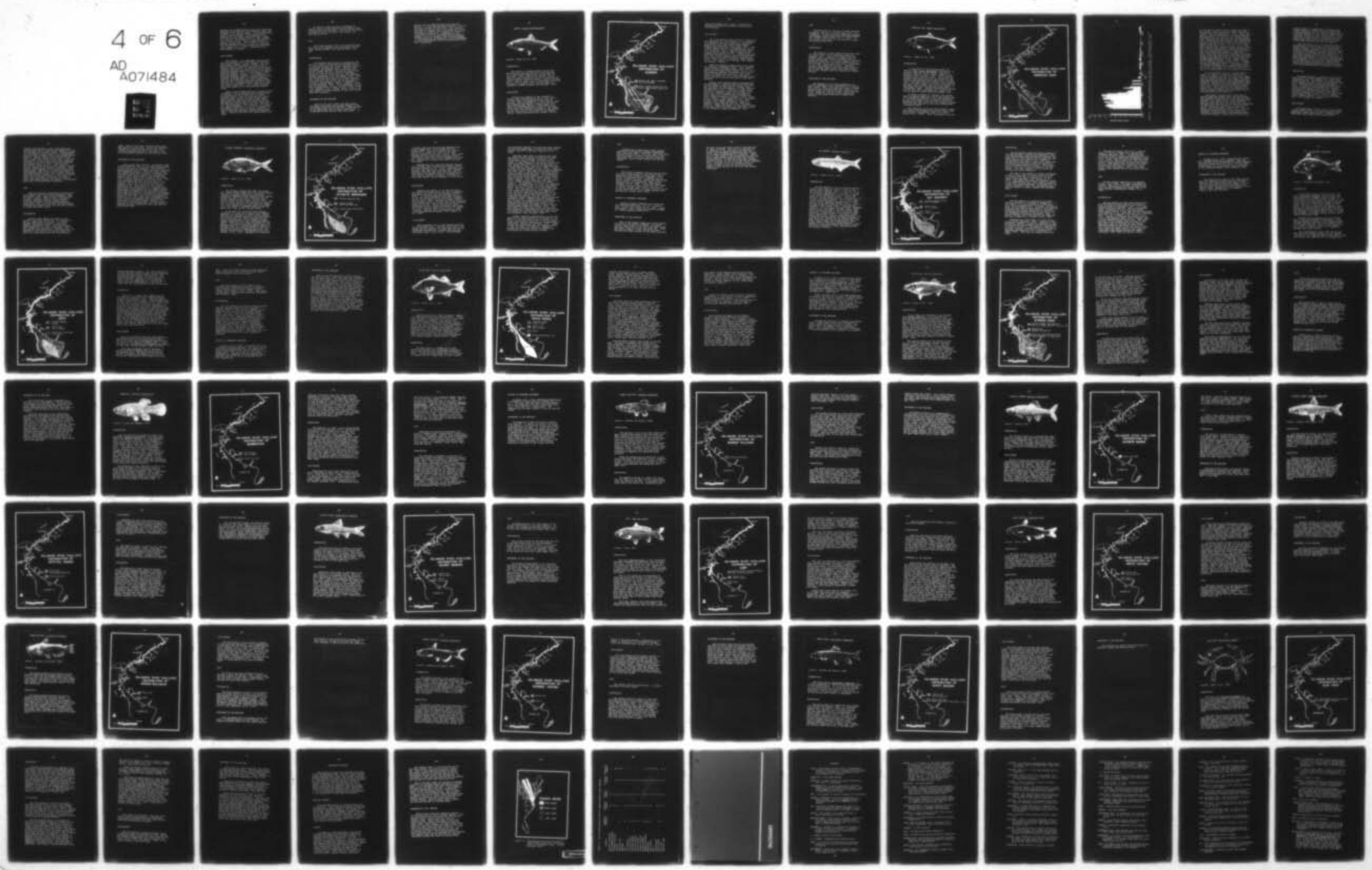
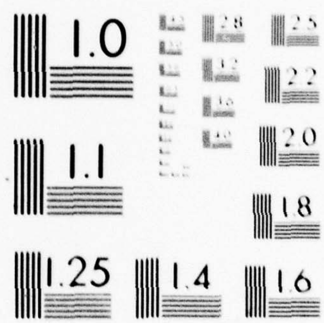




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

separate the blueback herring from the alewife and sometimes even from the larger American shad, also a member of the herring family. One characteristic which is more reliable in distinguishing the blueback from the other common herrings is that the lining of the stomach cavity of the blueback is blackish in color while in other herrings it is gray or pinkish gray. Adult blueback herrings average approximately 11-12 inches in length and 0.5-0.75 pounds in weight (Bigelow and Schroeder, 1953; Daiber, et al., 1976). Maximum size is approximately 15 inches.

LIFE HISTORY

The blueback is an anadromous species which uses the Delaware River and Estuary as spawning and nursery grounds. Adults, however, are open water fishes that spend most of their time in offshore areas, as far as 100 miles off the coast. Spawning runs begin in late March or early April generally several weeks after those of the alewife and shad (Schuler, et al., 1970; Schuler, 1971; Rohde and Schuler, 1974a,b). The difference in spawning schedules reflects the dependence of the blueback on warmer water to initiate spawning. Eggs are not deposited until water temperatures approach 70°F. Maximum spawning apparently takes place within the Delaware during the period from late April to mid-June. Tidal creeks and shore zone areas appear to be the preferred spawning sites.

Eggs of the blueback herring are demersal and covered by a sticky substance which adheres them to anything with which they come in contact. Hatching occurs in two to three days and larvae develop within a month into adult-like forms. Most juveniles leave the estuary before winter approaches, although some may remain within the bay and river during their first year (Schuler, et al., 1970; Anselmini, 1971; Schuler, 1971; Rohde and Schuler, 1974a,b,c). This is in contrast to the adults which leave the estuary generally as soon as they have spawned (Bigelow and Shroeder, 1953). Young do not return for approximately four years.

As with all other herrings, bluebacks are usually found in large schools often swimming with alewifes and other herrings. They can be efficiently captured by the use of wiers, haul seines, dip nets and gill nets.

DIET

Scott and Crossman (1973) have indicated that the food of the blueback consists mainly of copepods, pelagic shrimp, fish eggs and small fish fry.

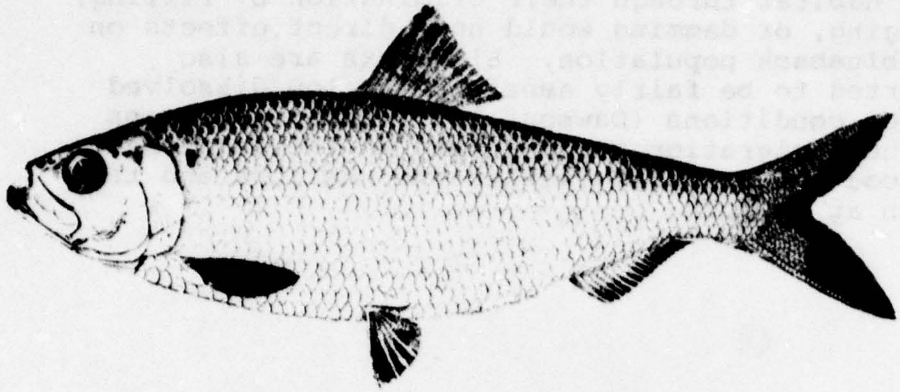
DISTRIBUTION

The blueback herring can be found along the Atlantic coast of North America from Nova Scotia to northern Florida, but is more abundant south of New England (Hildebrand, 1963). They are found throughout the Delaware Basin during the late spring, summer and fall. Adults have been found as far up river as river mile 205, with some spawning occurring up to river mile 200 (Ichthyological Associates, 1977; Chittendon, 1972). Eggs and larvae have been found in the lower estuary near river mile 40, so that the entire study area is within the boundaries noted for spawning or growing bluebacks (Wang, 1974a,b; Preddice, 1974a; Wik and Morrisson, 1974). Such widespread use has been substantiated in other studies of PECo (1977b, c,d), Anselmini (1971, 1974b), Kranz (1974a,b) and many others in which bluebacks of many life stages have been collected.

IMPORTANCE OF THE SHALLOWS

Most of the tidal creeks and shore zones throughout the study area provide spawning sites and nursery areas for the blueback. Some portions of the upper area such as near or above Biles Island may be more heavily used than others. It appears that all shallow water areas provide habitat for migrating and spawning adults, and for developing larvae and juveniles. Any losses of such habitat through their elimination by filling, dredging, or damming would have direct effects on the blueback population. Bluebacks are also reported to be fairly sensitive to low dissolved oxygen conditions (Dawson, 1933) and the success of their migration is dependent on the maintenance of good water quality within the shallows and the basin as a whole.

ALEWIFE (Alosa pseudoharengus)



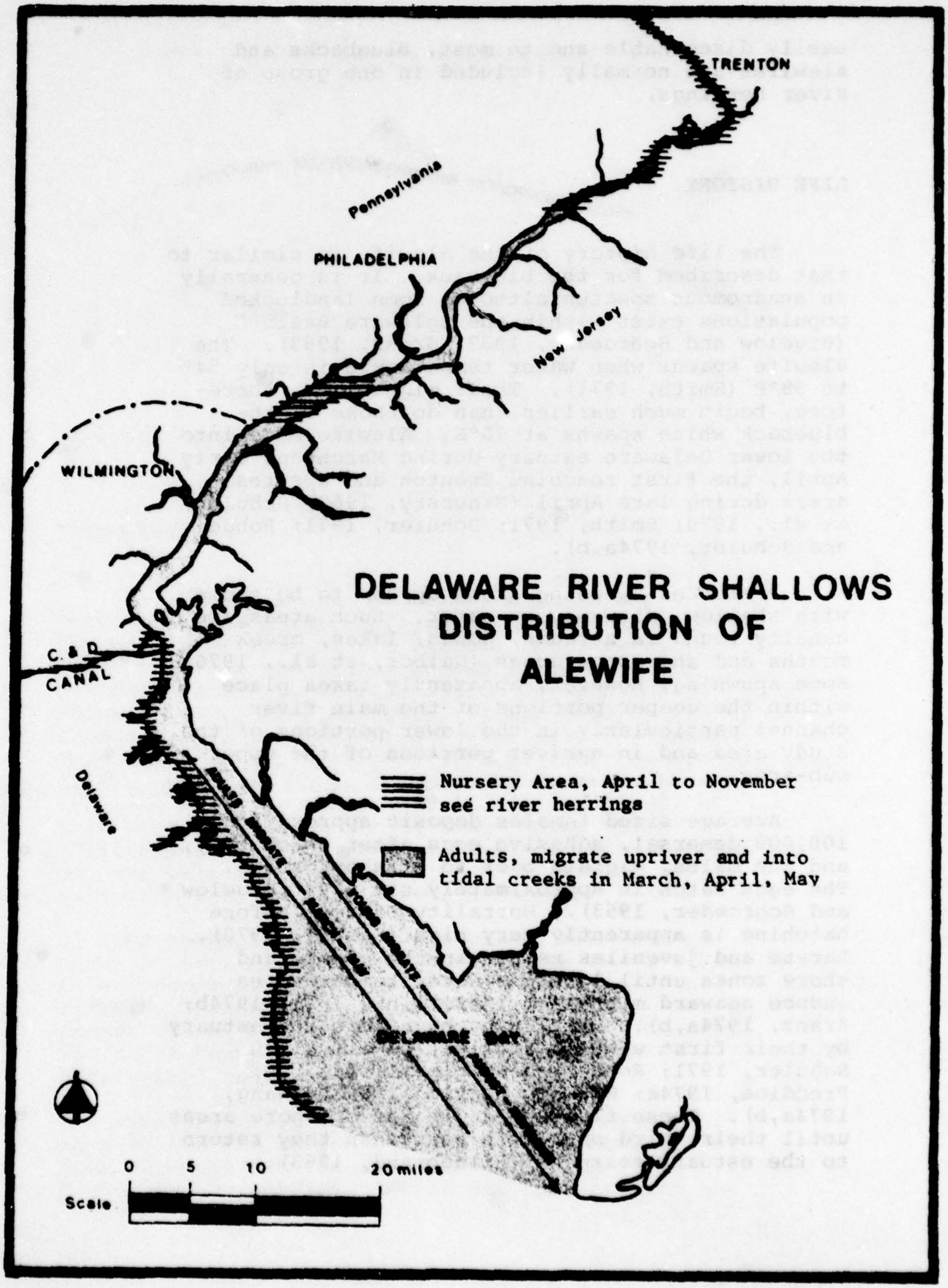
(Source: Goode, et al., 1884)

INTRODUCTION

The alewife is another common fish of the Delaware Basin and an important forage species. It is also caught commercially and has been for some time. Much of the catch, however, is not taken by ships originating within the basin but by foreign fishing vessels in offshore areas (Merriner, 1975). Most of these fish are processed as feed and fish meal (Gillepsie, 1967) although some are consumed by humans (Bigelow and Schroeder, 1953).

DESCRIPTION

Alewifes are similar to the bluebacks in general body characteristics and in size, and it is often hard to distinguish between the two species. They are generally a little stouter than the bluebacks and exhibit a greyish-green color while the blueback exhibits a blue-green color. There are also differences existing in the sizes of the eyes, the serrations present on the stomach and in the colors of the lining of the stomach cavity. These characteristics, however, are not


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C. & D.
CANAL
Delaware
DELAWARE BAY
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
ALEWIFE
Nursery Area, April to November
see river herrings
Adults, migrate upriver and into
tidal creeks in March, April, May
0
5
10
20 miles
Scale

easily discernable and to most, bluebacks and alewifes are normally included in one group of river herrings.

LIFE HISTORY

The life history of the alewife is similar to that described for the blueback. It is generally an anadromous species although some landlocked populations exist within the Delaware Basin (Bigelow and Schroeder, 1953; Gross, 1953). The alewife spawns when water temperature is only 54° to 58°F (Smith, 1971). Their migrations, therefore, begin much earlier than do those of the blueback which spawns at 70°F. Alewife move into the lower Delaware estuary during March and early April, the first reaching Trenton and upstream areas during late April (Mihursky, 1962; Schuler, et al., 1970; Smith, 1971; Schuler, 1971; Rohde and Schuler, 1974a,b).

Preferred spawning areas appear to be those with shallow, slow-moving water. Such areas are usually found in streams, ponds, lakes, creek mouths and shorezone areas (Daiber, et al., 1976). Some spawning, however, apparently takes place within the deeper portions of the main river channel particularly in the lower portions of the study area and in upriver portions of the upper sub-area.

Average sized females deposit approximately 100,000 demersal, adhesive eggs after which they, and the males, migrate back to offshore areas. The eggs hatch in approximately six days (Bigelow and Schroeder, 1953). Mortality of eggs before hatching is apparently very high (Edsall, 1970). Larvae and juveniles remain in the creeks and shore zones until lowering water temperatures induce seaward migration (Anselmini, 1971, 1974b; Kranz, 1974a,b). Most young have left the estuary by their first winter (Schuler, et al., 1970; Schuler, 1971; Rohde and Schuler, 1974a,b,c; Preddice, 1974a; Wik and Morrison, 1974; Wang, 1974a,b). These fish remain in the offshore areas until their third or fourth year when they return to the estuary to spawn (Hildebrand, 1963).

DIET

Alewife feed on a variety of foods depending on whether they are in fresh or salt water. In freshwater, the principle food items are copepods, cladocerans, mysids, ostracods and diatoms (Scott and Crossman, 1973; Daiber, et al., 1976). In salt water, they appear to feed mainly on mysid shrimps and small fish.

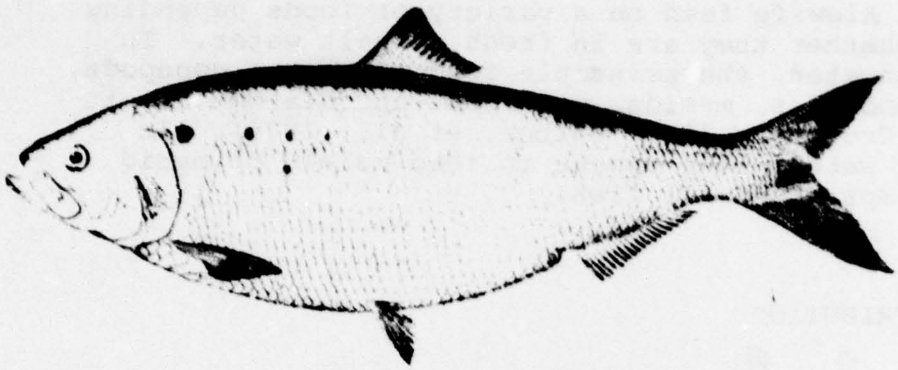
DISTRIBUTION

The alewife is found along the Atlantic coast from Nova Scotia to the Carolinas (Scott and Crossman, 1973). They can be found within the Delaware Basin from March to November and are widely distributed in all areas during this period. Spawning occurs both in the main channels and in the shallows, while young fish tend to concentrate in the tidal creeks and shallows. Important spawning areas appear to be near river miles 70-75 and 110-134, particularly near Biles Island. Most areas, however, serve as spawning or nursery grounds.

IMPORTANCE OF THE SHALLOWS

Maintenance of the alewife population is directly dependent on the availability of shallow water areas. While some spawning occurs in deeper estuarine and riverine areas, most occurs in the shallow waters of creeks, streams, shorelines and pools. These are also the areas in which the juveniles and young spend much of their time feeding.

AMERICAN SHAD (Alosa sapidissima)



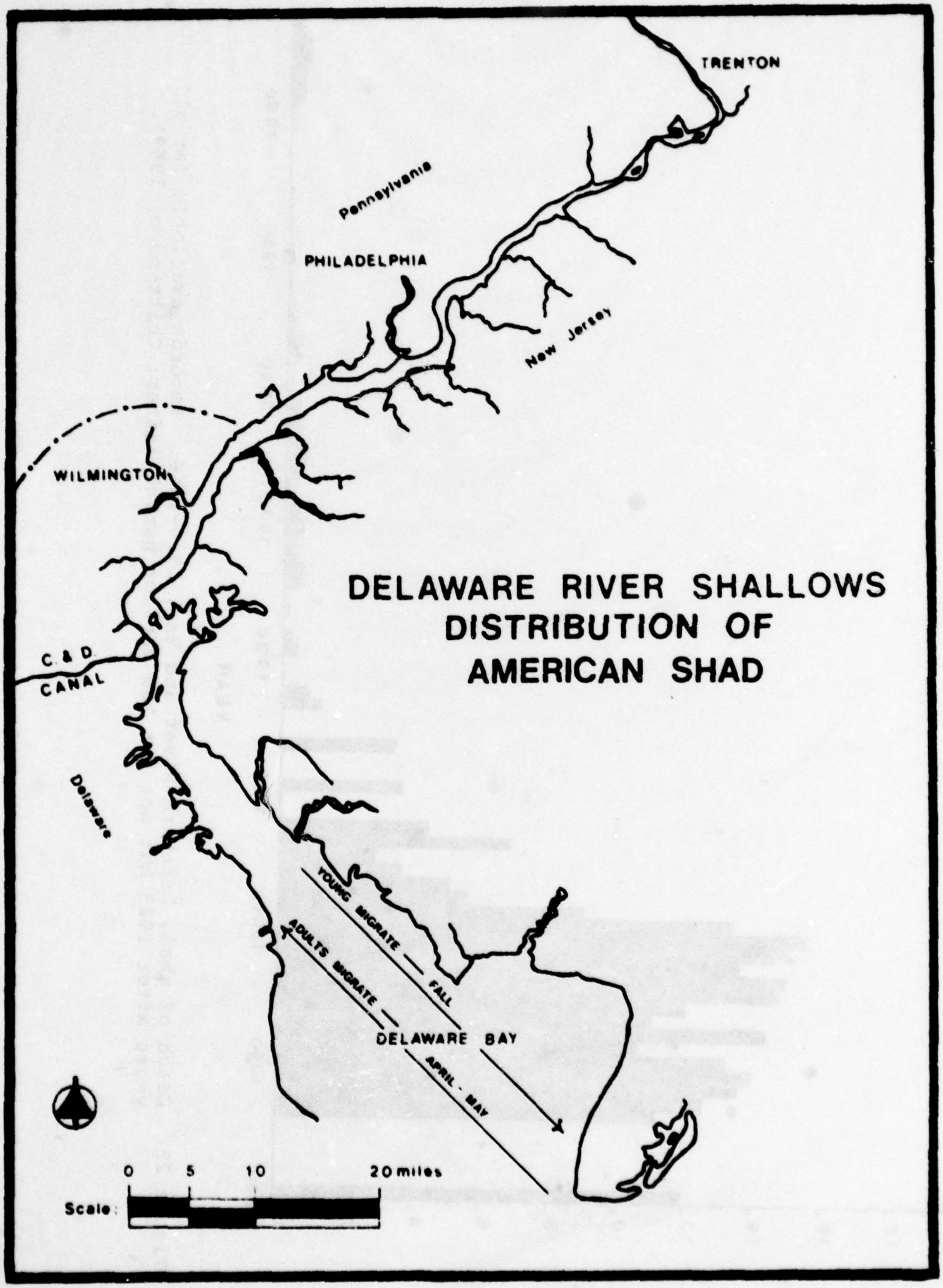
(Source: Goode, et al., 1884)

INTRODUCTION

To the people of the Delaware Basin the American shad, Alosa sapidissima, has been one of the most important of all fishes. Shad were plentiful when the Lennai Lenape Indians in the Delaware Valley (Loskiel, 1794). Early European colonists were also attracted to the area by the abundant shad populations and similarly took many from the Delaware each year (Myers, 1912; Jackson, 1967). The shad harvest continued to grow through the 1800's and by 1880, over 10 million pounds of shad were taken from the Delaware River Basin (Chittenden, 1969). Catches remained high throughout the late 1800's increasing to a peak of 19 million pounds in 1896 (Sykes and Lehman, 1957).

As shown in Figure 27, however, the catches began to decline after the turn of the century due to a tremendous reduction in the shad population. By 1910, the annual catch was down to 4 million pounds and by 1920 to only several hundred thousand. The catch has remained at this level through the intervening years.

The reduction in the size and success of shad runs within the Delaware has attracted much attention recently (Chittenden, 1969; Kiry, 1974; Miller et al., 1975a). While the present runs are


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
AMERICAN SHAD
C. & D.
CANAL
Delaware
YOUNG MIGRATE — FALL
ADULTS MIGRATE — APRIL - MAY
DELAWARE BAY
0 5 10 20 miles
Scale:

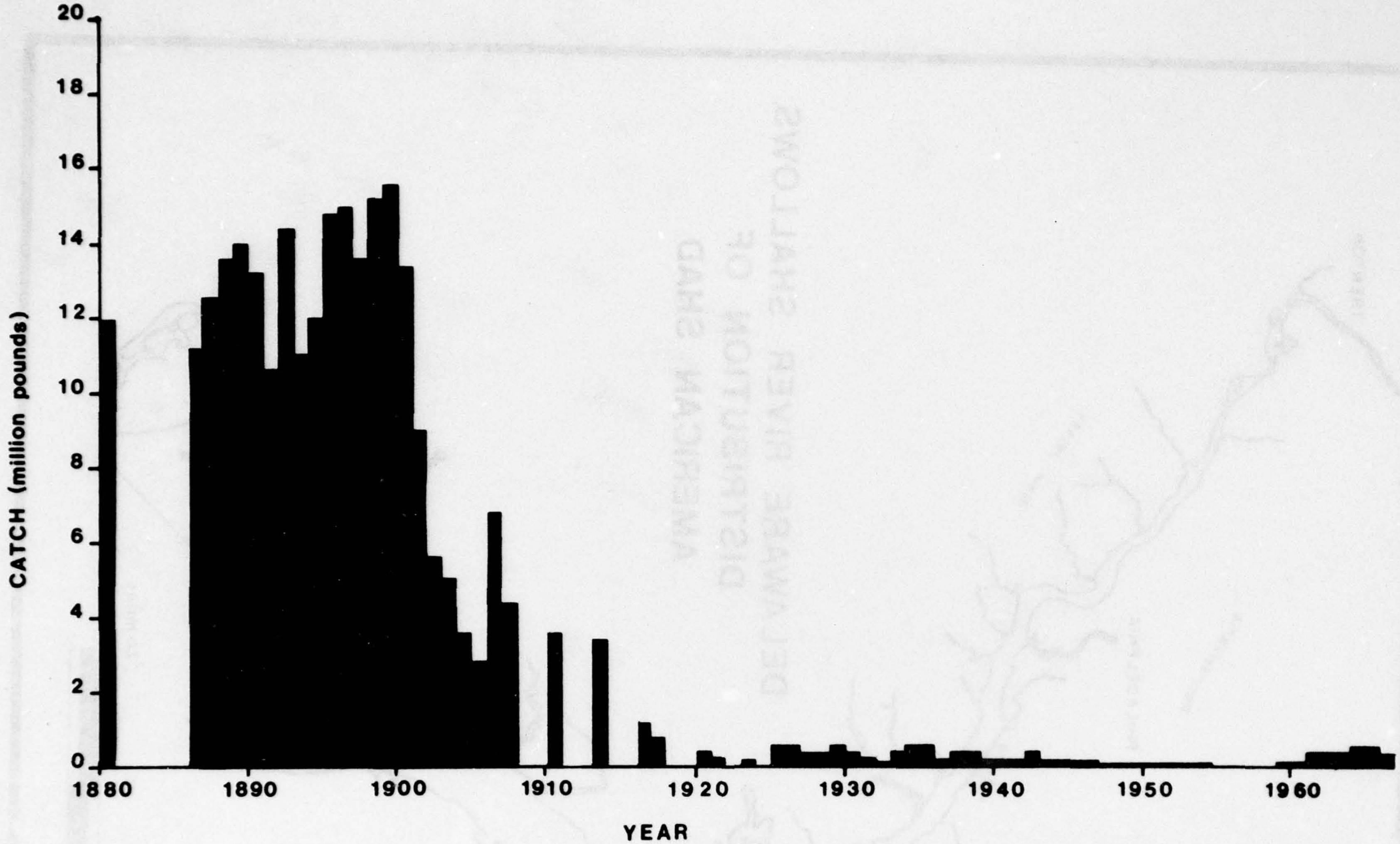


Figure 27. Catch of shad, Delaware River and Bay, 1980-1966. Records available for all years after 1925 but not for the earlier period (After: Chittenden, 1969).

not as large as those existing before the turn of the century, some fairly large runs still occasionally occur (Friedersdorff, 1976). These runs, however, are not as successful in maintaining the shad population as they once were. Many reasons have been given for their decline and unsuccessful runs. These include overfishing, dam construction and water pollution particularly as it affects the dissolved oxygen levels of the river (Gay, 1892; Meehan, 1897; Kiry, 1974). Miller, et al. (1933) have reported that dissolved oxygen levels of less than 5 mg/l are hazardous to adult and juvenile American shad and that levels of less than 4 mg/l will block migratory movement of these fish. These levels were determined from tagging studies. It was found that the upstream spawning run in the Delaware was completely cut off in 1971 when the minimum dissolved oxygen levels dropped to 4.0 mg/l at Chester (Miller, et al., 1971). Similar levels have been proposed by Ellis, et al. (1947) and Sykes and Lehman (1957). Chittenden (1969) has further indicated that dissolved oxygen levels of 2.0 mg/l will lead to significant levels of mortality, particularly of the migrating juveniles.

As was discussed earlier (and depicted in Figure 10, page 97), dissolved oxygen levels within the middle sub-area often are below these critical levels during the late spring and summer. Shad entering the estuary during these times are prevented from passing to upstream spawning areas. Similarly, juveniles migrating downstream in the early fall often do not survive passage through this region. While spawning may have been successful in a particular year, the population of young and adults remains relatively small due to this mortality of the juveniles.

Such oxygen problems have caused shad to abandon spawning grounds within the study area. Once spawning throughout the river from the tidal reaches of the upper estuary to the headwaters in New York, most spawning now occurs above the Delaware Water Gap with the greatest concentrations of shad found above Barryville (river mile 270) and in the East and West Branches (Sykes and Lehman, 1957; Chittenden, 1969, 1971). Not only are water conditions within these areas more conducive to the survival of the American shad, juveniles produced in these upriver areas have a greater chance of completing a successful downstream migration. These fish pass through the middle sub-area during the late fall when there is a greater probability that oxygen levels will be above the critical 4.0 mg/l concentration. Shad produced in areas closer to the oxygen sag may have to pass through this area earlier in the season when conditions are not as suitable.

That shad still run in the Delaware Basin supports the contention that they may once again become abundant. To this end, the Anadromous Fishery Project at Rosemont, New Jersey, has been studying the abundance, migratory patterns, and life history of the American shad since 1967. Of particular concern has been the evaluation of suspected problems on the success of the shad and other migratory species. With such identification and evaluation, it is hoped that these problems can be prevented from recurring, reducing the chances for further population declines and hopefully promoting significant population increases.

DESCRIPTION

The American shad is a member of the herring family and it closely resembles the alewife and blueback herring. All possess very large scales, single dorsal fin, small pectoral and ventral fins and a saw-edged belly (Bigelow and Schroeder, 1953). The shad can be distinguished from these others by specific characteristics of the jaw, lining of the stomach cavity and size. Shad are the largest of the herrings within the basin, reaching a maximum size of about 2 feet and weight of 12 pounds (Daiber, et al., 1976). Average sizes, however, are of 1.5 to 6 pounds for males and 3.5 to 8 pounds for females.

LIFE HISTORY

Shad spend most of their life in the offshore coastal areas, moving into brackish estuaries and freshwater rivers only to spawn. Spawning runs begin when water temperatures reach 50-55°F

(Bigelow and Schroeder, 1953), peak migrations usually occurring at temperatures between 55°F and 61°F (Walburg and Nichols, 1967). Spawning appears to take place in waters above 54°F, a temperature which is usually reached within the Delaware during mid-May. Average females produce about 30,000 eggs. As many as 150,000 and as few as 20,000 may be produced. Prime spawning areas are freshwater sections of the river where the bottom sediments are composed mainly of sand. Eggs are semi-buoyant and, unlike those of other common herrings, are not covered by any adhesive substance. These hatch in approximately 12-15 days at spring water temperatures. The larvae and juveniles remain in the spawning grounds until fall at which time they leave the estuary. Males do not return for approximately 4-5 years and females for 5-6 years. While they are capable of spawning for several years, few repeat spawners are found in the Delaware Basin due to its poor water conditions.

DIET

Shad are basically opportunistic feeders and will consume a variety of items (Atkinson, 1951; Chittenden, 1969). They have been shown to feed on mature insects, insect larvae, crustaceans, rotifers, copepods, diatoms, shrimp, worms, barnacles and small fish including, possibly, young shad. They will take food from the bottom, although they forage mostly near the water surface or within the water column.

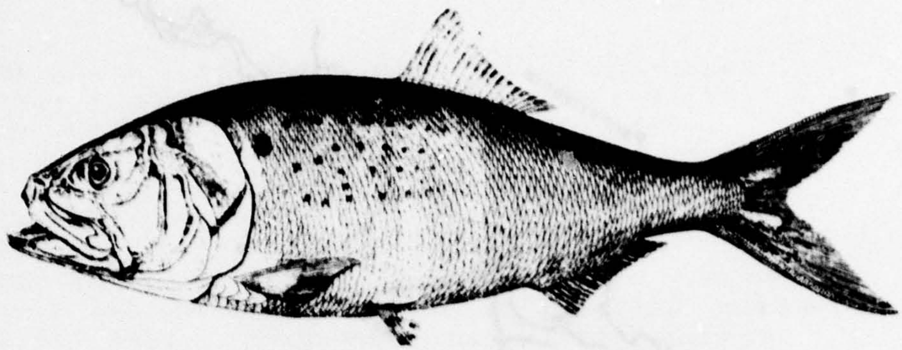
DISTRIBUTION

American shad inhabit the waters of the Atlantic coast from the Gulf of St. Lawrence to the St. Johns River in Florida. It is most abundant from North Carolina to Connecticut (Walburg and Nichols, 1967), with the Delaware Basin supporting, at least historically, one of the largest shad populations. Presence within the Delaware is only during the spring, summer and early fall when adults move into the estuary to spawn. Most of the actual spawning takes place well above the study area. Adults and juveniles, however, are found throughout the study area during the spawning period as they move to and from the spawning grounds and the Atlantic Ocean.

IMPORTANCE OF THE SHALLOWS

Given proper water quality, the American shad probably would use much of the shallow water zones of the study area for spawning. The preferred spawning grounds are the sandy shallows of brackish and freshwater systems. Such sites exist within the present study area and there is evidence that they were historically used by the shad during spawning runs. Now, however, most of the study area is used primarily as a migratory route. This is an extremely important function and is as directly responsible for the maintenance of the population as is the availability of suitable spawning sites. While there are many factors controlling the shad population, it appears that water quality improvements in the middle sub-area, particularly as regards dissolved oxygen levels, could lead to significant increases in the Delaware Basin shad runs simply by allowing more successful passage of the fish. Large scale improvements in water quality of the study area may possibly again lead to use of the shallow water zones of the study area as spawning grounds. Whether or not this occurs, the shallows must still be viewed as important habitats involved in the life cycle of the American shad.

ATLANTIC MENHADEN (Brevoortia tyrannus)

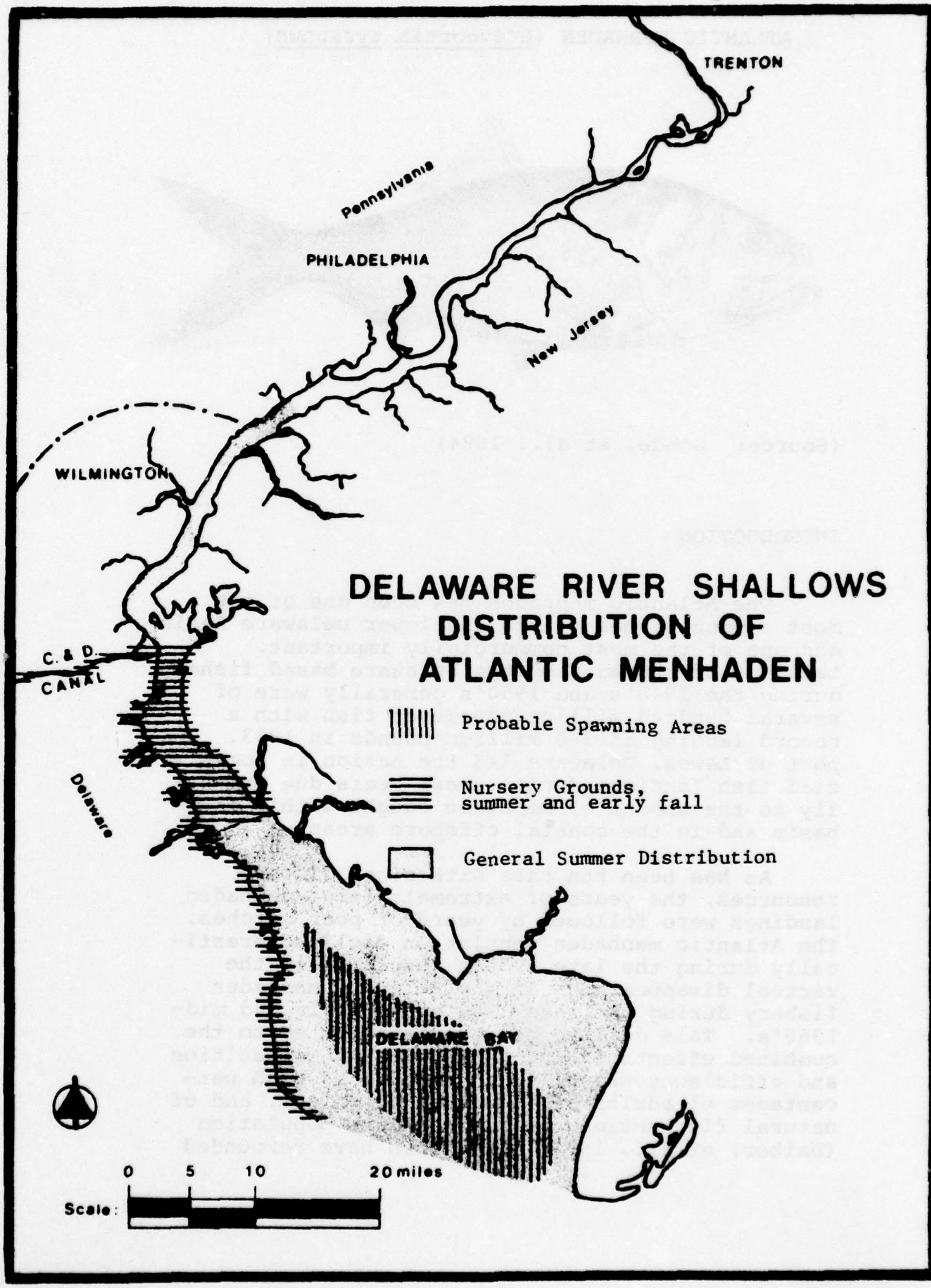


(Source: Goode, et al., 1884)

INTRODUCTION

The Atlantic menhaden has been one of the most common fishes within the lower Delaware Basin and one of the most commercially important. Landings of menhaden by the Delaware based fishery during the 1940's and 1950's generally were of several hundred million pounds of fish with a record landing of 360 million pounds in 1953. The port of Lewes, Delaware led the nation in commercial fish landings during these years due primarily to the amount of menhaden caught within the basin and in the coastal offshore areas.

As has been the case with other fishery resources, the years of extremely large menhaden landings were followed by years of poor catches. The Atlantic menhaden population declined drastically during the late 1950's resulting in the virtual disappearance of the Delaware menhaden fishery during the late 1950's and early and mid-1960's. This decline has been attributed to the combined effects of increased fishing competition and efficiency which led to removal of high percentages of adults and immature juveniles, and of natural fluctuations in the menhaden population (Daiber, et al., 1976). Menhaden have rebounded


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C. & D. CANAL
Delaware
DELAWARE BAY
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
ATLANTIC MENHADEN
Probable Spawning Areas
Nursery Grounds, summer and early fall
General Summer Distribution
0
5
10
20 miles
Scale:

in recent years and were the most abundant fish landed commercially in New Jersey from 1972 through 1974. They also accounted for approximately 25% of commercial catch in the lower Delaware Estuary in the early 1970's. While these landings are well below those recorded earlier, they indicate that the Atlantic menhaden can still be a commercially valuable fish within the Delaware Basin.

Menhaden are also important because they are food for many other estuarine and coastal fishes and birds (Daiber, et al., 1976). Porpoises, cod, pollock, hake, swordfish, striped bass, flounder, weakfish, bluefish, and sharks are all known to feed heavily on menhaden with the bluefish being a particularly important consumer. In addition, gulls and ospreys include menhaden in their diets.

DESCRIPTION

Menhaden are members of the herring family and exhibit the large scales and fin arrangements described previously for other members of this family. It can be separated from other herrings by its very large scaleless head which is approximately 1/3 the length of the total body (Bigelow and Schroeder, 1953). Menhaden also have relatively large mouths which open as far back as the posterior margin of the eye. Adults show little sexual dimorphism in size, males and females both averaging 12-14 inches in length and 0.5 to 1.25 pounds in weight. Maximum size is approximately 20-22 inches (Bigelow and Schroeder, 1953; Daiber, et al., 1976).

LIFE HISTORY

Adult menhaden live in near-coastal portions of the Atlantic Ocean. They are also found in the higher salinity portions of large bays such as the Chesapeake and Delaware, although they may move from these areas in the winter. While menhaden are euryhaline species, this distributional pattern reflects the preference of adults for water with greater than 20°/₀₀ salinity (deSylva, et al., 1962).

Spawning takes place in offshore and lower bay areas from late spring through early winter (Hildebrand, 1963; Mansueti and Hardy, 1967). Higham and Nicholson (1964) reported that the number of eggs produced by the average female each year ranged from 38,000 to 630,000 depending on size and age of fish. Eggs are buoyant and hatch in about 48 hours (Daiber, et al., 1976). Larvae move into the estuaries soon after hatching (Mansueti and Hardy, 1967). They seek low salinity waters found in tidal creeks and shore zone areas within estuaries such as the Delaware. In the Delaware, most larvae are found within creeks of the lower estuary (Smith, 1971; Wang, 1974c; Daiber, et al., 1976); however, larvae have been taken near Artificial Island from March through July (Wang, 1974b,c). Transformation of larvae into juveniles begins in the summer when the larvae are approximately one inch in length (June and Chamberlain, 1959). The juveniles grow to slightly more than three inches long during the first summer and fall, and after remaining approximately six to eight months in the estuary migrate back to the ocean with the adults. The fall migration is triggered by water temperatures falling below 60°F (Reintjes, 1975). Besides migrating offshore, many of these fish migrate south in the winter. A large portion of the population found in the Delaware area during the summer winters south of Cape Hatteras (Kroger and Guthrie, 1973). The young move into the estuary again the following year spawning at approximately three years of age. Individuals may live as long as ten years (June and Roithmayr, 1960; Reintjes, 1969).

Another important charactersitic of the menhaden and one which apparently contributed to its decline in the Delaware is that it moves in very large, tight schools numbering in the thousands of individuals (Bigelow and Schroeder, 1953). These schools are often found near the surface, making it easy for them to be spotted. Commercial fishing boats can then locate the schools and efficiently net large portions of most.

DIET

Menhaden are planktivorous fishes feeding primarily on diatoms and copepods (Hildebrand, 1963; Reintzes, 1969). They can filter very large amounts of water in short time periods as they swim with their mouths open and gill openings widespread, forcing water rapidly over the gill rakers.

DISTRIBUTION

The Atlantic menhaden occurs along the Atlantic coast of North America from Nova Scotia to eastern Florida (Bigelow and Schroeder, 1953). Within the Delaware Estuary, menhaden are primarily a summer resident. Adults have been found as far upriver as Philadelphia (PECo, 1977c), although most are found in the lower estuary (deSylva, et al., 1962). Larvae have been taken in creeks and shore zones as far up river as Artificial Island (Wang, 1974b,c) and young as far as the lower portion of the middle subarea (Wik and Morrison, 1974c; PECo, 1977c).

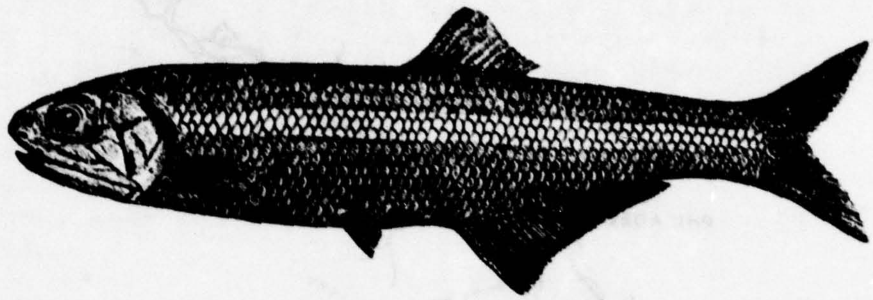
EFFECTS OF SUSPENDED SEDIMENTS

Juvenile Atlantic menhaden were classified as "suspension-sensitive" (1.0 g/l < 24 hour LC_{10} < 10 g/l) by O'Connor et al. (1976). Sherk and O'Connor (1971) classified juvenile menhaden as "highly suspension-sensitive".

IMPORTANCE OF THE SHALLOWS

Most of the present study area is not heavily utilized by the Atlantic menhaden. Principle nursery areas appear to be within the tidal creeks and shore zones of the mid- and lower bay. Young and adults, however, range through the lower sub-area and lower portions of the middle sub-area, and some larvae are always found in the shallows of these stretches. The fact that menhaden are so important to the maintenance of many other higher level consumers necessitates that as much of its range be protected as is possible. Important in this regard is the maintenance of both the proper physical and chemical shore zone habitat characteristics. As are other herrings, menhaden are not tolerant of very low oxygen levels (Thornton, 1975), and their use of the Delaware could be greatly reduced if the low oxygen conditions common to some sections of the study area become widespread.

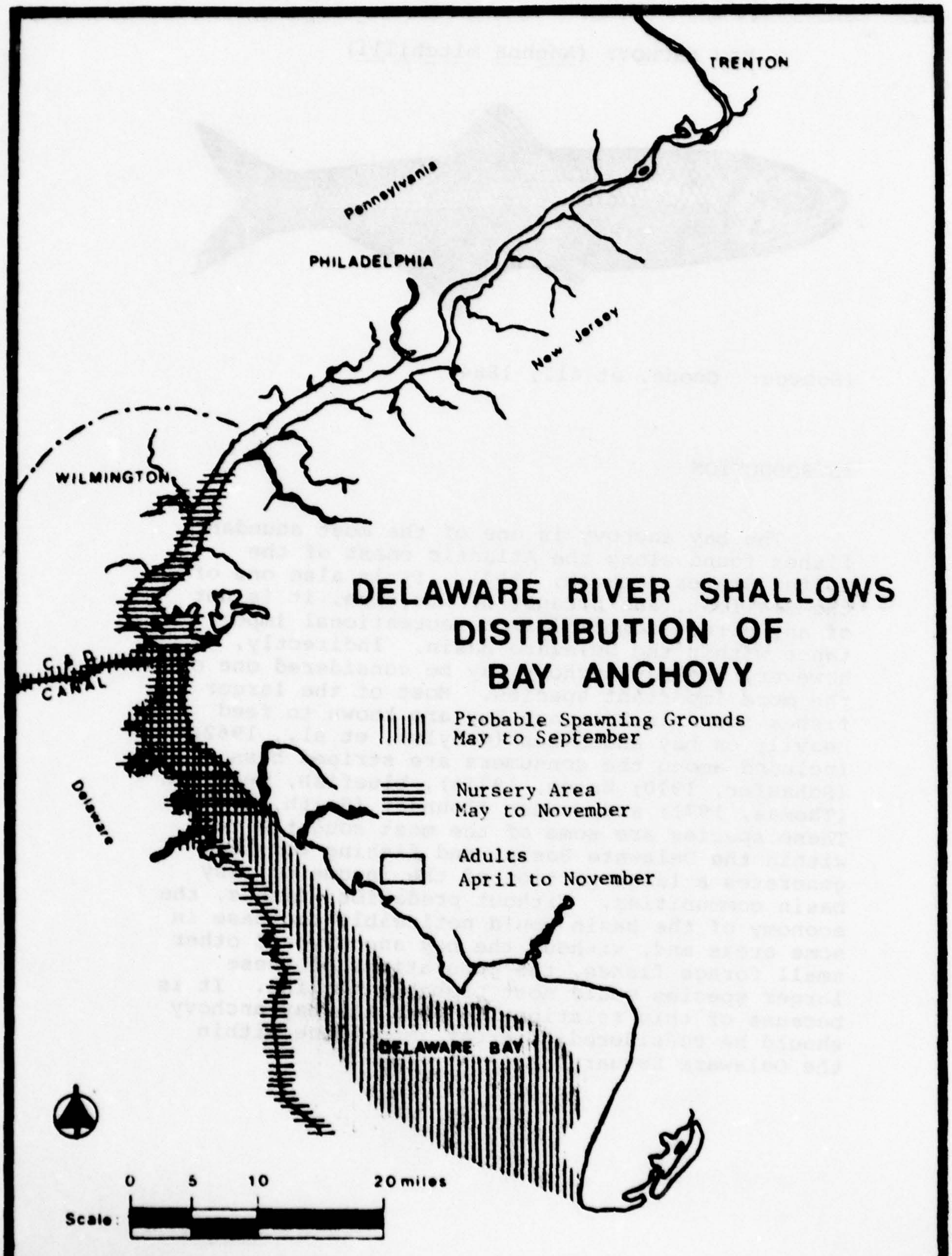
BAY ANCHOVY (*Anchoa mitchilli*)



(Source: Goode, et al., 1884)

INTRODUCTION

The bay anchovy is one of the most abundant fishes found along the Atlantic coast of the United States (McHugh, 1967). It is also one of the smallest, and because of its size, it is not of any direct commercial or recreational importance within the Delaware Basin. Indirectly, however, the bay anchovy may be considered one of the more important species. Most of the larger fishes found in Delaware Bay are known to feed heavily on bay anchovies (deSylva, et al., 1962). Included among the consumers are striped bass (Schaefer, 1970; Bason, 1971a), bluefish, weakfish (Thomas, 1971) and summer flounder (Smith, 1969). These species are some of the most sought after within the Delaware Basin, and fishing for them generates a large portion of the income of many basin communities. Without predacious fishes, the economy of the basin would noticeably decrease in some areas and, without the bay anchovy and other small forage fishes, the populations of these larger species would most probably decline. It is because of this relationship that the bay anchovy should be considered of great importance within the Delaware Estuary.


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
BAY ANCHOVY
Probable Spawning Grounds
May to September
Nursery Area
May to November
Adults
April to November
DELAWARE BAY
0
5
10
20 miles
Scale:

DESCRIPTION

The bay anchovy resembles smaller members of the herring family (Bigelow and Schroeder, 1953). Like the herrings, they possess large scales, one dorsal fin, a fairly deeply forked caudal fin and small pectoral and ventral fins. Anchovies possess very large eyes, a mouth which opens very far behind the eye and an upper jaw which distinctly projects beyond the lower. The arrangements of the fins is also different in the two groups. Once seen together, the anchovies and herrings are easily separated.

The body of the anchovy is almost translucent. A vague silvery band is present along the sides of the body from the gill opening to the tail (Bigelow and Schroeder, 1953; Daiber, et al., 1976). Many small dark spots are generally found on the body and the fins. Mean length for populations in the Delaware Estuary is approximately two inches (Stevenson, 1958) with the maximum size of the fish being 3.5 inches (Bigelow and Schroeder, 1953).

LIFE HISTORY

The bay anchovy is a schooling fish which migrates primarily in response to temperature. In the winter, it is found generally in deep water zones of the offshore area. In summer, the species moves into the shallow water areas of the estuaries. Anchovies have a fairly wide salinity tolerance and may be distributed throughout an estuary from the freshwater portions to the oceans. Most adults, however, are found concentrated where the salinity is above 5°/₀₀ (Daiber, et al., 1976).

Anchovies will also spawn in a wide variety of salinities (Stevenson, 1958). Spawning is most successful, however, in waters of moderate or high salinities with the spawning activity concentrated in areas of 13-15°/₀₀. The anchovy is generally a warm water spawner, spawning occurring from May to September and peaking in July in Delaware Bay (Wang, 1974c). Most eggs are spawned during the night.

The eggs are pelagic and hatch in approximately 24 hours at summer water temperatures (Manseuti and Hardy, 1967). Larvae are about 0.07-0.08 inches in length and metamorphose in 36 hours into fry with functional mouthparts (Daiber, et al., 1976). The fry then move into shore zone areas and tidal creeks and up into lower salinity waters. They remain there throughout the summer and early fall and may even spend their first winter within the estuary. Most of the young, however, move offshore during the winter with the adults.

DIET

The bay anchovy feeds mainly on copepods, shrimp, larval crabs, fish eggs, gastropods and diatoms. The young are primarily planktivorous while the adults apparently consume some of the larger benthic invertebrates (Daiber, et al., 1976).

DISTRIBUTION

The bay anchovy is found along the Atlantic and Gulf coasts of North America from Maine to Texas (Bigelow and Schroeder, 1953). It is most abundant south of Cape Cod. Within the Delaware Basin, the anchovy is one of the most common fishes, particularly in the lower estuary (Stevenson, 1958; deSylva, et al., 1962; Scotton, 1970; Derickson and Price, 1973; Campbell, 1975; Grieve, et al., 1977). Adults and juveniles are found as far up river as Philadelphia (PECo, 1977c), though, they are more abundant farther downstream. The lower portions of the Delaware River and most of the deep water areas of Delaware Bay are used as spawning grounds by the anchovy (Wang, 1974c). The larvae tend to move up bay and river or into tidal creeks and shore zones to lower salinity areas where they develop through the summer (Stevenson, 1958; Rohde and Schuler, 1974b,c).

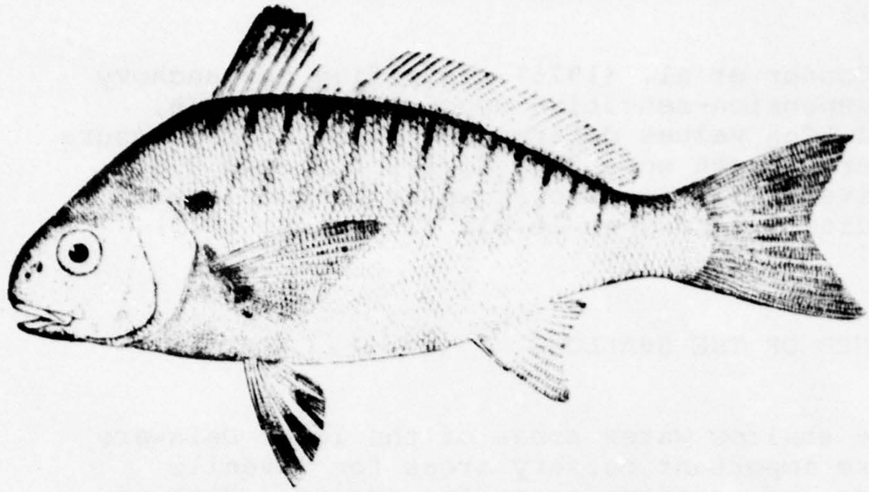
EFFECTS OF SUSPENDED SEDIMENTS

O'Connor et al. (1976) classified bay anchovy as a "suspension-sensitive species". The LC_{10}, LC_{50} and LC_{90} values determined for 24-hour exposure to Fuller's earth were 2.31 (g/l), 4.71 and 9.60, respectively. It is also known to be intolerant of low dissolved oxygen levels (Thornton, 1975).

IMPORTANCE OF THE SHALLOWS

The shallow water areas of the lower Delaware Basin are important nursery areas for juvenile anchovies and foraging areas for adults. Most of the lower sub-area of the present study area is used as nursery grounds and to some extent also as feeding areas. Anchovies are not commonly found in the other sub-areas.

SPOT (Leiostomus xanthurus)



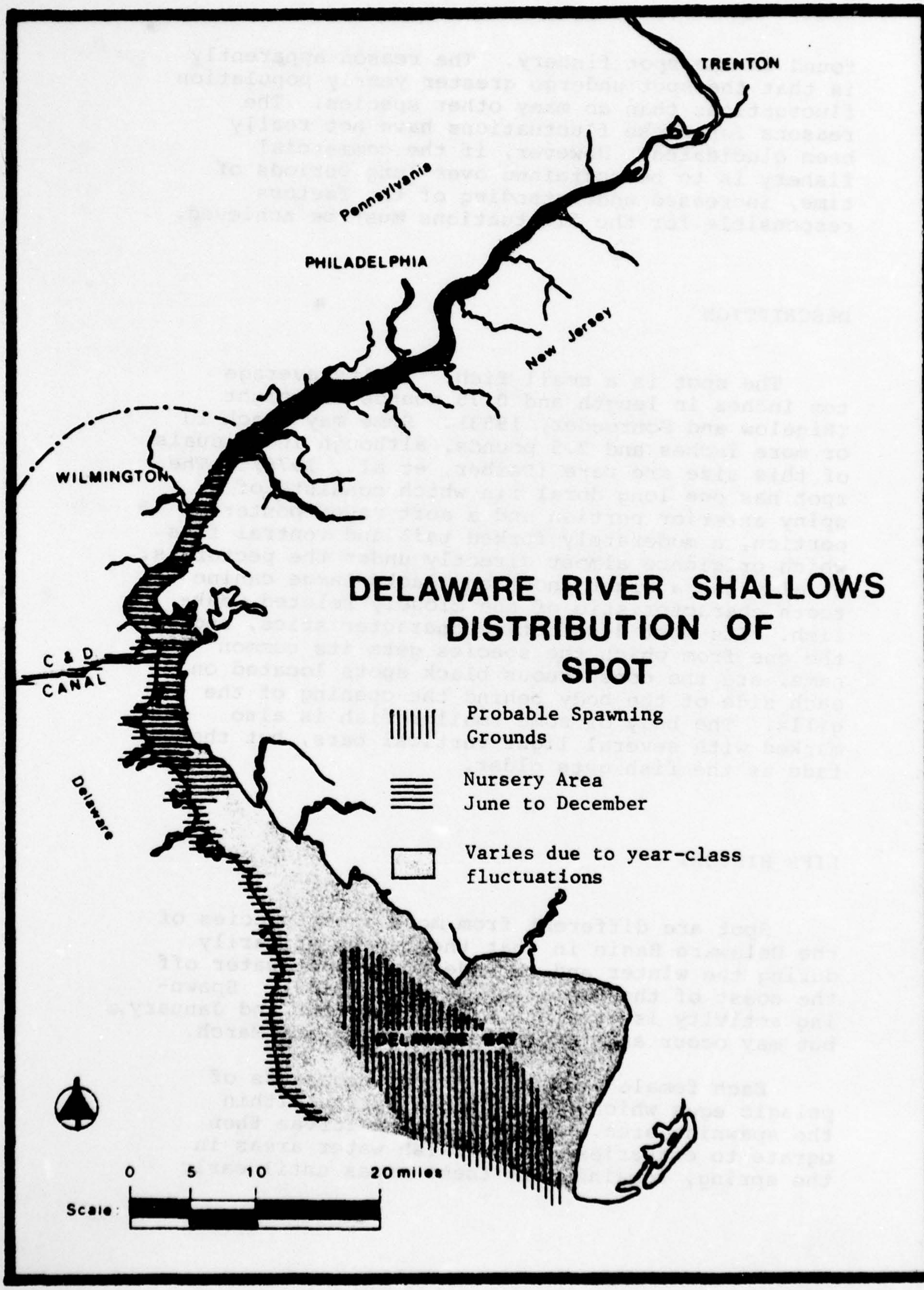
(Source: Evermann and Kendall, 1894)

INTRODUCTION

During certain parts of this century, the spot, Leiostomus xanthurus, has been one of the more commercially valuable fishes of both the Delaware Basin and Middle Atlantic Region. In the early 1950's the spot fishery was one of the top United States fin-fisheries as judged by weight landed and value of the catch (Daiber, et al., 1976). This was reflected in the Delaware Basin commercial landings during these years in which the spot varied from being the third to the eighth most abundant fish caught (Daiber, 1955). It was also abundant in the basin during 1967 and 1969 (Daiber and Smith, 1970).

In other years, however, the spot has been one of the least abundant fishes caught. There were no commercial landings in the Delaware Basin in 1968, and less than 500 pounds landed in the entire middle Atlantic region in 1970 (Daiber, et al., 1976). Presently, there is no commercial Delaware Basin spot fishery.

It is interesting to note that many of the most and least abundnt catches occur on consecutive years. All fisheries exhibit some year to year fluctuations but generally not of the magnitude


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE BAY
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
SPOT
Probable Spawning
Grounds
Nursery Area
June to December
Varies due to year-class
fluctuations
0 5 10 20 miles
Scale:

found in the spot fishery. The reason apparently is that the spot undergo greater yearly population fluctuations than do many other species. The reasons for these fluctuations have not really been elucidated. However, if the commercial fishery is to be sustained over long periods of time, increased understanding of the factors responsible for the fluctuations must be achieved.

DESCRIPTION

The spot is a small fish. Adults average ten inches in length and 0.75 pounds in weight (Bigelow and Schroeder, 1953). Some may reach 13 or more inches and 2.5 pounds, although individuals of this size are rare (Daiber, et al., 1976). The spot has one long doral fin which consists of a spiny anterior portion and a soft rayed posterior portion, a moderately forked tail and ventral fins which originate almost directly under the pectorals. It also has a blunt snout and lacks large canine teeth characteristic of the closely related weakfish. Its most distinctive characteristics, and the one from which the species gets its common name, are the conspicuous black spots located on each side of the body behind the opening of the gills. The body of some smaller fish is also marked with several light vertical bars, but these fade as the fish gets older.

LIFE HISTORY

Spot are different from most other species of the Delaware Basin in that they spawn primarily during the winter and in moderately deep water off the coast of the Carolinas (Dawson, 1958). Spawning activity is greatest during December and January, but may occur anytime between October and March.

Each female produces tens of thousands of pelagic eggs which develop into larvae within the spawning area. The adults and larvae then mgrate to estuaries and brackish water areas in the spring, remaining in these areas until early fall. Young are found primarily in the creeks and shore zones during this period while the adults range throughout the entire estuary.

DIET

Spot are primarily bottom feeders, most commonly taking nematodes, annelids, crustaceans and pelecypods from the upper sediment layers (Thomas, 1971; Daiber, et al., 1976). They also consume small fish and plant materials (Hildebrand and Schroeder, 1928).

DISTRIBUTION

Spot are found on the Atlantic Coast of North America from Massachusetts Bay to the Bay of Campeche, Mexico. They are most abundant in the Chesapeake Bay and near the Carolinas (Dawson, 1958). Spot are found in the Delaware Basin during the summer, fall and early winter (Smith, 1971; Thomas, 1971; Rohde and Schuler, 1974c). The young are common throughout the estuary, but remain in tidal creeks and ditches and along shallow shore zone areas (Rohde and Schuler, 1974c; Wik and Morrison, 1974). Individuals are occasionally found upriver of Philadelphia (Holmstrom, 1974). The extent of their penetration appears to be related to the size of the population entering the bay. Young move into the lower river only when large year classes are produced.

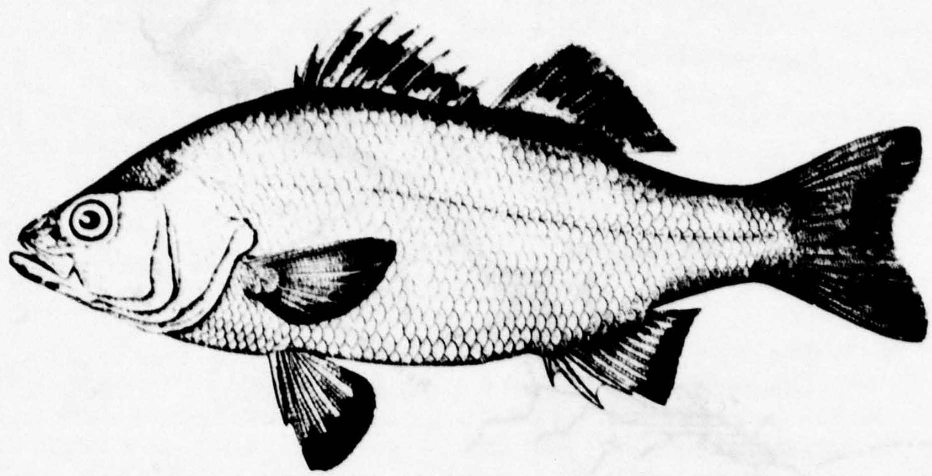
EFFECTS OF SUSPENDED SEDIMENTS

O'Connor et al. (1976) classified spot as a "suspension-tolerant species". The LC_{10}, LC_{50} and LC_{90} values determined for 24-hour exposure to Fuller's earth were 13.08 (gm/l), 20.34 and 31.62, respectively. The LC_{10}, LC_{50} and LC_{90} values determined for sediments from the Patuxent River, Maryland, were 68.75 (gm/l), 88.00 and 112.63 g/l, respectively.

IMPORTANCE OF THE SHALLOWS

Spot utilize shallow water zones as nursery and foraging areas. Such uses have been documented for the lower sub-area of the study area and for most of the estuary between this river stretch and the mouth of Delaware Bay. The species, however, is conspicuously absent from river sections above the lower sub-area. It is possible that conditions existing within the upper study area prevent the exploitation of this portion of the river by spot. The species has been demonstrated to be moderately tolerant of high turbidity levels (O'Conner, et al., 1976) and low dissolved oxygen levels (Sherk, et al., 1972). Considering that other less tolerant species are found in the upper areas, it does not appear that dissolved oxygen and turbidity levels characteristic of the middle and upper sub-areas would prohibit their use by the spot. If the factors responsible are related to the development of the upper river, it is possible that through their control many areas not presently utilized by the spot could be exploited by them.

WHITE PERCH (*Morone americana*)



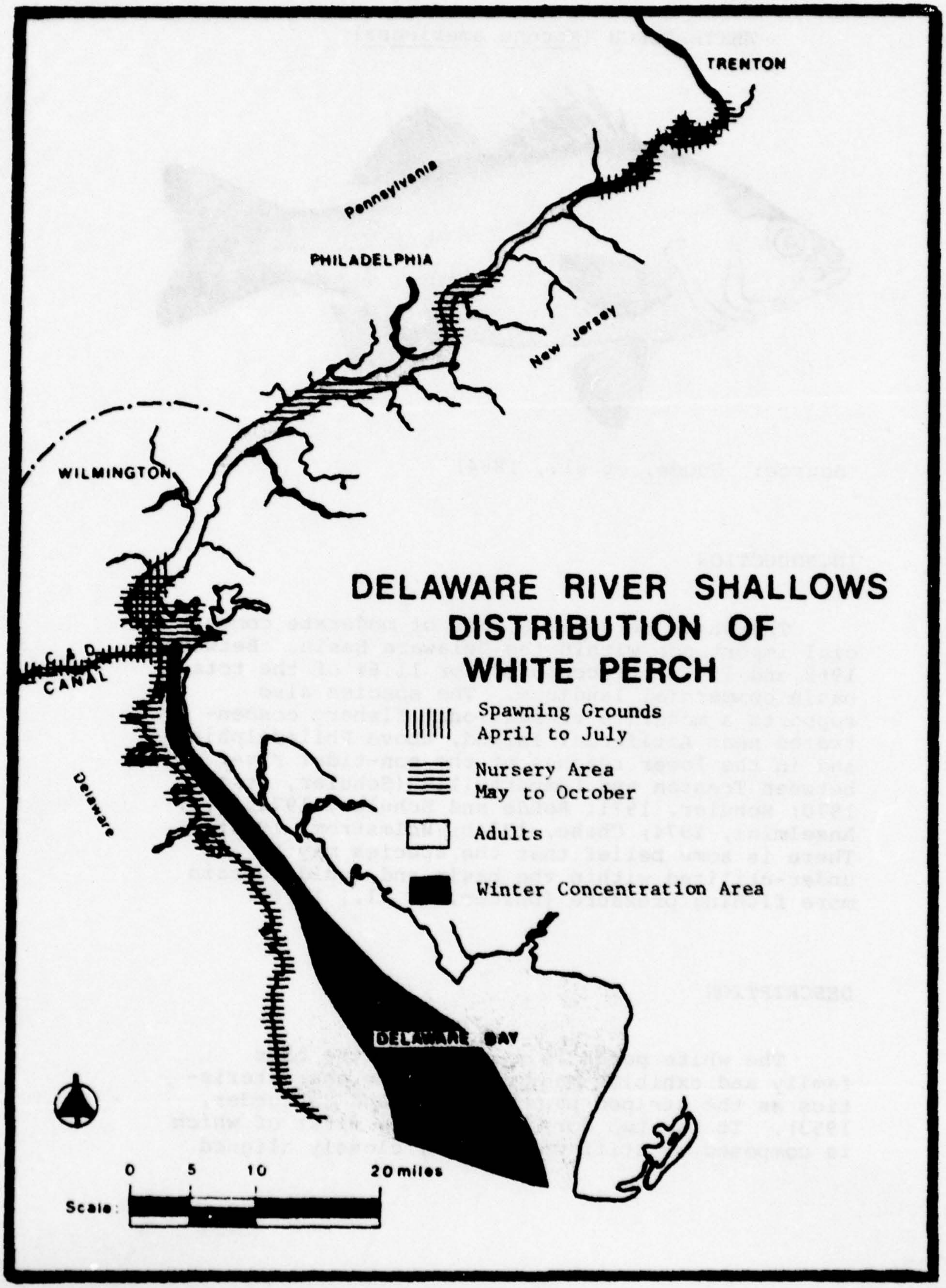
(Source: Goode, et al., 1884)

INTRODUCTION

The white perch is a fish of moderate commercial importance within the Delaware Basin. Between 1962 and 1971, it accounted for 11.6% of the total basin commercial landings. The species also supports a moderate recreational fishery concentrated near Artificial Island, above Philadelphia, and in the lower reaches of the non-tidal river between Trenton and Lambertville (Schuler, et al., 1970; Schuler, 1971; Rohde and Schuler, 1974a,b,c; Anselmini, 1974; Chase, 1974b; Holmstrom, 1974). There is some belief that the species may be under-utilized within the basin and could sustain more fishing pressure (Daiber, et al., 1976).

DESCRIPTION

The white perch is a member of the bass family and exhibits many of the same characteristics as the striped bass (Bigelow and Schroeder, 1953). It has two dorsal fins, the first of which is composed of stiff spiny rays, closely aligned


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D CANAL
Delaware
DELAWARE BAY
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
WHITE PERCH
Spawning Grounds
April to July
Nursery Area
May to October
Adults
Winter Concentration Area
0
5
10
20 miles
Scale:

pectoral and ventral fins, a slightly forked caudal fin and scale-covered head. The white perch, however, is much stouter bodied than the striped bass and has a relatively smaller mouth and larger eye. The adult perch also lacks the dark body stripes of the bass, although young may exhibit some such markings. Mean size of the white perch is eight to nine inches in length and 0.5 to 1.0 pounds in weight. Maximum size is approximately 12 to 15 inches and two or more pounds.

LIFE HISTORY

The white perch is a semi-anadromous species. Individuals migrate between fresh or brackish water areas and those of moderate salinity. Perch winter primarily in the deeper waters of bays and estuaries such as the Delaware and move into the river and tributaries during the spring and summer. Within the Delaware, the spring migration begins in March with most of the fish moving from deep water between April and June. Spawning occurs primarily in zones immediately above brackish water areas. Preferred sites are shallow weedy areas of creeks and shore zones (Daiber, et al., 1976), though some spawning occurs within the main stem of the Delaware. Spawning has been observed in the basin from Artificial Island to Lambertville (Mihursky, 1962), but is concentrated in areas below Trenton. Deposition of eggs begins when the water temperature reaches approximately 55°F and continues until temperatures approach 70°F (Smith, 1971). These temperatures are found in the Delaware area from April through July (Anselmini, 1974a; Kranz, 1974a; Wang, 1974a,b; Molzhan, 1975).

Average females produce from 50,000 to 150,000 eggs. The eggs are demersal and covered with a sticky substance. The period of incubation lasts from 30 hours to 6 days depending on water temperature (Bigelow and Schroeder, 1953; Daiber, et al., 1976). Larvae remain in brackish water areas or return to deeper, higher salinity waters to mature (Daiber, et al., 1976). The abundance of larvae and young within the upper estuary, particularly between Beverly and Newbold Island, indicates that many remain in the spawning areas until winter (Anselmini, 1974b; Chase, 1974; Holmstrom, 1974). These young begin moving with the adults to the deep water portion of the bay during September and October. Few are found in the shore zone areas during the winter (Schuler, et al., 1970; Rohde and Schuler, 1974b,c).

DIET

Larval and juvenile white perch are primarily planktivorous. Young feed on annelids, amphipods, isopods and copepods (Daiber, et al., 1976). Adults consume a variety of items feeding primarily on small fish fry, shrimps, crabs and eggs of other species (Bigelow and Schroeder, 1953).

DISTRIBUTION

White perch are common in the Atlantic coastal plain from the maritime provinces of Canada to South Carolina. It is capable of withstanding oceanic salinities but generally restricts its movements to near coastal and estuarine areas (Raney, 1965). Within the Delaware Basin, it is found from the mouth of Delaware Bay to approximately river mile 178. Its distribution within this range is controlled primarily by temperature. Juveniles and adults winter in the deeper water portion of the bay (Abbe, 1967; Daiber and Smith, 1972) and in the deep water of the lower river (Schuler, et al., 1970; Schuler, 1971; Rohde and Schuler, 1974a,b,c; Molzhan, 1975). During the spring and summer, individuals move into the shallower brackish and fresh water of creeks and shore zone areas. Most fish are found during these times in waters less than 12 feet deep.

EFFECTS OF SUSPENDED SEDIMENTS

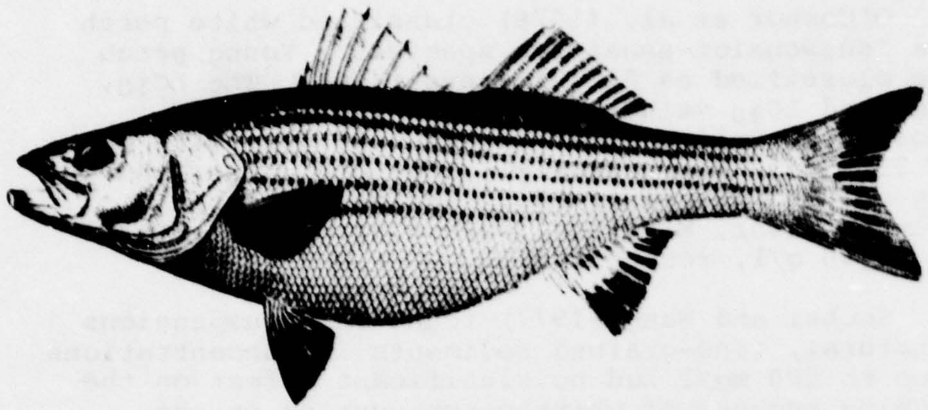
O'Connor et al. (1976) classified white perch as a "suspension-sensitive species". Young perch were classified as "highly sensitive". The LC_{10}, LC_{50}, and LC_{90} values determined for 24-hour exposure to Fuller's earth were 3.05 g/l, 9.85 g/l and 31.8 g/l, respectively. The LC_{10}, LC_{50}, and LC_{90} values determined using sediments of the Patuxent River, Maryland, were 9.97 g/l, 19.80 g/l and 39.40 g/l, respectively.

Scubel and Wang (1977) found that suspensions of natural, fine-grained sediments in concentrations of up to 500 mg/l had no significant effect on the hatching success of white perch eggs or on the development of the embryos. They did find, however, that the incubation period of eggs exposed to sediment concentrations of 100 mg/l and 500 mg/l was four to six hours longer than the period of eggs exposed to lower concentrations.

IMPORTANCE OF THE SHALLOWS

Shallows are important as spawning and feeding areas. Deeper water areas allow individuals to remain within the basin during the winter. All areas need to be abundant within the Delaware Basin. Their maintenance is especially important if fishing pressure on this species is to increase.

STRIPED BASS (*Morone saxatilis*)

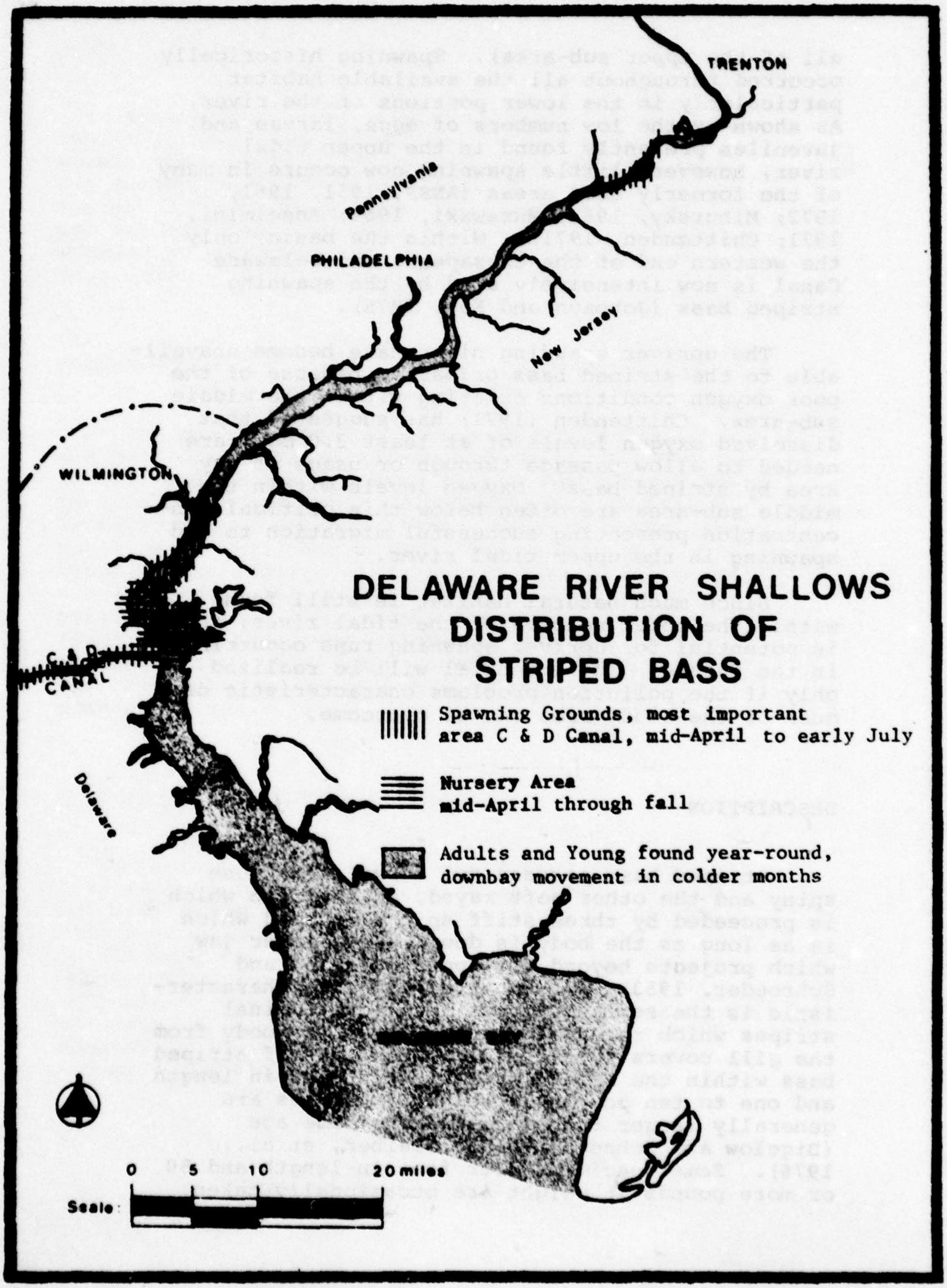


(Source: Goode, et al., 1884)

INTRODUCTION

As with shad, the abundance of the striped bass, *Morone saxatilis*, in the Delaware has steadily declined as the development of the basin has continued. Striped bass were plentiful when the early colonists first settled here (Jackson, 1967) and during most of the 19th century (Abbott, 1878). The stocks apparently began to decline during the latter portion of the 1800's and were significantly reduced by the 1930's and 1940's (Merriman, 1941). Today, while there are still enough striped bass within the basin to attract many recreational fishermen, the population can support only a marginal commercial fishery (Daiber, et al., 1976).

The apparent reason for the decline is that little of the Delaware Basin provides suitable spawning grounds (Chittenden, 1971). The preferred spawning sites of the striped bass are freshwater areas of rivers and streams immediately above brackish water zones (Raney, 1952; Tresselt, 1952; Talbot, 1966). Such areas can be found in the tributaries flowing into Delaware Bay and in the upper portion of the tidal section of the river (Chittenden, 1976). (The latter corresponds approximately to much of the middle sub-area and


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
STRIPED BASS
Spawning Grounds, most important
area C & D Canal, mid-April to early July
Nursery Area
mid-April through fall
Adults and Young found year-round,
downbay movement in colder months
0
5
10
20 miles
Scale

all of the upper sub-area). Spawning historically occurred throughout all the available habitat, particularly in the lower portions of the river. As shown by the low numbers of eggs, larvae and juveniles presently found in the upper tidal river, however, little spawning now occurs in many of the formerly used areas (ANSP, 1951, 1961, 1972; Mihursky, 1962; Murawski, 1969; Anselmini, 1971; Chittenden, 1971). Within the basin, only the western end of the Chesapeake and Delaware Canal is now intensively used by the spawning striped bass (Johnson and Koo, 1975).

The upriver spawning sites have become unavailable to the striped bass primarily because of the poor oxygen conditions existing within the middle sub-area. Chittenden (1971) has suggested that dissolved oxygen levels of at least 3.0 mg/l are needed to allow passage through or usage of any area by striped bass. Oxygen levels within the middle sub-area are often below this critical concentration preventing successful migration to and spawning in the upper tidal river.

Since much natural habitat is still found within the upper reaches of the tidal river, there is potential for upriver spawning runs occurring in the future. The potential will be realized only if the pollution problems characteristic of much of the study area can be overcome.

DESCRIPTION

Striped bass possess two dorsal fins, one spiny and the other soft rayed, an anal fin which is proceeded by three stiff spines, a head which is as long as the body is deep, and a lower jaw which projects beyond the upper (Bigelow and Schroeder, 1953). Its most distinctive characteristic is the seven or eight dark longitudinal stripes which run along each side of the body from the gill covers to the tail. Mean size of striped bass within the Delaware is 12-30 inches in length and one to ten pounds in weight. Females are generally larger than males of the same age (Bigelow and Schroeder, 1953; Daiber, et al., 1976). Some specimens four feet in length and 50 or more pounds in weight are occasionally taken.

LIFE HISTORY

During most of the year, adult stripers are generally found close to the coast (Bigelow and Schroeder, 1953). They congregate in large schools, each of which retain some identity within the larger population (Clark, 1968). The schools exhibit two types of migration, a north-south migration along the coast and one between areas of low and high salinity. Schools migrate to the north and into estuaries and rivers during the spring, and south and to higher salinity areas during the fall and winter. Fish younger than two years remain within the parent estuary (Bigelow and Schroeder, 1953).

Spawning takes place in this region from April to June when water temperatures are between 54° and 72°F (Murawski, 1969). Preferred spawning sites are freshwater river sections just above brackish water zones. There is also a preference for areas with a moderately swift current (Bigelow and Schroeder, 1953). Bass produce semi-buoyant eggs which need turbulence to keep them from settling to the bottom where they may be smothered by the sediments.

The fact that eggs are not adhesive has been partially responsible for the population reduction seen in striped bass in this region. While eggs may be deposited above polluted areas, many are carried by the current into areas with poor water quality. Survival of eggs and larvae under these conditions is often impossible.

Eggs hatch in approximately two to three days depending on water temperature. The larvae drift with the currents until they are 0.5 inch long. At this stage, they become capable of sustained swimming. Juveniles generally remain in the estuary two to three years before migrating to sea. They will migrate to the deeper water of the lower bay, however, during the winter. Most males become sexually mature by their third year while females not until their fifth (Bigelow and Schroeder, 1953).

DIET

Larval and juvenile striped bass feed primarily on microcrustaceans and it has been determined that a variety of species must be available for normal growth to occur (U.S. DOI, 1969, 1970). Larger individuals consume worms, squid, shrimp and various fish including herrings, silversides, anchovies, killifish and mummichogs (Daiber, et al., 1976).

DISTRIBUTION

The striped bass is native to the Atlantic and Gulf Coasts of North America (Raney and deSylva, 1953). Within the Delaware Basin, individuals can be found from the mouth of Delaware Bay to Easton, Pennsylvania (Mihursky, 1962). Most, however, are found below the lower river. The principle spawning and nursery areas within the Delaware are now located in and around the Chesapeake and Delaware Canal. Some adults and young can be found within the lower reaches of the Bay throughout the year. Others are present in the upper reaches of the river only during late spring, summer and early fall.

EFFECTS OF SUSPENDED SEDIMENTS

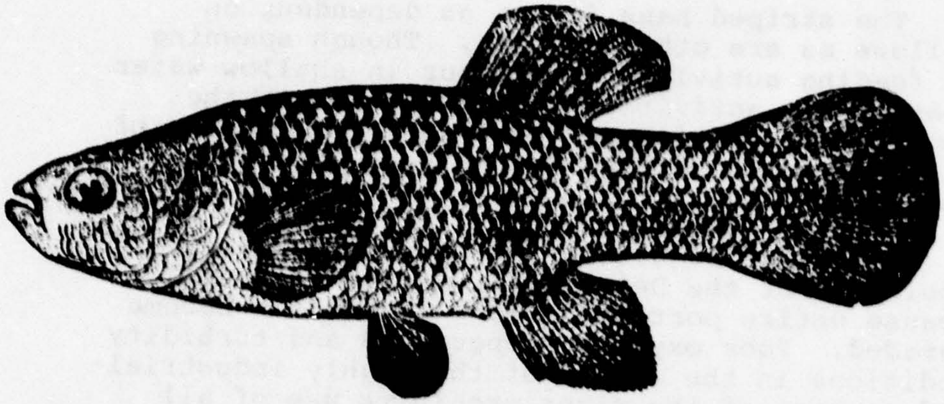
O'Connor et al. (1976) classified striped bass as a "suspension-sensitive species". Scubel and Wang (1973) found that suspensions of natural fine grained sediments in concentrations of up to 500 mg/l had no significant adverse effects on the hatching success of striped bass eggs. The only effect observed was a four to six hour extension of the incubation period when eggs were exposed to suspended sediment concentrations of 100 mg/l and 500 mg/l.

IMPORTANCE OF THE SHALLOWS

The striped bass is not as dependent on shallows as are other species. Though spawning and feeding activities can occur in shallow water areas, these activities may also occur in the deeper water portions of the river. All areas of the river could be used by the bass were they present.

The great reduction in the striped bass population of the Delaware River has occurred because entire portions of the river have become degraded. Poor oxygen, temperature and turbidity conditions in the waters of the highly industrialized section of the river prohibits use of all habitats within these reaches for spawning, feeding or migration. Poor water quality also prevents most striped bass from moving to suitable upriver spawning sites. Even if adults reach these areas and spawn successfully, only few eggs and larvae survive their movements through the polluted zones. Improvements in water conditions in all habitats within the study area would result in significant increases in the Delaware Basin population of striped bass.

MUMMICHOG (Fundulus heteroclitus)

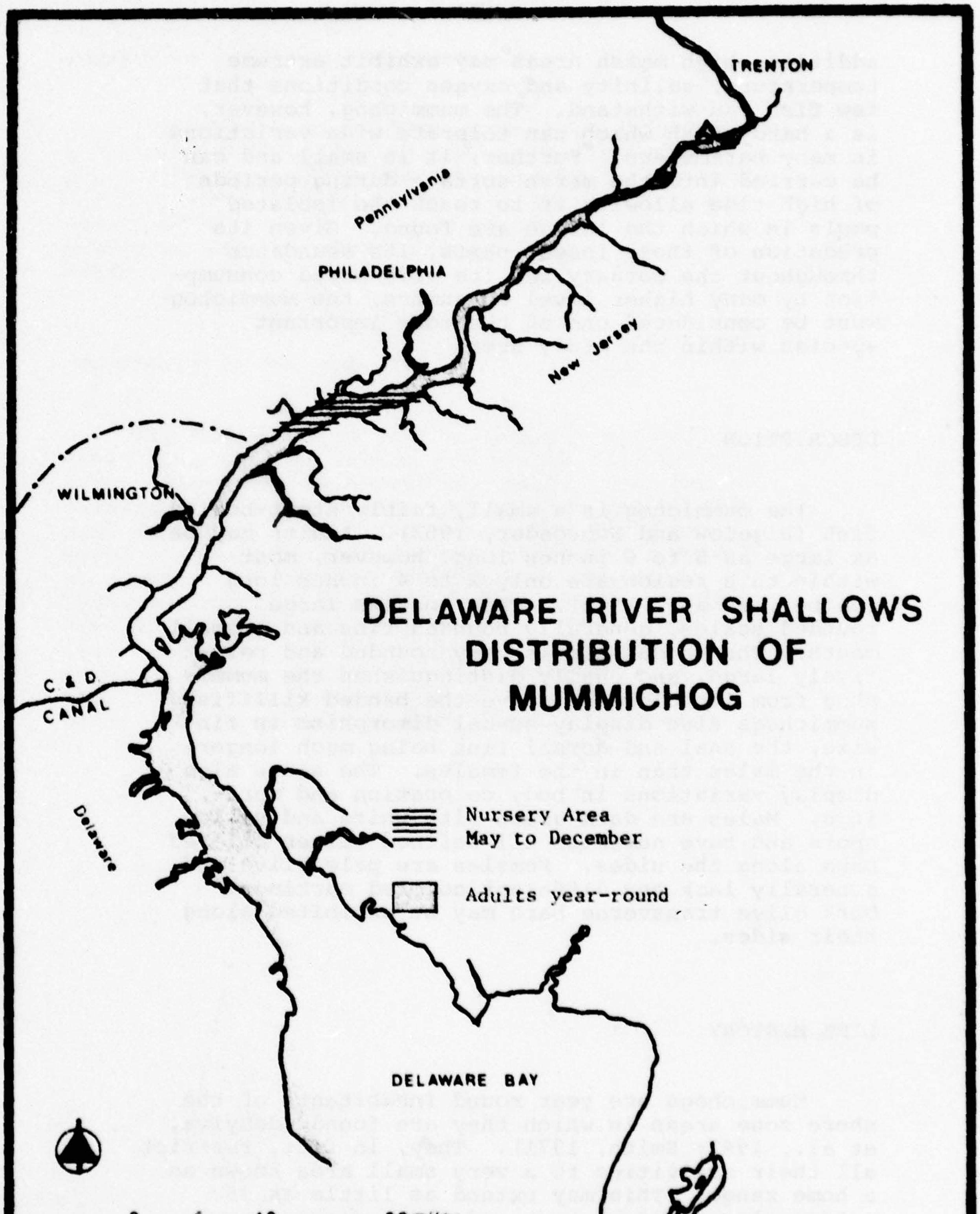


(Source: Jordan and Evermann, 1900)

INTRODUCTION

Like its relative the banded killifish, the mummichog, Fundulus heteroclitus, is a very widespread and important species. A truly euryhaline fish, it is found in the salt water marshes of lower Delaware Bay as well as in the brackish and fresh water areas of the upper estuary (deSylva, et al., 1962; Smith, 1971; Potter and Harmon, 1973). The mummichog is also highly productive and is a source of food for many higher level consumers (Daiber, et al., 1976). Included as its predators are the bluefish, white perch, American eel, striped bass, yellow perch, summer flounder and trout (White, et al., 1965; Daiber, et al., 1976). The mummichog is also taken by a variety of birds such as the herons, egrets and kingfishers. These small fishes are truly one of the cornerstones of the estuarine trophic structure.

The mummichog is also important in that it is a principal consumer of the larvae of the salt marsh mosquito and plays a significant role in controlling this pest (Chidester, 1916). Mosquitos breed on the surfaces of periodically flooded salt and brackish water marshes. Due to the very shallow waters in these areas, most fishes are not able to reach mosquito breeding areas. In


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
MUMMICHOG
Nursery Area
May to December
Adults year-round
DELAWARE BAY
0
5
10
20 miles
Scale:

addition, high marsh areas may exhibit extreme temperature, salinity and oxygen conditions that few fish can withstand. The mummichog, however, is a hardy fish which can tolerate wide variations in many parameters. Further, it is small and can be carried into the marsh surface during periods of high tide allowing it to reach the isolated pools in which the larvae are found. Given its predation of these insect pests, its abundance throughout the estuary and its widespread consumption by many higher level consumers, the mummichog must be considered one of the more important species within the study area.

DESCRIPTION

The mummichog is a small, fairly stout-bodied fish (Bigelow and Schroeder, 1953). Adults may be as large as 5 to 6 inches long, however, most within this region are only 2 to 4 inches long (Daiber, et al., 1976). They possess large rounded scales, generally rounded fins and a small mouth. The caudal fin is very rounded and relatively large, and easily distinguishes the mummichog from its close relative the banded killifish. Mummichogs also display sexual dimorphism in fin size, the anal and dorsal fins being much longer in the males than in the females. The sexes also display variations in body coloration and markings. Males are dark green with white and yellow spots and have numerous ill defined silver colored bars along the sides. Females are pale olive and generally lack any different colored markings. Dark olive transverse bars may be exhibited along their sides.

LIFE HISTORY

Mummichogs are year round inhabitants of the shore zone areas in which they are found (deSylva, et al., 1962; Smith, 1971). They, in fact, restrict all their activities to a very small area known as a home range. This may extend as little as 36 meters along a creek bank and three meters into the channel (Lotrich, 1975). Spawning takes place upon the surface of the vegetated marshes adjacent to the home range (Daiber, et al., 1976). Many of the eggs are deposited right on the stalks of grasses such as the salt marsh cordgrass, Spartina alterniflora. Spawning can occur from May through August (Smith, 1971), with individuals often spawning several times during this period (Daiber, et al., 1976). As the mummichog spawns upon the marsh surface, its cycle is correlated with the 14 day spring tide cycle. Eggs hatch in approximately 2.5 to 3.5 weeks depending on the water temperature. The larvae mature quickly and the young are able to spawn later in the same season in which they were produced.

DIET

Mummichogs are generally considered omnivorous, consuming small invertebrates, plants and detritus. They appear, however, to be predominantly carnivorous, consuming plant and detrital materials only incidentally when taking their prey (Daiber, et al., 1976). Prey organisms include molluscs, fish eggs and fry, copepods, insect larvae, small crabs and shrimp.

DISTRIBUTION

The mummichog is abundant in brackish and fresh water areas from Maine to Texas particularly within the creeks and sloughs of vegetated marshes (Eddy, 1957). They prefer areas with muddy bottoms which correlates well with their abundance in muddy shore zone areas of the Delaware Estuary (Briggs and O'Conner, 1971; Daiber, et al., 1976). Within the Delaware Basin, the mummichog is found primarily below Trenton and is a dominant species in the salt water areas of the lower bay as well as in the brackish areas of the middle sub-area (deSylva, et al., 1962; Smith, 1971; Potter and Harmon, 1973). Due to its high tolerance of low oxygen, high temperature and high turbidity conditions (O'Conner, et al., 1976; Daiber, et al., 1976), it does well in the polluted stretches of the river as demonstrated by its abundance below Philadelphia (PECo, 1977b,c,d).

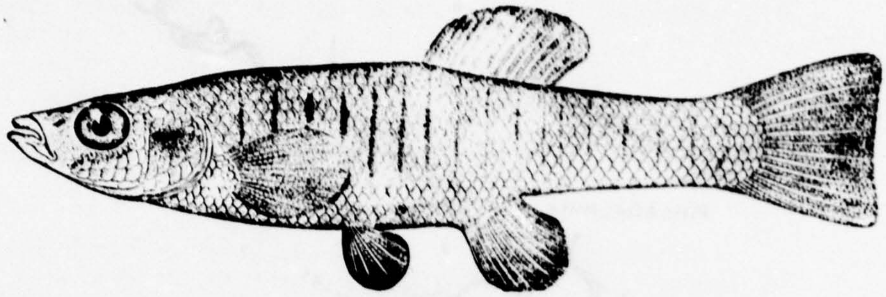
EFFECTS OF SUSPENDED SEDIMENTS

O'Connor et al. (1976) classified mummichog as a "suspension-tolerant species" (24-hour $LC_{10} \geq 10$ g/l). The LC_{10}, LC_{50} and LC_{90} values determined for 24-hour exposure to Fuller's earth were 24.27 (g/l), 39.00 and 62.17, respectively. The mummichog was the most tolerant of the six species tested.

IMPORTANCE OF THE SHALLOWS

The mummichog is most definitely a shallow water species. It spends its entire life within a few meters of the shoreline, moving into nearby vegetated areas to spawn. It is also one of the most important prey organisms within the estuary, being consumed by most larger fishes and a host of mammals and birds. Through the mummichog, these species are directly linked to the shallows even though they may only utilize these areas while foraging. It is through these kinds of feeding relationships that the importance of the shallows to the maintenance of the estuarine biological structure is most clearly defined.

BANDED KILLIFISH (Fundulus diaphanus)



(Source: Evermann and Kendall, 1894)

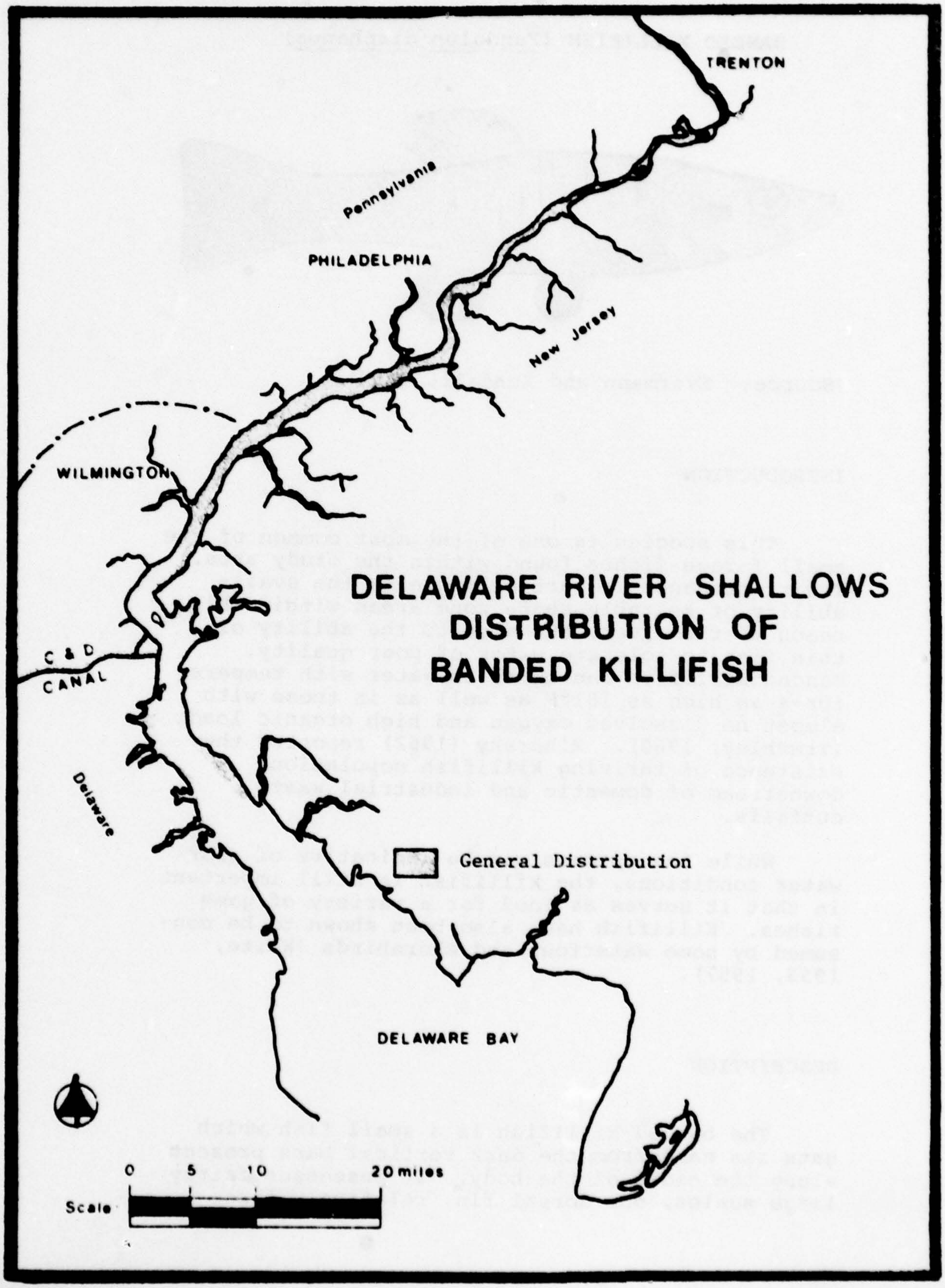
INTRODUCTION

This species is one of the most common of the small forage fishes found within the study area. Their abundance is partially due to the availability of suitable shore zone areas within this reach of the river, but also to the ability of this fish to tolerate water of poor quality. Banded killifish can exist in water with temperatures as high as 101°F as well as in those with almost no dissolved oxygen and high organic loads (Trembley, 1960). Mihursky (1962) reported the existence of thriving killifish populations downstream of domestic and industrial waste outfalls.

While the species may be indicative of poor water conditions, the killifish is still important in that it serves as food for a variety of game fishes. Killifish have also been shown to be consumed by some waterfowl and shorebirds (White, 1953, 1957).

DESCRIPTION

The banded killifish is a small fish which gets its name from the dark vertical bars present along the sides of the body. It possesses fairly large scales, one dorsal fin, relatively large


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
BANDED KILLIFISH
General Distribution
DELAWARE BAY
0
5
10
20 miles
Scale

pectoral and small ventral fins and a nearly square caudal fin. Mean size of individuals is between two and three inches with the largest specimens reaching about four inches (Trautman, 1957; Carlander, 1969).

LIFE HISTORY

The banded killifish is a year round inhabitant of the fresh and brackish water portions of many streams and rivers. They generally are found in small schools both during general feeding and moving activities and during spawning periods. Spawning takes place in quiet waters of weedy pools when water temperatures are near 70°F (Hildebrand and Schroeder, 1928; Richardson, 1939; Brummet, 1966). Within the Delaware, these temperatures are found from late April into September. Eggs are released near the water surface. They are demersal and connected by sticky threads that, as the eggs sink, attach them to vegetation.

DIET

Smaller killifish are known to consume primarily chironomid larvae, ostracods, cladocerans, copepods and some amphipods and insects (Keast and Webb, 1966). Adults consume the above as well as the nymphs of the Odonata and Ephemeroptera, some molluscs and some turbellarian worms.

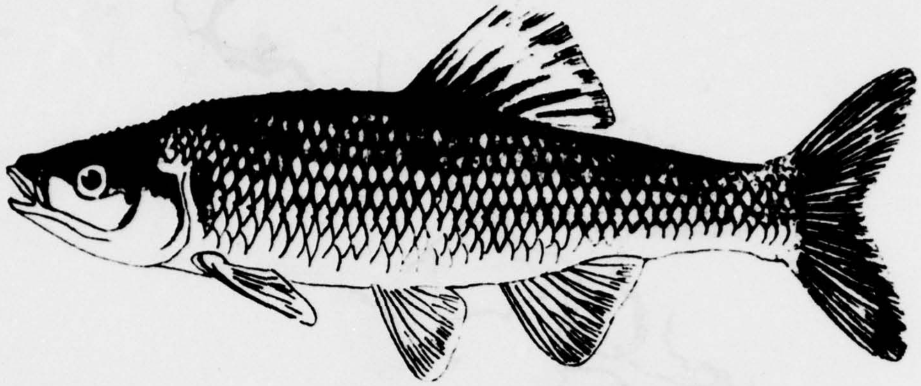
DISTRIBUTION

The banded killifish is found in fresh and brackish water from North Dakota and Iowa to New York and from Quebec to South Carolina (Carlander, 1969). Within the Delaware Basin, it is found from New York State to Artificial Island (Greeley, 1937; Mihursky, 1962; deSylva, et al., 1962; Anselmini, et al., 1976; PECo, 1977b,c,d). It is common in shallows with sand, gravel or detritus-covered bottoms and areas throughout which rooted aquatic plants are common. It is fairly abundant throughout the basin and is often the most abundant year round inhabitatnt of some sections, as has been noted for areas near Newbold Island (U.S. AEC, 1972).

IMPORTANCE OF THE SHALLOWS

The banded killifish is a predominantly shallow water fish that requires the existence of vegetated shore zone areas for its survival. Due to its high tolerance levels, the species occasionally becomes very common in some areas of the basin. Since it is an important food item of many larger fishes, the banded killifish must be considered as an integral member of the trophic structure of the basin. Its habitats, therefore, should be maintained. Where the killifish is the dominant form, however, its use by other species may be reduced because, due to poor water quality, the game fishes exist only in small numbers.

SATINFIN SHINER (Notropis analostanus)



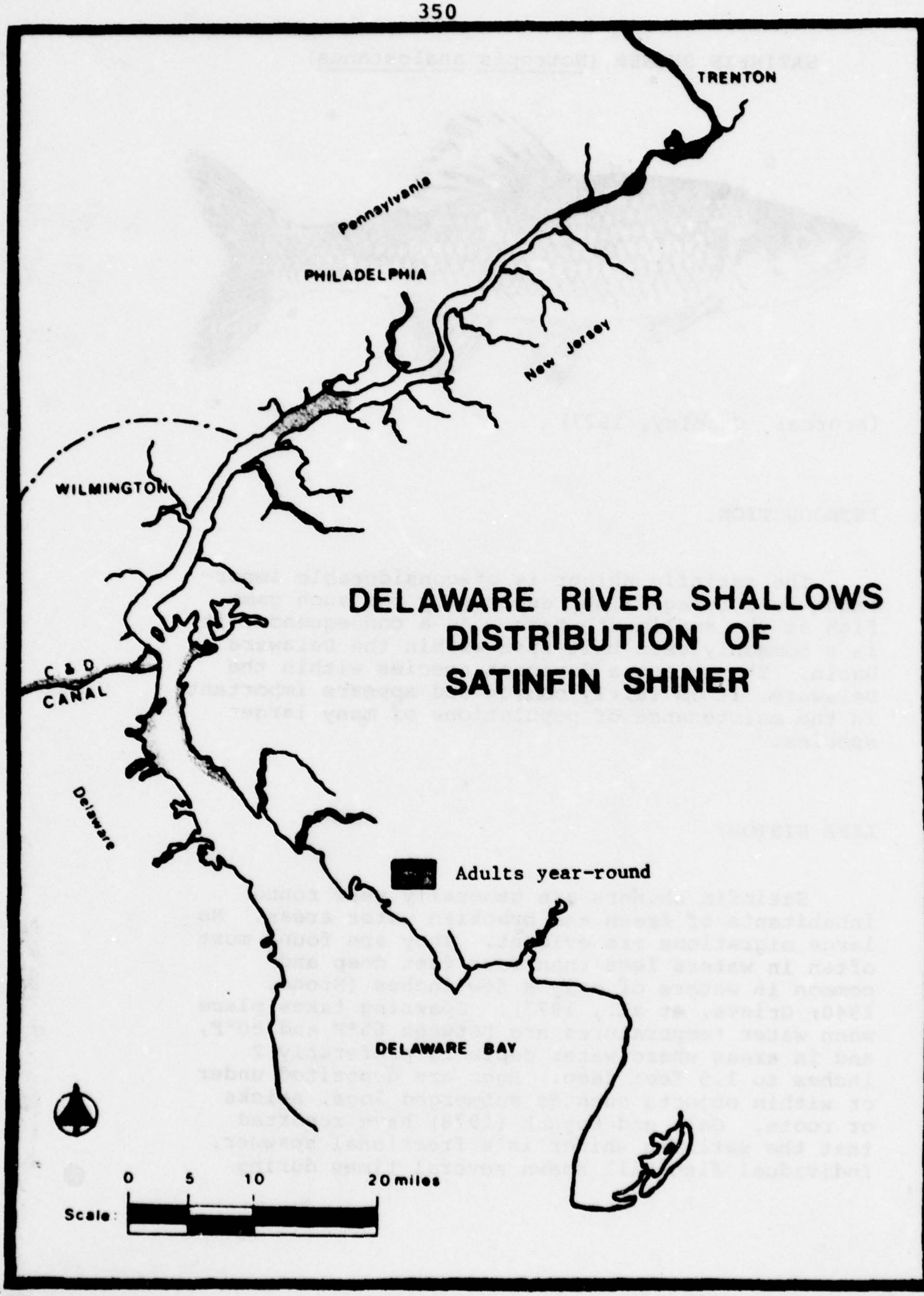
(Source: Greeley, 1927)

INTRODUCTION

The satinfin shiner is of considerable importance as a forage fish, especially for such game fish as the smallmouth bass. As a consequence, it is a commonly used bait fish within the Delaware Basin. Though not a dominant species within the Delaware, it is fairly common and appears important in the maintenance of populations of many larger species.

LIFE HISTORY

Satinfin shiners are generally year round inhabitants of fresh and brackish water areas. No large migrations are evident. They are found most often in waters less than four feet deep and common in waters of only a few inches (Stone, 1940; Grieve, et al., 1977). Spawning takes place when water temperatures are between 65°F and 80°F, and in areas where water depth is preferably 2 inches to 1.5 feet deep. Eggs are deposited under or within objects such as submerged logs, sticks or roots. Gale and Buynak (1978) have reported that the satinfin shiner is a fractional spawner. Individual fish will spawn several times during


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
SATINFIN SHINER
Adults year-round
DELAWARE BAY
0 5 10 20 miles
Scale:

one season. Some have been observed spawning as many as 11 times in a single season. Most females have been observed depositing only a few hundred to a few thousand eggs. Little is known of the development of the larvae and juveniles.

DIET

Stone (1940) stated that the satinfin shiner is primarily carnivorous, feeding mainly on insects and crustaceans. These the fish finds on or among vegetation growing along stream margins, or within shallow riffle zones.

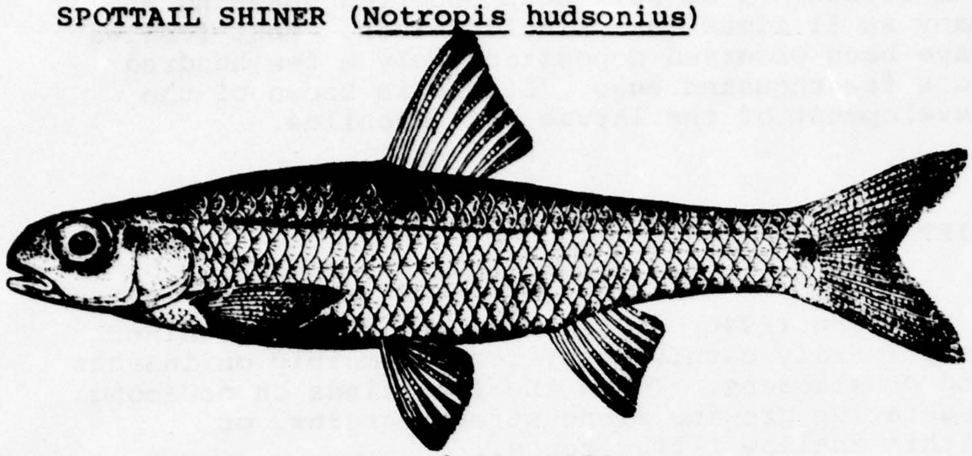
DISTRIBUTION

The satinfin is found mainly in coastal rivers from the St. Lawrence River to North Carolina (Eddy, 1957). Within the Delaware Basin, it is found mainly in the upper estuary above Artificial Island (Trembley, 1960; Mihursky, 1962; Grieve, et al., 1977). Mihursky (1962) collected the satinfin in two distinct habitats throughout the middle of the basin. These were larger streams of moderate gradient and relatively clear water and small streams less than 33 feet wide flowing through fertile agricultural areas. It inhabits both the mainstem and smaller streams within the study area, but may not venture into the head waters of either (Greeley, 1937).

IMPORTANCE OF THE SHALLOWS

Like the silvery minnow, the satinfin shiner is predominantly a shallow water species. Adults prefer waters of less than four feet depth, and spawning is concentrated in shore zone areas less than 1.5 feet deep.

SPOTTAIL SHINER (Notropis hudsonius)



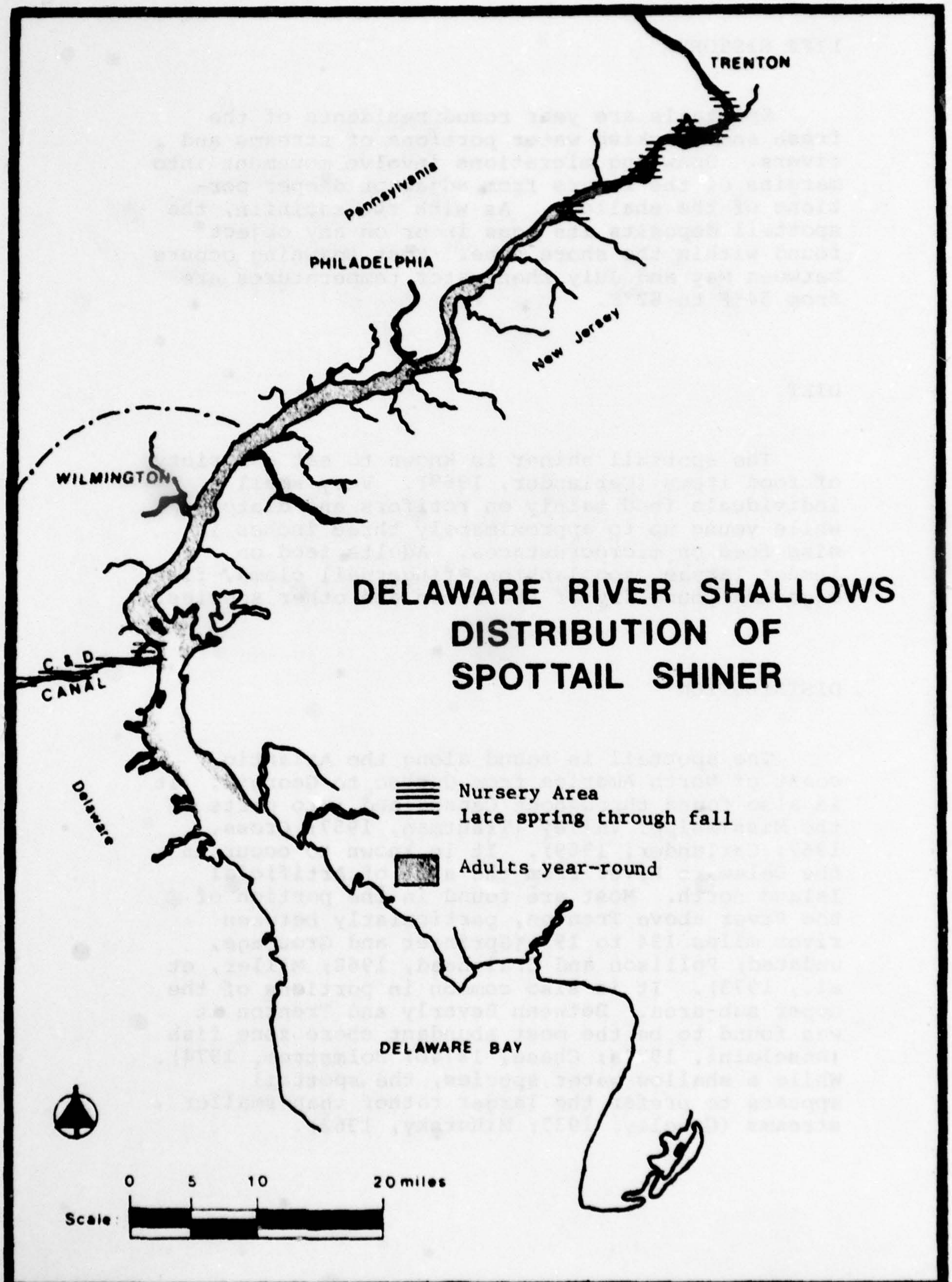
(Source: Evermann and Kendall, 1898)

INTRODUCTION

Like the satinfin shiner, the spottail shiner, Notropis hudsonius, is an important food item in the diet of many freshwater gamefish. It is more widely distributed than the satinfin, and more common within the Delaware Basin. The spottail is often the most abundant shore zone fish in some areas. It is a forage species of particular importance.

DESCRIPTION

Spottail shiners are similar to satinfins in the placement and number of fins. They differ from the satinfins in that the spottail has a more deeply forked tail, much larger eyes and mouth, and a much more truncated snout. The eyes of the spottail occupy approximately 1/3-1/2 the distance from the top to the bottom of the head while in the satinfin they occupy only approximately 1/5 of this distance. As their name implies, spottails possess a distinct dark spot on the sides of the body just forwards of the caudal fin. Average size of the species is between three and five inches.


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D
CANAL
Delaware
DELAWARE BAY
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
SPOTTAIL SHINER
Nursery Area
late spring through fall
Adults year-round
0
5
10
20 miles
Scale

LIFE HISTORY

Spottails are year round residents of the fresh and brackish water portions of streams and rivers. Spawning migrations involve movement into margins of the rivers from adjacent deeper portions of the shallows. As with the satinfin, the spottail deposits its eggs in or on any object found within the shore zone. Most spawning occurs between May and July when water temperatures are from 54°F to 82°F.

DIET

The spottail shiner is known to eat a variety of food items (Carlander, 1969). Very small individuals feed mainly on rotifers and diatoms, while young up to approximately three inches in size feed on microcrustacea. Adults feed on insect larvae, zooplankton, fingernail clams, fish eggs and young fry of their own and other species.

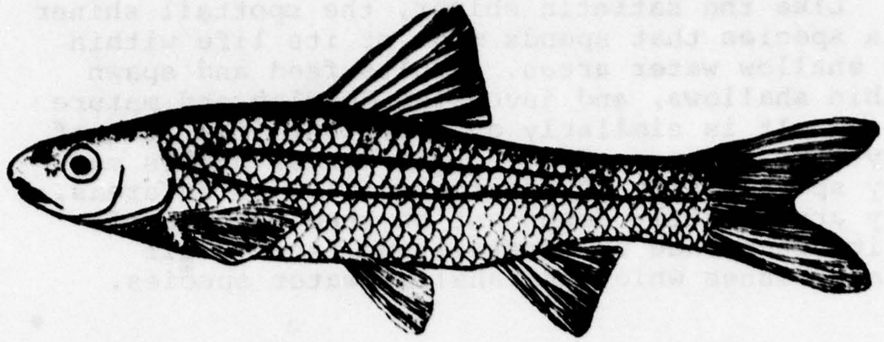
DISTRIBUTION

The spottail is found along the Atlantic coast of North America from Quebec to Georgia. It is also found throughout Canada and into parts of the Mississippi Valley (Trautman, 1957; Cross, 1967; Carlander, 1969). It is known to occur in the Delaware River from the area of Artificial Island north. Most are found in the portion of the River above Trenton, particularly between river miles 134 to 193 (Springer and Groutage, undated; Pollison and Craighead, 1968; Miller, et al., 1973). It is also common in portions of the upper sub-area. Between Beverly and Trenton it was found to be the most abundant shore zone fish (Anselmini, 1974a; Chase, 1974b; Holmstrom, 1974). While a shallow water species, the spottail appears to prefer the larger rather than smaller streams (Greeley, 1937; Mihursky, 1962).

IMPORTANCE OF THE SHALLOWS

Like the satinfin shiner, the spottail shiner is a species that spends most of its life within the shallow water areas. Adults feed and spawn within shallows, and juveniles develop and mature there. It is similarly an important food item of many game fishes. While these larger fishes may only sporadically invade the shallow water areas, they are directly dependent on them because of their dependence on spottail and other small forage fishes which are shallow water species.

SILVERY MINNOW (Hybognathus nuchalis)

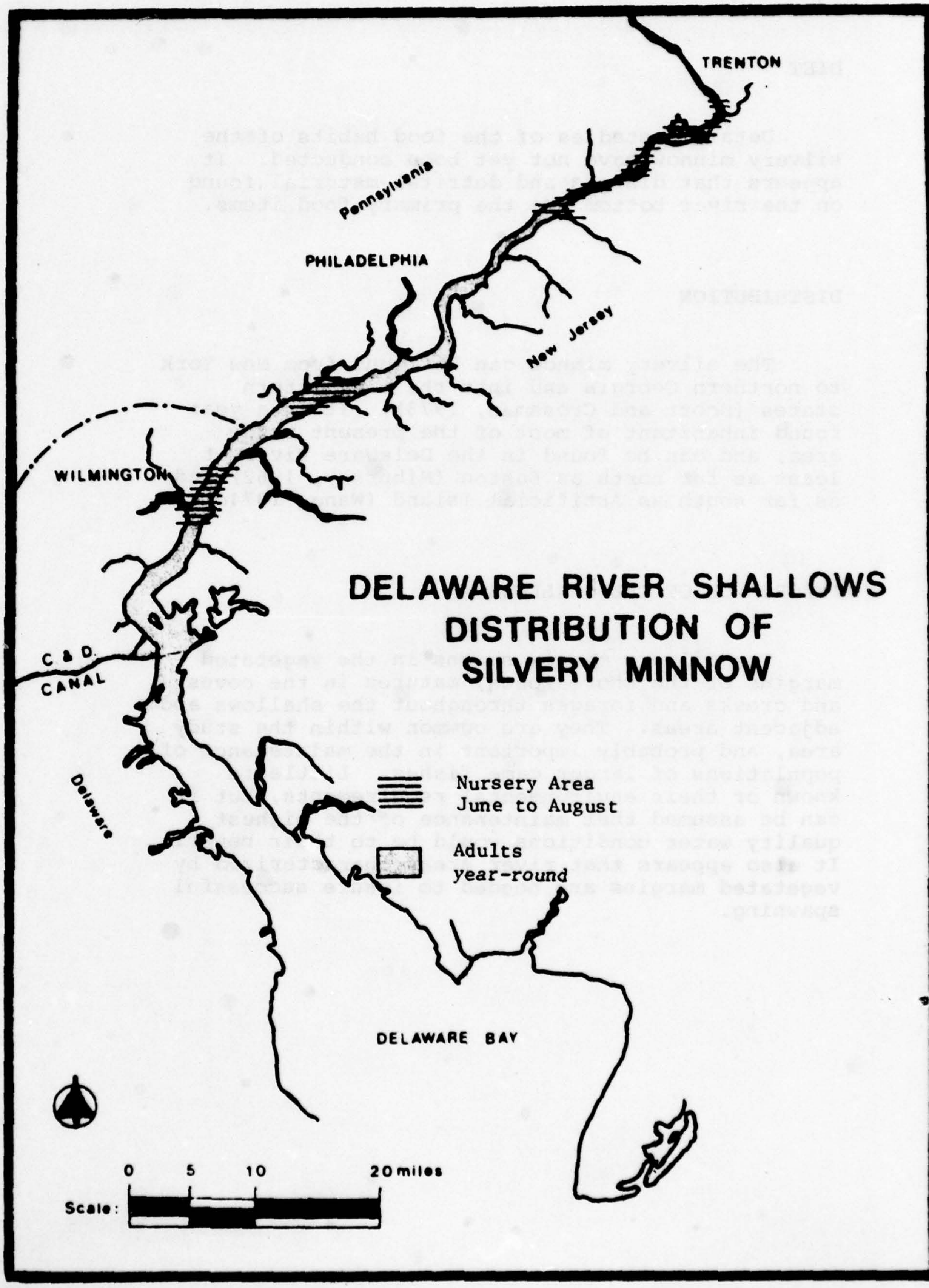


INTRODUCTION

The silvery minnow is another of the small forage fishes which inhabit the shallow water areas of the upper Delaware Basin. While direct evidence is lacking, it is probable that silvery minnows are consumed by some game species inhabiting the weedy inshore areas (Raney, 1939). It is one of the more abundant species within the freshwater zone of the study area.

LIFE HISTORY

Relatively little data is available on the life history of the silvery minnow. They are most plentiful in freshwater but may be found in water approaching 10°/₀₀ salinity (deSylva, et al., 1962). Some upstream/downstream migrations may occur (deSylva, et al., 1962), but adults are found throughout the year in any suitable location. The spawning migration that takes place involves movement from the major portion of the river into the quiet waters of small coves and creeks (Raney, 1939). Preferred spawning sites are apparently those with only two to three inches of water with rooted vegetation present. Most spawning takes place in water temperatures of 55° to 69°F (Smith, 1971).


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D.
CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
SILVERY MINNOW
Nursery Area
June to August
Adults
year-round
DELAWARE BAY
0
5
10
20 miles
Scale:

DIET

Detailed studies of the food habits of the silvery minnow have not yet been conducted. It appears that diatoms and detrital material found on the river bottom are the primary food items.

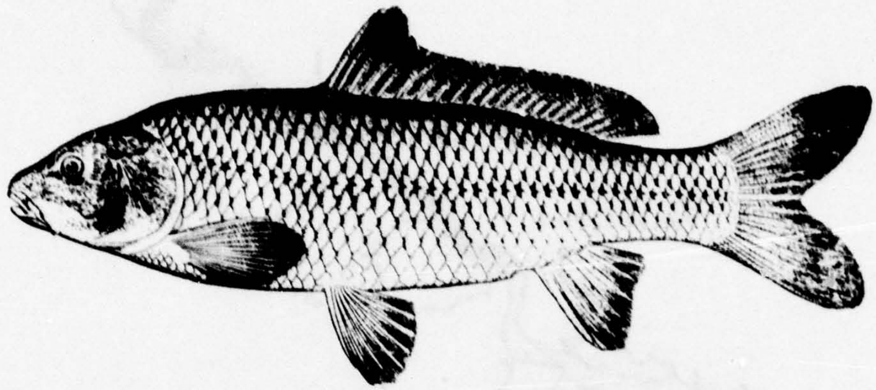
DISTRIBUTION

The silvery minnow can be found from New York to northern Georgia and into the mid-western states (Scott and Crossman, 1973). It is a year round inhabitant of most of the present study area, and can be found in the Delaware River at least as far north as Easton (Mihursky, 1962) and as far south as Artificial Island (Wang, 1974c).

IMPORTANCE OF THE SHALLOWS

The silvery minnow spawns in the vegetated margins of the shore zones, matures in the coves and creeks and forages throughout the shallows and adjacent areas. They are common within the study area, and probably important in the maintenance of populations of larger game fishes. Little is known of their environmental requirements, but it can be assumed that maintenance of the highest quality water conditions would be to their benefit. It also appears that river areas characterized by vegetated margins are needed to insure successful spawning.

CARP (Cyprinus carpio)



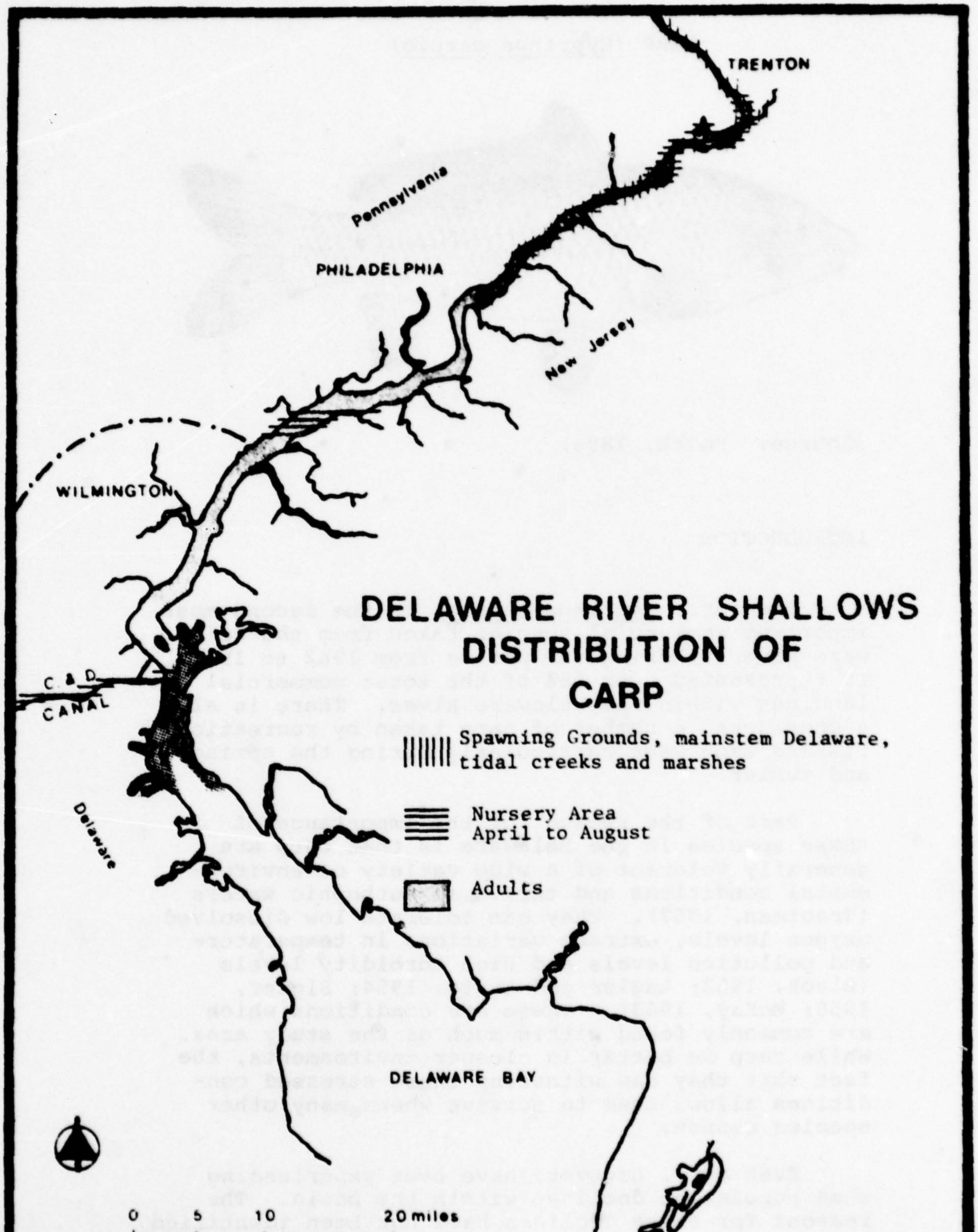
(Source: Smith, 1893)

INTRODUCTION

The carp, Cyprinus carpio, is the second most important commercial species taken from the Delaware River. During the period from 1962 to 1971, it represented over 16% of the total commercial landings within the Delaware River. There is also a considerable number of carp taken by recreational fishers each year particularly during the spring and summer.

Part of the reason for the importance of these species in the Delaware is that carp are generally tolerant of a wide variety of environmental conditions and thrive in euthophic waters (Trautman, 1957). They can tolerate low dissolved oxygen levels, extreme variations in temperature and pollution levels and high turbidity levels (Black, 1953; Lagler and Latta, 1954; Sigler, 1958; McKay, 1963). These are conditions which are commonly found within much of the study area. While carp do better in cleaner environments, the fact that they can withstand these stressed conditions allows them to survive where many other species cannot.

Even carp, however, have been experiencing some population declines within the basin. The reasons for these declines have not been identified


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C.&D. CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
CARP
Spawning Grounds, mainstem Delaware, tidal creeks and marshes
Nursery Area
April to August
Adults
DELAWARE BAY
0
5
10
20 miles
Scale:

but are probably reflective of natural population fluctuations and changes in the habitat conditions. Much more study is needed to clarify the reasons for these declines. Unless environmental balances are greatly upset, however, it appears the carp will continue to be a common inhabitat of the upper Delaware Basin.

Carp are not always considered a desirable species. They are often seen as detrimental to the survival of other fishes largely due to their uprooting and destroying submerged aquatic vegetation during feeding activity. This eliminates vegetated areas sought by other species and increases turbidity levels above those tolerated by many shore zone fishes. Such vegetational changes have also been known to adversely affect use of shore zone areas by waterfowl (Scott and Crossman, 1973).

LIFE HISTORY

The carp is predominantly a fresh and brackish water species that does not migrate. Spawning generally occurs within the areas inhabited by adults year round. In the Delaware, this would include most of the main stem, tributaries and marshes above Philadelphia. Little spawning occurs below Philadelphia although young and adults are occasionally found as far down river as Artificial Island (Wang, 1974a,b; Preddice, 1974a; Molzahn, et al., 1975). Spawning generally takes place from April to August, and maximum concentrations of larvae have been found in the Delaware during June and July when water temperatures were between 66° and 82°F (Anselmini, 1974b; Kranz, 1974a,b). Young generally concentrate in shore zone areas.

Growth rate of the species is variable, but it is known that adult carp are generally large fish. Most of those caught commercially are between 10 and 15 pounds. Few other details of their life history are presently available.

DIET

Carp are omnivorous and consume a variety of plants and animals.

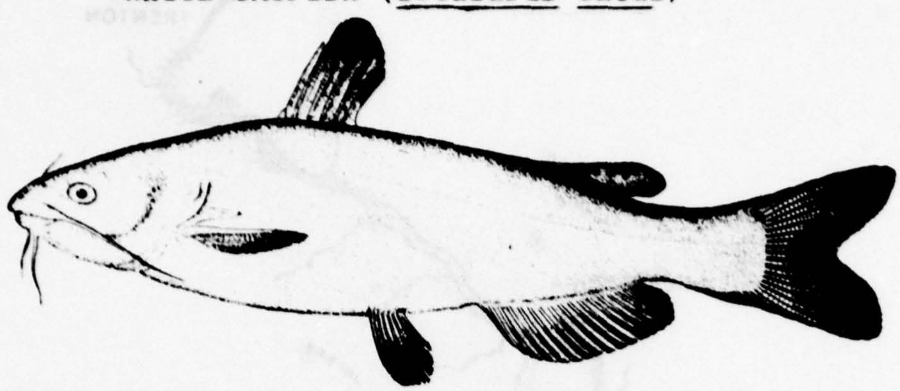
DISTRIBUTION

Carp are not native to the North American continent, but were introduced here from Asia as early as 1831 (DeKay, 1842). They were not successfully established, however, until 1877. Due to their tolerance of a wide variety of environmental conditions they rapidly spread through most of the United States. In the Delaware Basin, carp are prevalent from Artificial Island to Hancock, New York, with greatest densities above the Philadelphia area.

IMPORTANCE OF THE SHALLOWS

Carp utilize all portions of the upper estuary including the channels and the shallows. The adults are found in the shallows primarily feeding on plant material associated with these areas, while the young tend to concentrate in the shallows during most times during their developmental period. Elimination of such areas would lead to population reductions in this species. Since the carp is such a hardy fish, however, it is doubtful that it would be entirely eliminated from the study area. Only the most degraded water conditions would lead to the disappearance of this species. In fact, carp may be increasing is some areas in relation to other common Delaware fishes. Such patterns would indicate the existence of poor water conditions in these areas. While it is important to maintain the carp population, especially in those areas in which it may be one of the only fish, it is not desireable to have systems dominated by this species. Maintenance of good quality shallow areas is important not only to their survival but also to insure that carp do not become overly abundant.

WHITE CATFISH (Ictalurus catus)



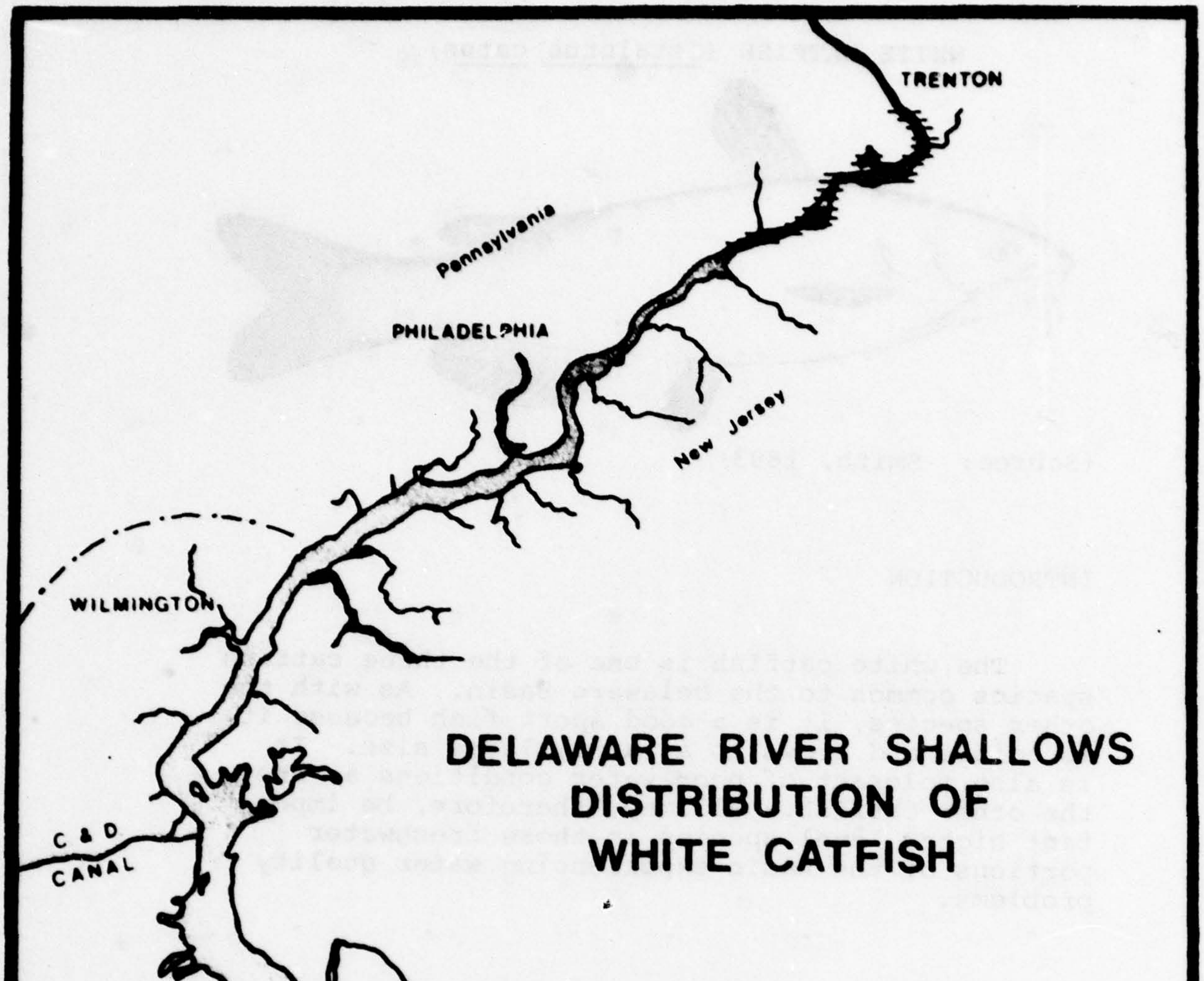
(Source: Smith, 1893)

INTRODUCTION

The white catfish is one of the three catfish species common to the Delaware Basin. As with the other species, it is a good sport fish because it is edible and grows to a fairly large size. It is also tolerant of poor water conditions as are the other catfish. All may, therefore, be important higher level species in those freshwater portions of the basin experiencing water quality problems.

DESCRIPTION

All catfishes exhibit the same distinctive characteristics that allow them to be easily separated from other groups of species (Daiber, et al., 1976). They all possess whisker-like sensory barbels, two dorsal fins the second of which is composed of fleshy adipose tissue, a broad and flat head, scaleless skins and a prominent spine as the first ray of the pectoral and first dorsal fins. The white catfish is distinguished from the others by possessing a forked tail with rounded lobes and body coloring which is blue above and silvery below. Average size of the white catfish is approximately 9-18 inches in length and 0.5-0.25 pounds in weight. Maximum length is approximately 24 inches.


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
WHITE CATFISH
C & D
CANAL
Delaware
Nursery Area
May through fall
Adults
year-round
DELAWARE BAY
0 5 10 20 miles
Scale:

LIFE HISTORY

White catfish are predominantly fresh water fish. They may, however, be found in waters up to 14°/oo salinity (Kendall, et al., 1968). They are year round residents of most fresh water habitats available to them and do not undertake seasonal migrations. Juveniles may, however, move into upriver areas during their first summer. Spawning generally takes place within most of the fresh water habitat with little spawning occurring in any brackish water areas.

Spawning of white catfish, and all other catfishes, is interesting in that it involves both the building of nests and the care of the young by the adults. Spawning activities begin in May in this region and continue through June as water temperatures approach or reach 70°F (Manseuti and Hardy, 1967; Smith, 1971). The nests are generally depressions approximately 30 inches in diameter and 12 to 18 inches deep which are scooped out, usually on a sand bar. Both the male and female are involved in the nest building, using their mouths and fins to remove the sand grains. Several tens of thousands of adhesive, demersal eggs are deposited by the average female (Menzel, 1945). Both sexes watch and care for the eggs during the six to seven day incubation period. When the eggs hatch, however, the male normally guards the larvae until they become self-sufficient.

DIET

The white catfish is an omnivorous primarily bottom feeding species. Smaller specimens eat aquatic insects, crustaceans and other invertebrates while larger specimens will also consume small fishes (Raney, 1967). Like sturgeon, the catfish use their sensory barbels to locate their prey.

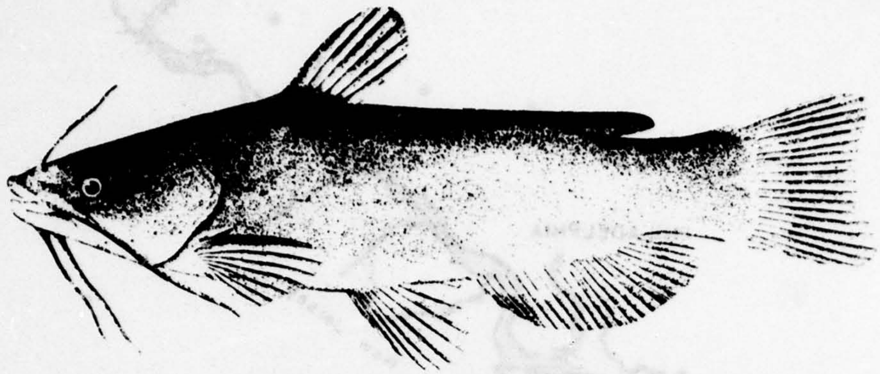
DISTRIBUTION

The white catfish is native to the East coast from southern New England to Florida (Hubbs and Lagler, 1958). It has been introduced elsewhere in the United States particularly to California (Curtis, 1949) and Ohio (Trautman, 1957). Within the Delaware River it occurs from the portion near Artificial Island upstream to Skinner's Falls (Mihursky, 1962; Grieve, et al., 1977). Most, however, are found downstream of Frenchtown.

IMPORTANCE OF THE SHALLOWS

The white catfish is dependent on the shallows primarily because of its preference for quiet pools and isolated backwater areas. Its nests are also built on sandy bars found in shallow coves and around creek mouths.

BROWN BULLHEAD (*Ictalurus nebulosus*)



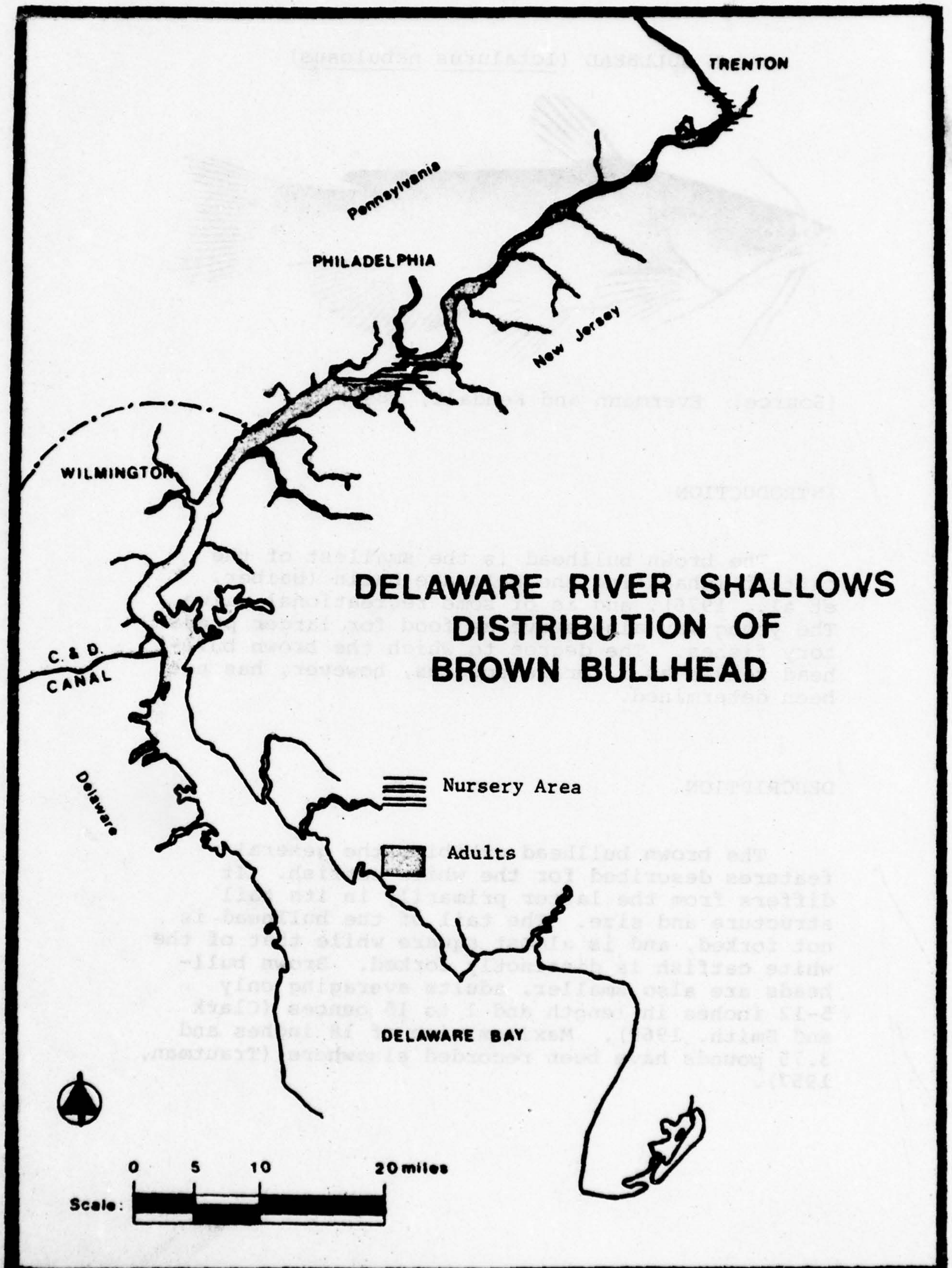
(Source: Evermann and Kendall, 1894)

INTRODUCTION

The brown bullhead is the smallest of the catfish inhabiting the Delaware Basin (Daiber, et al., 1976), and is of some recreational value. The young may also serve as food for larger predatory fishes. The degree to which the brown bullhead serves as a forage species, however, has not been determined.

DESCRIPTION

The brown bullhead exhibits the general features described for the white catfish. It differs from the latter primarily in its tail structure and size. The tail of the bullhead is not forked, and is almost square while that of the white catfish is distinctly forked. Brown bullheads are also smaller, adults averaging only 5-12 inches in length and 1 to 15 ounces (Clark and Smith, 1969). Maximum size of 18 inches and 3.75 pounds have been recorded elsewhere (Trautman, 1957).


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
BROWN BULLHEAD
C. & D.
CANAL
Delaware
Nursery Area
Adults
DELAWARE BAY
0 5 10 20 miles
Scale:

LIFE HISTORY

The life history of the bullhead is similar to that described previously. It is predominantly a freshwater fish but may withstand salinities to 10°/₀₀ (Daiber, et al., 1976). It spawns when water temperatures reach 70°F from the spring into the fall (Breder and Rosen, 1966). Nests are constructed in mud, sand or among roots of aquatic vegetation, primarily in nearshore coves or in creek mouths. Parents guard both the eggs and the young (Scott and Crossman, 1973). The young mature in approximately three years (Trautman, 1957).

DIET

The food of the brown bullhead has been studied by Raney and Webster (1940). They found the fish feeding on most small invertebrates, fish and fish eggs, rotifers, mites, worms, snails, diatoms and some rooted aquatics.

DISTRIBUTION

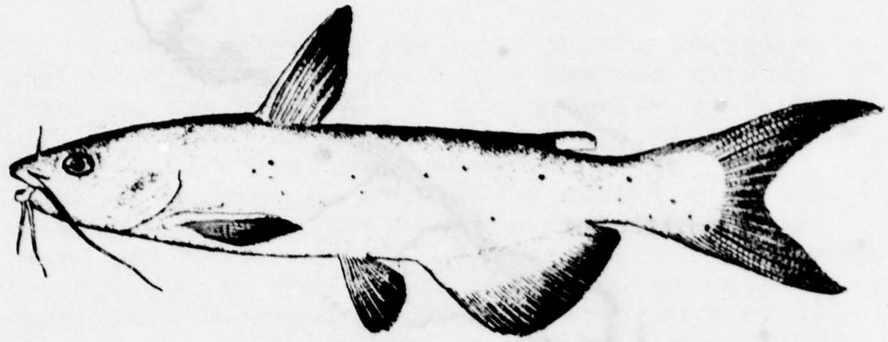
The brown bullhead is native to the Atlantic coast from Nova Scotia to Florida, and inland to the Mississippi River in the United States and to Saskatchewan in Canada (Trautman, 1957). It has also been introduced elsewhere (Calhoun, 1966). Within the Delaware, the brown bullhead is found throughout the fresh and brackish water areas of the basin (Greeley, 1937; Mihursky, 1962; deSylva, et al., 1962; Anselmini, et al., 1976).

IMPORTANCE OF THE SHALLOWS

Adult bullheads may live anywhere within the river. Preferred spawning sites, however, are generally located within the near shore shallows.

The species is also particularly tolerant of poor water quality, and may be an important higher level consumer in some portions of the study area.

CHANNEL CATFISH (Ictalurus punctatus)



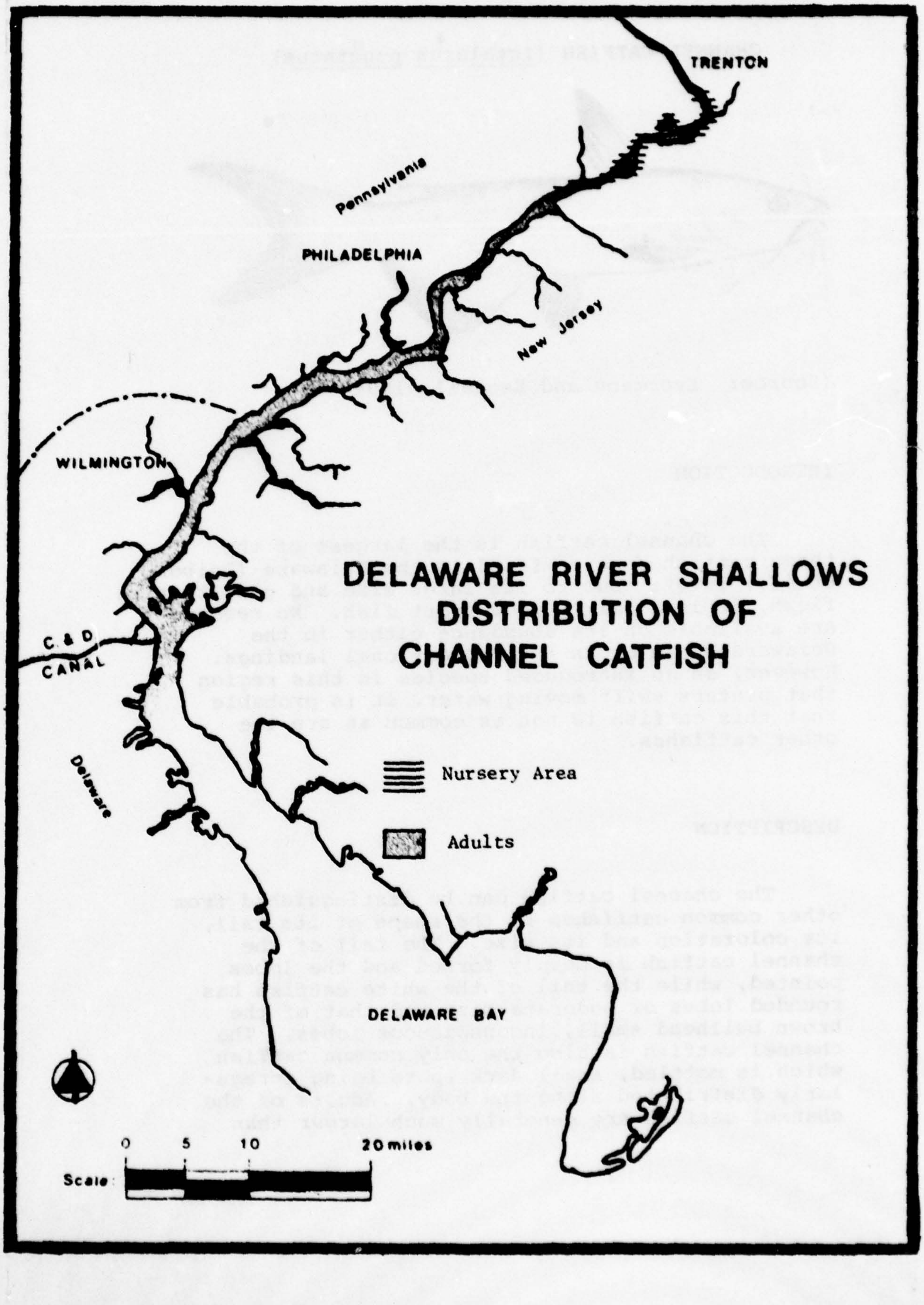
(Source: Evermann and Kendall, 1894)

INTRODUCTION

The channel catfish is the largest of the three catfish species found in the Delaware (Daiber, et al., 1976). Due to its large size and good tasting flesh, it is a fairly good sport fish. No records are available on its abundance either in the Delaware Basin or in the recreational landings. However, as an introduced species in this region that prefers swift moving water, it is probable that this catfish is not as common as are the other catfishes.

DESCRIPTION

The channel catfish can be distinguished from other common catfishes by the shape of its tail, its coloration and its size. The tail of the channel catfish is deeply forked and the lobes pointed, while the tail of the white catfish has rounded lobes or moderate size and that of the brown bullhead small, inconspicuous lobes. The channel catfish is also the only common catfish which is mottled, small dark spots being irregularly distributed along the body. Adults of the channel catfish are generally much larger than


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
CHANNEL CATFISH
C.& D
CANAL
Delaware
Nursery Area
Adults
DELAWARE BAY
0
5
10
20 miles
Scale

adults of the other species, averaging 11 to 30 inches in length and 1 to 15 pounds in weight within the Delaware Basin (Daiber, et al., 1976).

LIFE HISTORY

The life history of the channel catfish is similar to those described previously for the other species. Differences exist in that the channel catfish does not initiate spawning until water temperatures reach 75°F to 85°F (Miller, 1966; Carlander, 1969). Members of this species also seek fairly secluded, semi-dark areas for their nests. This factor links the channel catfish to shallow water shorezone areas, although most individuals are found in main stream portions of the rivers and creeks.

DIET

The channel catfish is omnivorous. It feeds throughout the water column.

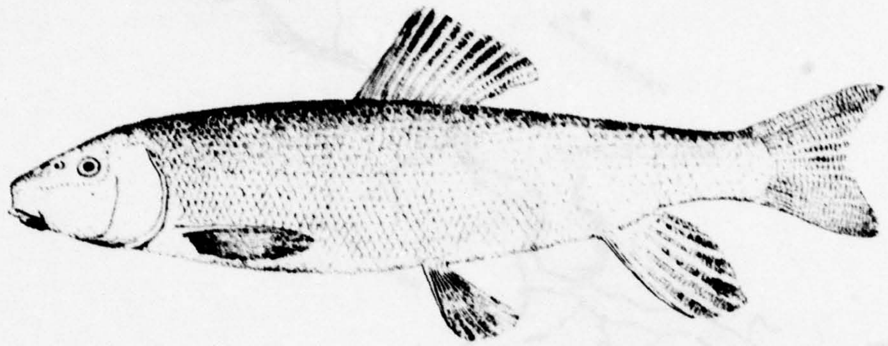
DISTRIBUTION

The channel catfish is native to the fresh and brackish waters of the central portion of North America and to some of the eastern portion (Scott and Crossman, 1973). It is apparently not native to the Delaware Basin and was probably introduced here in the late 1800's. Within the basin, it is found year round from the lower Delaware River upstream to Easton and in many of the tributaries. Spawning areas have not been completely delineated, although it is probable that most spawning occurs in the river section from just below Trenton to Easton.

IMPORTANCE OF THE SHALLOWS

Shallow water areas provide the secluded semi-dark locations which the channel catfish requires for its nesting and spawning activities. Like the other catfish, the channel catfish is fairly tolerant of poor water quality. It is known to be able to survive in waters with low dissolved oxygen levels and high temperatures (Moss and Scott, 1961). These tolerances allow the catfish to survive in the types of water conditions commonly associated with much of the basin. For this reason, it may be a very important upper level consumer in many areas.

WHITE SUCKER (Catostomus commersoni)



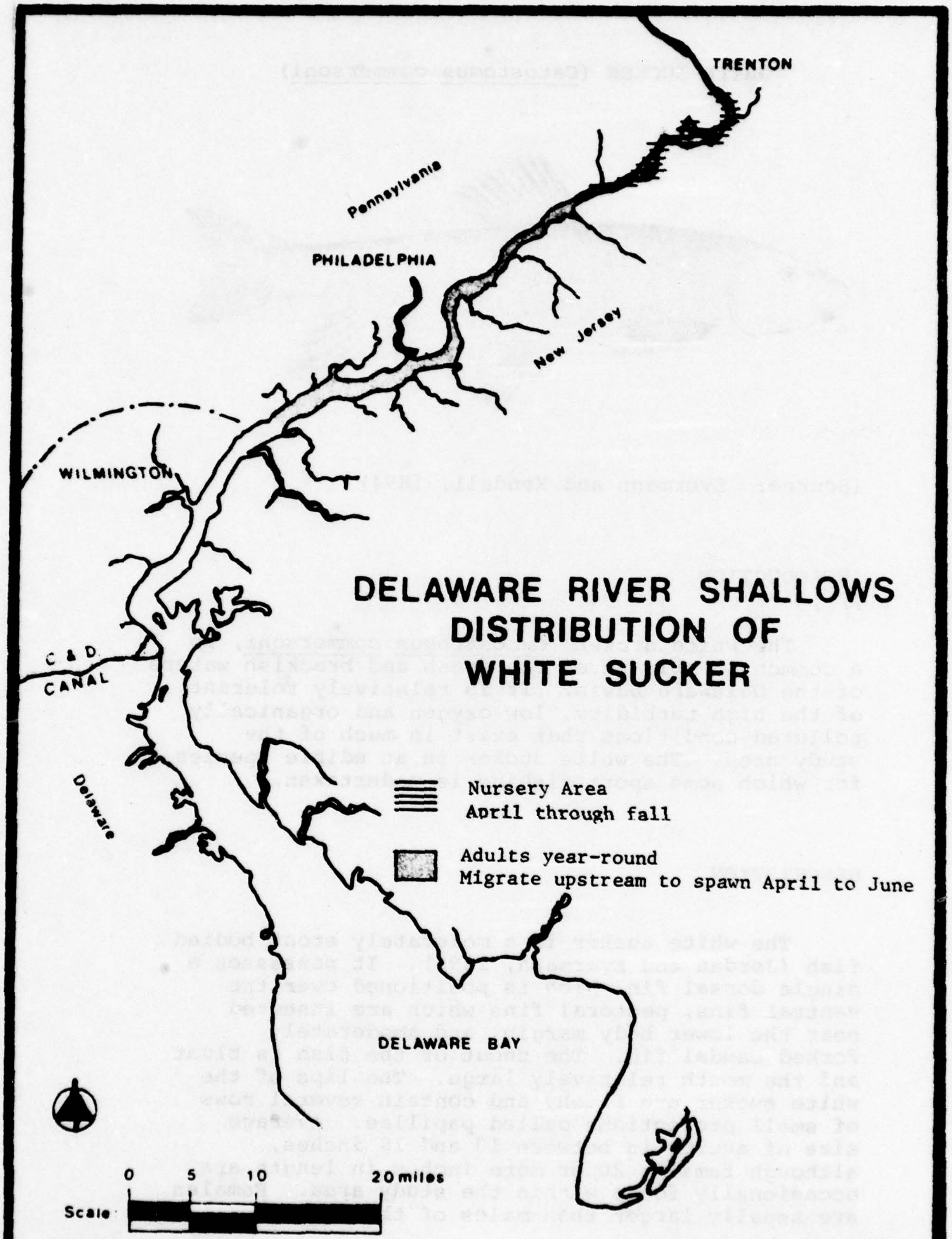
(Source: Evermann and Kendall, 1894)

INTRODUCTION

The white sucker, Catostromus commersoni, is a common inhabitant of the fresh and brackish waters of the Delaware Basin. It is relatively tolerant of the high turbidity, low oxygen and organically polluted conditions that exist in much of the study area. The white sucker is an edible species for which some sport fishing is undertaken.

DESCRIPTION

The white sucker is a moderately stout bodied fish (Jordan and Evermann, 1896). It possesses a single dorsal fin which is positioned over the ventral fins, pectoral fins which are inserted near the lower body margin, and amoderately forked caudal fin. The snout of the fish is blunt and the mouth relatively large. The lips of the white sucker are fleshy and contain several rows of small projections called papillae. Average size of adults is between 10 and 18 inches, although females 20 or more inches in length are occasionally found within the study area. Females are usually larger than males of the same age.


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
C & D CANAL
Delaware
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
WHITE SUCKER
Nursery Area
April through fall
Adults year-round
Migrate upstream to spawn April to June
DELAWARE BAY
0 5 10 20 miles
Scale

LIFE HISTORY

The white sucker is a fresh water species which only occasionally ventures into low salinity areas. Fish winter in deeper channels and pools of the river and creeks and migrate into the shallows in the spring to spawn. It is one of the earliest spawners inhabiting the study area. Spawning migrations begin when the water temperature is approximately 45°F (Raney and Webster, 1942). Spawning usually occurs at water temperatures of 50°F to 68°F (Raney, 1942; Trautman, 1957). Most spawning activity occurs in the study area in the period from late March to early May. Several tens of thousands of demersal, adhesive eggs are deposited by each female. Length of the incubation period varies greatly depending on water temperature. The larvae move to quiet waters along the river bank soon after hatching. They exhibit a tendency to school at this stage. Juveniles remain in schools through the first two years. Adults are less gregarious.

DIET

Young white suckers feed on entomostracans, insects, rotifers and algae (Nurnberger, 1928, 1930; Hayes, 1956; Dobie, 1962, 1966; Flemer and Woolcott, 1966). Adults feed primarily on cheronomids, entomorstraca, amphipods, fingernail clams, snails and detritus (Campbell, 1935; Bassett, 1957; Scidmore and Woods, 1960; Minckley, 1963).

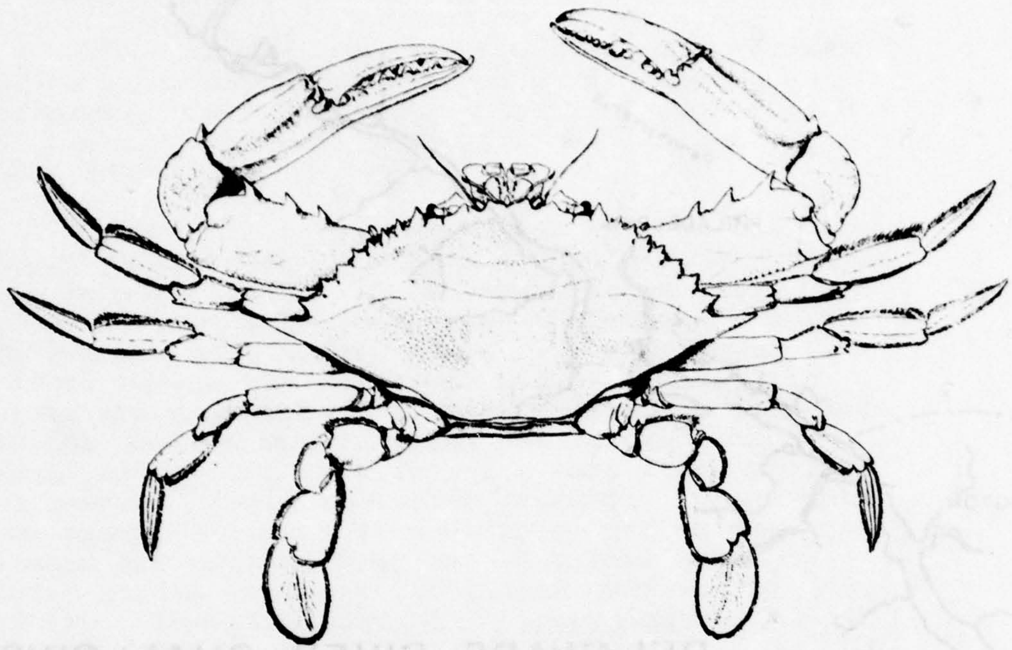
DISTRIBUTION

The white sucker is found east of the Rocky Mountains from northern Alberta to southern Labrador and south to northern Georgia, Oklahoma and Colorado (Eddy, 1957; Trautman, 1957). It is found throughout the Delaware Basin, excluding Delaware Bay (Greeley, 1937; Mihursky, 1962; Anselmini, 1971; Beck et al., 1977; Grieve, 1977). Within the study area, it is most common between Burlington and Trenton.

IMPORTANCE OF THE SHALLOWS

The shallows are used by the white sucker as spawning, nursery and foraging areas.

BLUE CRAB (Callinectes sapidus)

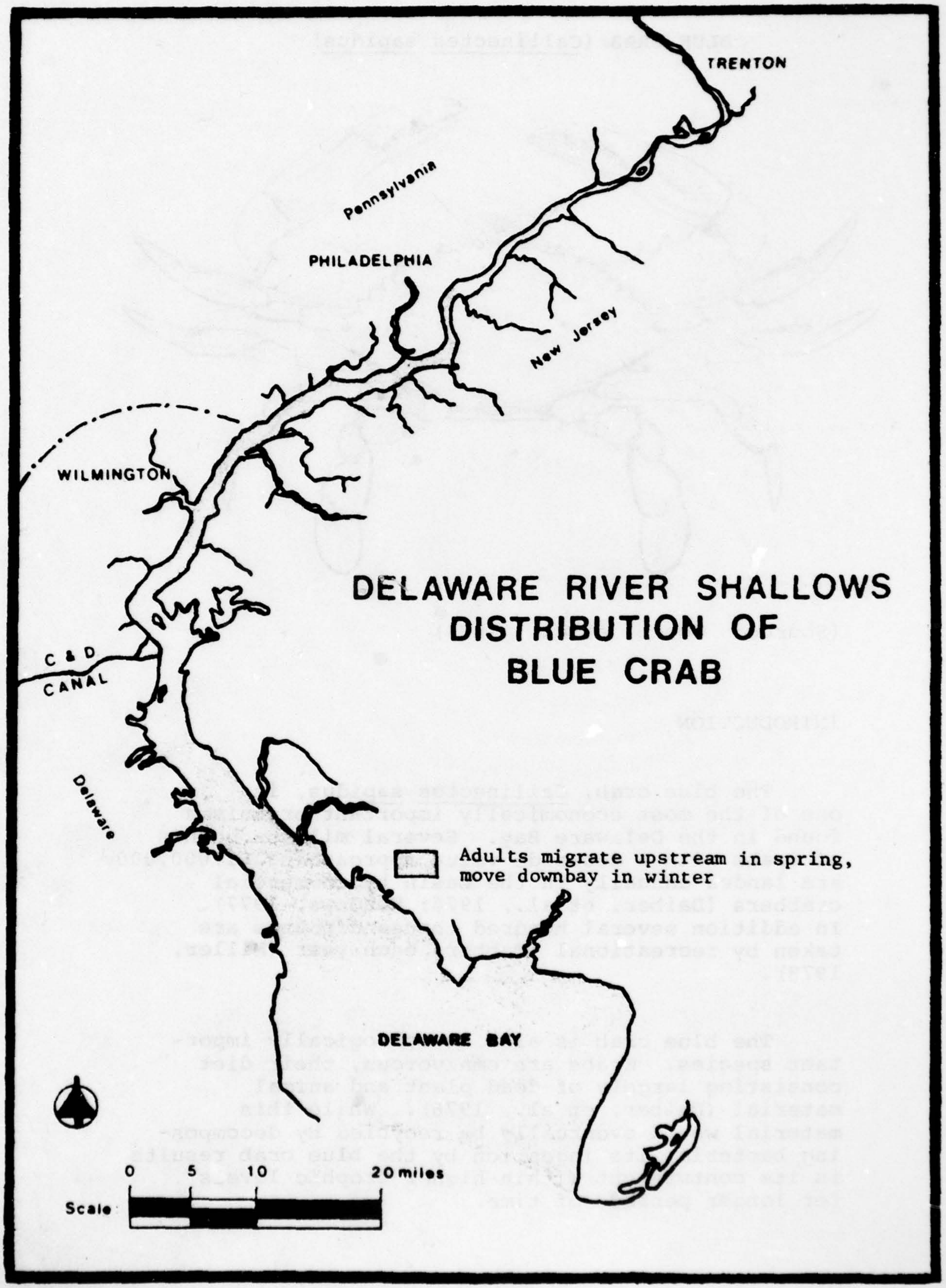


(Source: Goode, et al., 1884)

INTRODUCTION

The blue crab, Callinectes sapidus, is one of the most economically important organisms found in the Delaware Bay. Several million pounds of crabs with a dockside value approaching $1,000,000 are landed annually in the basin by commercial crabbers (Daiber, et al., 1976; Meadows, 1977). In addition several hundred thousand pounds are taken by recreational crabbers each year (Miller, 1978).

The blue crab is also an ecologically important species. Crabs are omnivorous, their diet consisting largely of dead plant and animal material (Daiber, et al., 1976). While this material would eventually be recycled by decomposing bacteria, its ingestion by the blue crab results in its containment within higher trophic levels for longer periods of time.


TRENTON
Pennsylvania
PHILADELPHIA
New Jersey
WILMINGTON
DELAWARE RIVER SHALLOWS
DISTRIBUTION OF
BLUE CRAB
C & D
CANAL
Delaware
Adults migrate upstream in spring,
move downbay in winter
DELAWARE BAY
0
5
10
20 miles
Scale

DESCRIPTION

The blue crab possesses ten legs and a hard exoskeleton characteristic of the decapod crustacean group. The first pair of legs are modified into claws while the last pair are flattened and enable the crab to swim. Males generally possess a distinctive blue coloration, particularly in the legs which are normally bright blue. Females are also basically blue, although the legs of mature individuals are generally tinged with red (Daiber, et al., 1976). Males and females can be separated primarily by the structure of the abdomen. In the male, the abdomen exists in the shape of an inverted "T". In immature females it is in the shape of a triangle and in mature females in the shape of a rounded flap.

LIFE HISTORY

The life history of the crab is complex. Eggs pass through three distinct larval stages and approximately 25 molts before they develop into mature crabs (Daiber, et al., 1976). Molting involves the shedding of the existing exoskeleton and the production of a new larger one in which the body of the crab can grow. The process is necessary because the exoskeleton cannot increase in size once it has been produced.

Mating generally occurs in low salinity waters of the estuary which males inhabit during the spring and summer. Females are generally found in the higher salinity waters of the near coastal areas, but move into the low salinity creeks and marshes during the spring. Each female can mate only once in her life since mating can occur only following her last molt. The timing of the mating process is, therefore, critical. To insure that the male and female are together when her last molt occurs, the male carries the female for several days prior to the actual shedding of the exoskeleton. After the molt is completed, copulation occurs with sperm being deposited in the female's specialized sperm sacs.

The female is capable of storing sperm for several months in this manner and, thus, is able to spawn several times after one mating.

After the mating, females migrate to higher salinity waters where the fertilized eggs are released. Each female is capable of producing 0.5 to 2 million eggs at each spawning (Daiber, et al., 1976).

Eggs hatch in approximately 15 days into the first larval stage called the zoeal stage (Fishler and Walburg, 1962). This larval stage lasts from 31 to 47 days and involves approximately 7 molts before the zoea metamorphose into the second larval stage, the megalopal stage. This stage lasts approximately 6 to 9 days with the last molt of the meglops transforming the larvae into a small adult-like crab slightly more than one inch in length. These juveniles generally remain with the males in lower salinity areas during the summer but migrate down bay to higher salinity water during the fall and winter (Miller, et al., 1975b). Juveniles mature in approximately 12-14 months (Daiber, et al., 1976). Crabs live an average of three years.

DIET

Blue crabs are omnivores. They have been shown to feed on zooplankton, phytoplankton, macrophytes, shellfish, fin fish, other molting crabs and dead plants and animals.

DISTRIBUTION

The blue crab can be found from Nova Scotia to Northern Argentina (Oesterling, 1976). Within the Delaware Basin, adults have been reported from the mouth of Delaware Bay up to river mile 104 (PECo, 1977d). They are, however, common in the lower portions of the study area.

IMPORTANCE OF THE SHALLOWS

Blue crabs are found throughout the estuary in deep and shallow areas. Many are found within the shallows during the spring and summer mating periods, while they tend to migrate to deeper water areas during the winter. Here, they bury in the mud until water temperatures rise in the spring.

Heavy use of shallows of the lower basin is demonstrated by the large numbers of crabs which are taken by recreational crabbers each year. Common methods of taking crabs are by pots, nets or traps which are limited to use in shallow waters of creeks, shore zones, coves and bays.

While the blue crab is found in greatest abundance outside the study area, they are plentiful near the lower sub-area. The blue crab is the most important commercial species taken in the region near Artificial Island (Meadows, 1977). In 1976, 1,501,500 pounds of hard crabs and several thousand pounds of soft shell, or peeler, crabs were landed from the Artificial Island area. These landings represent a significant portion of the total landed within the entire basin. While these crabs are not directly dependent on the shallows in the present study area, the proximity of very productive crabbing areas near the lower sub-area necessitates that water quality in the study area be maintained at levels which induce use of the upper bay by the blue crab.

MIGRATORY WATERFOWL

Many species of migratory waterfowl are found within the Delaware Basin. The most common species include Canada goose, black duck, pintail, mallard, green winged teal and scaup. While some individuals of these species are found within the basin throughout the year, it is during the fall and spring migratory periods that the waterfowl are most common. The basin is located within one of the major flyways used by waterfowl traveling between breeding grounds and wintering areas. While relatively few broods are produced within the basin, it is still extremely important to the maintenance of the populations of many waterfowl species.

BREEDING GROUNDS

Most waterfowl breed in isolated areas north of the basin. Primary breeding grounds include the northern Great Plains region of the United States and Canada, southern Greenland, the islands of Baffin Bay, Hudson Bay, Labrador, Quebec, Manitoba, all of the Canadian Maritime Provinces, most of the Canadian Northwest Provinces, Michigan, Wisconsin and northeastern Minnesota. Some species, particularly mallard, black and wood duck, do produce some broods within the basin.

FLYWAYS

A flyway is a vast geographic region which includes the breeding and wintering grounds of migratory waterfowl and the routes used by the species during their migrations. In 1935, Frederick C. Lincoln of the U.S. Fish and Wildlife Service proposed that waterfowl crossing the North American continent use four major migratory flyways. The breeding grounds associated with several of the flyways often overlap. During the nesting season, breeding areas may be populated by individuals of the same species that winter in different areas. Each group will usually use only one flyway, however, during migrations.

The Delaware Basin is located within one of the major flyways, the Atlantic Flyway (Figure 28). Most of the waterfowl breeding in Eastern and Central Canada, New England and the states surrounding the Great Lakes use some portion of the Atlantic Flyway during their migrations. It is because of this that many species and individuals pass through the basin each spring and fall.

One of the most common and important waterfowl utilizing the Delaware Estuary has been the Canada goose. It is estimated that some 500,000 geese pass through the basin each fall. A large portion of these, approximately 100,000-150,000 birds, winter within the Delaware Basin. Most of these remain in and around Delaware Bay, particularly in refuges such as Pea Patch Island and Bombay Hook. As shown in Figure 29, geese utilize several difference specific migratory routes within the Atlantic Flyway. Most of these routes, however, are directed through the Delaware Basin.

IMPORTANCE OF THE SHALLOWS

Shallow water areas are important feeding and resting areas for most waterfowl species. This is particularly true for many ducks, such as the mallard, black, pintail and teal, known as dabbling ducks. These ducks feed on plant and animal material found on the bottom of shallow water areas. When feeding, the ducks rotate their bodies so that their heads and necks are below the water and their tails and feet in the air. It is only in the shallow water zones that this type of feeding can occur. While other species of ducks and geese are not as dependent on the shallows for feeding, most use the shallows and adjacent intertidal marshes and flats as resting areas.

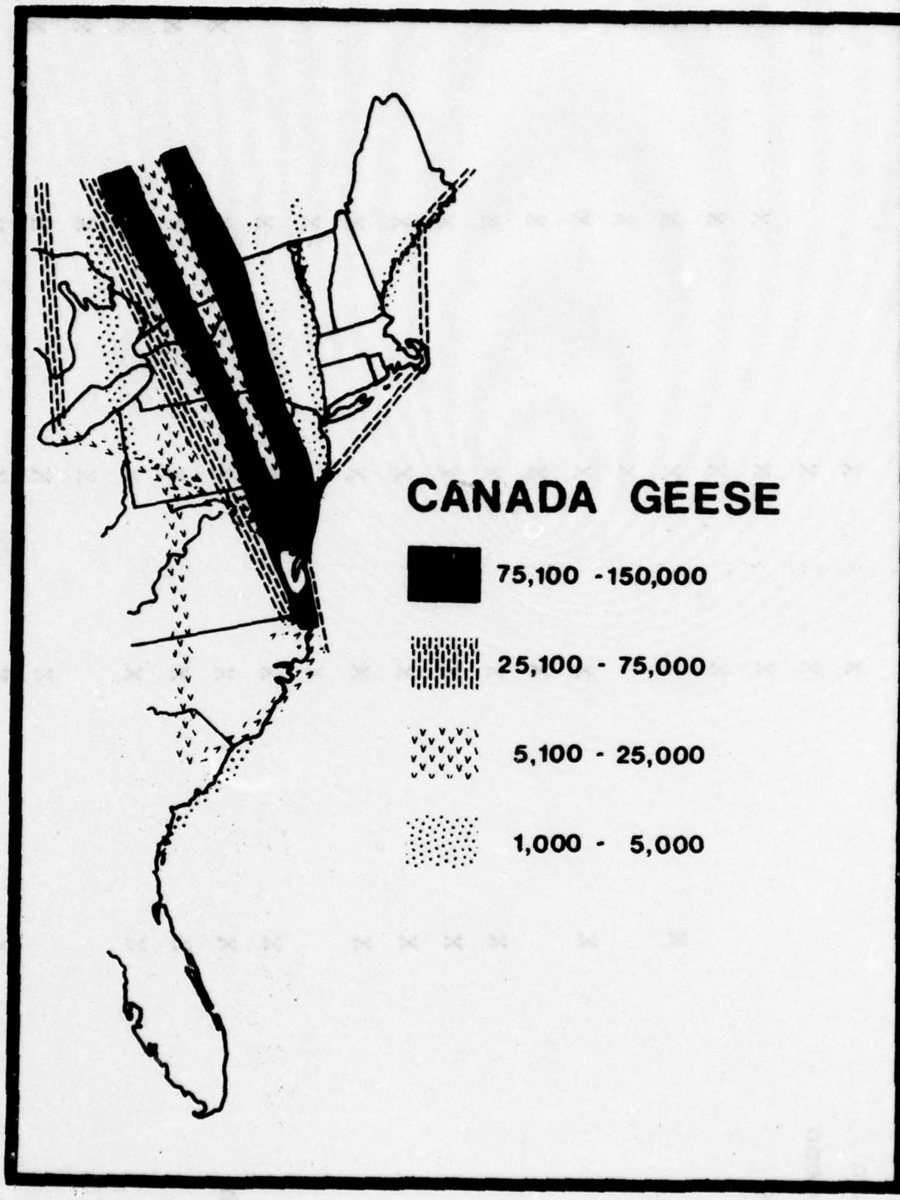


Figure 12. The migration corridors followed by Canada geese during their fall migration to the Atlantic Coast. (After: Bellrose, 1968)

Table 16. Use of Shallow Water Areas by Common Delaware Basin Species.

Species	Permanent Habitat	Spawning Areas	Nursery Areas	Foraging Areas	Migration Routes
Atlantic sturgeon		X	X		
Shortnosed sturgeon		X	X		
Blueback herring		X	X	X	X
Alewife		X	X	X	X
American eel	X		X	X	X
Menhaden			X	X	
Carp	X	X	X	X	
Bay anchovy		X	X	X	
Silvery minnow	X	X	X	X	
Satinfin shiner	X	X	X	X	
Spottail shiner	X	X	X	X	
White catfish	X	X	X	X	
Channel catfish		X		X	
Brown bullhead	X	X	X	X	
Banded killifish	X	X	X	X	X
Mummichog	X	X	X	X	X
White perch	X	X	X	X	X
Spot			X	X	X
Striped bass		X	X	X	X
White sucker	X	X	X	X	
Blue crab	X	X	X	X	X
American shad		X	X	X	X

GLOSSARY

GLOSSARY

ALGAE - Chlorophyll-bearing plants, predominantly aquatic. Size vary from unicells (30-millionths of an inch in diameter) to seaweeds (up to a few hundred feet in length).

ALOSA SPP. - See RIVER HERRING.

AMPHIPOD - A small shrimp-like animal belonging to the class of crustaceans.

ANADROMOUS FISH - A marine species of fish that ascends a river to spawn in fresh water. The young remain in the river for a short period of time then go to the sea.

ANSP - The Academy of Natural Sciences of Philadelphia.

BENTHIC - Referring to life on the bottom of a body of water. (The noun benthos refers to organisms attached to or crawling on the bottom.)

BOD - Biological oxygen demand, the quality of oxygen required by micro-organisms to stabilize the organic matter in a body of water.

BOTTOM - The ground or bed under any body of water the bottom of the sea.

BRACKISH WATER - Water having a mineral content in the general range between fresh and sea water. Water containing from 500 to 10,000 mg/l of dissolved solids.

BULKHEAD - A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

C - Degree Celsius (centigrade).

C & D CANAL - Chesapeake and Delaware Canal.

CANAL - An artificial watercourse cut through a land area for such uses as navigation and irrigation.

CATADROMOUS - Going back to or toward the sea to spawn; said of certain freshwater fishes (i.e., American eel).

CHANNEL - (1) A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. (2) The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation. (3) A large strait, as the Englist Channel. (4) The deepest part of a stream, bay or strait through which the volume or current of water flows.

CLUPEIDAE - See RIVER HERRING.

COASTAL PLAIN - The plain composed of horizontal or gently sloping strata of clastic materials fronting the coast, and generally representing a strip of sea bottom that has emerged from the sea in recent geologic time.

COASTLINE - (1) Technically, the line that forms the boundary bewteen the coast and the shore. (2) Commonly, the line that forms the boundary between the land and the water.

CONTROLLING DEPTH - The least depth in the navigable parts of a waterway, governing the maximum draft of vessels that can enter.

COPEPOD - A small (about 0.05 inch long) crustacean, a common zooplankter.

CRUSTACEAN - An animal having a hard but flexible exoskeleton.

CUBIC FEET PER SECOND (cfs) - A rate of flow; 1 cfs = 0646 mgd = 1.983 acre-feet per day.

CURRENT - A flow of water.

DRBC - Delaware River Basin Commission.

DWAR - Delaware Water and Air Resources Commission.

DEMERSAL EGG - Eggs which have a specific gravity greater than the water spawned in; therefore they sink in quiet water.

DEPTH - The vertical distance from a specified tidal datum to the sea floor.

DETRITUS - Any fragmentary material; waste; disintegrated matter.

DIATOMS - Unicellular greenish-brown plants with a siliceous covering (exoskeleton); often forming chains.

DISPOSAL AREA (DA) - A site where dredge spoil is deposited.

DISSOLVED SOLIDS - Solids that are present in water in solution; i.e., solids that cannot be removed by filtering.

DIURNAL - Having a period or cycle of approximately one tidal day.

DO - Dissolved oxygen, the concentration of oxygen in water, usually expressed in milligrams per liter (mg/l) or parts per million (ppm).

EBB CURRENT - The tidal current away from shore or down a tidal stream; usually associated with the decrease in the height of the tide.

EBB TIDE - The period of tide between high water and the succeeding low water; a falling tide.

ECOSYSTEM - A system made up of a community of animals, plants and bacteria, and the physical and chemical environment with which it is interrelated.

EIFAC - European Inland Fisheries Advisory Commission.

EPIFAUNAL - Refers to benthic organisms living on the surface of the bottom substrate, either attached or free moving. Most common in the intertidal zone.

EROSION - The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents or by deflation.

ESTUARY - (1) The part of a river that is affected by tides. (2) The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea.

EURYHALINE - Wide tolerance to salinity changes.

EUTRIFICATION - The process whereby a body of water becomes highly productive due to input of large quantities of nutrients. Common result is the excessive growth of algae and larger aquatic plants.

F - Degree Fahrenheit.

FALL LINE - A narrow zone of varying width, where falls or rapids commonly occur when streams enter the Coastal Plain.

FL - Fork length. In fish: measured from tip of snout to fork of tail.

FLOOD CURRENT - The tidal current toward shore or up a tidal stream, usually associated with the increase in the height of the tide.

FLOOD TIDE - The period of tide between low water and the succeeding high water; a rising tide.

FRESH WATER - Water having a relatively low mineral content, generally less than 500 mg/l of dissolved solids.

FWPCA - Federal Water Pollution Control Agency.

HERRING - See RIVER HERRING.

HIGH WATER LINE - In strictness, the intersection of the plane of mean high water with the shore.

HYDROID - A primitive aquatic invertebrate that resembles a small branched plant.

INCODEL - Interstate Commission on the Delaware River.

INTERTIDAL ZONE - Zone between high and low tide; also called the littoral zone.

LANDLOCKED - (1) An area of water enclosed by land, as a lake or pond. (2) A population of organisms (i.e., fishes) that live in a land-locked body of water.

LARVA - An embryo that becomes self-sustaining and independent before it has assumed the characteristic features of its parents.

LITTORAL - Of, or pertaining to a shore, especially of the sea.

LOAD - The quantity of sediment transported by a current. It includes the suspended load of small particles, and the bedload of large particles that move along the bottom.

LOW TIDE (LOW WATER) - The minimum elevation reached by each falling tide.

LOW WATER LINE - The intersection of any standard low tide datum plane with the shore.

MACROPHYTE - A macroscopic plant, especially living in an aquatic habitat.

MARSH - An area of soft, wet or periodically inundated land, generally treeless and usually characterized by grasses and other low growth.

MEAN LOW WATER (MLW) - The average height of the low waters over a 19-year period.

MEAN SEA LEVEL - The average height of the surface of the sea for all stages of the tide over a 19-year period.

MILLION GALLONS PER DAY (MGD) - A rate of flow, 1 mgd = 1.547 cubic feet per second - 3.07 acre-feet per day.

NEKTON - Swimming organisms able to navigate at will, as fish, amphibians and large swimming insects.

NPDES - National Pollution Discharge Elimination System.

OUTFALL - A structure extending into a body of water for the purpose of discharging sewage, storm runoff or cooling water.

PECo - Philadelphia Electric Company.

PERIPHYTON - Sessile biotal components of a freshwater ecosystem.

pH - The logarithm of the reciprocal of the hydrogen-ion concentration in the water, a measure of the degree of acidity of the water.

PHYTOPLANKTON - Planktonic plants (See diatoms, plankton).

PIER - A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, a recreational facility, etc., rather than to afford coastal protection.

PILE - A long, heavy timber or section of concrete or metal to be driven or jetted into the earth or seabed to serve as a support or protection.

PILING - A group of piles.

PLANKTON - Passively floating or weakly swimming aquatic organisms. Consists of both plants (phytoplankton) and animals (zooplankton).

PORT - A place where vessels may discharge or receive cargo; may be the entire harbor including its approaches and anchorages, or may be the commercial part of a harbor where the quays, wharves, facilities for transfer or cargo, docks and repair shops are situated.

PPT - Parts per thousand.

PRIMARY PRODUCTIVITY - The capacity of an ecosystem to build up at the expense of external energy both radiant and chemical-primary organic compounds of high chemical potential for further transformation and flow to high system levels.

PSE&G - Public Service Electric and Gas Company.

PWD - Philadelphia Water Department.

RIP RAP - A foundation or revetment in water or on soft ground made by irregularly placed stones or pieces of boulders; used chiefly for river and harbor work, for roadway filling and on embankments.

RIVER HERRING - Four species of herrings, blueback herring (Alosa aestivalis), hickory shad (A. mediocris), alewife (A. pseudoharengus) and American shad (A. sapidissima) are known to occur in the Delaware River Shallows study area. Because of the difficulty in differentiating eggs and young of some herrings, investigators have often identified specimens to the family (Clupeidae) and/or genus (Alosa) level. River herring (Alosa spp.) are most

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SHALLOWS OF THE DELAWARE RIVER-TRENTON, NEW JERSEY TO REEDY POI--ETC(U)

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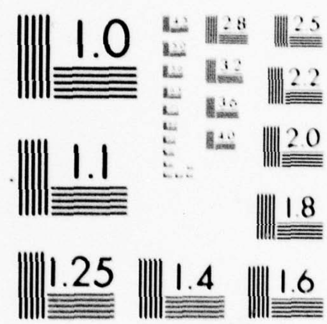

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

often considered to be blueback herring and/or alewife in the tidal Delaware. Individual reports should be consulted for specific details.

RIVER MILE - The Delaware River Basin Commission uses a stream location and identification system based on river mileage. The mileage system for the Delaware River and Bay consists of a "mile zero" at the mouth of Delaware Bay and a line along which distances from mile zero are measured. Mile zero is located at the mouth of Delaware Bay at the intersection of a line between the Cape May Light and the tip of Cape Henlopen. From the "zero" point, to Trenton, New Jersey, the mileage line is the centerline of the navigation channel. Upstream from Trenton, river mileages of the Delaware River are measured along the state boundaries as shown on United States Geological Survey maps.

A similar mileage system is applicable to each tributary of the Delaware River by establishing a "mile zero" at the mouth of the tributary, and measuring the distance in miles above its mouth to points located on the tributary.

SALINITY - Parts per thousand by weight of the dried solid residues obtained from water when all organic matter has been oxidized, all bromides and iodides replaced by chlorides and all carbonates converted to oxides usually expressed in grams/kilogram or parts per thousand (°/₀₀ or ppt).

SALT MARSH - A marsh periodically flooded by salt water.

SALT WATER - Water containing more than 250 mg/l of chlorides or more than 500 mg/l of dissolved solids.

SHALLOWS - In this report shallows refers to water areas ten feet or less below mean low tide.

SHOALING - Deposition of material on the bottom of a waterway which decreases the depth of water.

SHORE - The narrow strip of land in immediate contact with water, including the zone between high and low water lines.

SHORELINE - The intersection of a specified plane of water with the shore or beach (e.g., the highwater shoreline would be the intersection of the plane of mean high water with the shore or beach). The line delineating the shoreline on U.S. Coast and Geodetic Survey nautical charts and surveys approximates the mean high water line.

STREAM - A course of water flowing along a bed in the earth.

TIDAL FLATS - Marshy or muddy land areas which are covered and uncovered by the rise and fall of the tide.

TL - Total length. In fish: Measured from tip of snout to tip of caudal fin.

TRAINING STRUCTURE - In river work, a wall or jetty constructed to reduce shoaling in designated areas by changing the alignment of water currents.

TROPHIC - Pertaining to, or connected with, nutrition or feeding.

U.S. AEC - United States Atomic Energy Commission (now Nuclear Regulatory Commission).

U.S. EPA - United States Environmental Protection Agency.

WATER QUALITY - Those characteristics of water affecting its suitability for beneficial use.

ZOOPLANKTON - Minute planktonic animals.

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APPENDICES

APPENDIX A.

Water Quality Criteria Established by the U.S. Environmental Protection Agency.

Water quality criteria that are expected to result in an aquatic ecosystem suitable for the higher uses of water. (After: U.S. EPA, 1976)

PARAMETER	CRITERIA
AMMONIA	0.02 mg/l (as un-ionized ammonia) for freshwater aquatic life.
ARSENIC	50 ug/l for domestic water supplies (health). 100 ug/l for irrigation of crops.
BARIUM	1 mg/l for domestic water supply (health).
CADMIUM	10 ug/l for domestic water supply (health). Aquatic life: Fresh Water: Soft Water / Hard Water 0.4 ug/l / 1.2 ug/l for cladocerans and salmonid fishes; 4.0 ug/l / 12.0 ug/l for other, less sensitive, aquatic life. Marine: 5.0 ug/l
CHROMIUM	50 ug/l for domestic water supply (health). 100 ug/l for freshwater aquatic life.
COPPER	1.0 mg/l for domestic water supplies (welfare). For freshwater and marine aquatic life, 0.1 times a 96-hour LC_{50} as determined through nonaerated bioassay using a sensitive aquatic resident species.

PARAMETER	CRITERIA
CYANIDE	5.0 ug/1 for freshwater and marine aquatic life and wildlife.
DISSOLVED OXYGEN	Aesthetics: Water should contain sufficient dissolved oxygen to maintain aerobic conditions in the water column and, except as affected by natural phenomena, at the sediment-water interface. Freshwater aquatic life: A minimum concentration of dissolved oxygen to maintain good fish populations is 5.0 mg/1. The criterion for salmonid spawning beds is a minimum of 5.0 mg/1 in the interstitial water of the gravel.
FECAL COLIFORM BACTERIA	Bathing Waters Based on a minimum of five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log mean of 200 per 100 ml, nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml. Shellfish Harvesting Waters The median fecal coliform bacterial concentration should not exceed 14 MPN per 100 ml with not more than 10 percent of samples exceeding 43 MPN per 100 ml for the taking of shellfish.
IRON	0.3 mg/1 for domestic water supplies (health). 1.0 mg/1 for freshwater aquatic life.

PARAMETER	CRITERIA
LEAD	50 ug/l for domestic water supply (health). 0.01 times the 96-hour LC_{50} value, using the receiving or comparable water as the diluent and soluble lead measurements (using an 0.45 micron filter), for sensitive freshwater resident species.
MANGANESE	50 ug/l for domestic water supplies (welfare). 100 ug/l for protection of consumers of marine molluscs.
MERCURY	2.0 ug/l for domestic water supply (health). 0.05 ug/l for freshwater aquatic life and wildlife. 0.10 ug/l for marine aquatic life.
NICKEL	0.01 of the 96-hour LC_{50} for freshwater and marine aquatic life.
NITRATES, NITRITES	10 mg/l nitrate nitrogen (N) for domestic water supply (health).
OIL AND GREASE	For domestic water supply: Virtually free from oil and grease, particularly from the tastes and odors that emanate from petroleum products. For aquatic life: (1) Levels of individual petrochemicals in the water column should not exceed 0.01 of the lowest continuous flow 96-hour LC_{50} to several important freshwater or marine species, each having a demonstrated high susceptibility to oils and petrochemicals; (2) Levels of oils or petrochemicals in the sediment which cause deleterious effects to the

PARAMETER	CRITERIA
OIL AND GREASE (cont'd.)	biota should not be allowed; (3) Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum derived oils.
PHENOL	1 ug/l for domestic water supply (welfare), and to protect against fish flesh tainting.
pH	Range 5 -9 Domestic water supplies (welfare). 6.5-9.0 Freshwater aquatic life. 6.5-8.5* Marine aquatic life.
SOLIDS (DISSOLVED) AND SALINITY	250 mg/l for chlorides and sulfates in domestic water supplies (welfare).
SOLIDS (SUSPENDED, SETTLEABLE) AND TURBIDITY	Freshwater fish and other aquatic life: Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.
TEMPERATURE	Freshwater Aquatic Life For any time of year, there are two upper limiting temperatures for a location (based on the important sensitive species found there at that time): 1. One limit consists of a maximum temperature for short exposures that is time dependent and is given by the species-specific equation: Temperature (°C)=1/b[$\log_{10}$(time in min.)-a]-2 Where:

PARAMETER	CRITERIA
TEMPERATURE (cont'd.)	a = intercept on the "y" or logarithmic axis of the line fitted to experimental data which are available for some species from Appendix II-C, NAS, 1974. b = slope of the line fitted to experimental data which are available for some species from Appendix II-C, NAS, 1974. 2. The second value is a limit on the weekly average temperature that: a. in the cooler months (mid-October to mid-April in the north and December to February in the south) will protect against mortality of important species if the elevated plume temperature is suddenly dropped to the ambient temperature, with the limit being the acclimation temperature minus 2°C when the lower lethal threshold temperature equals the ambient water temperature (in some regions this limitation may also be applicable in summer); or b. in the warmer months (April through October in the north and March through November in the south) is determined by adding to the physiological optimum temperature (usually for growth) a factor calculated as one-third of the difference between the ultimate upper incipient lethal temperature and the optimum temperature for the most sensitive important species (and appropriate life state) that normally is found at that location and time; or

PARAMETER	CRITERIA
TEMPERATURE (cont'd.)	c. during reproductive seasons (generally April through June and September through October in the north and March through May and October through November in the south) meets site-specific requirements for successful migration, spawning, egg incubation, fry rearing, and other reproductive functions of important species. These local requirements should supersede all other requirements when they are applicable; or d. is a site-specific limit that is found necessary to preserve normal species diversity or prevent appearance of nuisance organisms.

Marine Aquatic Life

In order to assure protection of the characteristic indigenous marine community of a water body segment from adverse thermal effects:

1. the maximum acceptable increase in the weekly average temperature due to artificial sources is 1°C (1.8°F) during all seasons of the year, providing the summer maxima are not exceeded; and
2. daily temperature cycles characteristic of the water body segment should not be altered in either amplitude or frequency.

Summer thermal maxima, which define the upper thermal limits for the communities of the discharge area, should be established on a site-specific basis. Existing studies suggest the regional limits expressed in the Table.

PARAMETER	CRITERIA

TEMPERATURE (cont'd.)

Table

	Short term maximum	Maximum true daily mean**
Sub-tropical Regions (south of Cape Canaveral and Tampa Bay, Fla. and Hawaii)	32.2°C (90°F)	29.4°C (85°F)
Cape Hatteras, N.C., to Cape Canaveral, Fla.	32.2°C (90°F)	29.4°C (85°F)
Long Island (south shore) to Cape Hatteras, N.C.	30.6°C (87°F)	27.8°C (82°F)

Baseline thermal conditions should be measured at a site where there is no unnatural thermal addition from any source, which is in reasonable proximity to the thermal discharge (within 5 miles) and which has similar hydrography to that of the receiving waters at the discharge.

ZINC

5 mg/l for domestic water supplies (welfare). For freshwater aquatic life, 0.01 of the 96-hour LC_{50} as determined through biomassay using a sensitive resident species.

*But not more than 0.2 units outside normally occurring range.
**True daily mean - average of 24 hourly temperature readings.

APPENDIX B.

Delaware River Basin Water Code for the Delaware Estuary.

DELAWARE RIVER BASIN COMMISSION WATERCODE FOR THE DELAWARE ESTUARY (RIVER MILE 48.2 TO 133.4). RESOLUTIONS INCORPORATED THROUGH DECEMBER 1974. (Source: DRBC, 1975)

3.30.2 Zone 2

A. Description (Resolution No. 67-7). Zone 2 is that part of the Delaware River extending from the head of tidewater at Trenton, New Jersey, R.M. (River Mile) 133.4 (Trenton-Morrisville Toll Bridge) To R.M. 108.4 below the mouth of Pennypack Creek, including the tidal portions of the tributaries thereof.

B. Water uses to be protected (Resolution No. 74-1). The quality of Zone 2 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. public water supplies after reasonable treatment
   b. industrial water supplies after reasonable treatment
   c. agricultural water supplies;

2. a. maintenance and propagation of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;

3. a. recreation from R.M. 133.4 to R.M. 117.81,
   b. recreation-secondary contact from R.M. 117.81 to R.M. 108.4;

4. a. navigation.

C. Stream quality objectives. The stream quality objectives of Zone 2 waters shall be those specified as follows:

1. Dissolved oxygen (Resolution No. 74-1)
   a. 24 hour average concentration shall not be less than 5.0 mg/l.

b. During the periods from April 1 to June 15, and September 16 to December 31, the dissolved oxygen shall not have a seasonal average less than 6.5 mg/l.

2. Temperature (Resolution No. 74-1). Shall not exceed
   a. 5°F (2.8°C) above the average 24 hour temperature gradient displayed during the 1961-66 period or
   b. a maximum of 86°F (30.0°C), whichever is less.

3. pH (Resolution No. 67-7). Between 6.5 and 8.5.

4. Phenols (Resolution No. 74-1). Maximum 0.005 mg/l, unless exceeded due to natural conditions.

5. Threshold odor number (Resolution No. 67-7). Not to exceed 24 at 60°C.

6. Synthetic detergents (M.B.A.S.) (Resolution No. 74-1). Maximum 30-day average 0.5 mg/l.

7. Radioactivity (Resolution No. 67-7).
   a. alpha emitters - maximum 3 pc/l (picocuries per liter);
   b. beta emitters - maximum 1,000 pc/l.

8. Fecal coliform (Resolution No. 74-1). Maximum geometric average
   a. 200 per 100 milliliters above R.M. 117.81.
   b. 770 per 100 milliliters below R.M. 117.81.

   Samples shall be taken at such frequency and location as to permit valid interpretation.

9. Total dissolved solids (Resolution No. 74-1. Not to exceed
   a. 133 percent of background or,
   b. 500 mg/l, whichever is less.

10. Turbidity (Resolution No. 74-1). Unless exceeded due to natural conditions
    a. maximum 30-day average 40 units
    b. maximum 150 units;

c. except above R.M. 117.81 during the period May 30 to September 15 when the turbidity shall not exceed 30 units.

11. Alkalinity (Resolution No. 67-7). Between 20 and 100 mg/l.

12. Chlorides (Resolution No. 74-1). Maximum 15-day average 50 mg/l.

13. Hardness (Resolution No. 74-1). Maximum 30-day average 95 mg/l.

D. Effluent quality requirements (Resolutions 62-14 and 67-7).

1. All discharges shall meet the effluent quality requirements of Section 3.10.

2. The carbonaceous oxygen demand from all outfalls in the zone (exclusive of storm-water by-pass) shall not exceed that assigned by Commission regulations.

3. No discharge shall exceed a biochemical oxygen demand of 100 mg/l.

3.30.3 Zone 3

A. Description (Resolution No. 67-7). Zone 3 is that part of the Delaware River extending from R.M. 108.4 to R.M. 95.0 below the mouth of Big Timber Creek, including the tidal portions of the tributaries thereof.

B. Water uses to be protected (Resolution No. 74-1). The quality of Zone 3 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. public water supplies after reasonable treatment
   b. industrial water supplies after reasonable treatment
   c. agricultural water supplies;

2. a. maintenance of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;

3. a. recreation - secondary contact;

4. a. navigation.

C. Stream quality objectives

1. Dissolved oxygen (Resolution No. 74-1)
   a. 24 hour average concentration shall not be less than 3.5 mg/l.
   b. During the periods from April 1 to June 15, and September 16 to December 31, the dissolved oxygen shall not have a seasonal average less than 6.5 mg/l.

2. Temperature (Resolution No. 74-1). Shall not exceed
   a. 5°F (2.8°C) above the average 24 hour temperature gradient displayed during the 1961-66 period or
   b. a maximum of 86°F (30.0°C), whichever is less.

3. pH (Resolution No. 67-7). Between 6.5 and 8.5.

4. Phenols (Resolution No. 74-1). Maximum 0.005 mg/l, unless exceeded due to natural conditions.

5. Threshold odor number (Resolution No. 67-7). Not to exceed 24 at 60°C.

6. Synthetic detergents (M.B.A.S.) (Resolution No. 74-1). Maximum 30-day average 1.0 mg/l.

7. Radioactivity (Resolution No. 67-7).
   a. alpha emitters - maximum 3 pc/l (picocuries per liter)
   b. beta emitters - maximum 1,000 pc/l.

8. Fecal coliform (Resolution No. 74-1). Maximum geometric average 770 per 100 milliliters. Samples shall be taken at such frequency and location as to permit valid interpretation.

9. Total dissolved solids (Resolution No. 74-1). Not to exceed
   a. 133 percent of background, or
   b. 500 mg/l, whichever is less.

10. Turbidity (Resolution No. 74-1). Unless exceeded due to natural conditions,
    a. maximum 30 day average 40 units
    b. maximum 150 units.

11. Alkalinity (Resolution No. 67-7). Between 20 and 120 mg/l.

12. Chlorides (Resolution No. 74-1). Maximum 200 mg/l.

13. Hardness (Resolution No. 74-1). Maximum 30-day average 150 mg/l.

D. Effluent quality requirements (Resolution No. 67-7).

1. All discharges shall meet the effluent quality requirements of Section 3.10.

2. The carbonaceous oxygen demand from all outfalls in the zone (exclusive of stormwater by-pass) shall not exceed that assigned by Commission regulations.

3.30.4 Zone 4

A. Description (Resolution No. 67-7). Zone 4 is that part of the Delaware River extending from R.M. 95.0 to R.M. 78.8, the Pennsylvania-Delaware boundary line, including the tidal portions of the tributaries thereof.

B. Water uses to be protected (Resolution No. 74-1). The quality of Zone 4 waters shall be maintained in a safe and satisfactory condition for the following uses:

1. a. industrial water supplies after reasonable treatment

2. a. maintenance of resident fish and other aquatic life,
   b. passage of anadromous fish,
   c. wildlife;

3. a. recreation - secondary contact

4. a. navigation

C. Stream quality objectives

1. Dissolved oxygen (Resolution No. 74-1).
   a. 24 hour average concentration shall not be less than 3.5 mg/l.
   b. During the periods from April 1 to June 15, and September 16 to December 31, the dissolved oxygen shall not have a seasonal average of less than 6.5 mg/l.

2. Temperature (Resolution No. 74-1). Shall not exceed
   a. 5°F (2.8°C) above the average 24 hour temperature gradient displayed during the 1961-66 period, or
   b. a maximum of 86°F (30.0°C).

3. pH (Resolution No. 74-1). Between 6.5 and 8.5.

4. Phenols (Resolution No. 74-1). Maximum 0.02 mg/l, unless exceeded due to natural conditions.

5. Threshold odor number (Resolution No. 67-7). Not to exceed 24 at 60°C.

6. Synthetic detergents (M.B.A.S.) (Resolution No. 74-1). Maximum 30 day average 1.0 mg/l.

7. Radioactivity (Resolution No. 67-7).
   a. alpha emitters - maximum 3 pc/l (picocuries per liter)
   b. beta emitters - maximum 1,000 pc/l.

8. Fecal coliform (Resolution No. 74-1). Maximum geometric average 770 per 100 milliliters. Samples shall be taken at such grequency and location as to permit valid interpretation.

9. Total dissolved solids (Resolution No. 74-1). Not to exceed 133 percent of background.

10. Turbidity (Resolution No. 74-1). Unless exceeded due to natural conditions
    a. maximum 30 day average 40 units,
    b. maximum 150 units.

11. Alkalinity (Resolution No. 67-7). Between 20 and 120 mg/l.

12. Chlorides (Resolution No. 74-1). Maximum 250 mg/l at R.M. 92.47.

D. Effluent quality requirements (Resolution No. 67-7).

1. All discharges shall meet the effluent quality requirements of Section 3.10.

2. The carbonaceous oxygen demand from all outfalls in the zone (exclusive of stormwater by-pass) shall not exceed that assigned by Commission regulations.

3.30.5 Zone 5

A. Description (Resolution No. 67-7). Zone 5 is that part of the Delaware River extending from R.M. 78.8 to R.M. 48.2, Liston Point, including the tidal portions of the tributaries thereof.

B. Water uses to be protected (Resolution No. 74-1). The quality of waters in Zone 5 shall be maintained in a safe and satisfactory condition for the following uses:

1. a. industrial water supplies after reasonable treatment

2. a. Maintenance of resident fish and other aquatic life,
   b. propagation of resident fish from R.M. 70.0 to R.M. 48.2,
   c. passage of anadromous fish,
   d. wildlife;

3. a. recreation - secondary contact from R.M. 78.8 to R.M. 59.5,
   b. recreation from R.M. 59.5 to R.M. 48.2;

4. a. navigation.

C. Stream quality objectives

1. Dissolved oxygen (Resolution No. 74-1)
   a. 24 hour average concentration shall not be less than
      1). 3.5 mg/l at R.M. 78.8
      2). 4.5 mg/l at R.M. 70.0
      3). 6.0 mg/l at R.M. 59.5.
   b. During the periods from April 1 to June 15, and September 16 to December 31, the dissolved oxygen shall not have a seasonal average less than 6.5 mg/l in the entire zone.

2. Temperature (Resolution No. 74-1).
   a. Shall not be raised above ambient by more than
      1). 4°F (2.2°C) during September through May, or
      2). 1.5°F (0.8°C) during June through August,
   b. nor shall maximum temperatures exceed 86°F (30.0°C).

3. pH (Resolution No. 67-7). Between 6.5 and 8.5.

4. Phenols (Resolution No. 74-1). Maximum 0.01 mg/l, unless exceeded due to natural conditions.

5. Threshold odor number (Resolution No. 67-7). Not to exceed 24 at 60°C.

6. Synthetic detergents (M.B.A.S.) (Resolution No. 74-1). Maximum 30-day average 1.0 mg/l.

7. Radioactivity (Resolution No. 67-7).
   a. alpha emitters - maximum 3 pc/l (picocuries per liter)
   b. beta emitters - maximum 1,000 pc/l.

8. Fecal coliform (Resolution No. 74-1). Maximum geometric average
   a. 770 per 100 milliliters from R.M. 78.8 to 59.5
   b. 220 per 100 milliliters from R.M. 59.5 to 48.2.

9. Turbidity (Resolution No. 74-1). Unless exceeded due to natural conditions
   a. maximum 30-day average 40 units,
   b. maximum 150 units.

10. Alkalinity (Resolutions No. 67-7. Between 20 and 120 mg/l.

D. Effluent quality requirements (Resolution No. 67-7).

1. All discharges shall meet the effluent quality requirements of Section 3.10.

2. The carbonaceous oxygen demand from all outfalls in the zone (exclusive of storm-water by-pass) shall not exceed that assigned by Commission regulations.

APPENDIX C

Appendix Tables

Appendix Table 1.

List of fishes collected in ichthyoplankton samples from the Delaware River (river mile 61 to 63) April 1972 through April 1973 (Kernehan, 1973).

American eel	Brown bullhead
Herring sp.	Killifish sp.
Blueback herring	Northern pipefish
Alewife	Temperate bass sp.
Bay anchovy	White perch
Minnow sp.	Striped bass
	Sunfish sp.

Appendix Table 2.

Common genera of algae collected in the Delaware River (river mile 72.0 to 73.0) from May through December 1973 (Unruh, 1974a).

Chlorophyta	Chrysophyta
Ankistrodesmus	Asterionella
Cladophora	Chaetocerus
Microspora	Coscinodiscus
Pediastrum	Cymbella
Rhizoclonium	Fragilaria
Scenedesmus	Frustulia
Spirogyra	Meriodion
	Rhizosolenia
Cyanophyta	Synedra
	Tabellaria
Oscillatoria	

Appendix Table 3.

List of phytoplankton taken from the Delaware River (river mile 70.6 to 73.0) from January to May 1974 (Unruh and Krout, 1974).

Chlorophyta

- Actinastrum
- Ankistrodesmus
- Chlamydomonas
- Chlorella
- Chodatella
- Closteriopsis
- Closterium
- Pediastrum
- Scenedesmus
- Selenastrum
- Staurastrum
- Ulothrix
- Uronema

Euglenophyta

- Englena
- Trachelomonas

Chrysophyta

- Dinobryon

Bacillariophyta

Centric

- Biddulphia
- Coscinodiscus
- Cyclotella
- Melosira

Pennate

- Amphipleura
- Asterionella
- Campylodiscus
- Cereatoneis
- Cocconeis
- Cymbella
- Diatoma
- Fragilaria
- Frustulia
- Gyrosigma
- Hantzschia
- Meridion
- Navicula
- Nitzschia
- Scohiopleura
- Stauroneis
- Surirella
- Synedra
- Tabellaria

Cyanophyta

- Coleosphaerium
- Oscillatoria
- Lymgbya

Miscellenaous

- Cryptomonas
- Phytoflagellates (unidentified)

Appendix Table 4.

List of phytoplankton taken in the Delaware River (river mile 72.0 to 72.5) in September and November 1974 (Unruh and Krout, 1975).

Chlorophyta
- Tetrasporales
  - Palmellaceas
    - *Sphaerocystis schroeteri*
- Chlorococcales
  - Micratineoceae
    - *Colenkinia radiata*
    - *Micractinium* sp.
  - Dictyosphaeriaceae
    - *Distyosphaerium pulchellum*
  - Hydrodictyaceae
    - *Pediastrum duplex*
    - *Pediastrum* spp.
  - Oocystaceae
    - *Ankistrodesmus falcatus*
    - *Chorella* spp.
    - *Closteriopsis longissma*
    - *Franceia droescheri*
    - *Kirchneriella obesa*
    - *Selenastrum* sp.
  - Scenedesmaceae
    - *Actinastrum hantzchii*
    - *Scendesmus obliquus*
    - *Scendesmus quadricauda*
- Zygnematales
  - Desmidiaceae
    - *Staurastrum* sp.

Euglenophyta
- Euglenales
  - Euglenaceae
    - *Euglena* sp.
    - *Phacus* sp.

Chrysophyta
- Chrysomonadales
  - Ochromanadaceae
    - *Dinobryon* sp.

Appendix Table 4 (continued).

Bacillariophyta
    Centrales
        Coscinodisaceae
            Coscinodiscus radiatus
            Coscinodiscus spp.
            Cyclotella spp.
            Melosira granulata
            Melosira spp.
            Stephanodiscus spp.

        Rhizosoleniaceae
            Rhizosolenia sp.

    Pennales
        Tabellariaceae
            Tabellaria fenestrata

        Diatomaceae
            Diatoma sp.

        Fragilariaceae
            Fragilaria crotonensis
            Raphoneis sp.
            Synedra sp.

        Achnanthaceae
            Cocconeis sp.

        Naviculaceae
            Navicula spp.
            Neidium sp.
            Pinnularia sp.
            Pleurosigma sp.
            Stauroneis sp.

        Nitzschiaceae
            Hantzschia spp.
            Nitzschia linearis
            Nitzschia palea
            Nitzschia spp.

        Surirellaceae
            Suriella spp.

Cyanophyta
    Chroococcales
        Chroococcaceae
            Agmenellum spp.
            Anacystis sp.

Appendix Table 4 (continued).

Cyanophyta
Oscillatoriales
Oscillatoriaceae
Oscillatoria spp.
Nostocaeae
Anabaena sp.

Appendix Table 5.

List of phytoplankton taken in the Delaware River (river mile 72.0 to 72.5) January through September 1975 (Unruh and Krout, 1976).

Chlorophyta
- Volvocales
  - Chlamydomonadaceae
    - *Chlamydomonas* spp.
  - Volvoocaceae
    - *Pandorina* sp.
- Tetrasporales
  - Palmellaceae
    - *Sphaerocystis schroeteri*
- Ulotrichales
  - Ulotrichaceae
    - *Ulothrix* sp.
- Chlorococcales
  - Micratiniaceae
    - *Golenkinia* sp.
    - *Micratinium* sp.
  - Dictyosphaeriaceae
    - *Dictyosphaerium pulchellum*
  - Characiaceae
    - *Schroederia judayi*
  - Hydrodictyaceae
    - *Pediastrum duplex*
    - *Pediastrum* spp.
  - Oocystaceae
    - *Ankistrodesmus falcatus*
    - *Chlorella vulgaris*
    - *Chlorella* spp.
    - *Franceia droescheri*
    - *Kirchneriella* sp.
    - *Selenastrum* sp.
    - *Tetraedron hastatum*
    - *Tetraedron limneticum*
    - *Tetraedron* sp.
    - *Treubaria* sp.
  - Scenedesmaceae
    - *Actinastrum hantzschii*
    - *Crucigenia* sp.
    - *Scendesmus bijuga*
    - *Scendesmus dimorphus*
    - *Scendesmus quadricauda*
    - *Scendesmus* sp.

Appendix Table 5 (continued).

Euglenophyta
    Euglenales
        Euglenaceae
            Euglena sp.
            Phacus sp.

Chrysophyta
    Chrysomonadales
        Ochromonadaceae
            Dinobryon sp.

Bacillariophyta
    Centrales
        Coscinodisaceae
            Coscinodiscus lineatus
            Coscinodiscus spp.
            Cyclotella spp.
            Melosira granulata
            Melosira spp.
            Skeletonema costatum
            Stephanodiscus sp.
            Thalassiosira sp.
        Rhizosoleniaceae
            Rhizosolenia sp.
        Chaetoceraceae
            Chaetoceros sp.

    Pennales
        Tabellariaceae
            Tabellaria tenestrata
        Diatomaceae
            Diatoma spp.
        Fragilariaceae
            Asterionella formosa
            Fragilaria crotonensis
            Raphoneis sp.
            Synedra spp.
        Achnanthaceae
            Cocconeis sp.
        Naviculaceae
            Gyrosigma sp.
            Navicula spp.
            Neidium sp.
            Pinnularia sp.
            Stauroneis sp.
        Gomphonemataceae
            Gomphonema sp.
        Cymbellaceae
            Amphora sp.
            Cymbella spp.

Appendix Table 5 (continued).

Bacillariophyta
 Pennales
  Nitzschiaceae
   Hantzschia sp.
   Nitzschia longissma
   Nitzschia spp.
  Surirellaceae
   Surirella sp.

Cyanophyta
 Chroococcales
  Chroococcaceae
   Agmenellum sp.
   Anacystis sp.
   Gomphosphaeria sp.

 Oscillatoriales
  Oscillatoriaceae
   Oscillatoria spp.
  Nostocaceae
   Anabaena sp.

Appendix Table 6.

Taxonomic list of zooplankton collected from the Delaware (river mile 70.5 to 73.5) and Christina Rivers from January through May 1974 (Brewster, 1974).

Nematoda
    Nematoda spp.

Rotifera
    Rotifera spp.
    Bdelloida spp.
    Rotaria spp.
    Brachionus spp.
    B. angularis
    B. bidentata
    B. calyciflorus
    B. caudatus
    B. diversicornis
    B. havanaensis
    B. plicatilis
    B. quadridentata
    B. rubens
    B. urceolaris
    B. variabilis
    Euchlanis spp.
    Kellicottia bostoniensis
    K. longispina
    Keratella spp.
    K. cochlearis
    K. quadrata
    K. serrulata
    K. taurocephala
    K. valga
    Notholca spp.
    Lecane spp.
    Monostyla spp.
    Cephalodella spp.
    Trichocerca spp.
    Asplanchna spp.
    Ploesoma spp.
    Polyarthra spp.
    Filinia spp.

Tardigrada
    Tardigrada spp.

Annelida
  Oligochaeta
    Oligochaeta spp.

Appendix Table 6 (continued).

Annelida
  Polychaeta
    Polychaeta spp.

Arthropoda
  Crustacea
    Cladocera
      Daphnia spp.
      D. parvula
      D. pulex
      Moina spp.
      Bosmina spp.
      B. coregoni
      B. longirostris
      Ilyocryptus sordidus
      I. spinifer
      Alona spp.
      A. guttata
      Pleuroxus spp.
      Chydorus spp.
      C. sphaericus
      Juvenile Cladocera

    Ostracoda
      Ostracoda spp.

    Copepods
      Acartia tonsa
      Eurytemora affinis
      Diaptomus spp.
      Calanoid copepodid
      Macrocyclops albidus
      Paracyclops fimbriatus poppei
      Eucyclops spp.
      E. agilis
      E. prionophorus
      E. speratus
      Tropocyclops prasinus
      Cyclops spp.
      C. biscuspidatus thomasi
      C. vernalis
      Halicyclops fosteri
      Cyclopoid copepodid
      Harpacticoida spp.
      Aenippe sp.
      Attheyella sp.
      A. nodrenskioldii
      Bryocamptus spp.
      Canthocamptus sp.

Appendix Table 6 (continued)

Arthropoda
Crustacea
Copepods
Canthocamptus staphylinoides
Cletomesochra spp.
Mesochra spp.
Microarthridion littorale
Onychocamptus mohammed
Harpacticoid copepodid
Copepod nauplii
Copepodid
Insecta
Ephemeroptera
Ephemeroptera nymphs
Plecoptera
Plecoptera nymphs
Diptera
Chironomodae larvae
Arachnida
Acari

Appendix Table 7.

Taxonomic list of zooplankton collected from the Delaware (river mile 70.5 to 73.5) and the Christina rivers June through November 1974 (Brewster, 1975).

Rotifera
- Rotifera spp.
- Bdelloida spp.
- *Rotaria* spp.
- *Brachionus* spp.
- *B. angularis*
- *B. calyciflorus*
- *B. caudatus*
- *B. havanaensis*
- *B. quadridentata*
- *Euchlanis* spp.
- *Kellicottia bostoniensis*
- *K. longispina*
- *Keratella* spp.
- *K. valga*
- *Notholca* spp.
- *Platyias patulus*
- *Trichotria* spp.
- *Lecane* spp.
- *Monostyla* spp.
- *Trichocerca* spp.
- *Asplanchna* spp.
- *Ploesoma* spp.
- *Polyarthra* spp.
- *Filinia* spp.
- *Hexarthra* spp.
- *Macrochaetus* spp.

Nematoda
- Nematoda spp.

Polychaeta
- Polychaeta spp.

Oligochaeta
- Oligochaeta spp.

Gastropoda
- Gastropoda larvae

Arachnida
- Acari

Appendix Table 7 (continued).

Cladocera
- *Leptodora kindtii*
- *Diaphanosoma brachyurum*
- *Daphnia* spp.
- *D. middendorffiana*
- *D. pulex*
- *Scapholeberis* spp.
- *Ceriodaphnia* spp.
- *C. reticulata*
- *Moina* spp.
- *Bosmina* spp.
- *Ilyocryptus sordidus*
- *I. spinifer*
- *Kurzia latissima*
- *Leydigia quadrangularis*
- *Alona* spp.
- *A. affinis*
- *A. costata*
- *A. guttata*
- *Chydorus sphaericus*
- Juvenile Cladocera

Ostracoda
- Ostracoda spp.

Copepoda
- Calanoid spp.
- *Acartia* spp.
- *A. tonsa*
- *Eurytemora affinis*
- *Diaptomus* spp.
- *D. reighardi*
- Calanoid copepodid
- *Paracyclops fimbriatus poppei*
- *Eucyclops* spp.
- *E. agilis*
- *E. macrurus*
- *E. speratus*
- *Tropocyclops prasinus*
- *Cyclops bicuspidatus thomasi*
- *C. vernalis*
- *Mesocyclops* spp.
- *M. edax*
- *Halicyclops fosteri*
- Cyclopoid copepodid
- Harpacticoid spp.
- *Onychocamptus mohammed*
- *Scottolana canadensis*
- Harpacticoid copepodid

Appendix Table 7 (continued).

Copepoda
Argulus spp.
Copepod nauplii
Copepodid
Cirripedia
Balanus spp. nauplii
Gammaridae
Gammarus spp.
Decapoda
Neomysis spp.
Shrimp larvae
Crab zoea
Tardigrada
Tardigrada spp.
Insecta
Diptera
Chironomidae larvae

Appendix Table 8.

Taxonomic list of zooplankton collected from the Delaware (river mile 70.5 to 73.5) and Christina rivers December 1974 through September 1975 (Crecco and Matarese, 1976).

Rotifera
- Rotifera spp.
- Bdelloida spp.
- Rotaria spp.
- R. neptunia
- Brachionus spp.
- B. angularis
- B. calyciflorous
- B. caudatus
- B. havanaensis
- B. quadridentata
- B. variables
- Euchlanis spp.
- Kellicottia bostoniensis
- K. longispina
- Keratella spp.
- K. serrulata
- K. cochlearis
- K. quadrata
- K. taurocephata
- K. valga
- Notholca spp.
- Platyias patulus
- Trichotria spp.
- Lecane spp.
- Monostyla spp.
- Trichocerca spp.
- Asplanchna spp.
- Ploesoma spp.
- Polyarthra spp.
- Filinia spp.
- Hexarthra spp.

Cladocera
- Juvenile cladocera
- Leptodora kindtii
- Diaphanosoma brachyurum
- Daphnia spp.
- Daphnia pulex
- Ceriodaphnia spp.
- Moina spp.
- Bosmina spp.

Appendix Table 8 (continued).

Cladocera
- Ilyocryptus sordidus
- I. spinifer
- Leydigia quadrangularis
- Alona spp.
- A. affinis
- A. costata
- Chydorus spp.
- C. sphaericus
- Pleuroxus spp.

Copepoda
- Copepod nauplii
- Cyclopod copepodid
- Calanoid copepodid
- Harpacticoid copepodid
- Acartia tonsa
- Eurytemora affinis
- Diaptomus spp.
- Paracyclops fimbriatus poppei
- Eucyclops spp.
- E. agilus
- E. speratus
- E. prionophorous
- Tropocyclops prasinus
- Cyclops bicuspidatus thomasi
- C. vernalis
- Macrocyclops albidus
- Halicyclops fosteri
- Harpacticoid spp.
- Canthocamptus spp.
- Scottolana canadensis
- Microarthridan littorale
- Parastonocaris spp.

Nematoda
- Nematoda spp.

Polychaeta
- Polychaeta spp.

Oligochaeta
- Oligochaeta spp.

Ostracoda
- Ostracoda spp.

Appendix Table 8 (continued).

Gammaridae
    Gammarus spp.

Tardiagrada
    Tardigrada spp.

Insecta
  Diptera
    Chironomidae larvae

Appendix Table 9.

Taxonomic list of benthic macroinvertebrates collected from the Delaware River (river mile 71.0 to 73.7) from October 1973 through September 1975 (Browell, 1976).

Phylum Coelenterata
  Class Hydrozoa
    Order Hydroida
      Family Clavidae
        Cordylophora caspia

Phylum Annelida
  Class Polychaeta
    Order Spionida
      Family Spionidae
        Unidentified fragments

  Class Oligochaeta
        Unidentified fragments

  Class Hirudinea
    Order Arhynchobdellida
      Family Erpobdellidae
        Erpobdella punctatus

    Order Rhynchobdellida
      Family Glossiphoniidae
        Helobdella stagnallis
        Helobdella elongata

Phylum Mollusca
  Class Gastropoda
    Order Pulmonata
      Family Anchlidae

  Class Pelecypoda
        Pelecypoda

    Order Heterodonta
      Family Cyrenidae
        Corbicula manilensis
      Family Sphaeriidae
        Pisidium cf. *compressum*

Appendix Table 9 (continued).

Phylum Arthropoda
  Class Crustacea
    Order Mysidacea
      Family Mysidae
        Neomysis americana

    Order Isopoda
      Family Anthuridae
        Cyathura polita
      Family Idoteidae
        Chiridotea almyra
      Family Asellidae
        Assellus militaris

    Order Amphipoda
      Family Corophiidae
        Corophium lacustre
      Family Gammaridae
        Gammarus daiberi

    Order Decapoda
      Family Crangonidae
        Crangon septemspinosa
      Family Portunidae
        Callinectes sapidus
      Family Xanthidae
        Rhithropanopeus harrisi

  Class Insecta
    Order Diptera
      Family Culicidae
        Unidentified larvae
      Family Tendipedidae
        Unidentified larvae and pupae
      Family Ceratopogonidae
        Unidentified larvae

Appendix Table 10.

Catch per month of ichthyoplankton from the Delaware River (river mile 70.5 to 73.8), January through May 1974 (Wik and Morrisson, 1974).

Species	Larvae	Eggs	Length (mm)	% of Monthly Catch
		JANUARY		
American eel				
surface	2	-	59-60	100
bottom	-	-	-	-
Total - Larvae	2			
- Eggs		0		
% of Total Catch	<1			
		FEBRUARY		
American eel				
surface	5	-	57-68	56
bottom	4	-	57-66	44
Total - Larvae	9			
- Eggs		0		
% of Total Catch	2			
		MARCH		
American eel				
surface	6	-	57-63	60
bottom	4	-	55-64	40
Total - Larvae	10			
- Eggs		0		
% of Total Catch	2			
		APRIL		
Alosa spp.				
surface	5	-	4-6	26
bottom	6	-	4-5	32
American eel				
surface	4	-	51-62	21
bottom	4	-	52-58	21

Appendix Table 10 (continued).

Species	Larvae	Eggs	Length (mm)	% of Monthly Catch
		APRIL (continued)		
Striped bass				
surface	-	194	-	-
bottom	-	315	-	-
Total - Larvae	19			
- Eggs		509		
% of Total Catch	3	81		
		MAY		
Alosa spp.				
surface	203	25	3-13	39
bottom	62	14	3-14	12
Cyprinid spp.				
surface	14	-	3-6	3
bottom	199	-	3-6	38
White perch				
surface	24	-	3-6	5
bottom	16	-	3-5	3
American eel				
surface	2	-	56-59	1
bottom	-	-	-	-
Striped bass				
surface	-	30	-	-
bottom	3	60	4-6	1
Total - Larvae	523			
- Eggs		129		
% of Total Catch	93	19		

Appendix Table 11.

Mean densities ($n/100m^3$) of fishes taken in semimonthly collections and in 24-hour studies in the Delaware River (river mile 70.5 to 73.8) near Edge Moor, June through November 1974 (Morrisson, 1975).

DATE	American eel	*Alosa* spp.	Blueback herring	Atlantic menhaden	Bay anchovy	*Cyprinid* sp.	*Menidia* sp.	Northern pipefish	Spot	Atlantic croaker	Naked goby	Hogchoker	No. Taxa
SEMI-MONTHLY SAMPLING PERIOD													
6/7	0.2	11.2	-	-	-	127.5	-	-	-	-	-	-	3
6/27	-	4.0	-	-	-	0.2	-	-	-	-	-	-	2
7/10	-	0.83	-	-	-	-	-	-	-	-	-	-	1
7/22	-	0.4	-	-	11.8	-	-	-	-	-	0.2	0.3	4
8/13	-	0.3	-	0.2	6.1	-	-	-	-	-	1.6	0.2	5
8/27	-	-	-	0.3	1.3	-	-	-	-	-	0.1	0.7	4
9/11	-	-	-	-	-	-	-	-	-	-	-	-	0
9/23	-	-	-	-	-	-	-	-	-	-	-	-	0
10/10	-	-	-	0.5	-	-	-	-	-	0.4	0.4	-	3
10/28	-	-	-	-	0.8	-	-	-	-	1.5	-	-	2
11/13	-	-	0.2	-	-	-	-	-	-	-	-	-	1
11/26	-	-	-	-	-	-	-	-	-	-	-	-	0
24-HOUR SAMPLING PERIOD													
6/27	-	0.1	-	-	-	0.3	-	-	-	-	-	-	2
7/22	0.1	-	-	-	26.1	-	0.2	0.2	0.3	-	2.9	0.3	7
8/13	-	-	-	0.1	10.1	-	-	-	-	-	0.8	1.3	4
9/11	-	-	-	-	-	-	-	-	-	-	0.3	0.1	2
10/10	-	-	-	0.7	0.7	-	-	-	-	0.8	-	-	3

Appendix Table 12.

Mean densities ($n/100m^3$) of fish collected from the Delaware River (river mile 70.5 to 73.8) near Edge Moor, December through September 1974-75 (Morrisson, 1976).

Month	DEC.	DEC.	JAN.	JAN.	FEB.	MAR.	MAR.	APR.	APR.	MAY	MAY	JUNE
Day	12	30	14	30	19	6	21	8	25	12	27	10
$\bar{X}$ Water Temp. (C)	6.2	5.9	4.9	4.7	5.0	5.8	7.7	6.7	12.4	17.3	22.6	22.0
$\bar{X}$ Oxygen (ppm)	7.9	8.7	11.3	9.7	9.4	9.5	9.3	10.5	7.0	3.5	3.8	3.2
$\bar{X}$ Salinity (ppt)	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.1
FISHES												
$\bar{X}$ Taxa	0	1	1	1	1	1	1	2	3	3	4	6
$\bar{X}$ Taxa/Sample	0.0	0.2	0.3	0.5	0.4	0.3	0.3	0.6	1.4	0.8	2.3	3.4
American eel	-	0.8	1.2	0.2	0.9	1.0	0.8	5.4	4.1	-	-	4.8
Alosa spp.												
larvae	-	-	-	-	-	-	-	-	-	5.9	27.3	7.6
eggs	-	-	-	-	-	-	-	-	0.3	-	-	-
Gizzard shad	-	-	-	-	-	-	-	-	-	-	3.6	21.8
Bay anchovy	-	-	-	-	-	-	-	-	-	-	-	-
Cyprinidae	-	-	-	-	-	-	-	-	-	-	149.1	24.8
Carp - Goldfish	-	-	-	-	-	-	-	-	-	-	1.0	2.5
Silvery minnow	-	-	-	-	-	-	-	-	-	-	-	-
Striped bass												
larvae	-	-	-	-	-	-	-	-	-	0.3	-	-
eggs	-	-	-	-	-	-	-	-	13.7	1.3	-	-
Largemouth bass	-	-	-	-	-	-	-	-	-	-	-	-
Naked goby	-	-	-	-	-	-	-	-	-	-	-	0.4
Total Number	0.0	0.8	1.2	0.2	0.9	1.0	0.8	5.6	18.1	7.5	181.0	61.9

Appendix Table 12 (continued).

Month	JUNE	JULY	JULY	AUG.	AUG.	SEPT.	SEPT.			
Day	24	10	31	14	28	8	25			
$\overline{X}$ Water Temp. (C)	25.4	26.6	26.7	26.5	26.5	24.2	20.1			
$\overline{X}$ Oxygen (ppm)	5.3	2.5	3.8	3.8	3.1	3.5	3.9			
$\overline{X}$ Salinity (ppt)	0.0	0.0	0.2	0.5	0.2	0.2	0.1	$\overline{X}$	%	Rank
FISHES										
$\overline{X}$ Taxa	5	7	1	2	2	1	0			
$\overline{X}$ Taxa/Sample	2.5	1.8	0.3	0.6	0.2	0.7	0.0	0.87		
American eel	-	0.3	-	-	0.3	-	-	1.04	4.0	4
Alosa spp.										
larvae	0.3	1.3	2.0	0.2	-	-	-	2.35	9.1	3
eggs	-	-	-	-	-	-	-	0.02	0.1	
Gizzard shad	21.9	3.3	-	-	-	-	-	2.63	10.2	2
Bay anchovy	-	-	-	3.0	0.3	3.7	-	0.37	1.4	2
Cyprinidae	163.2	5.4	-	-	-	-	-	18.03	70.1	1
Carp - Goldfish	0.9	1.7	-	-	-	-	-	0.32	1.2	7
Silvery minnow	-	1.7	-	-	-	-	-	0.09	0.4	8
White perch	-	-	-	-	-	-	-	0.01	*	
Striped bass										
larvae	-	-	-	-	-	-	-	0.02	0.1	10
eggs	-	-	-	-	-	-	-	0.79	3.1	5
Largemouth bass	-	-	0.2	-	-	-	-	0.01	*	
Naked goby	0.3	-	-	-	-	-	-	0.04	0.2	9
Total Number	186.6	13.9	2.0	3.2	0.6	3.7	0.0			

*Less than 0.05%

Appendix Table 13.

Number of fishes (N) collected by seine and the number of collections (CF) in which each species appeared in the Delaware River (river mile 71.6 to 74.9) June through November 1974 (Molzahn, 1975).

	Total
No. Collections	114
No. Species	17
No. Specimens	1291
Spms/Coll	11.3

SPECIES	N	CF	%
Mummichog	748	55	57.9
Bay anchovy	323	8	25.0
Silvery minnow	137	14	10.6
American eel	35	14	2.7
Tidewater silverside	15	8	1.2
Banded killifish	13	7	1.0
Blueback herring	4	3	0.3
White perch	4	4	0.3
Gizzard shad	3	3	0.2
Spot	2	2	0.2
Naked goby	1	1	0.1
Black crappie	1	1	0.1
Pumpkinseed	1	1	0.1
Atlantic menhaden	1	1	0.1
White catfish	1	1	0.1
Carp	1	1	0.1
Striped bass	1	1	0.1

Appendix Table 14.

Number of fishes (N) collected by seine and the number of collections (CF) in which each species appeared in the Delaware River (river mile 71.6 to 74.9) December 1974 through September 1975 (Herrig, 1976).

	TOTAL
No. Collections	214
No. Species	25
No. Specimens	2519
Specimens/Collection	11.8

SPECIES	N	CF	%
Mummichog	861	82	34.2
Silvery minnow	839	52	33.3
Bay anchovy	339	18	13.5
Alosa ap.	135	3	5.4
Blueback herring	105	10	4.2
Banded killifish	51	19	2.0
White perch	36	15	1.4
Tidewater silverside	33	9	1.3
American eel	19	11	0.8
Carp	16	5	0.6
Alewife	14	4	0.6
Lepomis sp.	14	5	0.6
Atlantic menhaden	10	4	0.4
Gizzard shad	8	4	0.3
Bluegill	8	8	0.3
Brown bullhead	7	5	0.3
Atlantic croaker	7	2	0.3
Striped bass	5	4	0.2
Spot	3	2	0.1
Pumpkinseed	2	2	0.1
White crappie	2	2	0.1
White catfish	2	2	0.1
Golden shiner	1	1	+
Atlantic silverside	1	1	+
Largemouth bass	1	1	+

Appendix Table 15.

Zooplankton taxa identified from the Delaware River Estuary taken in semimonthly pump samples at river mile 81.2, 97.5, 101.2 and 104.3 from January through December 1976 (PECo, 1977a,b,c,d).

River Mile	81.2	97.5	101.2	104.3
ROTATORIA				
Rotatoria spp.	+	+	+	+
Philodina spp.	+	+	+	+
Rotaria spp.	+	+	+	+
R. citrinus	+	+		
R. neotunia	.	+		+
Conochilus hippocrepis	+	+	+	+
C. dossuarius	+	+	+	+
Testudinella patina	+		+	+
Filinia spp.	+			
F. brachiata	+	+	+	+
F. longiseta	+	+	+	+
F. opotiensis	+	+	+	+
Porophylyx sulcata		+		
Hexarthra spp.	+	+	+	+
Floscularia spp.				+
Harringia spp.	+			
Polyarthra spp.	+	+	+	+
P. dolichoptera			+	
Synchaeta spp.	+	+	+	+
S. oblonga	+	+	+	+
S. pectinata	+	+		+
S. stylata	+	+		+
Ploesoma spp.	+	+		
P. hudsonei				+
P. truncatum	+	+	+	+
Cephalodella spp.	+	+	+	+
C. auriculata	+	+	+	+
C. gibba	+	+	+	+
Notommata spp.				+
Asplanchna spp.	+	+	+	+
A. girodi	+	+	+	+
A. priodonta				+
Brachionus spp.	+	+	+	+
B. angularis	+	+	+	+
B. calyciflorus	+	+	+	+
B. caudatus	+	+	+	+
B. havanagensis	+	+	+	+
B. plicatilis	+	+		

Appendix Table 15 (continued).

River Mile	81.2	97.5	101.2	104.3
ROTATORIA (continued)				
B. quadridentata	+	+	+	+
B. rubens		+		
B. urceolaris	+	+	+	+
B. pterodinoides	+	+	+	
B. budapestinensis		+	+	+
Mytilina spp.	+	+	+	+
Euchlanis spp.	+	+	+	+
Kellicottia bosteniensis	+	+	+	+
K. longispina	+	+	+	+
Keratella spp.	+	+	+	+
K. crassa	+	+	+	+
K. cochlearis	+	+	+	+
K. earlinae	+	+	+	+
K. hiemalis	+	+	+	+
K. quadrata	+	+	+	+
K. hispida		+		
K. serrulata	+	+	+	+
K. tropica	+			
K. taurocephala		+		
Epiphanges spp.	+	+	+	+
E. clavulata		+	+	
E. pelagica	+	+	+	
E. senta	+			
Notholca spp.	+	+	+	+
N. acuminata	+	+	+	+
N. squamula	+	+	+	+
N. labis	+	+	+	+
N. striatus	+	+	+	+
Platyias spp.		+		
P. patulus		+	+	+
P. quadricornis	+	+	+	
P. polyacanthus	+			
Trichotrias tetractis	+	+	+	+
Lepadella spp.	+		+	
Lecane spp.	+	+	+	+
L. luna	+	+	+	+
L. ohioensis	+	+	+	
Monostyla spp.	+	+	+	+
M. bulla	+	+	+	+
M. closterocerca	+	+	+	
M. lunaris	+			
M. quadridentata	+	+	+	+
Trichocerca capucina	+	+	+	+
T. elongata		+	+	
T. longiseta	+			+

Appendix Table 15 (continued).

River Mile	81.2	97.5	101.2	104.3
ROTATORIA (continued)				
Trichocerca porcellus	+	+	+	+
T. multicrinis	+			
Ascomorpha spp.	+	+	+	+
A. ovalis	+	+	+	+
Gastropus spp.	+	+	+	+
G. stylifer	+	+	+	+
Tylotrocha spp.		+		
Callotheca spp.		+		+
NEMATODA				
Nematoda spp.	+	+	+	+
TARDIGRADA				
Tardigrada spp.	+	+	+	+
ANNELIDA				
Annelida spp.	+			
OLIGOCHAETA				
Oligochaeta spp.	+	+	+	+
ARTHROPODA				
Crustacea				
Cladocera				
Cladocera spp.	+	+		
Ceriodaphnia spp.	+		+	
C. reticulata	+			
Daphnia spp.	+	+	+	+
D. ambiqua	+			
D. longiremis			+	+
D. middendorfia				+
D. parvula	+			
D. pulex	+	+	+	+
D. galeata mendotae		+		
Moina spp.	+		+	+
M. affinis	+	+	+	+
Bosmina spp.	+	+		
B. coregoni	+			
B. longlrostris	+	+	+	+
Ilyocryptus spp.		+	+	+
I. spinifer	+	+	+	+
Chydoridae spp.		+		
Camptocercus rectirostris	+	+	+	
Chydorus sphaericus	+	+	+	+
Alona spp.	+		+	+
A. costata		+		

Appendix Table 15 (continued).

River Mile	81.2	97.5	101.2	104.3
Arthropoda (continued)				
A. guttata	+	+	+	
A. rectangula	+	+	+	+
Laydigia acanthocercoides		+		
L. quadrangularis		+	+	+
Diaphanosoma spp.			+	
D. brachyurum	+	+	+	+
Leptodora kindtii	+	+	+	+
Ostracoda				
Ostracoda spp.	+	+	+	+
Cop[illegible]				
[illegible] spp.	+	+	+	+
[illegible] spp.	+	+	+	+
[illegible] spp.				+
D. pa[illegible]dus				+
D. oregonensis		+	+	
D. pygmaeus			+	
Eurytemora spp.		+		
E. affinis	+	+	+	+
Cyclopoida spp.	+	+	+	+
Cyclops bicuspidatus thomasi	+	+	+	+
C. exilis		+		
C. nearcticus		+		
C. varicans rubellus	+	+	+	+
C. vernalis	+	+	+	+
Eucyclops agilis	+	+	+	+
Ectocyclops phaleratus			+	
Halicyclops spp.	+	+		
Paracyclops fimbriatus poppei	+	+	+	+
Harpacticoida spp.	+	+	+	+
Amphipoda				
Gammaridae spp.				+
Gammarus fasciatus	+			
Insecta				
Chironomidae spp.	+	+	+	+
Arachnida				
Acari				
Hydracarina spp.	+	+	+	+

+Indicates taxa present.

Appendix Table 16.

List of macroinvertebrates taken from the Delaware River (river mile 80.5 to 81.2) 1973 (Potter, et al., 1974a).

ANNELIDA
- Oligochaeta
  - Tubificidae
    - Aulodrilus limnobius
    - Limnodrilus cervix
    - L. claparedeianus
    - L. hoffmeisteri
    - L. profundicola
    - L. udekemianus
    - Peloscolex ferox
    - P. multisetosus
    - Psammoryctides curvisetosus
    - Tubifex tubifex
- Polychaeta
  - Sabellidae
    - Manayunkia speciosa
- Hirundinea
  - Glossiphoniidae
    - Helobdella fusca
    - H. stagnalis
  - Piscicolidae
    - Illinobdella sp.
  - Erpobdellidae
    - Erpobdella punctata
    - Mooreobdella fervida

ARTHROPODA
- Isopoda
  - Asellidae
    - Asellus communis
  - Anthuridae
    - Cyathura polita
- Amphipoda
  - Gammaridae
    - Gammarus fasciatus
- Decapoda
  - Palaemonidae
    - Palaemonetes paludosus
- Diptera
  - Psychodidae
    - Psychoda sp.
    - Telmatoscopus albipunctatus

Appendix Table 16 (continued).

ARTHROPODA (continued)
  Diptera (continued)
    Chironomidae
      Ablabesmyia
      Chironomus
      Cricotopus
      Cryptochironomus
      Pentaneura
      Polypedilum
      Procladius
      Psectrocladius
      Tanypus
      Trichocladius

MOLLUSCA
  Gastropoda
    Physidae
      Physa integra
    Ancylidae
      Ferrissia tarda
  Pelecypoda
    Sphaeriidae
      Pisidium casertanum
      Sphaerium striatinum

Appendix Table 17.

Summary of larval fish taken from the Delaware River (river mile 82.0 to 96.0) from April through August 1974 (Harmon and Smith, 1975).

Month	Apr	May	Jun	Jul	Aug	Total	% Total
No. of Specimens	1	2737	129	5	-	2872	
No. of Collections	12	26	31	35	7	111	
American eel	1	2	1	-	NO FISH TAKEN	4	0.1
Clupeidae	-	2102	72	-		2174	75.7
Alosa sp.	-	123	31	-		154	5.4
Blueback herring	-	-	-	1		1	+
Cyprinidae	-	483	16	-		499	17.4
Carp	-	6	4	-		10	0.4
Fundulus sp.	-	1	-	-		1	+
Mummichog	-	-	4	2		6	0.2
Morone sp.	-	17	1	2		20	0.7
Tessellated darter	-	1	-	-		1	+
Unidentified larvae	-	2	-	-		2	0.1

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SHALLOWS OF THE DELAWARE RIVER-TRENTON, NEW JERSEY TO REEDY POI--ETC(U)
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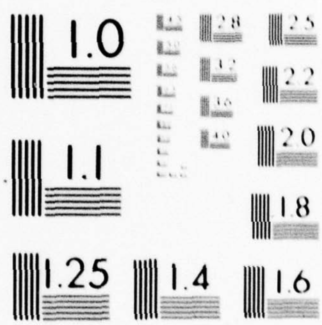

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Appendix Table 18.

List of fishes taken in the Delaware River (river mile 80.4 to 80.9) and its tributaries in 1973 and 1974 (Potter, et al., 1974a; Didun and Harmon, unpublished).

FRESHWATER EELS

American eel

HERRINGS

Blueback herring
Alewife
American shad
Atlantic menhaden
Gizzard shad

ANCHOVIES

Bay anchovy

MINNOWS AND CARPS

Goldfish
Carp
Silvery minnow
Golden shiner
Satinfin shiner
Spottail shiner
Swallowtail shiner
Spotfin shiner
Fathead minnow

SUCKERS

White sucker

FRESHWATER CATFISHES

White catfish
Brown bullhead
Channel catfish

KILLIFISHES

Banded killifish
Mummichog

SILVERSIDES

Tidewater silversides

STICKLEBACKS

Threespine stickleback

TEMPERATE BASSES

White perch
Striped bass

SUNFISHES

Pumpkinseed
Bluegill
Smallmouth bass
Largemouth bass
White crappie
Black crappie

PERCHES

Yellow perch

DRUMS

Spot
Atlantic croaker

SOLES

Hogchoker

Appendix Table 19.

List of fishes collected from the Delaware River on industrial screens (river mile 81.2, 97.5, 101.2, 104.3) in 1976 (PECo, 1977a, 1977b, 1977c, 1977d).

Bowfin	Banded killifish
American eel	Mummichog
Alosa sp.	Tidewater silverside
Blueback herring	White perch
Alewife	Striped bass
American shad	*Lepomis* sp.
Atlantic menhaden	Green sunfish
Bay anchovy	Bluegill
Chain pickerel	*Lepomis* Hybrid
Goldfish	Largemouth bass
Carp	White crappie
Silvery minnow	Black crappie
Golden shiner	Yellow perch
Spottail shiner	Bluefish
Minnow hybrid	Spot
White sucker	Atlantic croaker
White catfish	Naked goby
Brown bullhead	Hogchoker
Channel catfish	

Appendix Table 20.

List of benthos taken in the Delaware River (river mile about 84) in 1972 (Potter and Harmon, 1973).

Oligochaeta		
	Tubificidae	
		Peloscolex ferrox
		P. multisetosus
		Aulodrilus limnobius
		Limnodrilus cervix
		L. claparedeianus
		L. hoffmeisteri
		L. profundicola
		Potamothrix moldaviensis
Hirudinea		
	Glossiphoniidae	
		Helobdella stagnalis
	Erpobdellidae	
		Dina parva
		Mooreobdella fervida
Isopoda		
	Asellidae	
		Asellus communis
Diptera		
	Chironomidae	
		Procladius
Gastropoda		
	Ancylidae	
		Ferrissia tarda

Appendix Table 21.

List of benthos taken in the Delaware River (river mile 83.0 to 85.5) in 1973 (Potter, et al., 1974b).

CNIDARIA
- Hydrozoa
  - Hydridae
    - *Hydra* sp.

ANNELIDA
- Oligochaeta
  - Tubificidae
    - *Aulodrilus limnobius*
    - *Limnodrilus angustipenis*
    - *L. cervix*
    - *L. claparedianus*
    - *L. hoffmeisteri*
    - *L. profundicola*
    - *Peloscolex ferox*
    - *P. multisetosus*
    - *Tubifex tubifex*
- Hirudinea
  - Glossiphoniidae
    - *Glossiphonia complanata*
    - *Helobdella fusca*
    - *H. stagnalis*
  - Piscicolidae
    - *Illinobdella* sp.
  - Erpobdellidae
    - *Erpobdella punctata*
    - *Mooreobdella fervida*

ARTHROPODA
- Isopoda
  - Asellidae
    - *Asellus communis*
- Amphipoda
  - Gammaridae
    - *Gammarus fasciatus*
- Decapoda
  - Palaemonidae
    - *Palaemonetes paludosus*
- Diptera
  - Chironomidae
    - *Anatopynia*
    - *Chironomus*
    - *Cricotopus*
    - *Polypedilum*
    - *Procladius*
    - *Tanypus*
    - *Trichocladius*

Appendix Table 21 (continued).

MOLLUSCA
- Pelecypoda
  - Sphaeriidae
    - *Sphaerium striatinum*
- Gastropoda
  - Ancylidae
    - *Ferrissia tarda*

Appendix Table 22.

List of benthos taken in the Delaware River (river mile 83.0 to 85.5) in 1974 (Harmon and Smith, 1975).

Oligochaeta
- Lumbriculidae
- Branchiura sowerbyi
- Limnodrilus augustipenis
- L. cervix
- L. hoffmeisteri
- L. udekemianus
- Peloscolex

Hirudinea
- Helobdella elongata
- H. stagnalis
- Erpobdellidae (immature)
- Erpobdella punctata
- Mooreobdella fervida

Isopoda
- Asellus
- Cyathura polita

Amphipoda
- Gammarus fasciatus

Hydropsychidae
- Hydropsyche

Chironomidae
- Chironomus
- Cryptochironomus
- Dicrotendipes
- Polypedilum

Gastrpoda
- Gyraulus
- Lymnaea

Pelecypoda
- Sphaerium

Appendix Table 23.

Rank and percent of catch for fishes taken in 113 seine collections at 7 sites in the Delaware River (river mile 82.0 to 87.5) from June through October 1971 (Bason, 1971b).

Species	Overall		
	n	Rank	%
Mummichog	6,555	1	48.1
Pumpkinseed	1,958	2	14.4
Blueback herring	1,129	3	8.3
Brown bullhead	1,119	4	8.2
Banded killifish	1,098	5	8.1
Silvery minnow	868	6	6.4
Bluegill	515	7	3.8
White perch	184	8	1.3
Sunfish sp.	62	9	0.5
Largemouth bass	58	10	0.4
Carp	22	11	0.2
Golden shiner	10	12	0.1
Tidewater silverside	9	13	0.1
Black crappie	7	14	0.1
Alewife	6	15	T
Goldfish	6	15	T
American eel	6	15	T
White crappie	6	15	T
White sucker	5	16	T
Gizzard shad	3	17	T
Fathead minnow	3	17	T
Satinfin shiner	3	17	T
Spottail shiner	2	18	T
Grass pickerel	2	18	T
Creekchub sucker	1	19	T
Green sunfish	1	19	T
Number taken	13,638		

T = Trace

Appendix Table 24.

Total number and percent of catch for fishes taken in 118 seine collections at 7 sites in the Delaware River (river mile 82.0 to 87.5) in 1972 (Potter and Harmon, 1973).

Station	Total	% Catch
No. of Collections	118	
No. of Specimens	4743	
No. of Species	31	
American eel	10	0.2
Blueback herring	3	0.1
Alewife	41	0.9
Gizzard shad	2	+
Goldfish	12	0.3
Carp	4	0.1
Silvery minnow	371	7.8
Golden shiner	8	0.2
Satinfin shiner	12	0.3
Spottail shiner	18	0.4
Swallowtail shiner	7	0.1
Spotfin shiner	11	0.2
Bluntnose minnow	4	0.1
Fathead minnow	2	+
Quillback	6	0.1
Channel catfish	1	+
White sucker	2	+
Brown bullhead	20	0.4
Banded killifish	868	18.3
Mummichog	2815	59.4
Tidewater silverside	3	0.1
White perch	27	0.6
Striped bass	2	+
Green sunfish	1	+
Pumpkinseed	433	9.1
Lepomis hybrid	1	+
Bluegill	44	0.9
Largemouth bass	4	0.1
White crappie	4	0.1
Black crappie	5	0.1
Tessellated darter	1	+
Yellow perch	1	+

Appendix Table 25.

Summary of fishes taken in 181 seine collections from the Delaware River (river mile 82.0 to 87.5) from January through December 1973 (Potter, et al., 1974b).

	Total	% Catch
No. of Collections	181	
No. of Specimens	7484	
No. of Species	36	
American eel	33	0.4
Blueback herring	72	1.0
Alewife	41	0.5
Gizzard shad	1	+
Bay anchovy	3	+
Eastern mudminnow	3	+
Redfin pickerel	2	+
Goldfish	14	0.2
Carp	37	0.5
Silvery minnow	1527	20.4
Golden shiner	10	0.1
Satinfin shiner	104	1.4
Common shiner	3	+
Spottail shiner	35	0.5
Swallowtail shiner	31	0.4
Spotfin shiner	11	0.1
Fathead minnow	6	0.1
Fallfish	1	+
White sucker	1	+
Creek chubsucker	1	+
White catfish	20	0.3
Brown bullhead	59	0.8
Banded killifish	1597	21.3
Threespine stickleback	2	+
Mummichog	3220	43.0
Tidewater silverside	15	0.2
White perch	33	0.4
Redbreast sunfish	3	+
Green sunfish	14	0.2
Pumpkinseed	493	6.6
Bluegill	36	0.5
Smallmouth bass	1	+
Largemouth bass	42	0.6
White crappie	2	+
Black crappie	10	0.1
Atlantic croaker	1	+

Appendix Table 26.

Summary of fishes taken in 55 seine collections at 5 sites in the Delaware River (river mile 83.7 to 97.5) from January through December 1974 (Harmon and Smith, 1975).

	Total	% Total
No. of Species	23	
No. of Specimens	3708	
No. of Collections	55	
Spmn. per Collection	67.42	
American eel	8	0.2
Blueback herring	1	+
Gizzard shad	1	+
Goldfish	4	0.1
Carp	3	+
Silvery minnow	214	5.8
Spottail shiner	12	0.3
Swallowtail shiner	1	+
Spotfin shiner	22	0.6
Fathead minnow	2	+
White sucker	1	+
Brown bullhead	12	0.3
Banded killifish	874	23.6
Mummichog	2325	62.7
Tidewater silverside	1	+
Threespine stickleback	2	+
White perch	5	0.1
Green sunfish	4	0.1
Pumpkinseed	172	4.6
Bluegill	28	0.7
Largemouth bass	1	+
Black crappie	11	0.3
Hogchoker	4	0.1

Appendix Table 27.

List of zooplankton collected from the Delaware River (river mile 116.8 to 117.7) from February through June 1973 (Ritson, 1974).

PROTOZOA			
	CILIOPHORA		
		CILIATA	
			Carchesium
NEMATODA			
			Several species
ROTIFERA			
		BDELLOIDEA	
			Several species
		MONOGONONTA	
			Brachionus angularis
			Brachionus calyciflorus
			Brachionus caudatus
			Brachionus plicatilis
			Brachionus quadridentata
			Brachionus urceolaris
			Euchlanis
			Kellicottia bostoniensis
			Kellicottia longispina
			Keratella cochlearis
			Keratella hiemalis
			Keratella quadrata
			Keratella taurocephala
			Keratella valga
			Macrochaetus
			Notholca
			Platyias quadricornis
			Trichotria
			Colurella
			Lepadella
			Lecane
			Monostyla
			Cephalodella
			Asplanchna
			Polyarthra
			Filinia
TARDIGRADA			
		EUTARDIGRADA	
			Hypsibius

Appendix Table 27 (continued)

ANNELIDA				
	OLICOCHAETA			
				Aeolosoma hemprichi
				Aeolosoma niveum
	POLYCHAETA			
				Manayunkia speciosa
ARTHROPODA				
	CRUSTACEA			
		CLADOCERA		
				Leptodora kindtii
				Diaphanosoma brachyurum
				Ceroidaphnia
				Ceriodaphnia reticulata
				Daphnia
				Daphnia ambiqua
				Daphnia catawba
				Daphnia galeata
				Daphnia laevis
				Daphnia longiremis
				Daphnia middendorffiana
				Daphnia parvula
				Daphnia pulex
				Moina
				Moina brachiata
				Moina micrura
				Moina rectirostris
				Simocephalus
				Bosmina coregoni
				Bosmina longirostris
				Ilyocryptus sordidus
				Ilyocryptus spinifer
				Alona affinis
				Alona costata
				Alona guttata
				Alona quadrangularis
				Alona rectangula
				Camptocercus rectirostris
				Chydorus ovalis
				Chydorus sphaericus
				Leydigia
				Leydigia acanthocercoides
				Leydigia quadrangularis
				Pleuroxus denticulatus
	OSTRACODA			
				Several species
		COPEPODA		
			CALANOIDA	
				Centropages typicus
				Eurytemora affinis

Appendix Table 27 (continued)

ARTHROPODA (continued)
- COPEPODA
  - CALANOIDA
    - Diaptomus
    - Diaptomus birgei
  - CYCLOPOIDA
    - Cyclops
    - Cyclops bicuspidatus thomasi
    - Cyclops navus
    - Cyclops venustoides
    - Cyclops vernalis
    - Eucyclops
    - Eucyclops agilis
    - Eucyclops prionophorus
    - Halicyclops
    - Macrocyclops albidus
    - Mesocyclops edax
    - Orthocyclops modestus
    - Paracyclops fimbriatus poppei
    - Tropocyclops prasinus
  - HARPACTICOIDA
    - Attheyella
    - Attheyella illinoidensis
    - Attheyella nordenskioldii
    - Bryocamptus
    - Bryocamptus minutus complex
    - Bryocamptus zschokkei
    - Canthocamptus
    - Canthocamptus assimilis
    - Canthocamptus sinuus
    - Canthocamptus staphylinoides
    - Elaphoidella
    - Elaphoidella bidens coronata
- AMPHIPODA
  - Gammarus

INSECTA
- HYDRACARINA
- EPHEMEROPTERA
- ODONATA
  - COENAGRIONIDAE
- PLECOPTERA
- COLEOPTERA
- TRICHOPTERA
- DIPTERA
  - TENDIPEDIDAE
    - Hydrobaenus
    - Procladius
    - Procladius culiciformis

Appendix Table 28.

List of benthic macroinvertebrates collected from the Delaware River (river mile 116 to 131) August 1970 to October 1973. (After: Crumb, 1977)

Nematoda sp.
Dermosponga
    Spongilla lacustris
Phylactolaemata
    Pectinatella magnifica
    Plumatella sp.
Turbellaria
    Dugesia tigrina
    Phagocata
Oligochaeta
    Aeolosoma hemprichi
    Stylaria lacustris
    Branchiura sowerbyi
    Ilyodrilus templetoni
    Limnodrilus angustipenis
    Limnodrilus cervix
    Limnodrilus hoffmeisteri
    Limnodrilus profundicola
    Limnodrilus udekemianus
    Peloscolex ferox
    Peloscolex multisetosus
    Psammoryctides curvisetosus
    Lumbricidae sp.
    Lumbriculus incontans
Hirundinea
    Dina lateralis
    Eropbdella punctata
    Glossiphonia complanata
    Helobdella fusca
    Helobdella elongata
    Helobdella stagnalis
    Placobdella ornata
Polychaeta
    Manayunkia speciosa
Gastrpoda
    Campeloma sp.
    Ferrissia sp.
    Helizoma sp.
    Lumnaea sp.
    Physa sp.
    Valvata sp.
Pelecypoda
    Anodonta cataracta
    Elliptio complanata

Appendix Table 28 (continued)

Pelecypoda (continued)
- Lampsilis ochracea
- Ligumia nasuta
- Corbicula manilensis
- Pisidium sp.
- Sphaerium transversum

Crustacea
- Illocryptus sordidus
- Asellus militaris
- Cyathura polita
- Gammarus fasciatus
- Orconectes limosus

Acara
- Hydracarina spp.

Insecta
- Diptera
  - Chaoborus sp.
  - Chironomus riparius
  - Cryptochironomus sp.
  - Procladius culiciformis
  - Tipula sp.
  - Limnophora discreta
  - Stratiomys sp.
  - Ceratopogonidae sp.

Odonata
- Argia sp.
- Lestes sp.
- Didymops sp.
- Gomphus sp.
- Macromia sp.

Trichoptera
- Cheumatopsyche sp.
- Hydropsyche sp.
- Hesperophylax sp.
- Hydroptila sp.

Coleoptera
- Berosus sp.
- Elmidae sp.

Hemiptera
- Notonecta sp.
- Ranatra sp.

Ephemeroptera
- Baetis sp.

Lepidoptera
- Cataclysta

Appendix Table 29.

Rank, total number and percent of total catch for all fishes taken by trawl and seine in the Delaware River (river mile 115 to 120) in 1972. (After: Chase, 1974b)

	Rank	All Trawl	Seine	Total	% Total Catch
No. of species	-	24	33	36	-
No. of specimens	-	6,957	10,731	17,688	-
No. of collections	-	663	238	901	-
Blueback herring	1	1,087	2,695	3,782	21.38
White perch	2	2,938	411	3,349	18.93
Spottail shiner	3	1,599	1,583	3,182	17.98
Mummichog	4	-	2,186	2,186	12.35
Silvery minnow	5	413	1,156	1,569	8.87
Banded killifish	6	1	1,276	1,277	7.21
River herrings	7	56	541	597	3.37
Alewife	8	452	145	597	3.37
Satinfin shiner	9	-	283	283	1.59
Channel catfish	10	137	103	240	1.35
White catfish	11	83	9	92	0.50
White sucker	12	76	14	90	0.50
Golden shiner	13	11	68	79	0.40
American eel	14	11	65	76	0.40
Bluegill	15	6	61	67	0.30
Brown bullhead	16	48	-	48	0.27
Tassellated darter	17	7	37	44	0.20
Swallowtail shiner	18	-	26	26	0.10
Carp	19	7	10	17	0.10
Pumpkinseed	20	2	14	16	0.09
American shad	21	6	7	13	0.07
Spotfin shiner	22	-	11	11	0.06
Striped bass	23	9	1	10	0.05
Gizzard shad	24	1	7	8	0.04
Largemouth bass	25	-	7	7	0.03
Goldfish	26	1	3	4	0.02
Black crappie	26	2	2	4	0.02
White crappie	27	2	1	3	0.01
Comely shiner	28	-	2	2	0.01
Redbreast sunfish	28	-	2	2	0.01
Sea lamprey	29	1	-	1	*
Chain pickerel	29	-	1	1	*
Fallfish	29	1	-	1	*
Creek chubsucker	29	-	1	1	*
Tidewater silverside	29	-	1	1	*
Fourspine stickle-back	29	-	1	1	*
Green sunfish	29	-	1	1	*

*Less than 0.005%

Appendix Table 30.

Rank, total number and percent of total catch for all fishes taken by trawl and seine in the Delaware River (river mile 115 to 120) in 1973. (After: Holmstrom, 1974)

	Rank	Trawl	Seine	Total	% Total Catch
No. of species		15	21	27	
No. of specimens		1,345	1,098	2,444	
No. of collections		121	45	166	
Spottail shiner	1	267	307	574	23.48
White perch	2	483	34	517	21.15
Silvery minnow	3	377	49	426	17.43
River herrings	4	-	246	246	10.06
Banded killifish	5	-	165	165	6.75
Mummichog	6	-	163	163	6.66
Satinfin shiner	7	-	55	55	2.25
Channel catfish	8	48	3	51	2.08
White sucker	9	45	1	46	1.88
Brown bullhead	10	35	-	35	1.43
Golden shiner	11	12	16	28	1.14
American eel	12	8	18	26	1.06
White catfish	13	22	-	22	0.90
Carp	14	17	-	17	0.69
Blueback herring	15	15	-	15	0.61
Swallowtail shiner	16	-	14	14	0.57
Pumpkinseed	17	6	7	13	0.53
Alewife	18	5	-	5	0.20
Black crappie	18	-	5	5	0.20
Tessellated darter	18	5	-	5	0.20
Lepomis sp.	19	-	4	4	0.16
Bluegill	20	-	3	3	0.12
Comely shiner	21	-	2	2	0.08
Spotfin shiner	21	-	2	2	0.08
Gizzard shad	22	-	1	1	0.04
Goldfish	22	1	-	1	0.04
Fourspine stickleback	22	-	1	1	0.04
Redbreast sunfish	22	-	1	1	0.04
White crappie	22	-	1	1	0.04

Appendix Table 31.

List of phytoplankton taken in the Delaware River (river mile 117.3) March 1972 through October 1973 (Krout, 1974).

CHLOROPHYTA

Chlamydomonadaceae
- Chlamydomonas

Phacotaceae
- Pteromonas

Volvocaceae
- Eudorina
- Gonium
- Pandorina
- Volvox

Spondylomoraceae
- Spondylomorum

Palmellaceae
- Asterococcus
- Palmodictyon
- Sphaerocystis

Ulotrichaceae
- Binuclearia
- Ulothrix

Microsporaceae
- Microspora

Chaetophoraceae
- Stigeoclonium

Coleochaetaceae
- Coleochaete

Oedogoniaceae
- Oedogonium

Cladophoraceae
- Cladophora

Dictyosphaeriaceae
- Dictyosphaerium
- Dimorphococcus

Characiaceae
- Schroederia

Hydrodictyaceae
- Hydrodictyon
- Pediastrum

Coelastraceae
- Coelastrum

Oocystaceae
- Ankistrodesmus
- Chlorella
- Chodatella
- Closteridium
- Closteriopsis
- Pachycladon
- Selenastrum
- Westella

Scenedesmaceae
- Actinastrum
- Crucigenia
- Scenedesmus
- Tetrastrum

Zygnemataceae
- Mougeotia
- Spirogira
- Zygnema

Mesotaeniaceae
- Netrium

Desmidiaceae
- Closterium
- Cosmarium
- Spondylosium
- Staurastrum
- Xanthidium

Appendix Table 31 (continued)

EUGLENOPHYTA

Euglenaceae
Euglena
Phacus

Peranemaceae
Petalomonas

CHRYSOPHYTA

Tribonemataceae
Tribonema

Synuraceae
Synura

Ochromonadaceae
Dinobryon

BACILLARIOPHYTA

Coscinodiscaceae
Coscinodiscus
Cyclotella
Melosira

Tabellariaceae
Tabellaria

Meridionaceae
Meridion

Diatomaceae
Diatoma
Opephora

Fragilariaceae
Asterionella
Fragilaria
Synedra

Eunotiaceae
Ceratoneis
Rhoicosphenia

Naviculaceae
Amphiprora
Frustulia
Gyrosigma
Navicula
Stauroneis

Comphonematoaceae
Gomphonema

Cymbellaceae
Cymbella

Nitzschiaceae
Nitzschia

PYRROPHYTA

Gymnodiniaceae
Gymnodinium

Ceratiaceae
Ceratium

CYANOPHYTA

Chroococcaceae
Anacystis
Merismopedia
Polycystis
Synechocystis

Oscillatoriaceae
Lyngbya
Oscillatoria
Trichodesmium

Nostocaceae
Anabaena
Aphanizomenon

RHODOPHYTA

Chantransiaceae
Audouinella

Appendix Table 32.

List of zooplankters collected with a one-half meter net in the Delaware River (river mile 120.5 to 129.2) from June through December 1971 (Chase, 1976).

CILIOPHORA
  CILIATA
    Carchesium
    Epistylis
    Strombidium

COELENTERATA
  HYDROZOA
    Hydra

NEMATODA
  Several species

GASTROTRICHA
  Ichthydium
  Polymerurus

ROTIFERA
  BDELLOIDEA
    Several species
  MONOGONONTA
    Asplanchna
    Brachionus
    Cephalodella
    Euchlanis
    Filinia
    Gastropus
    Hexarthra
    Kellicottia
    Keratella
    Lecane
    Lepadella
    Monostyla
    Polyarthra
    Scaridium
    Trichocerca

ARTHROPODA
  CRUSTACEA
    CLADOCERA
      Alona affinis
      Alona quadrangularius
      Alona
      Bosmina longirostris

Appendix Table 32 (continued)

CLADOCERA (continued)
Ceriodaphnia
Chydorus
Chydorus sphaericus
Daphnia laevis
Daphnia parvula
Daphnia
Diaphanosoma
Ilyocryptus
Ilyocryptus spinifer
Latona setifera
Leptodora kindtii
Leydigia quadrangularis
Leydigia
Moina
Pleuroxus
Scapholeberis
OSTRACODA
Several species
COPEPODA
Cyclops bicuspidatus thomasi
Cyclops
Diaptomus
Epischura
Eucyclops agilis
Eucyclops speratus
Eurytemora affinis
Macrocyclops ater
Macrocyclops
Mesocyclops edax
HARPACTICOIDA
One species
PARASITIC COPEPODA
Ergasilus
INSECTA
DIPTERA
Calopsectra
Chaoborus
Cryptochironomus
Procladius culiciformis
Tanytarsus
Tendipes
PARASITENGONA
HYDROACARINA
Several species

Appendix Table 33.

Rank, total number and percent of total catch for all fishes taken by trawl and seine in the Delaware River (river mile 122 to 130) in 1970 (Anselmini, 1971).

	Rank	Trawl	Seine	Total	% Total Catch
No. of species		27	28	33	
No. of specimens		32,980	99,489	132,469	
No. of collections		574	208	782	
Blueback herring	1	11,506	62,312	73,818	55.72
Spottail shiner	2	4,481	16,997	21,478	16.21
Alewife	3	8,198	2,392	10,590	7.99
Silvery minnow	4	1,646	7,590	9,236	6.97
White perch	5	6,167	2,106	8,273	6.25
Mummichog	6	-	4,703	4,703	3.55
Brown bullhead	7	540	1,451	1,991	1.50
Banded killifish	8	6	1,491	1,497	1.13
White sucker	9	42	88	130	0.10
Golden shiner	10	73	36	109	0.08
Tessellated darter	11	14	87	101	0.08
Satinfin shiner	12	-	85	85	0.06
Pumpkinseed	13	51	28	79	0.06
American shad	14	67	1	68	0.05
Bluegill	15	7	52	59	0.04
Channel catfish	16	58	-	58	0.04
American eel	17	22	35	57	0.04
White catfish	18	30	5	35	0.03
Yellow perch	19	29	-	29	0.02
Goldfish	20	15	-	15	0.01
Carp	21	11	3	14	0.01
Largemouth bass	22	3	9	12	*
Chain pickerel	23	3	5	8	*
Black crappie	24	4	2	6	*
Redbreast sunfish	25	3	2	5	*
Spotfin shiner	26	-	3	3	*
Quillback	27	1	1	2	*
Tidewater silver-sides	27	-	2	2	*
White crappie	27	1	1	2	*
Sea lamprey	28	1	-	1	*
Redfin pickerel	28	-	1	1	*
Creek chubsucker	28	-	1	1	*
Striped bass	28	1	-	1	*

*Less than 0.01%

Appendix Table 34.

Summary of the total number of fishes captured by 10-foot common, 24-foot bag and 250-foot beach seines in the Delaware River (river mile 122 to 130) in 1971. (After: Anselmini, et al., 1976)

	10-foot common 24-foot bag seines			250-foot Beach Seine	Total All Seines
	Day	Night	Total		
No. of species	35	24	35	22	37
No. of specimens	47,073	9,045	56,118	346	56,464
No. of collections	384	85	486	17	486
American eel	149	54	203	1	204
Blueback herring	16,578	66	16,644	36	16,680
Alewife	5,421	183	5,604	22	5,626
American shad	1	2	3	1	4
Gizzard shad	2	-	2	-	2
Chain pickerel	2	1	3	-	3
Goldfish	-	-	-	2	2
Carp	6	5	11	11	22
Silvery minnow	2,085	1,648	3,733	14	2,747
Golden shiner	497	14	511	11	522
Comely shiner	1	-	1	-	1
Satinfin shiner	577	40	617	-	617
Spottail shiner	12,819	3,119	15,938	2	15,940
Swallowtail shiner	53	-	53	-	53
Spotfin shiner	46	1	47	-	47
Blacknose dace	3	-	3	-	3
Creek chub	1	-	1	-	1
Fall fish	1	-	1	-	1
Quillback	1	-	1	-	1
White sucker	41	15	56	6	62
White catfish	9	36	45	1	46
Brown bullhead	37	281	318	14	332

Appendix Table 34 (continued)

	10-foot common 24-foot bag seines			250-foot Beach Seine	Total All Seines
	Day	Night	Total		
No. of species	35	24	35	22	37
No. of specimens	47,073	9,045	56,118	346	56,464
No. of collections	384	85	486	17	486
Channel catfish	3	35	38	5	43
Banded killifish	1,906	1,125	3,031	25	3,056
Mummichog	6,337	1,186	7,523	38	7,561
Fourspine stickleback	5	-	5	-	5
White perch	262	1,062	1,324	63	1,387
Striped bass	-	-	-	28	28
Redbreast sunfish	5	5	10	4	14
Green sunfish	1	-	1	-	1
Pumpkinseed	46	22	68	35	103
Bluegill	82	5	87	-	87
Largemouth bass	3	-	3	9	12
White crappie	12	1	13	-	13
Black crappie	11	3	14	-	14
Tessellated darter	64	136	200	1	201
Yellow perch	6	-	6	17	23

Appendix Table 35.

List of zooplankton collected in the Delaware River (river mile 129.2 to 130.5) in 1971 and 1972 (Anselmini, 1974b).

NEMATODA	
	Several species
ROTIFERA	
BDELLOIDEA	
	Several species
MONOGONONTA	
	Brachionus sp.
	Brachionus calyciflorus
	Brachionus caudatus
	Brachionus quadridentata
	Euchlanis dilatata
	Kellicottia bostoniensis
	Kellicottia longispina
	Keratella canadensis
	Keratella cochlearis
	Keratella hiemalis
	Keratella quadrata
	Notholca acuminata
	Platyias polyacanthus
	Platyias quadricornis
	Trichotria tetractis
	Lepadella sp.
	Monostyla sp.
	Cephalodella sp.
	Trichocerca sp.
	Gastropus hyptopus
	Asplanchna sp.
	Polyarthra sp.
	Filinia terminalis
	Hexarthra sp.
TARDIGRADA	
EUTARDIGRADA	
	Hypsibius sp.
ANNELIDA	
OLIGOCHAETA	
	Aeolosoma sp.
	Aeolosoma hemprichi
	Aeolosoma niveum
	Peloscolex ferox
	Pristina schmiederi
POLYCHAETA	
	Manayunkia speciosa
HIRUDIDAE	
GLOSSIPHONIIDAE	

Appendix Table 35 (continued)

ARTHROPODA	
CRUSTACEA	
CLADOCERA	
	Leptodora kindtii
	Diaphanosoma sp.
	Diaphanosoma brachyurum
	Latona setifera
	Ceriodaphnia sp.
	Daphnia sp.
	Daphnia laevis
	Daphnia longiremis
	Daphnia longispina
	Daphnia pulex
	Moina sp.
	Moina brachiata
	Scapholeberis sp.
	Simocephalus serrulatus
	Bosmina coregoni
	Bosmina longirostris
	Ilyocryptus sp.
	Ilyocryptus sordidus
	Ilyocryptus spinifer
	Alona sp.
	Alona affinis
	Alona costata
	Alona quadrangularis
	Camptocercus rectirostris
	Chydorus sphaericus
	Leydigia sp.
	Leydigia quadrangularis
	Pleuroxus denticulatus
	Pleuroxus striatus
OSTRACODA	
	Several species
COPEPODA	
CALANOIDA	
	Eurytemora affinis
	Diaptomus sp.
	Diaptomus birgei
	Diaptomus reighardi
CYCLOPOIDA	
	Cyclops bicuspidatus thomasi
	Cyclops vernalis
	Eucyclops agilis
	Eucyclops speratus
	Macrocyclops ater
	Mesocyclops edax
	Paracyclops fimbriatus poppei
	Tropocyclops prasinus

Appendix Table 35 (continued)

	HARPACTICOIDA		
			Maraenobiotus sp.
			Attheyella illinoisensis
			Bryocamptus sp.
			Bryocamptus hiemalis brevifurca
			Bryocamptus zschokkei
			Canthocamptus sinuus
			Canthocamptus staphylinoides
	AMPHIPODA		
			Gammarus fasciatus
	HYDRACARINA		
INSECTA			
	EPHEMEROPTERA		
		BAETIDAE	
	ODONATA		
			Lestes sp.
		COENAGRIONIDAE	
	PLECOPTERA		
	COLEOPTERA		
	TRICHOPTERA		
	DIPTERA		
			Tanytarsus sp.
		CULICIDAE	
			Chaoborus sp.
			Culex sp.
		TENDIPEDIDAE	
			Cryptochironomus sp.
			Hydrobaenus sp.
			Pentaneura sp.
			Probezzia sp.
			Procladius culiciformis
		CERATOPOGONIDAE	

Appendix Table 36.

List of fish eggs, larvae and young taken in the Delaware River (river mile 130) from 1971 through 1973 (Anselmini, 1974b).

Common Name	Developmental Stage Egg	Larva	Young
LAMPREYS			
Sea lamprey		+	
FRESHWATER EELS			
American eel			+
HERRINGS			
Blueback herring			+
Alewife			+
American shad	+		
River herring (blueback and alewife)	+	+	
Gizzard shad		+	
MUDMINNOWS			
Eastern mudminnow			+
MINNOWS AND CARPS			
Carp		+	
Unidentified minnows (several species)		+	
SUCKERS			
Quillback		+	
White sucker		+	
FRESHWATER CATFISHES			
White catfish		+	
Channel catfish		+	+
KILLIFISHES			
Killifish (banded killifish and mummichog)		+	
TEMPERATE BASSES			
White perch	+	+	
SUNFISHES			
Unidentified sunfish (several species)		+	
Smallmouth bass		+	
Largemouth bass		+	

Appendix Table 36 (continued)

Common Name	Developmental Stage Egg	Larva	Young
SUNFISHES (continued)			
Crappies (white crappie and black crappie)		+	
PERCHES			
Tessellated darter		+	+
Yellow perch		+	

Appendix Table 37.

List of fishes taken from the Delaware River (about river mile 130) (Mihursky, 1962).

Alewife	Mummichog
American eel	Pumpkinseed
Atlantic sturgeon	Redbreast sunfish
Banded killifish	Silvery minnow
Blueback herring	Spottail shiner
Brown bullhead	Striped bass
Golden shiner	Tadpole madtom
Green sunfish	White catfish
Johnny darter	White perch
Longnose gar	White sucker