A Survey of Fish in the Delaware Estuary from the Area of the Chesapeake and Delaware Canal to Trenton FINAL REPORT

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By

John C. O'Herron, II, Thomas Lloyd, and Kim Laidig

Prepared For
Scientific and Technical Advisory Committee
Delaware Estuary Program

March 1, 1994

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EXECUTIVE SUMMARY

The combined results of studies conducted since 1980 record 87 species of fish in the Delaware estuary between Trenton and the Chesapeake and Delaware (C&D) Canal. In the present study, T. Lloyd Associates collected 47 of these species. In our collections, white perch, blueback herring, Atlantic croaker, bay anchovy, hogchoker, channel catfish, banded killifish, American shad, eastern silvery minnow, mummichog, and spottail shiner constituted 90% of the catch at Stations 1, 2, and 3. Hogchoker, bay anchovy, white perch, Atlantic croaker, and weakfish made up 91% of the catch at Station 4. The largest catch at all stations was made in the fall, when juvenile herring, white perch, hogchoker, and other species were migrating into deeper water or out to sea.

Our study showed that the estuary supported a diverse fish community consisting of both freshwater and saline water residents, as well as cool water and warm water oceanic migrants, including several anadromous and one catadromous species. All of the investigated habitats supported juvenile and adult fishes. Some 54% of the 6,028 individuals we measured were juveniles. In general, juvenile and adult individuals of most resident species were captured at all stations and habitats. Very few adult individuals of oceanic migratory (anadromous and/or nomadic types) species were captured, but their young were often the most abundant fish in the intermediate and deep water habitats. Of the three habitats sampled at each station, the shallow water habitat had the most diverse fish communities, supporting up to twice as many species as the intermediate or deep water habitats.

A review of published and unpublished studies suggests that there is little difference between the historical (pre-1980) fauna for the Delaware River mainstem from the C&D Canal to Trenton and the fauna reported since 1980. Among the changes that have occurred is the extirpation of rainbow smelt and longnose gar and recent appearance of some species not observed in the historical record (although probably present during those earlier times). We also note the presence of non-reproductive hybrids of both striped bass and muskellunge in the region's fauna. Overall, faunal composition within specific Delaware River Basin Commission (DRBC) Water Quality Zones differs little between historical and recent times or among the Water Quality Zones, except that the fauna of Water Quality Zone 5 (Wilmington

to the C&D Canal) always has included more species with a saltwater affinity in addition to the freshwater-associated species found in all the Water Quality Zones. Our sampling added one or two new species to the fauna of each Water Quality Zone, but only one of these species (black seabass) was a new addition to the documented fauna between Trenton and the C&D Canal.

ACKNOWLEDGEMENTS

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We extend our appreciation to Messrs. Thomas A. Baum (New Jersey Bureau of Marine Fisheries), Richard A. Snyder (Pennsylvania Fish and Boat Commission), and Stewart F. Michels (Delaware Division of Fish and Wildlife) for the retrieval of recent location-specific species occurrence data.

Mr. Robert M. Nyman (United States Environmental Protection Agency - Region II) was the project officer and provided liaison between T. Lloyd Associates, and the Delaware River Basin Commission, along with other entities important to the completion of this project.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

At the request of the Scientific and Technical Advisory Committee (STAC) of the Delaware Estuary Program, T. Lloyd Associates investigated the fishes of the Delaware Estuary in a 122-km reach extending from Trenton to the C&D Canal. The study is part of an overall effort to develop a Comprehensive Conservation and Management Plan (CCMP) for the estuary. In developing the plan, the STAC expressed interest in obtaining a picture of the fish resources of the estuary based on a combination of short-term (one year) field studies and a review of data from previous as well as ongoing fish studies.

The principal objectives of our study were as follows:

1. Determine the species present and their relative abundance throughout the 122-km study region and within specific aquatic habitats defined by depth.
2. Sample on a seasonal basis (spring, summer, and fall) to observe all available fish life stages at points in the river where fish diversity and abundance were thought to be maximal for each of the DRBC Water Quality Zones of the river.
3. Determine the use of the Delaware estuary as a nursery for juvenile fishes and a general habitat for adult fishes.
4. Compare current results with historical data to document suspected fish population improvements within the study area.

Although it was not one of our stated objectives, we have attempted to make this study "reproducible" by describing our gear, sampling methodology, and sampling sites in considerable detail as requested by the STAC.

METHODS

To accomplish the first objective, we sampled four stations, one within each Water Quality Zone (WQZ) as designated by the Delaware River Basin Commission (DRBC, 1986). As shown in Figure 1, the river between Trenton and the C&D Canal includes all or a major portion of Zones 2 to 5. Specific locations for sampling within each WQZ were based on the availability of supporting data and the areal extent of habitat suitable for sampling. Our sampling stations were centered on the mouth of the Rancocas Creek, Big Timber Creek, Raccoon Creek, and the Salem River because Pennsylvania, New Jersey, and Delaware state fishery agencies had been monitoring these locations and provided us with much data. Also, a review of nautical charts indicated that nearby there was ample shallow, intermediate, and deep water habitat in the mainstem Delaware River for us to conduct our sampling program.

We defined the three habitats as follows: 1) shallow water -- intertidal and submerged areas -3.05 meters (m) mean low water (MLW) or less; 2) intermediate water -- areas with depth of -3.05 to -7.62 m MLW; and 3) deep water -- areas with depths greater than -7.62 m MLW. The intermediate and deep water habitats were further subdivided into mid-water (pelagic) and bottom zones. Our definition for shallow water, -3.05 m MLW, follows Tyrawski (1979).

In order to provide some insight into the seasonal distribution of fishes in the Delaware estuary, we sampled in September and October 1992, and May 1993, when river water temperatures were representative of the summer, fall, and spring seasons.

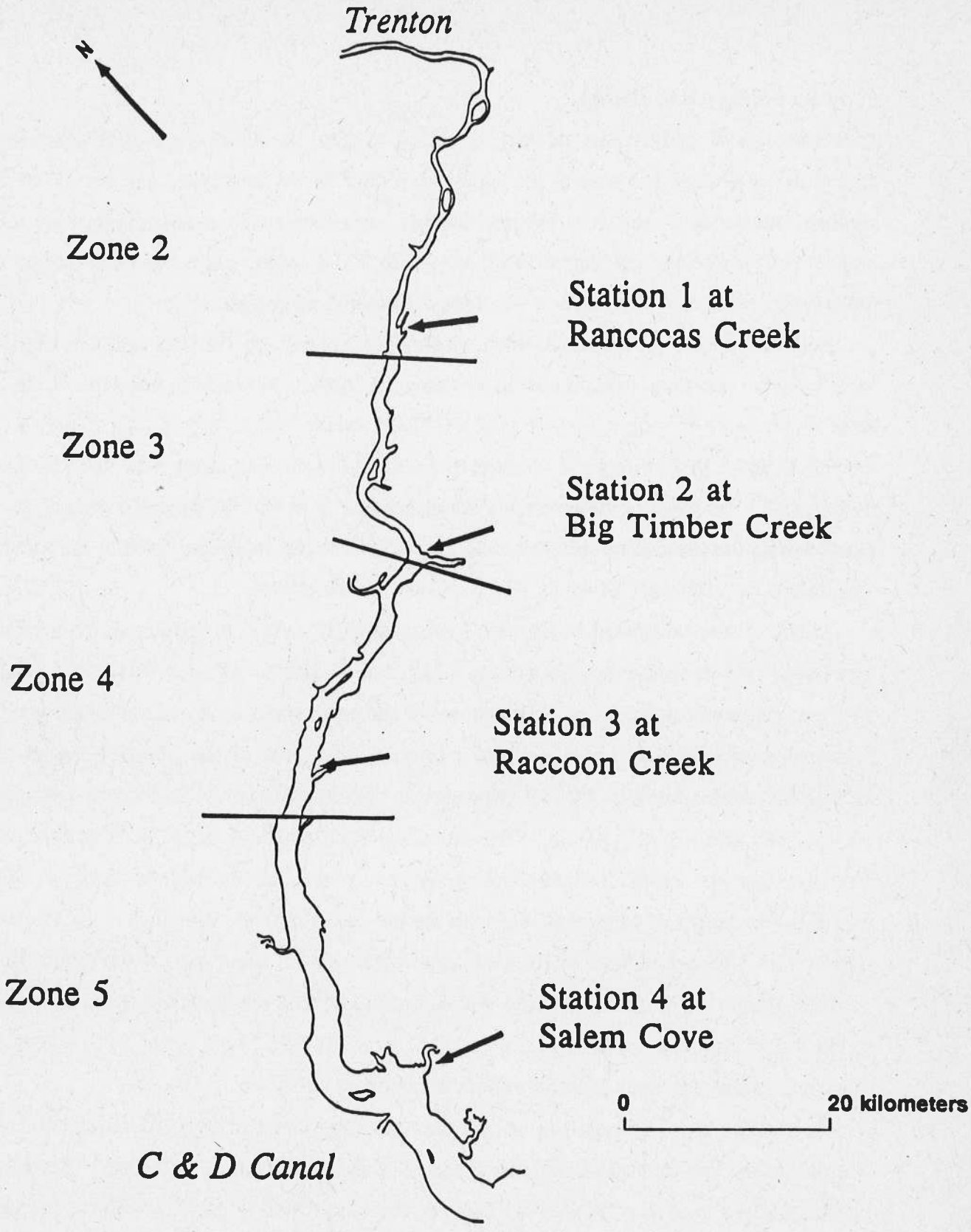

Figure 1. Map of the upper Delaware River estuary between Trenton, New Jersey, and the Chesapeake and Delaware Canal showing the sampling stations in the Delaware River Basin Commission's Water Quality Zones 2-5.

Field Sampling Methodology

Measurements of salinity, conductivity, dissolved oxygen, and temperature were taken once during the beginning and once at the end of each field day at the surface and bottom of the shallow, intermediate, and deep habitats. Salinity and conductivity measurements were taken with a Yellow Springs Instrument (YSI) Model 33 S-C-T meter, while dissolved oxygen and temperature were measured with a YSI Model 57 dissolved oxygen meter.

Both active gear (beach seine, trawl, electroshocker) and passive gear (gill net, trotline) were used for sampling at each station as shown in Table 1. Nominal dimensions of the beach seines were: 4.88 m long x 1.83 m deep x 0.32 cm mesh; 7.62 m long x 1.83 m deep x 0.48 cm mesh; and 15.24 m long x 2.44 m deep x 0.64 cm mesh. The fabric was Ace knotless nylon mesh. The beach seines were let out perpendicular to the shoreline and moved in parallel with the prevailing current before arcing back to the shoreline. Each of the three nets was fished for a distance of 61 m; this took two to four efforts.

Trawling was conducted in all three habitats at each station. A small, semi-balloon otter trawl was used to sample bottom species in the shallow habitat where it was fished parallel to and with the prevailing current. Dimensions for the small trawl were: 1.83-m headrope, 2.44-m footrope with 0.32-cm chain, body of 3.18-cm stretch mesh of No. 12 nylon thread, codend of 3.18-cm stretch mesh of No. 15 nylon thread, and codend liner of 0.48-cm Ace knotless nylon mesh with a catch retaining fyke within the liner mouth. A larger, semi-balloon otter trawl was used to sample bottom-dwelling species in both the intermediate and deep habitats where it was fished in parallel to and with the prevailing current. Dimensions for the larger trawl were: 5.49-m headrope, 6.10-m footrope with 0.48-cm chain only at the wings, body of 4.76-cm stretch mesh of No. 9 nylon thread, codend of 0.48-cm stretched mesh of No. 18 nylon thread, and codend liner of 0.48-cm Ace knotless nylon mesh with a 0.61-m catch retaining flap of the same material within the liner mouth.

A butterfly trawl was used to sample the mid-water zones of both the intermediate and deep habitats. The trawl was fished in a zone that extended from 0.61 m below the water surface to 3.05 m above the bottom. This net was also fished in parallel with the prevailing current. Nominal dimensions for the mid-water trawl were: 3.20-m mouth diameter, 0.48-cm chain along the footrope, body of 5.84 cm to 29.21 cm stretch mesh of No. 18 nylon and polypropylene threads, codend of 4.13-cm stretch mesh of No. 9 nylon thread, and codend

Table 1. Fish sampling effort expended during each season (spring, summer, and fall) in each of the four sampling areas (Rancocas Creek, Big Timber Creek, Raccoon Creek, and Salem River vicinities) during 1992 and 1993.

Gear[a]	Number of Units	Habitats[a]					
		Intertidal	Shallow	Inter-mediate Bottom	Inter-mediate Midwater	Deep Water	Deep Mid-water
BEACH SEINES:							
4.88 m	1	61 m haul distance					
7.62 m	1	"					
15.24 m	1	"					
GILL NETS:							
2.50 cm	2			6 hr soak time		6 hr soak time	
5.01 cm	2			"		"	
7.51 cm	2			"		"	
10.02 cm	2			"		"	
12.52 cm	2			"		"	
15.02 cm	2			"		"	
17.53 cm	2			"		"	
20.03 cm	2			"		"	
TRAWLS:							
1.83-m otter	1		4 x 5 min tows				
5.49-m otter	1			4 x 5 min tows		4 x 5 min tows	
3.20-m midwater	1				4 x 5 min tows		4 x 5 min tows
TROTLINE:							
30.48 m	4		2 units				
ELECTRO-SHOCKER:							
Boat mounted	1	1.00 hrs					

[a]See text for descriptions and specifications of habitats and gear.

liner of 0.48-cm Ace knotless nylon mesh with a 0.61-m-long catch retaining flap of 0.64-cm Ace knotless nylon mesh within the liner mouth.

Each of the three trawls was towed for a cumulative total of five minutes; most collections were made with a single deployment. However, if the trawl became entangled in the bottom, the entire effort was repeated or the trawl was deployed more than once to obtain five minutes of bottom time. All trawls were towed in the direction of the current from a 6.9-m craft powered by a 175-h.p. outboard motor. The 5.49-m bottom trawl and the mid-water trawl were towed at a speed of 1100 rpm; the 1.83-m bottom trawl was towed at a speed of 1400 rpm.

Bottom gill nets were set parallel to the current in the intertidal and deep water habitats at each station for a nominal fishing time of six hours. Two nets, each four panels (20.12 m long x 1.83 m deep) long, were set in each habitat. The eight panels in each habitat were of 2.50 cm to 20.03 cm stretch mesh nylon monofilament fabric in 2.50-cm increments. The panel sequences were randomly determined for each station's sampling, but the sequences between habitats at a station were identical.

A small electroshocker (Dirigo 500) was employed in the shallow habitat, along the shoreline and other structure that could not be sampled adequately by trawl or beach seine. The electroshocker had pulsed D.C. current. Output voltage was continuously variable 0-600 V peak. The maximum current output was 10 amps. Actual fishing time averaged one hour.

We set four trotlines during the summer season at each station, two each in both the intermediate and deep habitats, for a duration of 6 hours. Each trotline was 30.48 m long bearing 25 #6 hooks on 30.05-cm swiveled droppers. The hooks were baited with fresh fish and/or shrimp.

With few exceptions, we sampled each station, each season as described above. The trotlines were deployed only once because of interference from blue crabs. All other exceptions involved trawling. We made three unsuccessful attempts to fish the mid-water trawl in the intermediate depth habitat at Station 1 in the fall. Each time the net became fouled on the bottom and rather than risk severe damage or loss that would preclude mid-water trawling at the other three stations, we retired the net. Because of bottom snags and net damage, we had to substitute the small (1.83 m) otter trawl for the large (5.49 m) trawl at Stations 2 and 3 in the intermediate and deep water habitats during the summer sampling

round. The large trawl was used successfully at both stations during the subsequent sampling rounds.

After each gear effort, fish were identified, enumerated, and up to 20 individuals of each species were measured (fork length to nearest millimeter). Any fish that could not be identified readily in the field were fixed and preserved with 10% formalin solution for later identification. When individuals of any given species were disparate in size, a conscious effort was made to measure a representative sample of the catch. If all individuals of a given species were similar in size, individuals were selected randomly for measurement.

The measurements we made were used to investigate use of the estuary as a nursery for juvenile fishes (study objective 3). We consulted the literature to relate length of individuals to sexual maturity (our criterion for classifying an individual as an adult or juvenile). Minimum fork lengths (FL) for adults are presented in Table 2, followed by footnotes.

Table 2. Minimum fork lengths (FL) of adult fishes used for determining percentage of juveniles in catch by T. Lloyd Associates in the Delaware River and Estuary between Trenton, NJ, and the C & D Canal.

Common name	Adult length (FL) in mm	Footnotes
Shortnose sturgeon	400	14
Atlantic sturgeon	1527	16,23
American eel	279	4,13
Blueback herring	230	12
Alewife	104	12
American shad	275	1,14
Atlantic menhaden	210	10
Gizzard shad	204	2,14
Bay anchovy	37	1,14
Satinfin shiner	48	2,14
Common carp	196	2,14
Eastern silvery minnow	50	2,14
Golden shiner	58	1,14
Spottail shiner	68	2,14
Bluntnose minnow	36	2,14
White sucker	239	7,22
White catfish	189	2,21
Brown bullhead	150	4,22
Channel catfish	221	9,15
Tiger muskellunge	618	2,3,14
Banded killifish	50	4,14
Mummichog	76	4,14
Rough silverside	-	26
Inland silverside	38	2,8
Atlantic silverside	-	26
Fourspine stickleback	36	1,14
White perch	110	1,14
Striped bass	279	17,25
Black seabass	>35	5,24
Redbreast sunfish	54	2,14
Green sunfish	58	2,22
Pumpkinseed	58	2,22
Bluegill	81	2,22
Smallmouth bass	182	2,14
Largemouth bass	231	2,22
Tessellated darter	40	4,14
Yellow perch	138	2,14
Bluefish	350	18
Silver perch	143	1,14
Weakfish	228	2,20
Spot	194	2,11
Atlantic croaker	185	4,19
Naked goby	23	4,14
Butterfish	162	2,11
Smallmouth flounder	>25	4,5,24
Summer flounder	>166	4,6
Hogchoker	80	4,14

Table 2 Footnotes

1. Reported standard length (SL) converted to fork length (FL) using an arbitrary factor of 1.1, such that FL=1.100 SL. The result rounded-off to the nearest mm.

2. Reported total length (TL) converted to fork length (FL) using an arbitrary factor of 0.909 such that FL=0.909 TL. The result rounded-off to the nearest mm.

3. Used minimum adult length of muskellunge for this determination as tiger muskellunge very closely exhibit much of this parent's character.

4. For practical purposes FL=TL, as dorsal and ventral lobes of the caudal fin do not have rays longer than caudal fork rays, the caudal fin being either blunt, rounded, or tapering to a point.

5. Observed FL was barely larger than reported lengths of early metamorphosed juveniles.

6. Observed FL is less than normal first year's growth and maturity is reached during the second year (# 27).

7. Carlander, K. D. 1969. Handbook of freshwater fishery biology. Volume 1. The Iowa State University Press, Ames, Iowa.

8. Coorey, D. N., K. W. Able, and J. K. Shisler. 1985. Life history and food habits of the inland silversides, Menidia beryllina, in a New Jersey salt marsh. The Bulletin of the New Jersey Academy of Science 30:29-37.

9. DeRoth, G. C. 1965. Age and growth studies of channel catfish in western Lake Erie. J Wildl. Mgmt. 29(2):280-286.

10. Higham, J. R., and W. R. Nicholson. 1964. Sexual maturation and spawning of Atlantic menhaden. U.S. Fish Wildl. Serv. Fish. Bull. 63:255-271.

11. Hildebrand, S. F., and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. U. S. Fish and Wildl. Serv. Fishery Bulletin 53. Bur. Fish. Doc. 1024.

12. Johnson, H. B., S. E. Winslow, D. W. Crocker, B. F. Holland, Jr., J. W. Gillikin, and D. L. Taylor. 1979. Biology and management of Mid-Atlantic anadromous fishes under extended jurisdiction, Part I: North Carolina. Special Scientific Report No. 36 of the North Carolina Department of Natural Resources and Community Development.

13. Katz, M. 1954. Reproduction of fish. Data for Handbook of Biological Data.

14. Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Staufeer, Jr. 1980. Atlas of North American freshwater fishes. Publication #1980-12 of the North Carolina Biological Survey. North Carolina State Museum of Natural History.

15. Magnin, E. and G. Beaulieu. 1966. Divers aspects de la biologie et de l'ecologie de la barbue Ictalurus punctatus (Rafinesque) du fleuve Saint-Laurent d'apres les donnees du marquage. Naturaliste Canadien 92:277-291.

16. Magnin, E. 1962. Recherches sur la systematique et la biologie des Acipensendes, Acipenser sturio L., Acipenser oxyrhynchus Mitchill et Acipenser fulvescens Raf. Ann. Sta. Cent. Hydrobiol. Appl. 9:7-242.

17. Mansueti, R. J. 1961. Age, growth, and movements of the striped bass, Roccus saxatilis, taken in size selective fishing fear in Maryland. Chesapeake Sci. 2:9-36.

18. Pottern, G. B., M. T. Huish, and J. H. Kerby. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (mid-Atlantic)--bluefish. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.94). U.S. Army Corps of Engineers, TR EL-82-4.

19. Public Service Electric and Gas Company. 1984. Salem Generating Station 316(b) demonstration.

20. Shepherd, G. R., and C. B. Grimes. 1984. Reproduction of weakfish, Cynoscion regalis, in the New York Bight and evidence for geographically specific life history characteristics. U.S. Nat. Mar. Fish. Serv. Fish. Bull. 82(3):501-511.

21. Stevens, R. E. 1959. The white and channel catfishes of the Santee-Cooper Reservoir and tailrace sanctuary. Proc. S. E. Assoc. Game Fish Comm., 13:203-219.

22. Trautman, M. B. 1981. The fishes of Ohio. Ohio State University Press.

23. Vladykov, V. D., and J. R. Greeley. 1963. Order Acipenseroidei. Soft-rayed bony fishes. Fishes of Western North Atlantic, Mem. Sears Found. Mar. Res. 1(3):24-60.

24. Wang, J. C. S., and R. J. Kernehan. 1979. Fishes of the Delaware estuaries: a guide to the early life histories. EA Communications.

25. Westin, D. T., and B. A. Rogers. 1978. Synopsis of the biological data on the striped bass. Univ. R. I. Mar. Tech. No. 67.

26. Documentation of minimum fork length of the adult fish was not available, have therefore based the critical limit upon the reports (#8) for inland silverside.

27. Grimes, B.H., M.T. Huish, J.H. Kerby, and D. Moran. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic)--summer and winter flounder. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.112). U.S. Army Corps of Engineers, TR EL-82-4.

Review of Secondary Data Sources

To obtain additional information on historical and recent fish species occurrences within DRBC Water Quality Zones 2 through 5, we examined information from a number of published sources. Information for the period prior to 1922 came mainly from the work of Henry W. Fowler, who developed lists of fishes collected by himself or others (Kiry, 1974). Fish species occurrence data for the period 1957 through 1979, a period in which water quality levels exhibited considerable improvement (Marino et al. 1991), was extracted from Academy of Natural Sciences of Philadelphia (1974), Dadswell et al. (1984), Kiry (1974), and Tyrawski (1979).

A current (1980 to present) species list for the each of the DRBC Water Quality Zones was developed from the results of the present study and other sources (Beck et. al. 1985; Biosystems Analysis, Inc., 1990; Bureau of Marine Fisheries, 1993; Dadswell et. al. 1984; DRBC, 1988; Fisheries Management Division, 1993; Hastings, 1983a and 1983b; Lazzari et. al. 1986; O'Herron pers. obs., 1983; O'Herron and Able 1990; O'Herron and Hastings 1985; O'Herron and Lloyd 1986; RMC Environmental Services 1988; T. Lloyd Associates 1992, 1991b, and 1990; Shirey 1992a and b; Stutz 1992; Summers 1987).

DESCRIPTION OF SAMPLING STATIONS

Station 1

Station 1 was centered on the mouth of the Rancocas Creek at kilometer 179 (Figure 2), but sampling occurred between km 176 and km 183. All three habitats (shallows, intermediate, and deep water areas) occur here, but suitable intermediate habitat (-3.05 m to -7.62 m MLW) was difficult to find because of its limited areal extent and, where present, the prevalence of dredge spoils and debris hampered trawling. Deep water habitat was found mostly within the Torresdale and Mud Island Shoal Ranges where the channel is 100 meters wide. Shallow water habitat, including intertidal flats, was extensive around Mud Island on the Pennsylvania side and all along the New Jersey shoreline, including Dredge Harbor. Shallow habitats generally had a sand and gravel substrate, although fine sediments were readily found at Mud Island Shoal, Dredge Harbor, and within the mouth of Rancocas Creek. The sand and gravel areas supported a minor amount of emergent and submergent vegetation, including wild rice (Zizania aquatica), cow lily (Nuphar advena), and wild celery (Vallisneria americana), whereas the areas having fine sediments supported dense vegetation beds.

The trawls and gill nets were deployed upstream from Rancocas Creek in the vicinity of Mud Island and downstream off Wright Point, near red buoy No. 18 (Figure 2). Seining was done along the shoreline of Hawk Island and in Wright Cove. The electroshocker was used mainly along the shoreline of Dredge Harbor, where there was riprap and submerged pilings, but we also fished a cove on the south side of Rancocas Creek near Riverside Park.

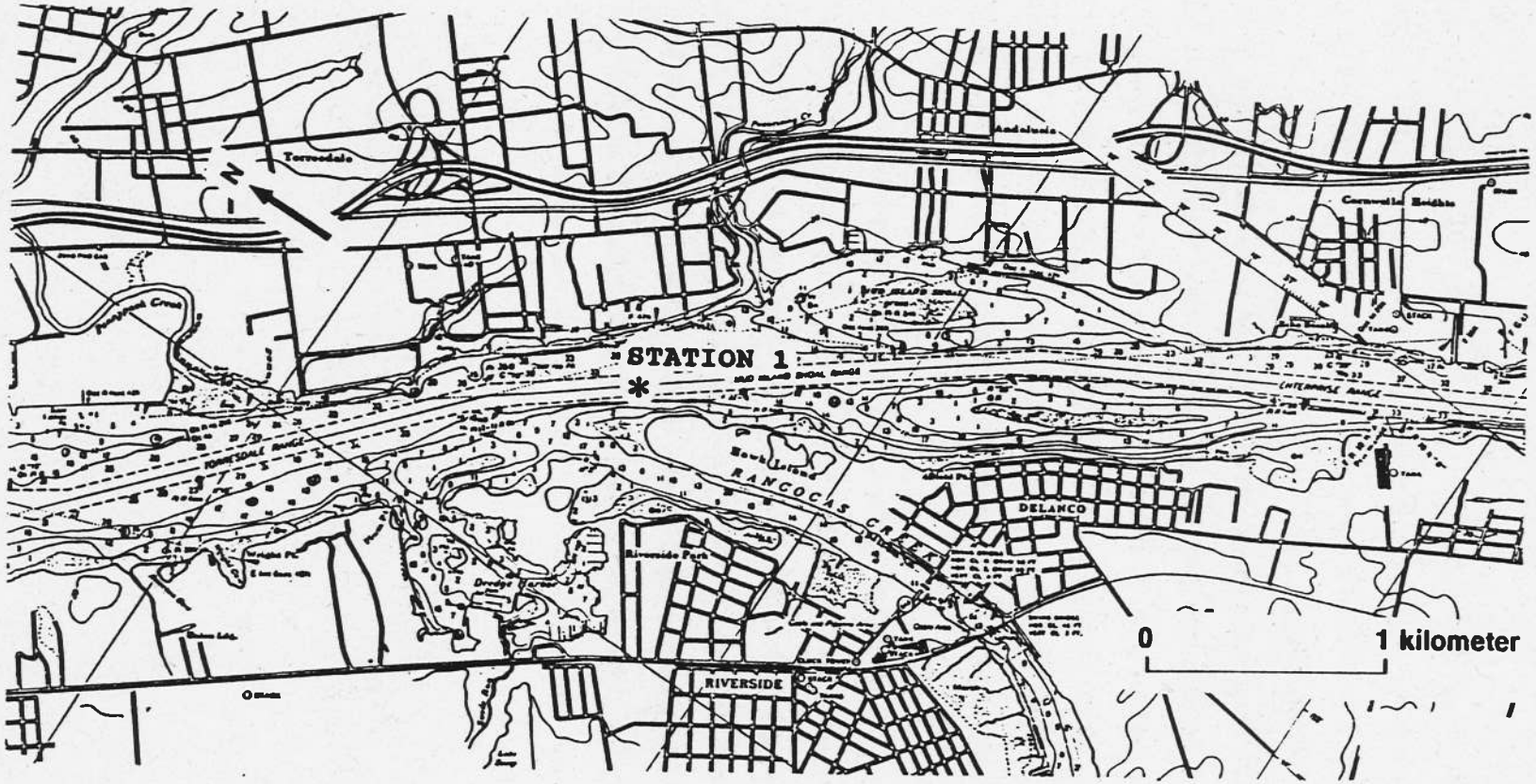

Figure 2. Map of the upper Delaware River estuary in the vicinity of Rancocas Creek showing the nominal location of Station 1. Portion of map from National Ocean Service (1990).

Station 2

Historically, the poorest water quality has been found in WQZ 3, primarily as a result of industrial and municipal wastewater discharges from Philadelphia and Camden (Marion et al., 1991). Our station 2 centered on the mouth of Big Timber Creek (km 153.5), opposite the Philadelphia waterfront (Figure 3).

Extensive shallows occur on the New Jersey side of the river in the vicinity of National Park, but not on the Pennsylvania side, where Horseshoe Shoal off League Island provided nearly all of this habitat type. A dense bed of wild celery was present in a cove west of National Park and beds of sago pondweed (Potamogeton pectinatus) were widespread in the shallows surrounding an island off the mouth of the Schuylkill River. Big Timber Creek and the river shoreline supported extensive stands of emergent species, such as cow lily and arrow arum (Peltandra virginica).

Shallow water trawling and seining were done in the cove off National Park and the island off the mouth of the Schuylkill River. Intermediate depth habitat suitable for trawling was found off League Island and in a trough offshore from National Park. Trawling was done, and gill nets were set, in the Eagle Point Range and in Anchorage Area No. 9 off National Park, where depths ranged from -11.0 m MLW to -12.8 m MLW.

Electroshocking collections were made along old bulkheads in the lower Big Timber Creek, in a lagoon upstream from Big Timber Creek, and across the river along the riprap shoreline of League Island.

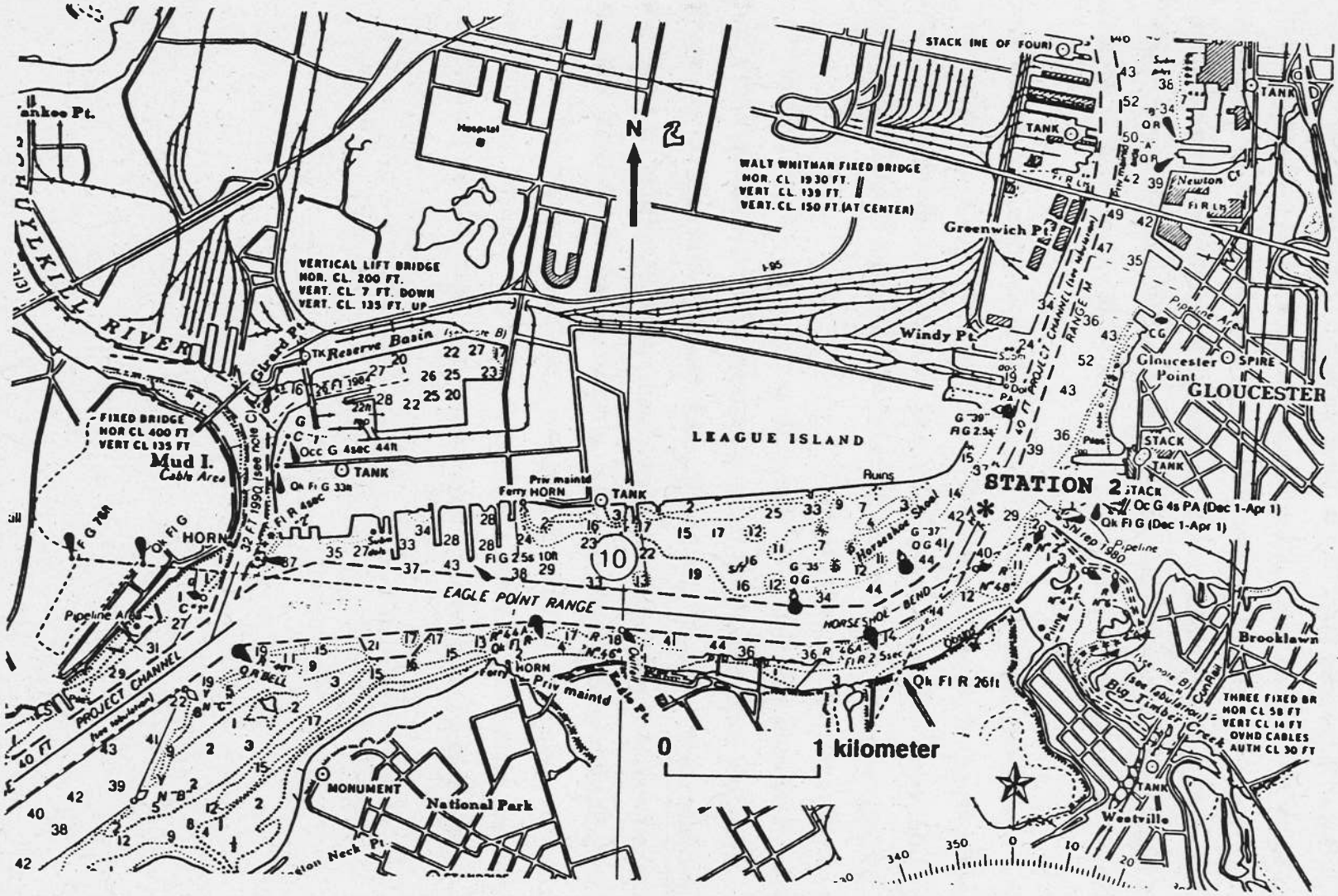

Figure 3. Map of the upper Delaware River estuary in the vicinity of Big Timber Creek showing the nominal location of Station 2. Portion of map from National Ocean Service (1991).

Station 3

Sampling at Station 3 extended from 1.9 km above the mouth of Raccoon Creek (km 129.7) to 4.67 km below it (Figure 4). Much of the intermediate depth habitat occurred as a narrow band adjacent to the New Jersey side of the channel, but downstream from the Commodore Barry Bridge an area up to 200 meters wide was found to be suitable for sampling. Below Raccoon Creek, shallow flats extend at least one-third of the way across the river; beyond the flats, the depth increases abruptly from -1 m to -1.5 m MLW to - 11 m MLW in Anchorage Area No. 7.

Shallow water habitat along the Pennsylvania side was limited in extent; the soft bottom was composed mainly of silt and organic matter. The flats on the New Jersey side, which were more firm, were composed mainly of silty sand. Emergent and submergent vegetation occurred sparingly along the riverfront, but the shallows of Raccoon Creek supported dense stands of cow lily, arrow arum, and wild rice.

Deep water trawling was done in the Marcus Hook Range and Anchorage Area 7. Suitable intermediate depth habitat was found downstream of the Commodore Barry Bridge on the New Jersey side, where gill nets also were set. Our deep water gill net sets were made in Anchorage Area No. 7 and at the edge of the channel downstream from the Commodore Barry Bridge. Shallow water trawling was done at the mouth of Raccoon Creek and over flats upstream and downstream of the creek. Seining was done along a sandy beach just north of the creek mouth, whereas most electrofishing was done in Raccoon Creek near the mouth, although we also fished a partially submerged creek system upstream from the creek mouth.

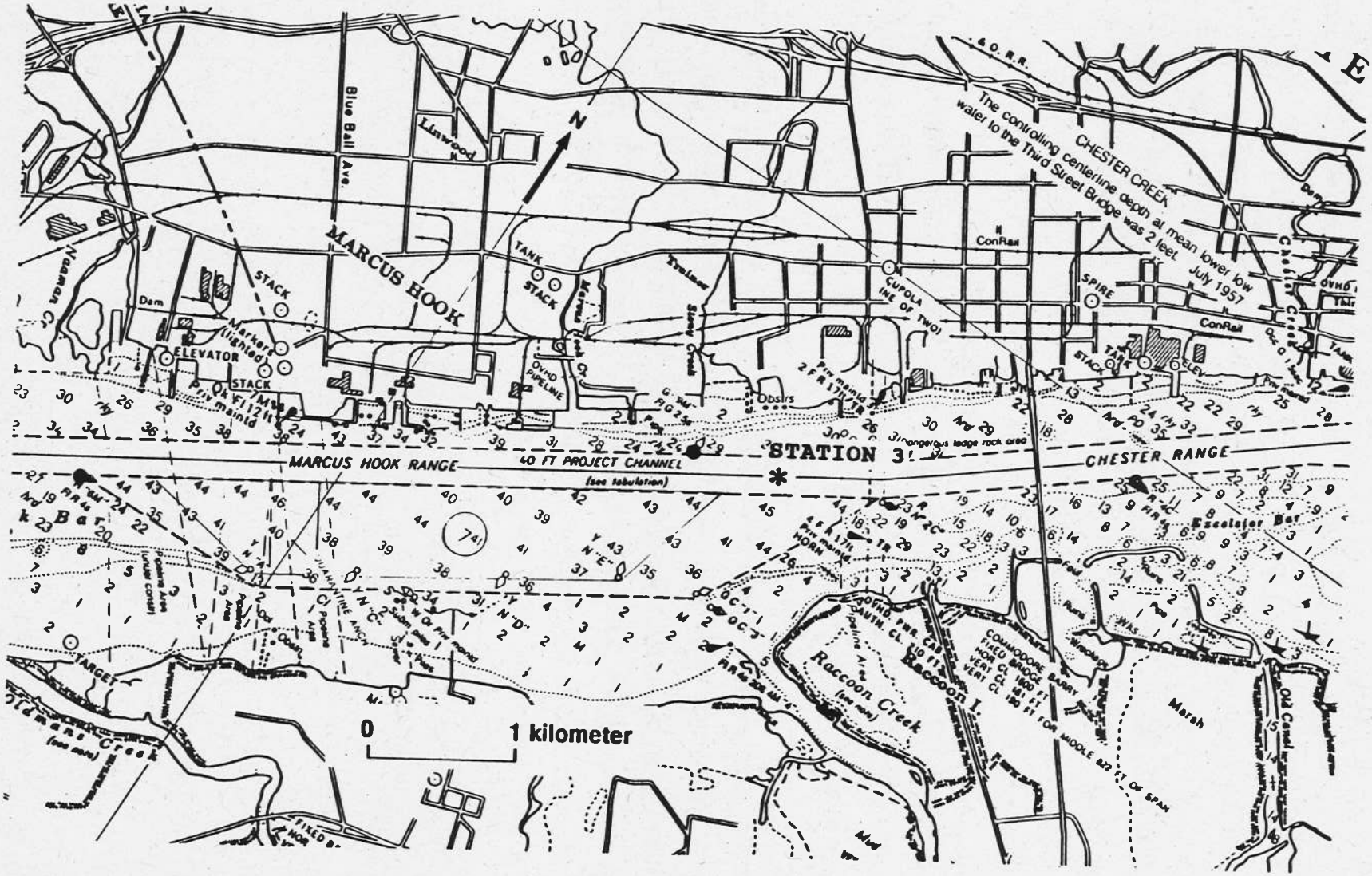

Figure 4. Map of the upper Delaware River estuary in the vicinity of Raccoon Creek showing the nominal location of Station 3. Portion of map from National Ocean Service (1991).

Station 4

Sampling at Station 4 extended from 1.75 km upstream from the mouth of the Salem River (km 94) to 3.7 km below the river mouth (Figure 5). There was ample space to sample all three habitats on the east side of the channel between Elsinboro Point (New Jersey) and Pea Patch Island. The estuary was conspicuously wider and deeper here than any station upstream. At its widest point, the river between Reedy Point on the Delaware side and the entrance to the Salem River on the New Jersey side is about 4.8 km across. Salem Cove offers about 1200 hectares of shallow water habitat. The Cove is bordered by a strip of intermediate depth habitat 5 km long and up to 200 meters wide. The channel exceeds -12 m MLW; we found depths up to -20 m MLW near the wreck of the Warrior Phoenix.

Common reed (Phragmites australis) dominated the shoreline, but below the apparent mean high tide line there were numerous stands of saltmarsh cordgrass (Spartina alterniflora). The sandy substrate seemed to extend across the river and provided a smooth, featureless bottom.

Trawling deep and intermediate depth habitats was done in the New Castle Range and to the east of the channel, where depths ranged from 4 to 6 m. Gill nets were deployed near the wreck of the Warrior Phoenix and at the seaward end of the New Castle Range near the "2N" red nun buoy. All shallow water trawling and some of the seining was done off Oakwood Beach. However, seining also was done at Elsinboro Point and at a man-made (dredge spoil) island on the northwest side of the channel near the Salem River.

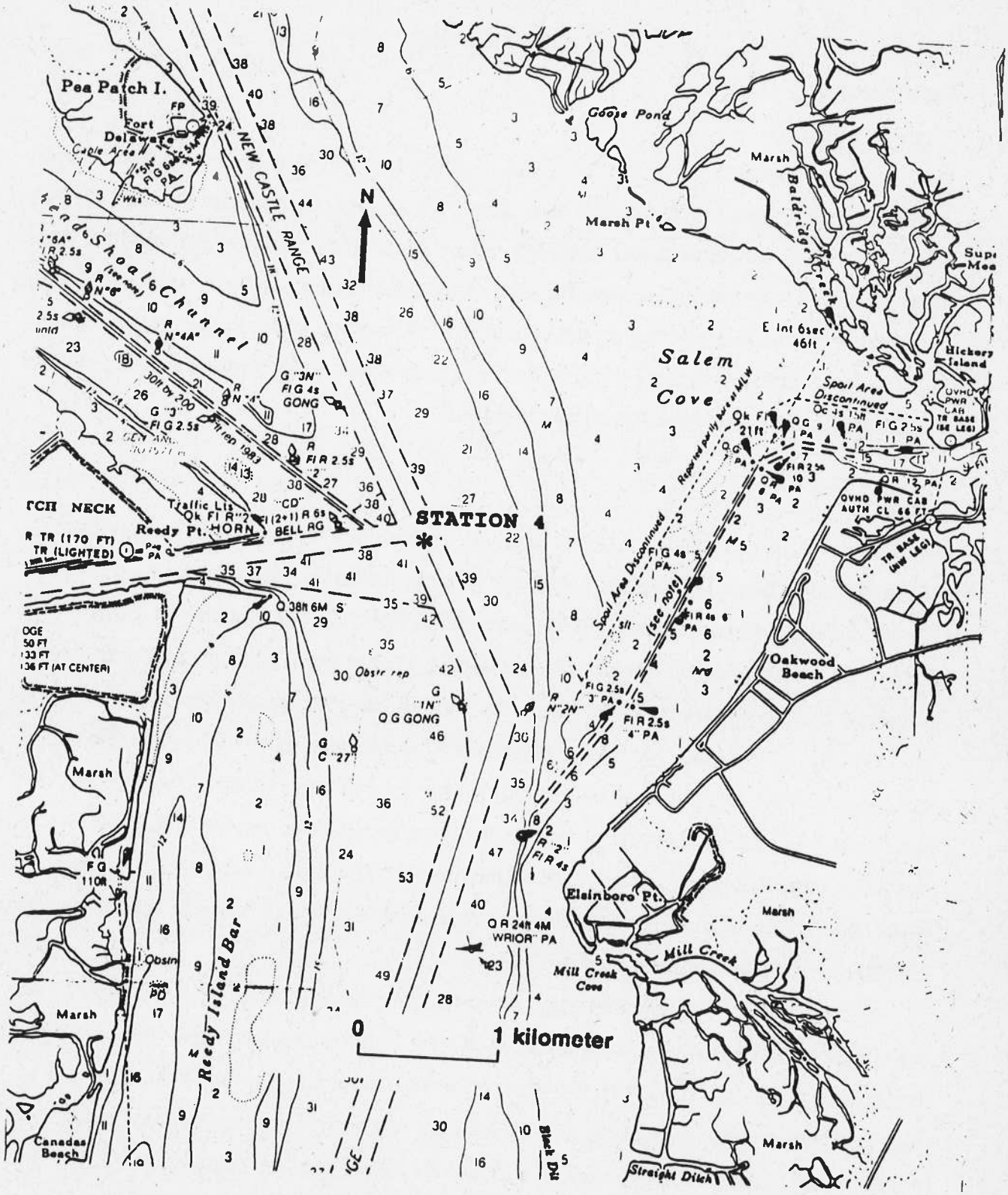

Figure 5. Map of the upper Delaware River estuary in the vicinity of Salem Cove showing the nominal location of Station 4. Portion of map from National Ocean Service (1991).

RESULTS

Field Studies

Water Quality

Data on water temperature, dissolved oxygen, conductivity, and salinity are reported for each station in Appendices 1-4. In general, these data were as might be expected for the Delaware River. The water temperature and dissolved oxygen conditions on each of the sampling dates were consistent with normal patterns for each of the three seasons studied. Salinity at Stations 3 and 4 was variable depending on tidal conditions, but generally was higher, reflecting the more seaward position of these stations. Overall, water quality data revealed nothing unusual that might have distorted the fish sampling results.

Station 1

Sampling at Station 1 yielded 5,184 individuals representing 31 species and 15 families (Table 3; Appendices 1-2 through 1-4). Four species constituted 78.3% of the catch: white perch (32.5%), blueback herring (26.5%), channel catfish (10.6%), and banded killifish (8.7%); four other species, Eastern silvery minnow, hogchoker, American shad, and bluegill, contributed an additional 10.2% of the catch. The fall sampling round, which was conducted from October 13th to October 20th, yielded almost three times more fish than either the summer or spring collections and somewhat higher diversity. In October, blueback herring numbered 1,222 individuals and accounted for more than 40% of the fall collection, but there were also large catches of white perch, channel catfish and banded killifish. The spring collection yielded only 21 species; the catch was dominated by white perch (38.6%), banded killifish (19.4%), and channel catfish (14.5%).

Among clupeids (blueback herring, American shad, gizzard shad, etc.) the majority of alewife, blueback herring, and American shad were outmigrating juveniles, which were caught in the deep water habitat by the mid-water trawl (see especially Appendix 5). However, species diversity was twice as high in the shallow water habitat which was favored by white perch, sunfish and minnow species. We measured 28% of the fish captured and found that 23 of the 31 species recorded at this station were represented by juveniles (Appendices 5-1 through 5-3). In the spring of 1993, 47% of the fish measured were juveniles compared to 62% the previous fall. Juveniles were found in all three habitats.

Table 3. Rank, numbers (#) and relative abundance (%) of individuals of fish species captured at Station 1 by season. Numbers presented are for the combined catch by each gear type, each season.

Common name	Summer			Fall			Spring		
	Rank	#	%	Rank	#	%	Rank	#	%
Atlantic sturgeon	17	1	0.1	-	0	0.0	-	0	0.0
American eel	17	1	0.1	16	11	0.4	14	3	0.3
Blueback herring	2	88	8.6	1	1222	40.4	5	65	6.3
Alewife	8	31	3.0	13	16	0.5	15	2	0.2
American shad	3	77	7.5	6	62	2.0	-	0	0.0
Gizzard shad	11	16	1.6	-	0	0.0	-	0	0.0
Bay anchovy	15	3	0.3	20	2	0.1	-	0	0.0
Common carp	-	0	0.0	21	1	0.0	-	0	0.0
Eastern silvery minnow	17	1	0.1	9	45	1.5	4	97	9.4
Golden shiner	16	2	0.2	-	0	0.0	9	27	2.6
Spottail shiner	12	13	1.3	12	17	0.6	13	8	0.8
Bluntnose minnow	-	0	0.0	-	0	0.0	16	1	0.1
White sucker	14	4	0.4	21	1	0.0	16	1	0.1
White catfish	15	3	0.3	15	12	0.4	10	15	1.5
Brown bullhead	16	2	0.2	21	1	0.0	-	0	0.0
Channel catfish	5	50	4.9	3	350	11.6	3	149	14.5
Banded killifish	9	27	2.6	4	223	7.4	2	199	19.4
Mummichog	-	0	0.0	11	22	0.7	6	52	5.1
Inland silverside	4	63	6.1	21	1	0.0	-	0	0.0
Fourspine stickleback	14	4	0.4	17	10	0.3	-	0	0.0
White perch	1	517	50.3	2	770	25.5	1	396	38.6
Striped bass	13	11	1.1	14	13	0.4	11	12	1.2
Redbreast sunfish	16	2	0.2	-	0	0.0	14	3	0.3
Green sunfish	-	0	0.0	21	1	0.0	16	1	0.1
Pumpkinseed	13	11	1.1	5	97	3.2	11	12	1.2
Bluegill	7	33	3.2	10	24	0.8	7	46	4.5
Largemouth bass	17	1	0.1	18	8	0.3	14	3	0.3
Tessellated darter	10	17	1.7	8	50	1.7	12	9	0.9
Yellow perch	-	0	0.0	20	2	0.1	-	0	0.0
Atlantic croaker	-	0	0.0	19	4	0.1	-	0	0.0
Hogchoker	6	49	4.8	7	60	2.0	8	31	3.0
Total Individuals		1027	100.0		3025	100.0		1132	100.0
Total Species		25			26			21	

Station 2

Station 2 yielded 28 species (only three fewer than Station 1), but about 38% fewer individuals (Table 4; Appendices 2-2 through 2-4). Nevertheless, the capture of two shortnose sturgeon, a smallmouth bass and more than half of the American shad taken at all four stations made this station noteworthy. The ten species listed below made up 92% of the catch:

White perch	27.6%	Hogchoker	6.7%
Blueback herring	11.5%	Channel catfish	5.9%
Bay anchovy	11.0%	Spottail shiner	4.8%
American shad	9.2%	Eastern silvery minnow	4.5%
Banded killifish	8.5%	Mummichog	2.3%

Although seasonal faunas differed slightly, each of the three samplings yielded 21 species (Table 4), The maximum number of individuals was caught in the fall and the fewest in May 1993. The shallows yielded more individuals and 1.6 to 1.8 times as many species as intermediate or deep water habitats. Species found only in the shallows included banded killifish, mummichog, rough and inland silverside, pumpkinseed, and naked goby. More than four times as many striped bass were caught in the shallows as in deep water, but the shortnose and Atlantic sturgeon, as well as most clupeids, came from water deeper than -10.0 MLW.

We measured 45% of the fish captured at Station 2 and found that juveniles constituted slightly more than half (51%) of those measured (Appendices 6-1 through 6-3). Of the 16 species represented by juveniles, 100% of blueback herring, alewife, American shad, Atlantic croaker, Atlantic menhaden, and hogchoker were juveniles.

Table 4. Rank, numbers (#) and relative abundance (%) of individuals of fish species captured at Station 2 by season. Numbers presented are for the combined catch by each gear type, each season.

Common name	Summer			Fall			Spring		
	Rank	#	%	Rank	#	%	Rank	#	%
Shortnose sturgeon	-	0	0.0	-	0	0.0	12	2	0.4
Atlantic sturgeon	-	0	0.0	-	0	0.0	13	1	0.2
American eel	12	13	1.1	18	2	0.1	13	1	0.2
Blueback herring	8	38	3.3	1	291	18.2	3	41	9.1
Alewife	16	2	0.2	11	39	2.4	13	1	0.2
American shad	3	107	9.2	4	188	11.8	-	0	0.0
Atlantic menhaden	15	4	0.3	-	0	0.0	-	0	0.0
Gizzard shad	14	5	0.4	17	4	0.3	-	0	0.0
Bay anchovy	2	267	23.0	6	85	5.3	12	2	0.4
Tiger muskellunge	17	1	0.1	-	0	0.0	-	0	0.0
Common carp	17	1	0.1	16	8	0.5	13	1	0.2
Eastern silvery minnow	5	73	6.3	9	58	3.6	6	12	2.7
Spottail shiner	6	68	5.8	8	66	4.1	4	21	4.7
White catfish	-	0	0.0	19	1	0.1	13	1	0.2
Brown bullhead	17	1	0.1	-	0	0.0	13	1	0.2
Channel catfish	7	48	4.1	7	73	4.6	2	67	14.9
Banded killifish	11	15	1.3	3	239	15.0	5	19	4.2
Mummichog	-	0	0.0	10	56	3.5	5	19	4.2
Rough silverside	-	0	0.0	-	0	0.0	10	5	1.1
Inland silverside	13	10	0.9	13	21	1.3	7	9	2.0
White perch	1	384	33.0	2	276	17.3	1	227	50.3
Striped bass	9	28	2.4	14	19	1.2	9	7	1.6
Pumpkinseed	16	2	0.2	17	4	0.3	11	3	0.7
Smallmouth bass	17	1	0.1	-	0	0.0	-	0	0.0
Tessellated darter	10	18	1.5	12	27	1.7	11	3	0.7
Atlantic croaker	-	0	0.0	15	9	0.6	-	0	0.0
Naked goby	-	0	0.0	18	2	0.1	-	0	0.0
Hogchoker	4	77	6.6	5	129	8.1	8	8	1.8
Total Individuals		1163	100.0		1597	100.0		451	100.0
Total Species		21			21			21	

Station 3

Sampling at Station 3 produced 5,589 individuals representing 31 species and 15 families (Table 5; Appendices 3-2 through 3-4). The nine species listed below made up 92% of the catch:

Atlantic croaker	30.6%	Mummichog	3.3%
White perch	22.4%	Eastern silvery minnow	2.5%
Bay anchovy	13.2%	Banded killifish	2.5%
Hogchoker	11.2%	Striped bass	2.0%
Channel catfish	3.9%		

Summer and fall collections included 25 species each, but the fall collection contained three times as many individuals. Young Atlantic croaker, many of which had only recently transformed from the larval stage, constituted 45% of the fall catch. They ranged in size from 16 to 59 mm.

The September collection at Station 3 was dominated by bay anchovy, white perch and hogchoker similar to Station 2, but 15 bluefish and 2 weakfish also were captured. As indicated in Appendix 3-1 (p. A-12), a saline wedge was present in September and October when the station was sampled. The highest salinity recorded here was 0.9‰.

Twenty-five species were collected in shallows compared to 16 and 15 species from the intermediate and deep water habitats, respectively. Most minnows and sunfishes, including largemouth bass, were found exclusively in the shallows. Most of the bluefish and Atlantic croaker, and all the weakfish, were collected in deeper water.

All but five of the 31 species captured at Station 3 were represented entirely or partially by juveniles (Appendices 7-1 through 7-3). Juveniles made up 55% of the individuals measured. Eastern silvery minnow, brown bullhead, inland silverside, tessellated darter and yellow perch were represented only by adults.

Table 5. Rank, numbers (#) and relative abundance (%) of individuals of fish species captured at Station 3 by season. Numbers presented are for the combined catch by each gear type, each season.

Common name	Summer			Fall			Spring		
	Rank	#	%	Rank	#	%	Rank	#	%
Atlantic sturgeon	16	1	0.1	-	0	0.0	-	0	0.0
American eel	10	8	0.7	13	7	0.2	10	3	0.4
Blueback herring	-	0	0.0	13	7	0.2	5	49	7.1
Alewife	-	0	0.0	18	2	0.1	-	0	0.0
American shad	4	45	3.9	12	31	0.8	-	0	0.0
Atlantic menhaden	16	1	0.1	10	43	1.1	-	0	0.0
Gizzard shad	13	4	0.3	17	3	0.1	-	0	0.0
Bay anchovy	2	309	27.0	3	428	11.4	11	1	0.1
Common carp	16	1	0.1	-	0	0.0	11	1	0.1
Golden shiner	-	0	0.0	-	0	0.0	11	1	0.1
Eastern silvery minnow	11	7	0.6	11	33	0.9	3	101	14.6
Satinfin shiner	-	0	0.0	19	1	0.0	-	0	0.0
Spottail shiner	8	27	2.4	11	33	0.9	9	7	1.0
White catfish	16	1	0.1	16	4	0.1	11	1	0.1
Brown bullhead	13	4	0.3	-	0	0.0	11	1	0.1
Channel catfish	6	40	3.5	5	93	2.5	4	87	12.6
Banded killifish	13	4	0.3	6	84	2.2	5	49	7.1
Mummichog	16	1	0.1	8	67	1.8	2	114	16.5
Inland silverside	5	41	3.6	9	62	1.7	11	1	0.1
White perch	3	263	23.0	2	784	20.9	1	206	29.8
Striped bass	7	29	2.5	7	68	1.8	7	16	2.3
Pumpkinseed	12	5	0.4	14	6	0.2	8	13	1.9
Bluegill	-	0	0.0	15	5	0.1	10	3	0.4
Largemouth bass	15	2	0.2	18	2	0.1	-	0	0.0
Tessellated darter	12	5	0.4	14	6	0.2	10	3	0.4
Yellow perch	16	1	0.1	19	1	0.0	11	1	0.1
Bluefish	9	15	1.3	-	0	0.0	-	0	0.0
Weakfish	15	2	0.2	17	3	0.1	-	0	0.0
Atlantic croaker	-	0	0.0	1	1712	45.6	-	0	0.0
Naked goby	14	3	0.3	-	0	0.0	-	0	0.0
Hogchoker	1	326	28.5	4	268	7.1	6	33	4.8
Total Individuals		1145	100.0		3753	100.0		691	100.0
Total Species		25			25			20	

Station 4

Sampling at Station 4 produced 7,501 individuals representing 29 species and 17 families (Table 6; Appendices 4-2 through 4-4). Species diversity was higher upriver, but the number of individuals captured at Station 4 was almost three times greater than at Station 2 and about 1.5 times greater than Stations 1 or 3. Two species, bay anchovy and hogchoker, accounted for 74% of the catch in September and 65% in October. In May 1993, these two species were less numerous, but still accounted for 44% of the fishes captured for this station. Other numerically important species in the catch included white perch (9.3%), Atlantic croaker (9.2%), and weakfish (3.8%). Juvenile Atlantic croaker were caught in September and October, just as at Station 3, but the croaker were far less abundant here.

Some freshwater species commonly encountered at Stations 1-3 were absent or encountered only in the spring when the highest salinity recorded was lower than before (the previous fall salinity ranged from 4.9% to 10.0%). Conversely, we captured marine species (black seabass, butterfish, smallmouth flounder, and summer flounder) here, but not at Station 3 or farther upriver.

Station 4 yielded 168 striped bass; about half were captured in October and the remainder split evenly between September and May. More than 80% of the striped bass catch came from the shallows as did more than 50% of the white perch. In contrast, about 80% of the weakfish and a slightly higher percentage of hogchoker came from deeper water. The catch of bay anchovy, another numerically important species, was split evenly among all three habitats.

We measured 18% of the catch; 57% of the fishes measured were juveniles (Appendices 8-1 through 8-3). Channel catfish was the only species represented by adults only.

Table 6. Rank, numbers (#) and relative abundance (%) of individuals of fish species captured at Station 4 by season. Numbers presented are for the combined catch be each gear type, each season.

Common name	Summer			Fall			Spring		
	Rank	#	%	Rank	#	%	Rank	#	%
Atlantic sturgeon	13	3	0.1	-	0	0.0	13	1	0.1
American eel	12	5	0.2	9	8	0.2	8	10	1.0
Blueback herring	-	0	0.0	12	4	0.1	13	1	0.1
Alewife	-	0	0.0	11	5	0.1	-	0	0.0
American shad	-	0	0.0	12	4	0.1	13	1	0.1
Atlantic menhaden	9	10	0.4	7	15	0.4	5	54	5.3
Gizzard shad	14	2	0.1	-	0	0.0	-	0	0.0
Bay anchovy	2	560	19.7	3	459	12.7	3	131	13.0
Common carp	-	0	0.0	-	0	0.0	11	2	0.2
Golden shiner	-	0	0.0	-	0	0.0	13	1	0.1
Channel catfish	11	6	0.2	13	2	0.1	9	5	0.5
Mummichog	15	1	0.0	-	0	0.0	-	0	0.0
Rough silverside	-	0	0.0	-	0	0.0	10	3	0.3
Inland silverside	4	197	6.9	6	61	1.7	-	0	0.0
Atlantic silverside	-	0	0.0	-	0	0.0	4	122	12.1
White perch	5	117	4.1	4	346	9.5	2	309	30.6
Striped bass	7	41	1.4	5	82	2.3	6	44	4.4
Black seabass	15	1	0.0	-	0	0.0	-	0	0.0
Bluefish	10	7	0.2	-	0	0.0	10	3	0.3
Silver perch	14	2	0.1	-	0	0.0	-	0	0.0
Weakfish	3	270	9.5	8	12	0.3	-	0	0.0
Spot	-	0	0.0	-	0	0.0	13	1	0.1
Atlantic croaker	6	54	1.9	2	714	19.7	-	0	0.0
Naked goby	8	15	0.5	10	7	0.2	-	0	0.0
Butterfish	12	5	0.2	-	0	0.0	-	0	0.0
Smallmouth flounder	15	1	0.0	14	1	0.0	-	0	0.0
Summer flounder	15	1	0.0	-	0	0.0	-	0	0.0
Hogchoker	1	1546	54.4	1	1908	52.6	1	323	31.9
Total Individuals		2843	100.0		3628	100.0		1011	100.0
Total Species		20			15			17	

Secondary Data Sources

To obtain more comprehensive species lists for each of the DRBC Water Quality Zones, we combined the data from our field studies with species lists from ongoing state monitoring programs and other fisheries studies performed since 1980. The year 1980 was selected because it is since then that water quality in the Delaware River has been much improved compared to its worst period of the 1940s and 1950s (Marino et al., 1991). This improvement has been most evident especially between Philadelphia and Chester. The species list for the period 1980-present is referred to here as the "recent" fauna.

To gain some insight into possible changes in the fauna that may have occurred as a result of man's use of the estuary, we developed a second list for comparison. This species list covered the period prior to 1980 and is referred to here as the "historical" fauna. We relied primarily on works by Kiry and Scheir (1974) and Tyrawski (1979) for these data. Kiry and Scheir obtained most of their data from nine papers by Henry W. Fowler presented between 1907 and 1921. Most of Tyrawski's data came from detailed ecological field studies conducted in the 1970s in the vicinity of existing and proposed electric generating facilities.

Species lists covering the periods before 1980 and 1980-present are presented in Appendix 9. The first list, Appendix 9-1, summarizes the faunas in WQZs 2-5; subsequent lists detail the faunas of each of the individual WQZs. In summary, when the entire 122-km reach of the estuary is considered, the fauna before 1980 is not much different than afterwards. The historical fauna includes 78 species, whereas the recent fauna includes 87 species; however, four species, longnose gar, rainbow smelt, comely shiner, and bridle shiner, are conspicuously absent from the recent fauna. The first two have been extirpated from the Delaware drainage system, whereas Shirey (1991) reported comely shiner and bridle shiner in tributaries to the Delaware estuary but not in the river itself. The most significant changes have occurred in Water Quality Zone 4 (Delaware River between Big Timber Creek and Raccoon Creek) and Water Quality Zone 5 (Delaware River between Wilmington and the C&D Canal). The former WQZ has lost two pickerel species and seven cyprinids while gaining five marine species; the latter has gained saltwater species, including striped searobin, black seabass, and conger eel.

In Water Quality Zone 2, the recent and historical faunas were represented by 59 and 58

species, respectively (Appendix 9-2). Absent from the recent fauna were longnose gar, comely shiner, bridle shiner, creek chub, eastern mudminnow, rainbow smelt, pirate perch, and Atlantic needlefish. "New" species included bowfin, bay anchovy, bluntnose minnow, yellow bullhead, margined madtom, tiger muskellunge, rough silverside, Atlantic silverside, and three-spine stickleback.

Twenty-four species comprised the fauna for Water Quality Zone 3 before 1980 and 49 species afterwards (Appendix 9-3). Absent from the recent fauna were bowfin, bridle shiner, pirate-perch, and four-spine stickleback; previously unreported species included sea lamprey, ladyfish, tiger muskellunge, chain pickerel, and striped bass hybrid.

In Water Quality Zone 4, the historical fauna consisted of 61 species, compared to 59 species for the recent fauna (Appendix 9-4). Much of the deficit was due to the absence of seven cyprinids (minnows and carps): goldfish, common shiner, bridle shiner, swallowtail shiner, bluntnose minnow, fathead minnow, and fallfish. Also absent from the recent fauna were bowfin, redfin pickerel, chain pickerel, eastern mudminnow, pirate perch, fourspine stickleback, and three-spine stickleback. Previously unreported species in the recent fauna included shortnose sturgeon, Atlantic herring, striped anchovy, tiger muskellunge, inshore lizardfish, silver hake, striped cusk eel, and hybrid striped bass.

Fifty-three species were reported for Water Quality Zone 5 prior to 1980 and 63 species afterward (Appendix 9-5). Satinfin shiner, bridle shiner, redfin pickerel, and rainbow smelt, present before 1980, have not been reported since. Most of the additional species in the recent fauna are marine or lower bay species, including conger eel, striped anchovy, striped cusk eel, striped searobin, and black seabass. However, cutlips minnow, white sucker, and hybrid striped bass, each of which have a freshwater orientation, also are included in the recent fauna.

DISCUSSION

Fish Communities

Currently, the Delaware estuary supports a diverse fish fauna. Since 1980, 87 species have been recorded in the 122-km reach between Trenton and the C&D Canal. T. Lloyd Associates recorded 47 of these 87 species in collections made at four stations selected to represent the habitats within the DRBC Water Quality Zones 2 through 5 and situated near locations monitored by state fishery ecologists. As indicated in Table 7, 91% of our catch consisted of the following species:

Hogchoker	25.0%	Channel catfish	4.3%
White perch	20.6%	Banded killifish	3.8%
Atlantic croaker	11.2%	American shad	2.3%
Bay anchovy	10.1%	Inland silverside	2.1%
Blueback herring	8.1%	Eastern silvery minnow	1.9%
		Striped bass	1.7%

The catch varied somewhat from station to station and by season and habitat (Appendices 1-4). Such temporal and spatial variability in occurrences and abundances of species and life stages can be caused by a number of factors, including patchiness of fish species in the environment, migratory patterns, daily movement behavior, gear bias, and temporally and spatially limited sampling.

The estuary provides habitat for species that are valued for sport and commercial purposes or for their ecological role. Six of the most numerous species in our collections (white perch, Atlantic croaker, blueback herring, channel catfish, American shad, and striped bass) are important sport or commercial species, as are the less abundant largemouth bass, pumpkinseed, and bluegill sunfish. We commonly encountered sunfishes in shallow water habitats from Station 3 upstream.

Species such as bay anchovy (the fourth most abundant species), inland silverside, and eastern silvery minnow are important in Delaware estuary food chains because they consume

Table 7. Total number (#) of individuals and their relative abundance (%) at each station.

Station:	1		2		3		4		TOTAL	
	#	%	#	%	#	%	#	%	#	%
Shortnose Sturgeon	0	0.0	2	0.0	0	0.0	0	0.0	2	0.0
Atlantic sturgeon	1	0.0	1	0.0	1	0.0	4	0.0	7	0.0
American eel	15	0.3	16	0.5	18	0.3	23	0.3	72	0.3
Blueback herring	1375	26.5	370	11.5	56	1.0	5	0.1	1806	8.1
Alewife	49	0.9	42	1.3	2	0.0	5	0.1	98	0.4
American shad	139	2.7	295	9.2	76	1.4	5	0.1	515	2.3
Atlantic menhaden	0	0.0	4	0.1	44	0.8	79	0.9	127	0.6
Gizzard shad	16	0.3	9	0.3	7	0.1	2	0.0	34	0.2
Bay anchovy	5	0.1	354	11.0	738	13.2	1167	13.9	2264	10.1
Satinfin shiner	0	0.0	0	0.0	1	0.0	0	0.0	1	0.0
Common carp	1	0.0	10	0.4	2	0.0	2	0.0	15	0.1
Eastern silvery minnow	143	2.8	143	4.5	141	2.5	0	0.0	427	1.9
Golden shiner	29	0.6	0	0.0	1	0.0	1	0.0	31	0.1
Spottail shiner	38	0.7	155	4.8	67	1.2	0	0.0	260	1.2
Bluntnose minnow	1	0.0	0	0.0	0	0.0	0	0.0	1	0.0
White sucker	6	0.1	0	0.0	0	0.0	0	0.0	6	0.0
White catfish	30	0.6	2	0.1	6	0.1	0	0.0	38	0.2
Brown bullhead	3	0.1	2	0.1	5	0.1	0	0.0	10	0.0
Channel catfish	549	10.6	188	5.9	220	3.9	13	0.2	970	4.3
Tiger muskellunge	0	0.0	1	0.0	0	0.0	0	0.0	1	0.0
Banded killifish	449	8.7	273	8.5	137	2.5	0	0.0	859	3.8
Mummichog	74	1.4	75	2.3	182	3.3	1	0.0	332	1.5
Rough silverside	0	0.0	5	0.2	0	0.0	3	0.0	8	0.0
Inland silverside	64	1.2	40	1.2	104	1.9	258	3.1	466	2.1
Atlantic silverside	0	0.0	0	0.0	0	0.0	122	1.4	122	0.5
Fourspine stickleback	14	0.3	0	0.0	0	0.0	0	0.0	14	0.1
White perch	1683	32.5	887	27.6	1253	22.4	785	9.3	4608	20.6
Striped bass	36	0.7	54	1.7	113	2.0	168	2.0	371	1.7
Black seabass	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0
Redbreast sunfish	5	0.1	0	0.0	0	0.0	0	0.0	5	0.0
Green sunfish	2	0.0	0	0.0	0	0.0	0	0.0	2	0.0
Pumpkinseed	120	2.3	9	0.3	24	0.4	0	0.0	153	0.7
Bluegill	103	2.0	0	0.0	8	0.1	0	0.0	111	0.5
Smallmouth bass	0	0.0	1	0.0	0	0.0	0	0.0	1	0.0
Largemouth bass	12	0.2	0	0.0	4	0.1	0	0.0	16	0.1
Tessellated darter	76	1.5	48	1.5	14	0.3	0	0.0	138	0.6
Yellow perch	2	0.0	0	0.0	3	0.1	20	0.2	25	0.1
Bluefish	0	0.0	0	0.0	15	0.3	10	0.1	25	0.1
Silver perch	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0
Weakfish	0	0.0	0	0.0	5	0.1	316	3.8	321	1.4
Spot	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0
Atlantic croaker	4	0.1	9	0.3	1712	30.6	773	9.2	2498	11.2
Naked goby	0	0.0	2	0.1	3	0.1	22	0.3	27	0.1
Butterfish	0	0.0	0	0.0	0	0.0	5	0.1	5	0.0
Smallmouth flounder	0	0.0	0	0.0	0	0.0	2	0.0	2	0.0
Summer flounder	0	0.0	0	0.0	0	0.0	1	0.0	1	0.0
Hogchoker	140	2.7	214	6.7	627	11.2	4623	54.9	5604	25.0
Total	5184	100.0	3211	100.0	5589	100.0	8418	100.0	22402	100.0

minute plant and animal life and serve as food for striped bass, weakfish, and other predators.

The relative position of Atlantic croaker in our catch (third most abundant) probably overestimates its true significance in the fish community as a whole because the mortality rate for larvae and recently metamorphosed juveniles, which comprised most of our catch, typically is very high. Larvae and young juveniles of almost all fishes are prone to predation from a host of invertebrates and vertebrates and they may suffer mortality from relatively minor changes in their physical and chemical environments. We caught only three adult croaker. Moreover, more than two-thirds of our catch came from one station (Station 3) and was made in one season (fall), whereas less than 20 croaker were caught at all stations combined in September and none the following spring.

Two of the species we caught have been afforded special status. Atlantic sturgeon is the subject of a federal management plan; shortnose sturgeon is listed as an endangered species by the federal government and by all three states bordering the estuary. We captured juvenile Atlantic sturgeon at Stations 1, 3, and 4 in this study and near Station 2 in a previous study (T. Lloyd Associates, 1992c). We captured two adult shortnose sturgeon in deep water habitat at Station 2. Most shortnose sturgeon overwinter in the channel above Florence (km 198), but they are known to migrate downstream in the spring (O'Herron and Able, 1991).

Fish diversity was highest in the freshwater zone of the river (Stations 1-3), but our largest catches were made in the brackish zone (Station 4), which yielded almost three times as many individuals as Station 2 and about 1.5 times as many individuals as Stations 1 and 3. Our largest catches at all stations occurred in October when blueback herring and American shad were migrating seaward and at the same time white perch and hogchoker were moving downriver into deeper water. The smallest catches occurred in May 1993, when fewer individuals were present and the bulk of the adult herring species (including American shad) already had utilized the estuary to spawn or pass through.

Life History and Habitats

Although the Delaware estuary supports some truly resident species, which spend all their time within a small area, most of the fishes in this estuary migrate, either to points within or outside of the estuary. This is true for 8 of the 11 most common species we caught. The

seasonal movements of abundant anadromous species through the saline and freshwater segments of the estuary, which also support resident faunas characteristic of each respective salinity regime, account for much of the variability in relative abundances of fishes observed in the estuary. Blueback herring is a familiar example of an anadromous oceanic species, whose adults migrate into the estuary in great numbers during the spring from nearby coastal oceanic waters to spawn throughout the study area; some spawn well above the head of tide at Trenton. Surviving adults rapidly leave the non-tidal river and upper estuary after spawning. After reaching an age of about 30 days (Lee et al., 1980), the young begin moving seaward and leave the upper tidal Delaware River during September and October (PSE&G, 1980). As they pass downstream, their vast numbers profoundly influence relative abundances in samples taken at stations along the path of their migration.

White perch is an example of an anadromous estuarine resident whose adults and juveniles overwinter in the deeper, warmer saline waters of Delaware Bay, then enter the less saline (brackish) and freshwater portions of the estuary during the spring for spawning and foraging. This species is ubiquitous in the estuary until late fall, when the adults and most juveniles gather below the level of the C&D Canal (see PSE&G, 1984).

As shown in Table 8, the catch from the shallows (less than -3.05 m MLW) at all stations combined had more species (39) compared to the catch from intermediate depths (-3.05 m to -7.62 m MLW, 25 species) and deep water (greater than -7.62 m MLW, 25 species). At Station 1, the shallows yielded 26 species compared to 13 species each from the intermediate and deep water habitats. At Stations 2 and 3, the shallows yielded 1.6 to 1.8 times as many species as the intermediate and deep water habitats, but at Station 4, where shallow water habitat was more uniform, each of the three habitats yielded about the same number of species (18-20). Various minnows and sunfishes, as well as banded killifish, conspicuously absent at Station 4, were major components of the shallow water fauna at Stations 1-3. These fishes tend to orient themselves to the structure provided by rocks, anthropogenic debris, and aquatic vegetation. The smooth bottom at Station 4, composed of mud, sand, and gravel, differed greatly from the river bottom upstream. Also, the shoreline here supported saltmarsh cordgrass and common reed, but not beds of floating or submerged aquatic vegetation.

Juvenile striped bass also favored the shallows (Table 8). However, since catches of this

Table 8. Total number (#) and relative abundance (%) of fishes captured in the shallow, intermediate, and deep water habitats at all four stations combined.

Common Name	Shallow		Intermediate		Deep		Total
	#	%	#	%	#	%	#
Shortnose sturgeon	0	0	0	0	2	100	2
Atlantic sturgeon	0	0	3	43	4	57	7
American eel	40	56	18	25	14	19	72
Blueback herring	97	5	246	14	1463	81	1806
Alewife	6	8	26	33	66	59	98
American shad	152	30	172	34	191	36	515
Atlantic menhaden	77	61	26	20	24	19	127
Gizzard shad	12	35	17	50	5	15	34
Bay anchovy	980	43	282	13	1002	44	2264
Satinfin shiner	1	100	0	0	0	0	1
Common carp	12	80	2	13	1	7	15
Eastern silvery minnow	414	99	10	1	3	<1	427
Golden shiner	31	100	0	0	0	0	31
Spottail shiner	255	98	5	2	0	0	260
Bluntnose minnow	1	100	0	0	0	0	1
White sucker	1	17	0	0	5	83	6
White catfish	0	0	17	46	21	54	38
Brown bullhead	3	30	0	0	7	70	10
Channel catfish	16	2	347	36	607	62	970
Tiger muskellunge	1	100	0	0	0	0	1
Banded killifish	859	100	0	0	0	0	859
Mummichog	332	100	0	0	0	0	332
Rough silverside	8	100	0	0	0	0	8
Inland silverside	466	100	0	0	0	0	466
Atlantic silverside	122	100	0	0	0	0	122
Fourspine stickleback	14	100	0	0	0	0	14
White perch	2581	56	1287	28	740	16	4608
Striped bass	308	83	46	12	17	5	371
Black seabass	0	0	1	100	0	0	1
Redbreast sunfish	5	100	0	0	0	0	5
Green sunfish	2	100	0	0	0	0	2
Pumpkinseed	153	100	0	0	0	0	153
Bluegill	111	100	0	0	0	0	111
Smallmouth bass	1	100	0	0	0	0	1
Largemouth bass	16	100	0	0	0	0	16
Tessellated darter	117	86	21	14	0	0	138
Yellow perch	25	100	0	0	0	0	25
Bluefish	8	52	3	12	14	56	25
Silver perch	0	0	0	0	1	100	1
Weakfish	21	17	48	15	252	68	321
Spot	0	0	1	100	0	0	1
Atlantic croaker	39	1	1367	55	1092	44	2498
Naked goby	9	33	13	49	5	18	27
Butterfish	0	0	3	60	2	40	5
Smallmouth flounder	0	0	1	50	1	50	2
Summer flounder	1	100	0	0	0	0	1
Hogchoker	740	13	2930	53	1934	34	5604
Total # of Species	39		25		25		47
Total # of Individuals	8037		6892		7413		22,402

and other predominantly marine species became progressively larger proceeding downstream from Station 1, it appears that salinity, as well as availability of structure, is an important factor affecting distribution below Station 3.

Some species, such as sturgeons, blueback herring, catfishes, and hogchoker, clearly favored intermediate and deep water habitats, whereas species such as white perch, bay anchovy, and juvenile American shad seemed to be ambivalent (Table 8). It should be noted, however, that this statement is based on the results of our daytime sampling effort; night time sampling may indicate more intensive use of the shallows by juvenile herring and other species.

Although shallow water habitats are important to aquatic organisms due to the environmental opportunities they offer, the intermediate and deep water habitats areas, which typically have fewer species, cannot be dismissed because they are larger in surface area and volume. In aggregate, the non-shallow areas yielded twice as many individuals as the shallow habitat in our study.

Faunal Changes

As measured by dissolved oxygen concentration, water quality is much improved relative to that of the 1940s to 1950s when it was worst (Marino et al. 1991). A definite positive trend began in the late 1970s, but the extent to which changes in water quality within the study area have affected the fish fauna still can be described only generally for most species because of the lack of fisheries data.

Comparison of the historical fauna compiled by Kiry (1974), by Tyrawski (1979), and in other references we mention on page 11, with the recent fauna derived from our study and other recent efforts, indicates that the present fauna of the entire 122-km reach is not greatly different from what existed in 1979 and earlier. The numbers of individuals, however, are much reduced. This is especially true for commercial species. Atlantic sturgeon, for example, occur in the river quite commonly today, but the population is a fraction of what it was in the 1880s, when one caviar packer shipped more than 50 tons to Europe in one year (Shirey, 1993). Also, it should be noted that comprehensive systematic fish surveys only became common after the 1950s; certainly they were not conducted in the early 20th century by

Henry W. Fowler and other workers. Thus, the 1921 river fauna presented by Kiry (1974) surely must be incomplete because biologists had to rely on relatively simple gear such as hook and line and haul seines, and they rarely had the opportunity, if at all, to sample some habitats that modern gear enables us to do. For example, bottom trawls were not used to sample deep water habitats, nor could biologists sample rubble strewn shorelines as effectively as electroshocking equipment permits us to do now.

Although the species list we generated from fish collections after 1980 in Water Quality Zones 2-5 is slightly larger (87 versus 78) than the historical list (Appendix 9-1), 14 species are absent from this new list. Of these, only longnose gar and rainbow smelt can be regarded as being extirpated from the Delaware River drainage basin. The remaining 12 species are:

Common shiner	Eastern mudminnow
Comely shiner	Pirate perch
Bridle shiner	Blackbanded sunfish
Fathead minnow	Bluespotted sunfish
Creek chub	Banded sunfish
Tadpole madtom	Spotted hake

With the exception of spotted hake, a marine species, these fishes are not typically found in the mainstems of large rivers, but all 11 have been reported in tributaries of the Delaware (Shirey, 1991). Four species, eastern mudminnow, blackbanded sunfish, bluespotted sunfish, and banded sunfish, are plainly adapted to waters with very little current; if they occur in the mainstem tidal river, it is only by the catastrophe of being flushed downstream by a freshet. The twelfth species, spotted hake, was reported in Delaware Bay by Michels and Seagraves (1991).

CONCLUSIONS

1. Of the 47 species T. Lloyd Associates captured in this study, 11 species constituted slightly more than 90% of the catch.

2. The largest catches were made in the fall and coincided with seaward migration of blueback herring and American shad and movements of white perch and hogchoker down river into deeper water.

3. The shallow water habitats supported up to twice as many species of fish, but the intermediate and deep water habitats were used heavily by migrating clupeids, weakfish, channel catfish, bay anchovy, and other numerically important species in the estuary.

4. More than half of the 6,000 individuals we measured were juveniles, demonstrating that the estuary serves as a nursery for striped bass, weakfish, Atlantic and shortnose sturgeon, river herring, and many other species.

5. Based on our review of secondary sources, rainbow smelt and longnose gar are the only species that have been extirpated from the Delaware estuary. The number of species (87) recorded in the Delaware estuary between Trenton and the C&D Canal since 1980 actually exceeds the number recorded through 1979, but the absolute abundance of sturgeons, striped bass, American shad, and other species is much reduced compared to historical levels.

RECOMMENDATIONS

1. Assuming that dissolved oxygen concentrations will continue at their present levels or improve, loss of habitat by dredging and filling or by increased turbidity (which negatively impacts submerged vegetation) appear to be the most severe threats to aquatic life. Protection and enhancement of the Delaware estuary's fish populations will require continued enforcement of state and federal habitat protection regulations as well as improved public awareness of the estuary's past and present aquatic resources.

2. Special studies that target fishes identified by the Delaware Estuary Program as priority species are warranted. For example, we should have a better understanding of how shortnose and Atlantic sturgeon use the estuary. Study design, including gear, sampling frequency, and sampling locations, would have to be tailored to the target species and its life stages.

3. Fish monitoring studies should be continued. At the very least, data obtained by New Jersey, Delaware, and Pennsylvania biologists should be gathered together, synthesized, and made available to researchers at a central location. Other sources of data that often are not generally available include research by academic researchers and original data generated by private consultants used as input to environmental impact assessments.

4. Habitat in the Delaware estuary, including water quality, could be monitored by measuring fish diversity and abundance, but only if a variety of collecting techniques are employed and the collections are at least semiquantitative. (Standardized quantitative collections throughout the estuary would be optimum, but probably not practical, because of the effort involved and sampling limitations.) Fish should be collected in all habitats using trawls, seines, gill nets, and electroshocking equipment because no one gear type is effective for all species and all life stages. Because of the effort involved and poor success, we do not recommend deploying trotlines.

5. There is increased use of the estuary by sport and commercial fishermen. Monitoring sport and commercial catches and unit effort more closely could provide state and federal resource managers with useful biological and economic data.

LITERATURE CITED

Academy of Natural Sciences of Philadelphia. 1974. Ecological studies in New Jersey, Oldmans Creek, Raccoon Creek, Birch Creek and the Delaware River 1972 - 1973. Prepared for the Shell Oil Company by Academy of Natural Sciences of Philadelphia, Philadelphia, PA. 297 p.

Beck, S. J., A. L. Maiden, H. M. Brundage III, and G. A. Hayes. 1985. An aquatic ecological study of the proposed Wilmington harbor dredged-material disposal area and environs. Prepared for U.S. Army Corps of Engineers, Philadelphia District, by V. J. Schuler Associates, Inc., Middletown, DE.

BioSystems Analysis, Inc. 1990. Results of an ichthyoplankton and juvenile fish survey conducted near the Keystone Cogeneration Project site, April - August, 1990. Prepared for Bechtel by BioSystems Analysis, Inc., Tiburon, CA. 31 p. and appendices.

Bureau of Marine Fisheries. 1993. Unpublished data from juvenile striped bass survey, 1987 - 1992. Division of Fish, Game and Wildlife, New Jersey Department of Environmental Protection and Energy. Trenton, NJ.

Dadswell, M. J., B. D. Taubert, T. S. Squiers, D. Marchette, and J. Buckley. 1984. Synopsis on biological data on shortnose sturgeon, Acipenser brevirostrum Le Sueur 1818. NOAA Tech. Rep. NJFS 14 (FAO Fisheries Synopsis No. 140). 45 p.

Delaware River Basin Commission. 1991. Delaware Estuary Program request for proposals. 6 p.

Delaware River Basin Commission. 1988. Fish health and contamination study. Delaware Estuary Use Attainability Project. DEL USA Project Element 10. Delaware River Basin Commission, West Trenton, NJ. 116 p.

Delaware River Basin Commission. 1986. Administrative Manual - Part III. Water Quality Regulations. Delaware River Basin Commission, West Trenton, NJ. 73 p.

Fisheries Management Division. 1993. Unpublished data from Delaware River fish survey, 1984 - 1986. Pennsylvania Fish and Boat Commission. Bellefont, PA.

Hastings, R. W. 1983a. A study of the shortnose sturgeon (Acipenser brevirostrum) population in the upper tidal Delaware River: Assessment of impacts of maintenance dredging. Prepared for U.S. Army Corps of Engineers, Philadelphia District, by Center for Coastal and Environmental Studies, Rutgers, The State University of New Jersey, New Brunswick, NJ. 129 p.

Hastings, R. W. 1983b. A study of the shortnose sturgeon (Acipenser brevirostrum) population in the upper tidal Delaware River: Assessment of impacts of maintenance dredging (pre-dredge study of Duck Island and Perriwig Ranges). Prepared for U.S. Army Corps of Engineers, Philadelphia District, by Center for Coastal and Environmental Studies, Rutgers, The State University of New Jersey, New Brunswick, NJ. 29 p.

Kiry, P. R. 1974. An historical look at the water quality of the Delaware River Estuary to 1973. Contributions from the Department of Limnology. Number 4. Academy of Natural Sciences of Philadelphia, Philadelphia, PA. 76 p.

Lazzari, M. A., J. C. O'Herron, II, and R. W. Hastings. 1986. Occurrence of juvenile Atlantic sturgeon (Acipenser oxyrhynchus) in the upper tidal Delaware River. Estuaries 9(4B):356-361.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina State Museum of Natural History. 854 p.

Marino, G. R., J. L. DiLorenzo, H. S. Litwack, T. O. Najarian, and M. L. Thatcher. 1991. General water quality assessment and trend analysis of the Delaware estuary. Part one: Status and trends. Final report. Prepared for Delaware Estuary Program and USEPA/Delaware River Basin Commission by Najarian Associates, L. P., Eatontown, NJ. 217 p. and appendices.

Michels, S. F. and R. S. Seagraves. 1991. Stream and inland bays fish survey. Part II. Monitoring fish populations in Delaware's estuaries. Federal aid in fisheries restoration project F-37-R-5 Final Report. Delaware Division of Fish and Wildlife, Dover, DE. 13 p. and figures and tables.

National Ocean Service. 1990. Nautical chart No. 12XHA12314: Delaware River, Philadelphia to Trenton. 27th edition. National Oceanic and Atmospheric Administration. Washington, D.C.

National Ocean Service. 1991. Nautical chart No. 12AHA12312: Delaware River, Wilmington to Philadelphia. 42nd edition. National Oceanic and Atmospheric Administration. Washington, D.C.

National Ocean Service. 1991. Nautical chart No. 12AHA12311: Delaware River, Smyrna to Wilmington. 33rd edition. National Oceanic and Atmospheric Administration. Washington, D.C.

O'Herron, J. C. II. Personal observations. Sea lamprey and hickory shad identified from the Delaware River at Yardley, Pennsylvania during Spring 1982.

O'Herron, J. C., II, and Able, K. W. 1990. A study of the endangered shortnose sturgeon (Acipenser brevirostrum) in the Delaware River. Final performance report. Project No. AFS-10-R-3. Prepared for the U.S. Dept. of Interior. Center for Coastal and Environmental Studies, Rutgers, New Brunswick, NJ. 41 p.

O'Herron, J. C., II, and Hastings, R. W. 1985. A study of the shortnose sturgeon (Acipenser brevirostrum) population in the upper tidal Delaware River: Assessment of the impact of maintenance dredging (post-dredge study of Duck Island and Perriwig Ranges). Final report, Prepared for U.S. Army Corps of Engineers, Philadelphia District. Center for Coastal and Environmental Studies, Rutgers, New Brunswick, NJ. 100 p. and addendum.

O'Herron , J. C., II and T. Lloyd. 1986. Macroinvertebrate and fish studies in the Delaware Estuary near Camden and National Park, New Jersey. Prepared for S. T. Hudson Engineers, Inc. by T. Lloyd Associates, Philadelphia. 29 p.

RMC Environmental Services. 1988. A survey of fish impingement at Eddystone Generating Station, July-December, 1987. Prepared for Philadelphia Electric Company by RMC Environmental Services, Pottstown, PA.

Shirey, C. A. 1991. Stream and inland bays fish survey. Part I. An inventory of fishes and macroinvertebrates in Delaware's streams. Federal aid in fisheries restoration project F-37-R Final Report. Delaware Division of Fish and Wildlife, Dover, DE. 231 p.

Shirey, C. A. 1992a. Delaware River Atlantic sturgeon tagging program, 1991. Final report. Delaware Division of Fish and Wildlife, Dover, DE. 21 p.

Shirey, C. A. 1992b. Incidental species occurrence during the conduct of the Atlantic sturgeon tagging program, 1991. Unpublished data. Delaware Division of Fish and Wildlife, Dover, DE. 1 p.

Shirey, C. A. 1993. The search for sturgeon. Outdoor Delaware, Vol. 2, No. 1. Delaware Department of Natural Resources, Dover. 5 p.

Stutz, B. A. 1992. Natural lives, modern times: People and places of the Delaware River. Crown Publishers, Inc., New York. 390 p.

Summers, P. 1987. Fish population study. Delaware Estuary Use Attainability Project. DEL USA Project Element 9. Delaware River Basin Commission, West Trenton, NJ. 4 p.

T. Lloyd Associates. 1990. Aquatic biological studies in the Delaware River at the South Jersey Port Corporation in Camden, New Jersey. Prepared for S. T. Hudson Engineers, Inc., by T. Lloyd Associates, Burlington, NJ. 25 p.

T. Lloyd Associates. 1991. Summary of fish collection data taken from the Delaware River near Amico Island, 1989. Unpublished data. Burlington, NJ. 2 p.

T. Lloyd Associates. 1992a. Dredge monitoring study in the Delaware River. Prepared for U.S. Army Corps of Engineers, Philadelphia District. Contract No. DACW 61-92-M-1024. T. Lloyd Associates, Burlington, NJ. 22 p. and appendix.

T. Lloyd Associates. 1992b. Dredge monitoring study in the Delaware River at the B.P. Oil Company waterfront, Marcus Hook, PA. Prepared for B.P. Oil Company by T. Lloyd Associates, Burlington, NJ. 22 p. and appendix.

T. Lloyd Associates. 1992c. An evaluation of aquatic habitat at the old New York Shipbuilding drydocks at South Jersey Port Corporation's Broadway Terminal. Prepared for S.T. Hudson Engineers, Inc., by T. Lloyd Associates, Burlington, NJ. 16 p.

Tyrawski, J. M. 1979. Shallows of the Delaware River: Trenton, New Jersey to Reedy Point, Delaware. Prepared for the Environmental Resources Branch, U.S. Army Corps of Engineers. Contract No. DACW61-79-M-0445, Army COE, Philadelphia, PA. 519 p.

APPENDIX 1

DATA FROM STATION 1

Appendix 1-1. Water quality data from Station 1. S = Shallows; I = Intermediate; D = Deep.

Date	Time (EST)	Tidal stage	Habitat	Depth (m)	Temp (C)		D.O. (ppm)		Cond. (umhos)		Salinity (ppt)	
					Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
09/01/92	1600	FLOOD	S	1.0	NA	23.1	NA	6.30	NA	211	NA	0.0
			I	7.5	22.9	23.0	5.80	5.90	227	222	0.0	0.0
			D	9.0	22.9	22.9	5.50	5.60	229	222	0.0	0.0
09/02/92	0845	FLOOD	S	1.0	NA	21.8	NA	5.80	NA	212	NA	0.0
			I	7.0	22.1	22.1	5.70	5.80	210	212	0.0	0.0
			D	17.0	22.0	22.0	5.60	5.80	210	210	0.0	0.0
	1602	FLOOD	S	1.0	NA	22.2	6.00	NA	202	NA	NA	0.0
			I	6.6	22.2	22.1	5.90	5.90	210	209	0.0	0.0
			D	13.6	22.2	22.2	5.80	5.70	215	210	0.0	0.0
09/04/92	0900	EBB	S	1.5	NA	22.0	NA	5.72	NA	210	NA	0.0
			I	5.0	21.9	22.0	5.51	5.62	215	218	0.0	0.0
			D	17.0	21.9	21.9	5.75	5.86	217	211	0.0	0.0
09/08/92	1017	FLOOD	S	1.0	NA	21.7	NA	5.43	NA	217	NA	0.0
			I	5.5	21.7	21.8	5.32	5.42	218	217	0.0	0.0
			D	15.0	21.8	21.8	5.22	5.30	221	217	0.0	0.0
	1410	EBB	S	1.5	NA	22.0	NA	5.59	NA	219	NA	0.0
			I	7.0	21.9	22.3	5.41	5.81	218	222	0.0	0.0
			D	15.0	21.9	22.1	5.34	5.69	222	218	0.0	0.0
10/13/92	0800	EBB	S	2.0	NA	14.8	NA	7.80	NA	184	NA	0.0
			I	5.0	14.5	14.8	7.71	7.75	194	195	0.0	0.0
			D	14.0	14.3	14.9	7.80	7.79	190	195	0.0	0.0
	1600	FLOOD	S	3.0	NA	15.0	NA	8.29	NA	188	NA	0.0
			I	6.0	14.9	14.9	8.15	7.71	187	194	0.0	0.0
			D	15.0	14.9	14.9	8.10	8.15	188	188	0.0	0.0
10/14/92	0810	EBB	S	1.0	NA	14.1	NA	7.99	NA	177	NA	0.0
			I	5.8	13.8	14.2	7.95	7.89	181	183	0.0	0.0
			D	10.0	14.1	14.7	7.93	7.99	189	190	0.0	0.0
	1535	FLOOD	S	2.0	NA	14.4	NA	8.05	NA	189	NA	0.0
			I	7.2	14.3	14.5	7.82	8.97	189	185	0.0	0.0
			D	16.5	14.4	14.5	7.80	7.82	190	166	0.0	0.0
10/20/92	1600	EBB	S	2.0	NA	11.7	NA	9.15	NA	170	NA	0.0
			I	7.2	11.8	12.2	8.42	8.63	162	169	0.0	0.0
			D	11.0	12.0	12.4	8.19	8.23	154	159	0.0	0.0
05/10/93	0921	EBB	S	2.4	NA	15.8	NA	8.90	NA	135	NA	0.0
	0925		I	4.3	16.2	15.8	8.98	9.02	143	135	0.0	0.0
	0930		D	16.0	16.0	15.8	9.08	9.20	142	135	0.0	0.0
	1702	FLOOD	S	1.8	NA	17.2	NA	8.90	NA	141	NA	0.0
			I	8.3	16.4	16.1	9.08	9.20	132	139	0.0	0.0
			D	15.5	16.2	16.0	9.02	9.11	140	139	0.0	0.0
05/11/93	0855	EBB	S	2.0	NA	16.0	NA	9.63	NA	140	NA	0.0
	0905		I	8.3	16.1	15.9	9.40	9.48	148	141	0.0	0.0
	0910		D	16.5	16.1	15.9	9.49	9.41	145	141	0.0	0.0
	1635	FLOOD	S	1.0	NA	17.2	NA	9.34	NA	140	NA	0.0
	1650		I	6.2	17.0	16.8	9.20	9.45	151	140	0.0	0.0
			D	15.5	16.7	16.4	9.22	9.40	142	139	0.0	0.0
05/12/93		EBB	S	1.0	NA	18.8	NA	10.15	NA	148	NA	0.0
	1322		I	6.5	17.0	17.7	9.26	9.51	142	142	0.0	0.0
	1320		D	14.2	17.4	17.4	9.33	9.88	144	141	0.0	0.0

Appendix 1-2. Numbers of individuals of fish species captured at Station 1 during the summer season (Sept. 1 - Oct. 1, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW						INTERMEDIATE				DEEP			TOTALS
Gear:	TL	SBS	MBS	LBS	EL	SOT	TL	GN	LOT	MWT	GN	LOT	MWT	
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	-	1	-	1
American eel	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Blueback herring	-	4	11	65	-	-	-	1	-	1	-	-	6	88
Alewife	-	-	-	-	-	2	-	-	-	-	-	-	29	31
American shad	-	1	-	-	-	-	-	3	5	11	-	2	55	77
Gizzard shad	-	-	-	-	1	-	-	14	-	-	-	1	-	16
Bay anchovy	-	-	-	-	-	-	-	-	-	3	-	-	-	3
Eastern silvery minnow	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Golden shiner	-	2	-	-	-	-	-	-	-	-	-	-	-	2
Spottail shiner	-	-	6	-	-	6	-	-	1	-	-	-	-	13
White sucker	-	-	-	-	-	-	-	-	-	-	4	-	-	4
White catfish	-	-	-	-	-	-	-	1	-	-	1	1	-	3
Brown bullhead	2	-	-	-	-	-	-	-	-	-	-	-	-	2
Channel catfish	-	-	-	-	-	4	-	13	-	-	13	20	-	50
Tiger muskellunge	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Banded killifish	-	25	1	1	-	-	-	-	-	-	-	-	-	27
Inland silverside	-	61	-	2	-	-	-	-	-	-	-	-	-	63
Fourspine stickleback	-	-	-	4	-	-	-	-	-	-	-	-	-	4
White perch	-	-	50	9	-	205	4	96	19	-	75	56	3	517
Striped bass	-	-	-	2	-	6	-	3	-	-	-	-	-	11
Redbreast sunfish	-	-	-	-	2	-	-	-	-	-	-	-	-	2
Pumpkinseed	1	-	-	10	-	-	-	-	-	-	-	-	-	11
Bluegill	-	-	3	28	2	-	-	-	-	-	-	-	-	33
Largemouth bass	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Tessellated darter	-	-	6	11	-	-	-	-	-	-	-	-	-	17
Hogchoker	-	-	-	-	-	16	-	1	1	-	-	31	-	49
Total	3	93	79	132	5	240	4	132	26	15	93	112	93	1027

Appendix 1-3. Numbers of individuals of fish species captured at Station 1 during the fall season (Oct. 13 - Oct. 30, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW					INTERMEDIATE		DEEP			TOTALS
Gear:	SBS	MBS	LBS	EL	SOT	GN	LOT	GN	LOT	MWT	
American eel	-	-	-	11	-	-	-	-	-	-	11
Blueback herring	-	-	3	2	-	-	-	-	-	1217	1222
Alewife	-	-	-	-	-	-	-	-	-	16	16
American shad	-	1	2	1	2	-	3	-	-	53	62
Bay anchovy	-	-	-	-	-	-	-	-	1	1	2
Common carp	-	-	-	-	1	-	-	-	-	-	1
Eastern silvery minnow	-	10	34	1	-	-	-	-	-	-	45
Spottail shiner	-	8	-	-	7	-	2	-	-	-	17
White sucker	-	-	-	-	-	-	-	1	-	-	1
White catfish	-	-	-	-	-	-	-	-	12	-	12
Brown bullhead	-	-	-	-	-	-	-	-	1	-	1
Channel catfish	-	-	-	-	-	-	2	4	344	-	350
Banded killifish	195	21	1	6	-	-	-	-	-	-	223
Mummichog	21	-	-	-	1	-	-	-	-	-	22
Inland silverside	1	-	-	-	-	-	-	-	-	-	1
Fourspine stickleback	1	6	3	-	-	-	-	-	-	-	10
White perch	-	28	10	-	562	5	155	1	9	-	770
Striped bass	-	-	-	-	12	1	-	-	-	-	13
Green sunfish	-	-	-	1	-	-	-	-	-	-	1
Pumpkinseed	-	-	13	84	-	-	-	-	-	-	97
Bluegill	-	-	5	19	-	-	-	-	-	-	24
Largemouth bass	-	1	2	5	-	-	-	-	-	-	8
Tessellated darter	-	19	23	3	5	-	-	-	-	-	50
Yellow perch	-	-	2	-	-	-	-	-	-	-	2
Atlantic croaker	-	-	-	-	-	-	-	-	4	-	4
Hogchoker	-	1	6	-	7	-	8	-	38	-	60
Total	218	95	104	133	597	6	170	6	409	1287	3025

Appendix 1-4. Numbers of individuals of fish species captured at Station 1 during the spring season (May 10-12, 1993) per gear type. Gear types are: SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; GN = bottom set gill net; SOT = 1.83-m otter trawl; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW					INTERMEDIATE			DEEP			TOTALS
Gear:	SBS	MBS	LBS	EL	SOT	GN	LOT	MWT	GN	LOT	MWT	
American eel	-	1	-	1	-	-	1	-	-	-	-	3
Blueback herring	-	-	-	-	1	42	4	9	-	1	8	65
Alewife	-	-	-	2	-	-	-	-	-	-	-	2
Eastern silvery minnow	1	1	90	-	3	1	1	-	-	-	-	97
Golden shiner	-	27	-	-	-	-	-	-	-	-	-	27
Spottail Shiner	-	-	2	-	6	-	-	-	-	-	-	8
Bluntnose minnow	-	-	1	-	-	-	-	-	-	-	-	1
White sucker	-	-	1	-	-	-	-	-	-	-	-	1
White catfish	-	-	-	-	-	1	9	-	-	5	-	15
Channel catfish	-	-	-	-	1	6	54	-	3	85	-	149
Banded killifish	-	191	5	3	-	-	-	-	-	-	-	199
Mummichog	-	48	4	-	-	-	-	-	-	-	-	52
White perch	-	-	45	-	95	51	117	-	8	80	-	396
Striped bass	-	-	3	-	1	2	1	-	1	4	-	12
Redbreast sunfish	-	-	-	3	-	-	-	-	-	-	-	3
Green sunfish	-	-	-	1	-	-	-	-	-	-	-	1
Pumpkinseed	-	3	1	8	-	-	-	-	-	-	-	12
Bluegill	-	-	-	46	-	-	-	-	-	-	-	46
Largemouth bass	-	-	-	3	-	-	-	-	-	-	-	3
Tessellated darter	1	-	1	3	1	-	3	-	-	-	-	9
Hogchoker	-	-	-	-	-	-	21	-	-	10	-	31
Total	2	271	153	70	108	103	211	9	12	185	8	1132

APPENDIX 2

DATA FROM STATION 2

Appendix 2-1. Water quality data from Station 2. S = Shallows; I = Intermediate; D = Deep.

Date	Time (EST)	Tidal stage	Habitat	Depth (m)	Temp (C)		D.O. (ppm)		Cond. (umhos)		Salinity (ppt)	
					Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
09/08/92	1750	EBB	S	2.0	NA	22.2	NA	4.43	NA	272	NA	0.0
			I	7.0	21.9	21.9	4.32	4.41	262	266	0.0	0.0
			D	13.5	21.8	21.9	4.25	4.52	259	256	0.0	0.0
09/09/92	1025	FLOOD	S	2.0	NA	22.1	NA	4.96	NA	272	NA	0.0
			I	8.0	22.2	21.9	4.56	4.50	275	270	0.0	0.0
			D	11.0	22.0	21.8	4.43	4.30	275	270	0.0	0.0
	1610	EBB	S	2.1	NA	23.0	NA	5.62	NA	286	NA	0.0
			I	7.0	23.2	23.2	5.18	5.60	277	272	0.0	0.0
			D	10.8	22.5	22.3	4.46	4.43	279	278	0.0	0.0
09/10/92	0940	FLOOD	S	1.0	NA	22.2	NA	4.49	NA	283	NA	0.0
			I	3.2	22.1	22.8	4.48	4.48	271	260	0.0	0.0
			D	14.0	22.0	22.1	4.37	4.47	252	273	0.0	0.0
	1630	EBB	S	1.5	NA	22.7	NA	5.35	NA	297	NA	0.0
			I	8.3	22.7	22.5	4.83	4.83	300	283	0.0	0.0
			D	14.0	22.5	22.5	4.82	4.76	300	300	0.0	0.0
09/11/92	1010	FLOOD	S	2.0	NA	21.8	NA	5.35	NA	272	NA	0.0
			I	5.5	21.9	22.1	4.72	4.71	259	263	0.0	0.0
			D	14.5	21.9	22.1	4.53	4.50	251	259	0.0	0.0
	1745	EBB	S	1.5	NA	22.3	NA	4.42	NA	288	NA	0.0
			I	7.0	22.1	22.2	4.32	4.31	274	279	0.0	0.0
			D	14.5	22.1	22.2	4.57	4.51	272	276	0.0	0.0
10/15/92	1004	EBB	S	1.0	NA	14.9	NA	7.01	NA	297	NA	0.0
			I	6.3	14.9	15.0	7.00	6.95	272	272	0.0	0.0
			D	14.5	15.1	15.3	6.83	6.82	264	269	0.0	0.0
	1558	FLOOD	S	2.3	NA	15.8	NA	7.29	NA	288	NA	0.0
			I	5.0	15.9	15.7	7.12	7.21	299	299	0.0	0.0
			D	17.8	16.0	15.8	7.19	7.12	298	299	0.0	0.0
10/16/92	0950	EBB	S	1.5	NA	15.4	NA	7.12	NA	260	NA	0.0
			I	6.5	15.6	15.4	6.78	7.27	257	259	0.0	0.0
			D	18.5	15.5	15.3	6.70	6.81	252	248	0.0	0.0
	1545	FLOOD	S	3.0	NA	16.3	NA	8.60	NA	258	NA	0.0
			I	4.5	16.1	15.8	7.42	7.38	258	262	0.0	0.0
			D	14.5	15.9	15.7	7.18	7.11	268	270	0.0	0.0
10/20/92	0942	FLOOD	S	1.0	NA	12.8	NA	7.98	NA	232	NA	0.0
			I	7.1	12.7	13.2	7.55	7.75	238	245	0.0	0.0
			D	18.5	12.7	13.5	7.45	7.42	238	250	0.0	0.0
5/21/93	1445	EBB	S	1.5	NA	17.6	NA	7.30	NA	199	NA	0.0
	1450	EBB	I	8.3	16.7	16.8	6.52	6.65	235	198	0.0	0.0
	1458	EBB	D	13.5	16.3	16.8	6.61	6.68	201	200	0.0	0.0
5/25/93	0845	EBB	S	2.5	NA	16.8	NA	8.62	NA	200	NA	0.0
	0850	EBB	I	6.3	16.8	16.9	8.78	8.50	196	197	0.0	0.0
	0853	EBB	D	16.5	16.8	16.7	8.08	8.29	205	201	0.0	0.0
	1615	FLOOD	S	1.5	NA	18.8	NA	8.88	NA	213	NA	0.0
	1620	FLOOD	I	5.0	17.8	17.2	8.01	8.30	210	205	0.0	0.0
	1625	FLOOD	D	14.3	17.4	17.2	8.00	8.29	210	206	0.0	0.0
5/26/93	0855	EBB	S	2.0	NA	16.9	NA	8.32	NA	211	NA	0.0
		EBB	I	5.3	16.8	17.0	8.46	8.30	210	211	0.0	0.0
		EBB	D	12.0	16.8	17.0	8.10	8.25	209	211	0.0	0.0
		EBB SL	S	2.0	NA	18.8	NA	11.80	NA	228	NA	0.0
		EBB SL	I	6.5	17.8	17.4	9.32	9.64	220	216	0.0	0.0
		EBB SL	D	13.0	17.3	17.3	8.92	9.11	216	215	0.0	0.0

Appendix 2-2. Numbers of individuals of fish species captured at Station 2 during the summer season (Sept. 1 - Oct. 1, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW						INTERMEDIATE			DEEP			TOTALS
Gear:	TL	SBS	MBS	LBS	EL	SOT	TL	GN	SOT	GN	SOT	MWT	
American eel	-	-	-	-	1	9	-	-	-	-	3	-	13
Blueback herring	-	-	4	-	1	-	-	-	-	-	-	33	38
Alewife	-	-	-	-	1	1	-	-	-	-	-	-	2
American shad	-	19	29	13	-	21	-	-	1	-	-	24	107
Atlantic menhaden	-	-	-	-	-	-	-	-	-	-	-	4	4
Gizzard shad	-	-	-	-	1	-	-	3	-	1	-	-	5
Bay anchovy	-	-	-	2	5	2	-	-	-	-	-	258	267
Common carp	-	-	-	-	-	-	-	1	-	-	-	-	1
Eastern silvery minnow	-	2	29	26	8	2	-	6	-	-	-	-	73
Spottail shiner	-	2	27	20	-	17	-	2	-	-	-	-	68
Brown bullhead	1	-	-	-	-	-	-	-	-	-	-	-	1
Channel catfish	3	-	-	-	-	-	5	10	27	3	-	-	48
Tiger muskellunge	-	-	1	-	-	-	-	-	-	-	-	-	1
Banded killifish	-	-	1	2	-	12	-	-	-	-	-	-	15
Inland silverside	-	1	9	-	-	-	-	-	-	-	-	-	10
White perch	-	-	1	3	7	95	-	147	63	50	18	-	384
Striped bass	-	2	-	13	1	5	-	7	-	-	-	-	28
Pumpkinseed	-	-	-	-	2	-	-	-	-	-	-	-	2
Smallmouth bass	-	-	-	-	1	-	-	-	-	-	-	-	1
Tessellated darter	-	-	-	-	-	-	-	-	18	-	-	-	18
Hogchoker	-	-	-	-	-	3	-	-	61	-	13	-	77
Total	4	26	101	79	28	167	5	176	170	54	34	319	1163

Appendix 2-3. Numbers of individuals of fish species captured at Station 2 during the fall season (Oct. 13 - Oct. 30, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW					INTERMEDIATE			DEEP			TOTALS
Gear:	SBS	MBS	LBS	EL	SOT	GN	LOT	MWT	GN	LOT	MWT	
American eel	-	-	-	2	-	-	-	-	-	-	-	2
Blueback herring	-	1	-	-	-	-	-	131	-	-	159	291
Alewife	-	-	-	-	-	-	-	20	-	1	18	39
American shad	-	-	4	-	10	-	-	137	-	-	37	188
Gizzard shad	-	-	-	-	-	-	-	-	4	-	-	4
Bay anchovy	47	14	18	-	2	-	-	2	-	-	2	85
Common carp	-	-	-	8	-	-	-	-	-	-	-	8
Eastern silvery minnow	2	-	56	-	-	-	-	-	-	-	-	58
Spottail shiner	6	4	53	-	3	-	-	-	-	-	-	66
White catfish	-	-	-	-	-	-	-	-	-	1	-	1
Channel catfish	-	-	-	-	-	-	67	-	3	3	-	73
Banded killifish	113	48	56	22	-	-	-	-	-	-	-	239
Mummichog	-	1	1	54	-	-	-	-	-	-	-	56
Inland silverside	17	-	3	1	-	-	-	-	-	-	-	21
White perch	-	21	43	-	98	6	36	-	27	43	2	276
Striped bass	-	-	16	-	2	1	-	-	-	-	-	19
Pumpkinseed	-	-	-	4	-	-	-	-	-	-	-	4
Tessellated darter	2	20	4	-	1	-	-	-	-	-	-	27
Atlantic croaker	1	-	-	-	-	-	-	-	-	8	-	9
Naked goby	-	1	1	-	-	-	-	-	-	-	-	2
Hogchoker	-	6	10	-	71	-	19	-	-	23	-	129
Total	188	116	265	91	187	7	122	290	34	79	218	1597

Appendix 2-4. Numbers of individuals of fish species captured at Station 2 during the spring season (May 3- June 7, 1993) per gear type. Gear types are: SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; SOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW					INTERMEDIATE			DEEP			TOTALS
Gear:	SBS	MBS	LBS	EL	SOT	GN	LOT	MWT	GN	LOT	MWT	
Shortnose sturgeon	-	-	-	-	-	-	-	-	1	1	-	2
Atlantic sturgeon	-	-	-	-	-	-	-	-	1	-	-	1
American eel	-	-	-	-	-	-	-	-	-	1	-	1
Blueback herring	-	-	-	-	-	-	-	16	-	-	25	41
Alewife	-	-	-	-	-	-	-	-	-	-	1	1
Bay anchovy	-	2	-	-	-	-	-	-	-	-	-	2
Common carp	-	-	-	-	1	-	-	-	-	-	-	1
Eastern silvery minnow	1	2	5	2	2	-	-	-	-	-	-	12
Spottail Shiner	1	-	11	-	9	-	-	-	-	-	-	21
White catfish	-	-	-	-	-	-	-	-	1	-	-	1
Brown bullhead	-	-	-	-	-	-	-	-	1	-	-	1
Channel catfish	-	-	-	1	-	5	-	-	2	59	-	67
Banded killifish	5	3	1	10	-	-	-	-	-	-	-	19
Mummichog	-	14	3	2	-	-	-	-	-	-	-	19
Inland silverside	3	2	4	-	-	-	-	-	-	-	-	9
Rough silverside	-	-	5	-	-	-	-	-	-	-	-	5
White perch	6	-	5	-	79	8	20	-	-	109	-	227
Striped bass	-	-	3	-	2	-	2	-	-	-	-	7
Pumpkinseed	-	-	-	3	-	-	-	-	-	-	-	3
Tessellated darter	1	-	2	-	-	-	-	-	-	-	-	3
Hogchoker	-	-	-	-	2	-	1	-	-	5	-	8
Total	17	23	39	18	95	13	23	16	6	175	26	451

APPENDIX 3

DATA FROM STATION 3

Appendix 3-1. Water quality data from Station 3. S = Shallows; I = Intermediate; D = Deep.

Date	Time (EST)	Tidal stage	Habitat	Depth (m)	Temp (C)		D.O. (ppm)		Cond. (umhos)		Salinity (ppt)	
					Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
09/15/92	0800	EBB	S	1.0	NA	20.8	NA	6.63	NA	530	NA	0.0
			I	6.0	20.9	21.0	6.52	6.61	462	450	0.0	0.0
			D	13.0	21.0	21.1	6.42	6.75	452	433	0.0	0.0
	1600	EBB	S	2.0	NA	22.1	NA	7.20	NA	500	NA	0.0
			I	8.0	21.8	22.0	6.70	6.99	630	510	0.0	0.0
			D	12.0	21.8	21.9	6.49	6.94	710	510	0.0	0.0
09/16/92	0902	EBB	S	1.0	NA	21.2	NA	6.22	NA	580	NA	0.0
			I	7.0	21.0	21.2	6.35	6.32	510	520	0.0	0.0
			D	12.0	20.6	21.3	6.32	6.41	540	520	0.0	0.0
	1740	EBB	S	2.8	NA	22.3	NA	7.17	NA	820	NA	0.3
			I	7.5	21.9	22.0	6.26	6.78	780	690	0.5	0.3
			D	15.5	22.0	22.0	6.27	6.62	1130	820	0.9	0.3
09/17/92	1130	EBB	S	1.3	NA	21.6	NA	7.00	NA	520	NA	0.0
			I	4.0	21.3	21.3	6.62	6.68	510	510	0.0	0.0
			D	15.0	21.4	21.4	6.60	6.81	481	483	0.0	0.0
10/22/92	0820	FLOOD	S	2.0	NA	12.6	NA	8.55	NA	368	NA	0.0
			I	7.3	12.2	12.7	8.40	8.40	419	411	0.0	0.0
			D	14.0	12.3	12.7	8.42	8.40	430	442	0.0	0.0
	1640	EBB	S	1.0	NA	13.7	NA	8.39	NA	890	NA	0.5
			I	7.0	13.2	13.3	8.02	8.05	462	421	0.0	0.0
			D	16.5	13.0	13.2	8.03	8.19	357	362	0.0	0.0
10/23/92	0903	FLOOD	S	2.0	NA	12.7	NA	8.45	NA	510	NA	0.1
			I	7.0	12.3	12.7	8.45	8.43	500	500	0.1	0.1
			D	15.2	12.1	12.7	8.48	8.60	492	495	0.1	0.1
	1535	EBB	S	1.3	NA	13.0	NA	8.65	NA	580	NA	0.1
			I	4.5	12.9	13.0	8.50	8.65	600	530	0.2	0.1
			D	13.3	13.0	12.9	8.88	8.50	520	610	0.1	0.2
10/27/92	0900	EBB	S	1.8	NA	10.1	NA	9.75	NA	420	NA	0.0
			I	7.5	10.5	10.9	8.90	8.95	388	390	0.0	0.0
			D	10.5	10.9	10.7	9.00	8.85	398	398	0.0	0.0
5/17/93	0930	FLOOD	S	2.0	NA	16.9	NA	9.95	NA	180	NA	0.0
		FLOOD	I	7.0	16.6	16.8	9.50	9.63	180	180	0.0	0.0
	0935	FLOOD	D	17.0	16.6	17.0	9.42	9.82	179	180	0.0	0.0
	1535	EBB	S	1.5	NA	18.3	NA	13.2	NA	186	NA	0.0
	1540	EBB	I	6.8	17.8	17.7	11.59	12.1	188	187	0.0	0.0
	1545	EBB	D	13.3	17.8	17.8	11.65	12.1	187	186	0.0	0.0
5/18/93		FLOOD	S	1.5	NA	16.8	NA	10.4	NA	184	NA	0.0
		FLOOD	I	6.3	16.8	16.9	10.08	10.35	188	187	0.0	0.0
		FLOOD	D	14.5	17.0	16.7	10.08	10.2	187	185	0.0	0.0
		EBB	S	0.6	NA	16.8	NA	11.00	NA	184	NA	0.0
	1558	EBB	I	5.3	16.9	16.3	10.17	10.11	187	181	0.0	0.0
	1555	EBB	D	15.3	17.0	16.8	9.04	9.06	185	188	0.0	0.0
5/21/93	1035	FLOOD	S	1.5	NA	15.8	NA	9.06	NA	192	NA	0.0
	1045	FLOOD	I	5.0	16.2	16.0	7.75	7.80	199	195	0.0	0.0
	1047	FLOOD	D	16.8	16.1	16.5	6.98	7.43	200	200	0.0	0.0

Appendix 3-2. Numbers of individuals of fish species captured at Station 3 during the summer season (Sept. 1 - Oct. 1, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW						INTERMEDIATE			DEEP			TOTALS
Gear:	TL	SBS	MBS	LBS	EL	SOT	TL	GN	SOT	GN	SOT	MWT	
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	1	-	1
American eel	-	-	-	1	6	-	-	-	1	-	-	-	8
American shad	-	11	5	12	-	5	-	-	1	-	2	9	45
Atlantic menhaden	-	-	-	-	-	-	-	-	-	-	-	1	1
Gizzard shad	-	-	-	-	4	-	-	-	-	-	-	-	4
Bay anchovy	-	25	27	68	-	26	-	-	-	-	27	136	309
Common carp	-	-	-	-	1	-	-	-	-	-	-	-	1
Eastern silvery minnow	-	-	6	1	-	-	-	-	-	-	-	-	7
Spottail shiner	-	5	7	14	-	1	-	-	-	-	-	-	27
White catfish	-	-	-	-	-	-	1	-	-	-	-	-	1
Brown bullhead	-	-	-	-	-	-	-	-	-	4	-	-	4
Channel catfish	1	-	-	-	-	2	-	4	27	1	5	-	40
Banded killifish	-	2	-	1	1	-	-	-	-	-	-	-	4
Mummichog	-	-	-	-	1	-	-	-	-	-	-	-	1
Inland silverside	-	27	13	1	-	-	-	-	-	-	-	-	41
White perch	-	1	29	28	2	75	-	54	59	-	13	2	263
Striped bass	-	-	2	9	-	5	-	-	12	-	-	1	29
Redbreast sunfish	-	-	-	-	-	-	-	-	-	-	-	-	0
Pumpkinseed	-	-	-	-	5	-	-	-	-	-	-	-	5
Largemouth bass	-	-	-	-	2	-	-	-	-	-	-	-	2
Tessellated darter	-	3	-	-	-	2	-	-	-	-	-	-	5
Yellow perch	-	-	-	-	1	-	-	-	-	-	-	-	1
Bluefish	-	-	-	1	-	2	-	-	-	-	-	12	15
Weakfish	-	-	-	-	-	-	-	-	-	-	1	1	2
Naked goby	-	-	-	-	-	-	-	-	3	-	-	-	3
Smallmouth flounder	-	-	-	-	-	-	-	-	-	-	-	-	0
Hogchoker	-	-	-	1	-	14	-	-	257	-	54	-	326
Total	1	74	89	137	23	132	1	58	360	5	103	162	1145

Appendix 3-3. Numbers of individuals of fish species captured at Station 3 during the fall season (Oct. 13 - Oct. 30, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW					INTERMEDIATE			DEEP			TOTALS
Gear:	SBS	MBS	LBS	EL	SOT	GN	LOT	MWT	GN	LOT	MWT	
American eel	-	-	-	-	-	-	6	-	-	1	-	7
Blueback herring	-	1	1	-	1	-	-	2	-	-	2	7
Alewife	-	-	-	-	-	-	-	2	-	-	-	2
American shad	-	1	4	-	11	-	-	7	-	1	7	31
Atlantic menhaden	-	9	16	-	1	1	-	7	-	-	9	43
Gizzard shad	-	-	2	1	-	-	-	-	-	-	-	3
Bay anchovy	8	63	52	3	93	-	2	28	-	12	167	428
Satinfin shiner	-	-	-	1	-	-	-	-	-	-	-	1
Eastern silvery minnow	1	-	1	29	2	-	-	-	-	-	-	33
Spottail shiner	1	-	-	18	14	-	-	-	-	-	-	33
White catfish	-	-	-	-	-	-	4	-	-	-	-	4
Channel catfish	-	-	-	-	2	2	77	-	-	12	-	93
Banded killifish	-	-	-	84	-	-	-	-	-	-	-	84
Mummichog	-	2	-	65	-	-	-	-	-	-	-	67
Inland silverside	2	25	35	-	-	-	-	-	-	-	-	62
White perch	-	4	126	6	499	-	107	9	1	15	17	784
Striped bass	-	2	35	1	29	-	-	-	-	-	1	68
Pumpkinseed	-	-	-	6	-	-	-	-	-	-	-	6
Bluegill	-	-	-	5	-	-	-	-	-	-	-	5
Largemouth bass	-	-	-	2	-	-	-	-	-	-	-	2
Tesselated darter	-	-	-	6	-	-	-	-	-	-	-	6
Yellow perch	-	-	-	-	1	-	-	-	-	-	-	1
Weakfish	-	-	-	-	-	-	-	1	-	-	2	3
Atlantic croaker	-	1	6	-	3	-	680	289	-	368	365	1712
Hogchoker	-	-	-	-	7	-	156	-	1	104	-	268
Total	12	108	278	227	663	3	1032	345	2	513	570	3753

Appendix 3-4. Numbers of individuals of fish species captured at Station 3 during the spring season (May 3-June 7, 1993) per gear type. Gear types are: SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW					INTERMEDIATE			DEEP			TOTALS
Gear:	SBS	MBS	LBS	EL	SOT	GN	LOT	MWT	GN	LOT	MWT	
American eel	-	-	-	1	-	-	-	-	-	2	-	3
Blueback herring	-	-	-	1	-	22	-	16	-	-	10	49
Bay anchovy	-	-	-	-	-	-	-	1	-	-	-	1
Common carp	-	-	-	-	-	-	1	-	-	-	-	1
Eastern silvery minnow	-	-	76	20	-	-	2	-	1	2	-	101
Golden shiner	-	1	-	-	-	-	-	-	-	-	-	1
Spottail Shiner	1	-	6	-	-	-	-	-	-	-	-	7
White catfish	-	-	-	-	-	-	1	-	-	-	-	1
Brown bullhead	-	-	-	-	-	-	-	-	-	1	-	1
Channel catfish	1	-	1	-	-	4	34	-	9	38	-	87
Banded killifish	-	-	3	46	-	-	-	-	-	-	-	49
Mummichog	11	66	-	37	-	-	-	-	-	-	-	114
Inland silverside	1	-	-	-	-	-	-	-	-	-	-	1
White perch	2	-	3	-	30	9	-	130	2	30	-	206
Striped bass	-	-	-	-	7	6	3	-	-	-	-	16
Pumpkinseed	-	-	-	13	-	-	-	-	-	-	-	13
Bluegill	-	-	1	2	-	-	-	-	-	-	-	3
Tessellated darter	-	-	-	1	2	-	-	-	-	-	-	3
Yellow perch	-	-	1	-	-	-	-	-	-	-	-	1
Hogchoker	-	-	-	-	1	-	-	2	-	30	-	33
Total	16	67	91	121	40	41	41	149	12	103	10	691

APPENDIX 4

DATA FROM STATION 4

Appendix 4-1. Water quality data from Station 4. S = Shallows; I = Intermediate; D = Deep.

Date	Time (EST)	Tidal stage	Habitat	Depth (m)	Temp (C)		D.O. (ppm)		Cond. (umhos)		Salinity (ppt)	
					Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
09/21/92	1010	EBB	S	2.3	NA	21.3	NA	7.49	NA	6900	NA	4.9
			I	7.1	21.6	21.3	7.21	7.42	9900	7400	7.0	5.2
			D	15.0	21.6	21.6	7.22	7.49	10000	8400	7.1	5.9
	1605	FLOOD	S	1.5	NA	21.4	NA	8.19	NA	6500	NA	4.7
			I	5.3	21.4	21.4	7.48	7.52	7200	6900	5.1	4.9
			D	11.0	21.3	21.3	7.49	7.52	7100	7000	5.1	4.9
09/22/92	2	EBB	S	2.2	NA	21.8	NA	7.49	NA	7900	NA	5.6
			I	6.2	21.9	21.7	7.16	7.45	10900	8000	7.8	5.8
			D	11.5	21.9	21.6	7.21	7.59	11200	8100	8.1	5.9
	1600	EBB	S	2.2	NA	21.7	NA	7.59	NA	6300	NA	4.6
			I	7.0	22.1	21.9	7.57	7.70	6800	6800	4.9	4.8
			D	13.3	22.0	21.9	7.41	7.61	6800	6600	4.9	4.9
09/23/92	0800	FLOOD	S	2.4	NA	20.8	NA	7.82	NA	5900	NA	4.7
			I	6.1	20.1	20.8	7.80	7.80	5900	6000	4.7	4.7
09/29/92	0945	FLOOD	S	1.0	NA	16.5	NA	7.70	NA	6100	NA	4.7
			I	5.2	16.0	16.7	7.50	7.65	5900	6000	4.4	4.7
10/01/92	0950	EBB	S	1.8	NA	14.5	NA	8.63	NA	5800	NA	4.7
			I	7.8	15.0	15.3	8.31	8.21	6200	5900	5.1	4.9
			D	13.5	15.9	15.0	8.60	8.39	7100	5900	5.9	4.9
	1835	EBB	S	2.0	NA	16.1	NA	8.75	NA	7900	NA	6.1
			I	8.5	16.3	16.2	8.41	8.60	12500	8000	10.0	6.3
			D	11.0	16.3	16.8	8.31	8.39	12200	11800	9.8	9.2
10/27/92	1300	FLOOD	S	1.5	NA	11.2	NA	9.62	NA	5500	NA	4.9
10/29/92	0815	EBB	S	1.0	NA	10.4	NA	9.95	NA	4190	NA	3.5
			I	6.3	11.1	10.9	9.20	9.25	6400	4880	5.5	4.3
			D	13.5	11.0	11.1	9.10	9.30	5800	5500	5.1	4.9
	1655	FLOOD	S	1.8	NA	11.4	NA	9.35	NA	7200	NA	6.2
			I	6.3	11.5	11.3	9.25	9.30	9500	7200	8.2	6.2
			D	13.5	11.6	11.4	9.35	9.45	9800	7100	8.4	6.2
10/30/92	0915	EBB	S	1.3	NA	11.0	NA	9.45	NA	5900	NA	5.0
			I	5.3	11.1	11.2	9.25	9.35	6400	6000	5.5	5.1
			D	14.5	11.2	11.1	9.30	9.30	6500	5400	4.9	5.1
	1507	FLOOD	S	2.0	NA	11.4	NA	9.40	NA	7000	NA	6.1
			I	6.0	11.4	11.6	9.40	9.50	9700	9000	8.3	7.9
			D	12.3	11.3	11.6	9.50	9.60	10100	9800	8.9	8.2
5/21/93	1310	FLOOD	S	1.0	NA	16.6	NA	9.03	NA	1290	NA	0.8
	1315	FLOOD	I	4.8	16.6	16.4	8.96	8.96	1330	1300	0.9	0.8
6/02/93		FLOOD	S	1.5	NA	17.2	NA	9.06	NA	3200	NA	2.4
		FLOOD	I	6.3	17.0	17.1	8.71	9.04	5000	4280	3.9	3.2
		FLOOD	D	12.0	17.1	17.2	8.75	9.06	5300	4700	4.2	3.6
		EBB	S	1.0	NA	18.0	NA	10.60	NA	2200	NA	1.5
		EBB	I	5.2	17.3	17.8	9.12	10.40	2340	2250	1.6	1.5
	1650	EBB	D	16.5	17.4	18.1	8.82	10.28	2690	2035	1.9	1.6
6/03/93	0855	FLOOD	S	1.0	NA	16.6	NA	9.15	NA	2640	NA	1.9
	0900	FLOOD	I	6.5	16.8	17.0	8.77	8.91	2802	2880	1.9	2.0
	0907	FLOOD	D	13.3	17.0	17.3	8.61	8.65	2800	2790	1.9	1.9
	1545	EBB	S	2.0	NA	18.3	NA	10.20	NA	2510	NA	1.7
		EBB	I	3.5	18.4	18.2	9.86	9.88	2690	2520	1.9	1.8
	1545	EBB	D	12.5	18.0	18.6	9.21	10.40	3210	2560	2.3	1.8

Appendix 4-2. Numbers of individuals of fish species captured at Station 4 during the summer season (Sept. 1 - Oct. 1, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW				INTERMEDIATE				DEEP			TOTALS
Gear:	SBS	MBS	LBS	SOT	TL	GN	LOT	MWT	GN	LOT	MWT	
Atlantic sturgeon	-	-	-	-	-	3	-	-	-	-	-	3
American eel	-	-	3	2	-	-	-	-	-	-	-	5
Atlantic menhaden	-	1	-	-	-	-	-	1	-	-	8	10
Gizzard shad	-	-	-	-	-	-	-	2	-	-	-	2
Bay anchovy	19	18	136	12	-	-	4	124	-	10	237	560
Channel catfish	-	-	-	-	2	1	3	-	-	-	-	6
Mummichog	1	-	-	-	-	-	-	-	-	-	-	1
Inland silverside	12	5	180	-	-	-	-	-	-	-	-	197
Fourspine stickleback	-	-	-	-	-	-	-	-	-	-	-	0
White perch	-	-	1	2	-	13	71	3	1	25	1	117
Striped bass	1	2	35	2	-	-	-	-	-	-	1	41
Black seabass	-	-	-	-	-	-	-	1	-	-	-	1
Bluefish	-	2	-	-	-	-	-	3	-	-	2	7
Silver perch	-	-	-	-	-	-	-	-	-	1	-	1
Weakfish	-	2	-	18	-	1	5	3	-	16	225	270
Atlantic croaker	-	-	-	12	-	3	-	31	-	8	-	54
Naked goby	-	6	-	1	-	-	6	-	-	2	-	15
Butterfish	-	-	-	-	-	-	1	2	-	1	1	5
Smallmouth flounder	-	-	-	-	-	-	-	1	-	-	-	1
Summer flounder	-	-	-	1	-	-	-	-	-	-	-	1
Hogchoker	-	-	-	349	-	4	812	-	1	380	-	1546
Total	33	36	355	399	2	25	902	171	2	443	475	2843

Appendix 4-3. Numbers of individuals of fish species captured at Station 4 during the fall season (Oct. 13 - Oct. 30, 1992) per gear type. Gear types are: TL = trotline; SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW				INTERMEDIATE			DEEP		TOTALS
Gear:	SBS	MBS	LBS	SOT	GN	LOT	MWT	LOT	MWT	
Atlantic sturgeon	-	-	-	-	-	3	1	4	-	8
American eel	-	-	1	-	-	-	1	-	2	4
Blueback herring	-	-	-	-	-	-	4	-	1	5
Alewife	-	-	-	-	-	-	4	-	-	4
American shad	-	-	-	-	-	-	13	-	2	15
Atlantic menhaden	-	14	7	195	-	4	95	20	124	459
Bay anchovy	-	-	-	-	-	1	1	-	-	2
Channel catfish	9	23	29	-	-	-	-	-	-	61
Inland silverside	2	3	10	129	8	23	42	110	19	346
White perch	4	7	27	38	-	1	2	2	1	82
Striped bass	-	-	-	1	-	1	3	-	7	12
Weakfish	-	-	1	15	-	94	265	210	129	714
Atlantic croaker	-	-	-	-	-	3	1	1	2	7
Naked goby	-	-	-	-	-	-	-	1	-	1
Smallmouth flounder	-	-	-	49	-	681	12	1166	-	1908
Hogchoker										
Total	15	47	75	427	8	811	444	1514	287	3628

Appendix 4-4. Numbers of individuals of fish species captured at Station 4 during the summer season (May 3-June 7, 1993) per gear type. Gear types are: SBS = 4.88-m beach seine; MBS = 7.62-m beach seine; LBS = 15.24-m beach seine; EL = electrofishing; SOT = 1.83-m otter trawl; GN = bottom set gill net; LOT = 5.49-m otter trawl; MWT = 3.2-m midwater trawl.

Zone:	SHALLOW				INTERMEDIATE			DEEP			TOTALS
Gear:	S-16	S-25	S-50	OT-6	GN	OT-18	MWT	GN	OT-18	MWT	
Atlantic sturgeon	-	-	-	-	-	-	-	1	-	-	1
American eel	-	1	-	1	-	6	-	-	2	-	9
Blueback herring	-	-	-	-	-	-	1	-	-	-	1
American Shad	-	-	-	-	-	-	-	-	-	1	1
Atlantic menhaden	6	20	24	-	4	-	-	-	-	-	54
Bay anchovy	7	92	23	-	-	-	2	-	-	7	131
Common carp	-	-	-	-	-	-	-	1	-	-	2
Golden shiner	-	-	1	-	-	-	-	-	-	-	1
Channel catfish	-	-	-	-	-	2	-	2	1	-	5
Atlantic silverside	87	3	32	-	-	-	-	-	-	-	122
Rough silverside	1	2	-	-	-	-	-	-	-	-	3
White perch	102	48	9	108	4	8	7	2	9	12	309
Striped bass	-	2	31	1	-	4	-	-	5	1	44
Yellow perch	15	-	5	-	-	-	-	-	-	-	20
Bluefish	1	-	2	-	-	-	-	-	-	-	3
Spot	-	-	-	-	-	1	-	-	-	-	1
Hogchoker	-	-	3	194	-	48	-	-	77	1	323
Total	219	168	130	304	8	69	10	6	94	22	1030

APPENDIX 5

FISH LENGTH AND PERCENT JUVENILES, STATION 1

Appendix 5-1. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 1, showing percentage of juveniles (J) during the summer season (Sept. 1-Oct. 1, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	1	167	167	167.0	100.0
American eel	1	183	183	183.0	100.0	-	-	-	-	-	-	-	-	-	-
Blueback herring	35	42	64	54.6	100.0	2	75	186	130.5	100.0	6	38	84	57.7	100.0
Alewife	2	67	69	68.0	100.0	-	-	-	-	-	24	52	117	76.9	100.0
American shad	1	188	188	188.0	100.0	19	59	88	71.0	100.0	21	66	83	74.3	100.0
Gizzard shad	1	252	252	252.0	0.0	9	242	318	258.6	0.0	1	305	305	305.0	0.0
Bay anchovy	-	-	-	-	-	3	40	54	47.0	0.0	-	-	-	-	-
Eastern silvery minnow	1	104	104	104.0	0.0	-	-	-	-	-	-	-	-	-	-
Golden shiner	2	55	70	62.5	50.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	12	58	101	78.4	50.0	1	90	90	90.0	0.0	-	-	-	-	-
White sucker	-	-	-	-	-	-	-	-	-	-	4	265	431	377.3	0.0
White catfish	-	-	-	-	-	1	280	280	280.0	0.0	2	60	183	121.5	0.0
Brown bullhead	2	227	304	265.5	0.0	-	-	-	-	-	-	-	-	-	-
Channel catfish	4	130	387	261.5	50.0	13	312	405	343.0	0.0	33	19	517	215.8	60.6
Banded killifish	21	27	69	45.0	66.7	-	-	-	-	-	-	-	-	-	-
Inland silverside	22	19	82	39.5	27.3	-	-	-	-	-	-	-	-	-	-
Fourspine stickleback	4	37	41	39.3	0.0	-	-	-	-	-	-	-	-	-	-
White perch	53	37	192	82.1	77.4	40	51	213	126.1	35.0	50	34	188	124.9	30.0
Striped bass	8	61	170	100.3	100.0	3	214	307	248.7	66.7	-	-	-	-	-
Redbreast sunfish	2	101	103	102.0	0.0	-	-	-	-	-	-	-	-	-	-
Pumpkinseed	11	98	161	119.2	0.0	-	-	-	-	-	-	-	-	-	-
Bluegill	25	30	103	40.0	96.0	-	-	-	-	-	-	-	-	-	-
Largemouth bass	1	56	56	56.0	100.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	17	55	69	60.9	0.0	-	-	-	-	-	-	-	-	-	-
Hogchoker	16	47	67	59.1	100.0	1	66	66	66.0	100.0	20	55	78	62.8	100.0

Appendix 5-2. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 1, showing percentage of juveniles (J) during the fall season (Oct. 13-Oct. 30, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
American eel	2	190	266	228.0	100.0	-	-	-	-	-	-	-	-	-	-
Blueback herring	5	54	60	57.4	100.0	-	-	-	-	-	20	64	85	75.4	100.0
Alewife	-	-	-	-	-	-	-	-	-	-	16	73	118	92.1	81.2
American shad	6	65	81	71.5	100.0	2	82	93	87.5	100.0	20	67	106	84.4	100.0
Bay anchovy	-	-	-	-	-	-	-	-	-	-	2	24	39	31.5	50.0
Common carp	1	770	770	770.0	0.0	-	-	-	-	-	-	-	-	-	-
Eastern silvery minnow	31	84	135	113.4	0.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	15	48	110	82.9	6.7	2	56	103	79.5	50.0	-	-	-	-	-
White sucker	-	-	-	-	-	-	-	-	-	-	1	375	375	375.0	0.0
White catfish	-	-	-	-	-	-	-	-	-	-	12	94	270	212.9	25.0
Channel catfish	-	-	-	-	-	2	70	418	244.0	50.0	24	79	366	204.8	75.0
Banded killifish	47	37	96	57.6	42.6	-	-	-	-	-	-	-	-	-	-
Mummichog	20	31	67	49.7	100.0	-	-	-	-	-	-	-	-	-	-
Inland silverside	1	20	20	20.0	100.0	-	-	-	-	-	-	-	-	-	-
Fourspine stickleback	10	34	45	39.2	30.0	-	-	-	-	-	-	-	-	-	-
White perch	50	51	138	71.3	92.0	25	58	176	124.0	24.0	10	41	161	105.5	50.0
Striped bass	12	59	74	66.8	100.0	1	202	202	202.0	100.0	-	-	-	-	-
Green sunfish	1	44	44	44.0	100.0	-	-	-	-	-	-	-	-	-	-
Pumpkinseed	33	51	171	129.3	3.0	-	-	-	-	-	-	-	-	-	-
Bluegill	24	30	144	67.5	66.7	-	-	-	-	-	-	-	-	-	-
Largemouth bass	6	78	259	197.2	50.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	47	47	84	69.4	0.0	-	-	-	-	-	-	-	-	-	-
Yellow perch	2	193	197	195.0	0.0	-	-	-	-	-	-	-	-	-	-
Atlantic croaker	-	-	-	-	-	-	-	-	-	-	4	19	28	22.0	100.0
Hogchoker	14	34	80	53.9	92.9	7	59	67	62.7	100.0	20	59	84	67.9	95.0

Appendix 5-3. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 1, showing percentage of juveniles (J) during the spring season (May 10-12, 1993). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
American eel	2	127	217	172.0	100.0	1	250	250	250.0	100.0	-	-	-	-	-
Blueback herring	1	225	225	225.0	100.0	34	81	247	191.8	76.5	9	80	231	164.3	89.0
Alewife	2	119	220	169.5	0.0	-	-	-	-	-	-	-	-	-	-
Golden shiner	27	38	87	49.4	81.5	-	-	-	-	-	-	-	-	-	-
Eastern silvery minnow	42	75	118	92.6	0.0	2	99	105	102.0	0.0	-	-	-	-	-
Spottail shiner	8	77	103	90.8	0.0	-	-	-	-	-	-	-	-	-	-
Bluntnose minnow	1	60	60	60.0	0.0	-	-	-	-	-	-	-	-	-	-
White sucker	1	64	64	64.0	100.0	-	-	-	-	-	-	-	-	-	-
White catfish	-	-	-	-	-	10	80	387	150.9	90.0	5	58	367	181.4	60.0
Channel catfish	1	401	401	401.0	0.0	26	72	375	214.0	73.1	23	74	375	196.4	69.6
Banded killifish	28	47	111	71.4	3.6	-	-	-	-	-	-	-	-	-	-
Mummichog	24	43	104	61.2	83.3	-	-	-	-	-	-	-	-	-	-
White perch	44	56	198	88.8	63.6	40	134	207	155.9	0.0	32	104	187	145.0	6.2
Striped bass	4	66	96	75.0	100.0	3	220	513	335.3	66.7	5	188	346	236.4	80.0
Redbreast sunfish	3	84	141	116.0	0.0	-	-	-	-	-	-	-	-	-	-
Green sunfish	1	140	140	140.0	0.0	-	-	-	-	-	-	-	-	-	-
Pumpkinseed	12	62	150	114.4	0.0	-	-	-	-	-	-	-	-	-	-
Largemouth bass	3	185	257	220.0	66.7	-	-	-	-	-	-	-	-	-	-
Tessellated darter	6	60	69	64.2	0.0	3	70	82	77.3	0.0	-	-	-	-	-
Hogchoker	-	-	-	-	-	21	37	74	63.3	100.0	10	56	90	70.4	80.0

APPENDIX 6

FISH LENGTH AND PERCENT JUVENILES, STATION 2

Appendix 6-1. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 2, showing percentage of juveniles (J) during the summer season (Sept. 1-Oct. 1, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
American eel	10	87	286	112.0	90.0	-	-	-	-	-	3	111	289	197.7	66.7
Blueback herring	4	46	50	48.3	100.0	-	-	-	-	-	20	47	77	55.7	100.0
Alewife	2	63	75	69.0	100.0	-	-	-	-	-	-	-	-	-	-
American shad	63	55	87	73.4	100.0	1	82	82	82.0	100.0	20	76	90	83.2	100.0
Atlantic menhaden	-	-	-	-	-	-	-	-	-	-	4	109	133	119.3	100.0
Gizzard shad	1	282	282	282.0	0.0	3	233	252	242.3	0.0	1	290	290	290.0	0.0
Bay anchovy	9	37	56	45.9	0.0	-	-	-	-	-	22	27	50	40.2	13.6
Common carp	-	-	-	-	-	1	610	610	610.0	0.0	-	-	-	-	-
Eastern silvery minnow	52	78	129	111.9	0.0	6	103	119	109.3	0.0	-	-	-	-	-
Spottail shiner	59	44	120	92.2	8.5	1	100	100	100.0	0.0	-	-	-	-	-
Brown bullhead	1	310	310	310.0	0.0	-	-	-	-	-	-	-	-	-	-
Channel catfish	3	332	402	360.3	0.0	35	44	570	208.4	60.0	3	453	552	495.7	0.0
Tiger muskellunge	1	702	702	702.0	0.0	-	-	-	-	-	-	-	-	-	-
Banded killifish	15	38	105	78.5	13.3	-	-	-	-	-	-	-	-	-	-
Inland silverside	10	24	54	42.8	20.0	-	-	-	-	-	-	-	-	-	-
White perch	31	42	147	76.1	96.8	42	52	185	142.0	11.9	38	42	187	110.9	47.4
Striped bass	20	48	177	94.5	100.0	7	355	457	399.3	0.0	-	-	-	-	-
Pumpkinseed	2	55	62	58.5	50.0	-	-	-	-	-	-	-	-	-	-
Smallmouth bass	1	152	152	152.0	100.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	-	-	-	-	-	18	26	69	55.4	16.7	-	-	-	-	-
Hogchoker	3	14	38	24.7	100.0	20	22	72	55.4	100.0	13	29	77	68.2	100.0

Appendix 6-2. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 2, showing percentage of juveniles (J) during the fall season (Oct. 13-Oct. 30, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Blueback herring	1	49	49	49.0	100.0	21	57	94	71.9	100.0	22	57	87	65.0	100.0
Alewife	-	-	-	-	-	20	69	102	90.6	100.0	19	68	106	93.4	94.7
American shad	14	68	102	82.6	100.0	20	76	108	93.7	100.0	20	77	109	90.8	100.0
Gizzard shad	-	-	-	-	-	-	-	-	-	-	4	304	346	316.3	0.0
Bay anchovy	54	29	80	43.9	18.5	2	42	54	48.0	0.0	2	47	61	54.0	0.0
Eastern silvery minnow	26	63	117	86.3	0.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	33	59	103	81.8	9.1	-	-	-	-	-	-	-	-	-	-
White catfish	-	-	-	-	-	-	-	-	-	-	1	161	161	161.0	100.0
Brown bullhead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	20	59	295	129.6	90.0	6	122	442	271.5	33.3
Banded killifish	80	31	109	68.1	15.0	-	-	-	-	-	-	-	-	-	-
Mummichog	22	57	97	78.5	36.4	-	-	-	-	-	-	-	-	-	-
Inland silverside	21	28	64	55.0	4.8	-	-	-	-	-	-	-	-	-	-
White perch	60	42	111	67.1	96.7	26	80	167	134.1	11.5	46	54	238	119.3	37.0
Striped bass	18	44	72	56.5	100.0	1	200	200	200.0	100.0	-	-	-	-	-
Pumpkinseed	4	58	133	90.8	50.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	27	53	81	68.3	0.0	-	-	-	-	-	-	-	-	-	-
Atlantic croaker	1	12	12	12.0	100.0	-	-	-	-	-	8	23	35	29.1	100.0
Naked goby	2	33	34	33.5	0.0	-	-	-	-	-	-	-	-	-	-
Hogchoker	17	22	61	32.9	100.0	20	31	71	59.3	100.0	20	38	83	70.1	95.0

Appendix 6-3. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 2, showing percentage of juveniles (J) during the spring season (May 21-26, 1993). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Shortnose sturgeon	-	-	-	-	-	-	-	-	-	-	2	601	619	610.0	0.0
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	1	381	381	381.0	100.0
American eel	-	-	-	-	-	-	-	-	-	-	1	276	276	276.0	100.0
Blueback herring	-	-	-	-	-	16	85	107	97.8	100.0	21	86	113	99.4	100.0
Alewife	-	-	-	-	-	-	-	-	-	-	1	193	193	193.0	0.0
Bay anchovy	2	64	64	64.0	0.0	-	-	-	-	-	-	-	-	-	-
Common carp	1	440	440	440.0	0.0	-	-	-	-	-	-	-	-	-	-
Eastern silvery minnow	12	76	122	92.8	0.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	21	72	115	89.8	0.0	-	-	-	-	-	-	-	-	-	-
White catfish	-	-	-	-	-	-	-	-	-	-	1	328	328	328.0	0.0
Brown bullhead	-	-	-	-	-	-	-	-	-	-	1	280	280	280.0	0.0
Channel catfish	1	75	75	75.0	100.0	5	465	538	505.2	0.0	22	64	382	170.8	81.8
Banded killifish	19	54	101	76.4	0.0	-	-	-	-	-	-	-	-	-	-
Mummichog	16	46	90	65.2	87.5	-	-	-	-	-	-	-	-	-	-
Rough silverside	5	75	91	80.8	0.0	-	-	-	-	-	-	-	-	-	-
Inland silverside	9	55	67	59.4	0.0	-	-	-	-	-	-	-	-	-	-
White perch	31	65	170	94.5	64.5	27	67	205	133.9	18.5	20	78	180	133.0	10.0
Striped bass	5	72	218	139.0	100.0	2	216	223	219.5	100.0	-	-	-	-	-
Pumpkinseed	3	108	141	129.7	0.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	3	65	79	71.0	0.0	-	-	-	-	-	-	-	-	-	-
Hogchoker	2	37	73	55.0	100.0	1	95	95	95.0	0.0	5	31	72	54.0	100.0

APPENDIX 7

FISH LENGTH AND PERCENT JUVENILES, STATION 3

Appendix 7-1. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 3, showing percentage of juveniles (J) during the summer season (Sept. 1-Oct. 1, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	1	200	200	200.0	100.0
American eel	7	170	315	258.3	57.1	1	236	236	236.0	100.0	-	-	-	-	-
American shad	33	61	90	72.4	100.0	1	88	88	88.0	100.0	10	73	90	81.4	100.0
Atlantic menhaden	-	-	-	-	-	-	-	-	-	-	1	126	126	126.0	100.0
Gizzard shad	4	212	256	230.3	0.0	-	-	-	-	-	-	-	-	-	-
Bay anchovy	80	21	57	41.1	31.2	-	-	-	-	-	40	23	75	47.8	35.0
Eastern silvery minnow	7	75	133	102.3	0.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	26	54	111	83.0	7.7	-	-	-	-	-	-	-	-	-	-
White catfish	-	-	-	-	-	1	365	365	365.0	0.0	-	-	-	-	-
Brown bullhead	-	-	-	-	-	-	-	-	-	-	2	223	226	224.5	0.0
Channel catfish	2	66	86	76.0	100.0	28	52	370	121.0	92.9	6	66	461	214.2	66.7
Banded killifish	4	37	103	78.0	25.0	-	-	-	-	-	-	-	-	-	-
Mummichog	1	76	76	76.0	0.0	-	-	-	-	-	-	-	-	-	-
Inland silverside	34	43	87	58.0	0.0	-	-	-	-	-	-	-	-	-	-
White perch	63	42	205	117.9	39.7	41	50	190	138.0	17.1	13	39	124	57.9	92.3
Striped bass	12	49	162	79.4	100.0	11	50	284	94.8	90.9	1	282	282	282.0	0.0
Pumpkinseed	5	99	134	117.4	0.0	-	-	-	-	-	-	-	-	-	-
Largemouth bass	2	240	250	245.0	0.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	5	52	72	65.4	0.0	-	-	-	-	-	-	-	-	-	-
Yellow perch	1	224	224	224.0	0.0	-	-	-	-	-	-	-	-	-	-
Bluefish	3	83	139	107.3	100.0	-	-	-	-	-	12	66	95	81.3	100.0
Weakfish	-	-	-	-	-	-	-	-	-	-	1	103	103	103.0	100.0
Naked goby	-	-	-	-	-	3	19	25	22.0	66.7	-	-	-	-	-
Hogchoker	15	26	68	54.8	100.0	20	59	86	74.0	85.0	20	26	77	67.7	100.0

Appendix 7-2. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 3, showing percentage of juveniles (J) during the fall season (Oct. 13-Oct. 30, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American eel	-	-	-	-	-	6	218	282	250.0	16.7	1	291	291	291.0	0.0
Blueback herring	3	57	64	60.7	100.0	2	75	126	100.5	100.0	2	79	128	103.5	100.0
Alewife	-	-	-	-	-	2	103	145	124.0	50.0	-	-	-	-	-
American shad	16	65	92	77.5	100.0	7	74	96	89.4	100.0	8	82	99	90.1	100.0
Atlantic menhaden	26	44	123	68.8	100.0	8	112	255	140.0	87.5	9	79	132	108.6	100.0
Gizzard shad	2	103	131	117.0	100.0	-	-	-	-	-	-	-	-	-	-
Bay anchovy	63	30	63	45.7	14.3	22	29	72	53.0	18.2	32	36	70	52.7	3.1
Satinfin shiner	1	47	47	47.0	100.0	-	-	-	-	-	-	-	-	-	-
Eastern silvery minnow	23	64	135	86.9	0.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	32	68	121	91.4	0.0	-	-	-	-	-	-	-	-	-	-
White catfish	-	-	-	-	-	4	94	323	222.5	25.0	-	-	-	-	-
Channel catfish	2	71	73	72.0	100.0	22	66	218	111.5	100.0	12	63	147	93.4	100.0
Banded killifish	20	40	90	58.7	25.0	-	-	-	-	-	-	-	-	-	-
Mummichog	22	48	80	60.5	90.9	-	-	-	-	-	-	-	-	-	-
Inland silverside	42	45	93	69.1	0.0	-	-	-	-	-	-	-	-	-	-
White perch	50	54	180	97.6	56.0	31	46	155	73.6	80.6	33	48	158	79.1	78.8
Striped bass	46	47	209	60.9	100.0	-	-	-	-	-	1	187	187	187.0	100.0
Pumpkinseed	6	64	127	109.0	16.7	-	-	-	-	-	-	-	-	-	-
Bluegill	5	60	109	77.6	60.0	-	-	-	-	-	-	-	-	-	-
Largemouth bass	2	127	138	132.5	100.0	-	-	-	-	-	-	-	-	-	-
Tessellated darter	6	63	77	71.2	0.0	-	-	-	-	-	-	-	-	-	-
Yellow perch	1	275	275	275.0	0.0	-	-	-	-	-	-	-	-	-	-
Weakfish	-	-	-	-	-	1	78	78	78.0	100.0	2	47	72	59.5	100.0
Atlantic croaker	10	19	40	30.8	100.0	40	17	30	22.1	100.0	40	16	59	23.4	100.0
Hogchoker	7	60	84	72.7	71.4	20	30	78	64.8	100.0	23	37	90	73.3	69.6

Appendix 7-3. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 3, showing percentage of juveniles (J) during the spring season (May 17-21, 1993). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
American eel	1	264	264	264.0	100.0	-	-	-	-	-	2	143	185	164.0	100.0
Blueback herring	1	34	34	34.0	100.0	33	84	246	155.3	97.0	10	86	98	91.7	100.0
Bay anchovy	-	-	-	-	-	1	53	53	53.0	0.0	-	-	-	-	-
Common carp	-	-	-	-	-	1	689	689	689.0	0.0	-	-	-	-	-
Eastern silvery minnow	40	76	125	91.2	0.0	2	84	89	86.5	0.0	3	83	108	96.3	0.0
Golden shiner	1	89	89	89.0	0.0	-	-	-	-	-	-	-	-	-	-
Spottail shiner	7	87	113	101.7	0.0	-	-	-	-	-	-	-	-	-	-
Brown bullhead	-	-	-	-	-	-	-	-	-	-	1	275	275	275.0	0.0
White catfish	-	-	-	-	-	1	300	300	300.0	0.0	-	-	-	-	-
Channel catfish	2	72	90	81.0	100.0	23	73	560	201.9	73.9	29	57	438	191.3	65.5
Banded killifish	23	52	90	68.9	0.0	-	-	-	-	-	-	-	-	-	-
Mummichog	32	41	101	65.7	81.2	-	-	-	-	-	-	-	-	-	-
Inland silverside	1	45	45	45.0	0.0	-	-	-	-	-	-	-	-	-	-
White perch	35	55	157	83.1	74.3	29	112	203	149.5	0.0	22	55	182	95.3	63.3
Striped bass	7	63	100	75.0	100.0	9	220	608	334.4	33.3	-	-	-	-	-
Pumpkinseed	13	57	151	97.9	15.4	-	-	-	-	-	-	-	-	-	-
Bluegill	3	33	132	70.3	66.7	-	-	-	-	-	-	-	-	-	-
Tessellated darter	3	63	83	73.7	0.0	-	-	-	-	-	-	-	-	-	-
Yellow perch	1	238	238	238.0	0.0	-	-	-	-	-	-	-	-	-	-
Hogchoker	1	32	32	32.0	100.0	5	61	73	67.8	100.0	21	30	86	60.7	90.5

APPENDIX 8

FISH LENGTH AND PERCENT JUVENILES, STATION 4

Appendix 8-1. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 4, showing percentage of juveniles (J) during the summer season (Sept. 1-Oct. 1, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Atlantic sturgeon	-	-	-	-	-	3	556	778	673.0	100.0	-	-	-	-	-
American eel	5	160	262	198.0	100.0	-	-	-	-	-	-	-	-	-	-
Atlantic menhaden	1	71	71	71.0	100.0	1	46	46	46.0	100.0	8	91	210	128.6	87.5
Gizzard shad	-	-	-	-	-	2	153	166	159.5	100.0	-	-	-	-	-
Bay anchovy	32	12	85	38.3	50.0	41	23	82	64.1	9.8	28	19	75	56.9	10.7
Channel catfish	-	-	-	-	-	6	237	330	281.3	0.0	-	-	-	-	-
Mummichog	1	72	72	72.0	100.0	-	-	-	-	-	-	-	-	-	-
Inland silverside	30	36	86	58.1	3.4	-	-	-	-	-	-	-	-	-	-
White perch	3	150	171	159.3	0.0	43	120	198	168.5	0.0	21	133	206	161.6	0.0
Striped bass	23	65	180	98.1	100.0	1	58	58	58.0	100.0	1	278	278	278.0	100.0
Black seabass	-	-	-	-	-	1	19	19	19.0	100.0	-	-	-	-	-
Bluefish	2	71	83	77.0	100.0	3	88	100	94.0	100.0	2	84	195	139.5	100.0
Silver perch	-	-	-	-	-	-	-	-	-	-	1	105	105	105.0	100.0
Weakfish	20	34	164	74.7	100.0	29	39	143	83.4	100.0	35	45	250	79.9	97.1
Atlantic croaker	12	11	16	14.3	100.0	27	10	201	29.9	92.6	8	13	24	17.6	100.0
Naked goby	7	17	21	18.7	100.0	5	22	39	30.4	20.0	2	23	26	24.5	0.0
Butterfish	-	-	-	-	-	3	91	95	92.7	100.0	2	79	83	81.0	100.0
Smallmouth flounder	-	-	-	-	-	1	23	23	23.0	100.0	-	-	-	-	-
Summer flounder	1	166	166	166.0	100.0	-	-	-	-	-	-	-	-	-	-
Hogchoker	20	66	104	77.2	80.0	44	67	171	90.1	38.6	21	67	144	104.8	9.5

Appendix 8-2. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 4, showing percentage of juveniles (J) during the fall season (Oct. 13-Oct. 30, 1992). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
American eel	-	-	-	-	-	4	186	275	234.8	100.0	4	135	310	223.8	75.0
Blueback herring	1	52	52	52.0	100.0	1	135	135	135.0	100.0	2	79	126	102.5	100.0
Alewife	-	-	-	-	-	4	81	149	116.5	50.0	1	103	103	103.0	100.0
American shad	-	-	-	-	-	4	84	103	94.3	100.0	-	-	-	-	-
Atlantic menhaden	-	-	-	-	-	13	104	199	137.7	100.0	2	107	114	110.5	100.0
Bay anchovy	42	32	85	58.6	2.4	24	27	81	61.4	12.5	40	33	83	62.1	5.0
Channel catfish	-	-	-	-	-	2	265	392	328.5	0.0	-	-	-	-	-
Inland silverside	49	46	96	68.4	0.0	-	-	-	-	-	-	-	-	-	-
White perch	35	53	174	129.9	22.9	48	58	185	146.1	6.2	39	61	184	136.6	10.3
Striped bass	52	56	176	96.8	100.0	3	137	270	192.0	100.0	2	219	300	259.5	50.0
Weakfish	1	68	68	68.0	100.0	4	47	70	58.8	100.0	6	67	100	77.8	100.0
Atlantic croaker	16	17	30	23.9	100.0	42	18	37	27.2	100.0	40	20	40	28.1	100.0
Naked goby	-	-	-	-	-	4	16	26	22.8	25.0	3	24	46	31.7	0.0
Smallmouth flounder	-	-	-	-	-	-	-	-	-	-	1	25	25	25.0	100.0
Hogchoker	20	43	88	70.9	80.0	32	62	120	78.4	31.2	20	66	112	78.0	70.0

Appendix 8-3. Numbers of individuals of fish species measured in each of the three habitats sampled at Station 4, showing percentage of juveniles (J) during the spring season (May 21-June 3, 1993). N = number measured; %J = percent of measured individuals which were juveniles.

Habitat:	SHALLOW					INTERMEDIATE					DEEP				
	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J	N	MIN	MAX	MEAN	%J
Atlantic sturgeon	-	-	-	-	-	-	-	-	-	-	1	378	378	378.0	100.0
American eel	1	295	295	295.0	0.0	6	121	368	201.0	83.3	2	222	235	228.5	100.0
American shad	-	-	-	-	-	-	-	-	-	-	1	147	147	147.0	100.0
Blueback herring	-	-	-	-	-	1	112	112	112.0	0.0	-	-	-	-	-
Atlantic menhaden	47	32	57	44.2	100.0	4	291	298	292.8	0.0	-	-	-	-	-
Bay anchovy	47	42	63	50.9	0.0	2	52	75	63.5	0.0	6	52	83	65.3	0.0
Common carp	1	101	101	101.0	100.0	-	-	-	-	-	1	629	629	629.0	0.0
Golden shiner	1	72	72	72.0	0.0	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	-	-	-	2	267	287	277.0	0.0	3	248	275	264.7	0.0
Rough silverside	3	81	90	87.0	19.3	-	-	-	-	-	-	-	-	-	-
Atlantic silverside	57	16	106	76.3	0.0	-	-	-	-	-	-	-	-	-	-
White perch	126	14	172	72.1	96.8	17	16	218	111.6	58.8	23	15	196	103.5	43.5
Striped bass	27	66	118	82.5	100.0	4	14	17	15.0	100.0	6	14	135	36.5	100.0
Yellow perch	20	25	35	31.2	100.0	-	-	-	-	-	-	-	-	-	-
Bluefish	3	54	59	56.7	100.0	-	-	-	-	-	-	-	-	-	-
Spot	-	-	-	-	-	1	25	25	25.0	100.0	-	-	-	-	-
Hogchoker	23	34	107	64.5	91.3	20	43	87	66.1	90.0	21	39	84	67.3	85.7

APPENDIX 9

OVERALL COMPARISON OF HISTORICAL AND RECENT FAUNAS

Appendix 9-1. Comparison of historical and recent faunas of the mainstem Delaware River in DRBC Water Quality Zones 2-5.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
PETROMYZONTIDAE - lampreys			
Petromyzon marinus	sea lamprey	X	X
ACIPENSERIDAE - sturgeons			
Acipenser brevirostrum	shortnose sturgeon	X	X
Acipenser oxyrhynchus	Atlantic sturgeon	X	X
LEPISOSTEIDAE - gars			
Lepisosteus osseus	longnose gar	X	-
AMIIDAE - bowfins			
Amia calva	bowfin	X	X
ELOPIDAE - tarpons			
Elops saurus	ladyfish	-	X
ANGUILLIDAE - freshwater eels			
Anguilla rostrata	American eel	X	X
CONGRIDAE - marine eels			
Conger oceanicus	conger eel	-	X
CLUPEIDAE - herrings			
Alosa aestivalis	blueback herring	X	X
Alosa mediocris	hickory shad	X	X
Alosa pseudoharengus	alewife	X	X
Alosa sapidissima	American shad	X	X
Brevoortia tyrannus	Atlantic menhaden	X	X
Clupea harengus harengus	Atlantic herring	-	X
Dorosoma cepedianum	gizzard shad	X	X
ENGRAULIDAE - anchovies			
Anchoa hepsetus	striped anchovy	-	X
Anchoa mitchilli	bay anchovy	X	X
CYPRINIDAE - carps and minnows			
Carassius auratus	goldfish	X	X
Cyprinella analostana	satinfin shiner	X	X
Cyprinella spiloptera	spotfin shiner	X	X
Cyprinus carpio	common carp	X	X
Exoglossum maxillingua	cutlips minnow	-	X
Hybognathus regius	eastern silvery minnow	X	X
Luxilus cornutus	common shiner	X	-
Notemigonus crysoleucas	golden shiner	X	X
Notropis amoenus	comely shiner	X	-
Notropis bifrenatus	bridle shiner	X	-
Notropis hudsonius	spottail shiner	X	X
Notropis procne	swallowtail shiner	X	X
Pimephales notatus	bluntnose minnow	X	X
Pimephales promelas	fathead minnow	X	-
Rhinichthys atratulus	blacknose dace	X	X
Semotilus atromaculatus	creek chub	X	-
Semotilus corporalis	fallfish	X	X
CATOSTOMIDAE - suckers			
Carpiodes cyprinus	quillback	X	X
Catostomus commersoni	white sucker	X	X
Erimyzon oblongus	creek chubsucker	X	X

Appendix 9-1, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
ICTALURIDAE - bullhead catfishes			
Ameiurus catus	white catfish	X	X
Ameiurus natalis	yellow bullhead	-	X
Ameiurus nebulosus	brown bullhead	X	X
Ictalurus punctatus	channel catfish	X	X
Noturus gyrinus	tadpole madtom	X	-
Noturus insignis	margined madtom	-	X
ESOCIDAE - pikes			
Esox americanus americanus	redfin pickerel	X	X
Esox lucius x E. masquinongy	tiger muskellunge	-	X
Esox niger	chain pickerel	X	X
UMBRIDAE - mudminnows			
Umbra pygmaea	eastern mudminnow	X	-
OSMERIDAE - smelts			
Osmerus mordax	rainbow smelt	X	-
SYNODONTIDAE - lizardfishes			
Synodus foetens	inshore lizardfish	-	X
APHREDODERIDAE - pirate perches			
Aphredoderus sayanus	pirate perch	X	-
GADIDAE - codfishes			
Merluccius bilinearis	silver hake	-	X
Urophycis regia	spotted hake	X	-
OPHIDIIDAE - cusk-eels			
Ophidion marginatum	striped cusk-eel	-	X
BELONIDAE - needlefishes			
Strongylura marina	Atlantic needlefish	X	X
CYPRINODONTIDAE - killifishes			
Fundulus diaphanus	banded killifish	X	X
Fundulus heteroclitus	mummichog	X	X
Fundulus majalis	striped killifish	-	X
ATHERINIDAE - silversides			
Membras martinica	rough silverside	X	X
Menidia beryllina	inland silverside	X	X
Menidia menidia	Atlantic silverside	X	X
GASTEROSTEIDAE - sticklebacks			
Apeltes quadracus	fourspine stickleback	X	X
Gasterosteus aculeatus	threespine stickleback	-	X
SYNGNATHIDAE - pipefishes			
Syngnathus fuscus	northern pipefish	X	X
TRIGLIDAE - searobins			
Prionotus evolans	striped searobin	-	X
PERCICHTHYIDAE - temperate basses			
Morone americana	white perch	X	X
Morone saxatilis	striped bass	X	X
Morone saxatilis x M. chrysops	striped bass hybrid	-	X
SERRANIDAE - sea basses			
Centropristis striata	black sea bass	-	X

Appendix 9-1, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
CENTRARCHIDAE - sunfishes			
Ambloplites rupestris	rock bass	-	X
Enneacanthus chaetodon	blackbanded sunfish	X	-
Enneacanthus gloriosus	bluespotted sunfish	X	-
Enneacanthus obesus	banded sunfish	X	-
Lepomis auritus	redbreast sunfish	X	X
Lepomis cyanellus	green sunfish	X	X
Lepomis gibbosus	pumpkinseed	X	X
Lepomis macrochirus	bluegill	X	X
Micropterus dolomieu	smallmouth bass	X	X
Micropterus salmoides	largemouth bass	X	X
Pomoxis annularis	white crappie	X	X
Pomoxis nigromaculatus	black crappie	X	X
PERCIDAE - perches			
Etheostoma olmstedi	tessellated darter	X	X
Perca flavescens	yellow perch	X	X
Stizostedion vitreum	walleye	X	X
POMATOMIDAE - bluefishes			
Pomatomus saltatrix	bluefish	X	X
CARANGIDAE - jacks			
Caranx hippos	crevalle jack	X	-
SCIAENIDAE - drums			
Bairdiella chrysoura	silver perch	X	X
Cynoscion regalis	weakfish	X	X
Leiostomus xanthurus	spot	X	X
Menticirrhus saxatilis	northern kingfish	-	X
Micropogonias undulatus	Atlantic croaker	X	X
Pogonias cromis	black drum	X	-
MUGILIDAE - mullets			
Mugil cephalus	striped mullet	-	X
URANOSCOPIDAE - stargazers			
Astroscopus guttatus	northern stargazer	-	X
GOBIIDAE - gobies			
Gobiosoma bosc	naked goby	X	X
SCOMBRIDAE - mackerels			
Scomberomorus maculatus	Spanish mackerel	-	X
STROMATEIDAE - butterfishes			
Peprilus alepidotus	harvestfish	-	X
Peprilus triacanthus	butterfish	-	X
BOTHIDAE - lefteye flounders			
Etropus microstomus	smallmouth flounder	-	X
Paralichthys dentatus	summer flounder	X	X
Scopthalmus aquosus	windowpane	-	X
PLEURONECTIDAE - righteye flounders			
Pleuronectes americanus	winter flounder	X	X
SOLEIDAE - soles			
Trinectes maculatus	hogchoker	X	X
TETRAODONTIDAE - puffers			
Sphaeroides maculatus	northern puffer	X	X

Appendix 9-2. Comparison of historical and recent faunas of the mainstem Delaware River between Trenton, New Jersey and the Chesapeake and Delaware Canal in DRBC WQZ 2.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
PETROMYZONTIDAE - lampreys			
Petromyzon marinus	sea lamprey	X	X
ACIPENSERIDAE - sturgeons			
Acipenser brevirostrum	shortnose sturgeon	X	X
Acipenser oxyrhynchus	Atlantic sturgeon	X	X
LEPISOSTEIDAE - gars			
Lepisosteus osseus	longnose gar	X	-
AMIIDAE - bowfins			
Amia calva	bowfin	-	X
ANGUILLIDAE - freshwater eels			
Anguilla rostrata	American eel	X	X
CLUPEIDAE - herrings			
Alosa aestivalis	blueback herring	X	X
Alosa mediocris	hickory shad	X	X
Alosa pseudoharengus	alewife	X	X
Alosa sapidissima	American shad	X	X
Brevoortia tyrannus	Atlantic menhaden	X	X
Dorosoma cepedianum	gizzard shad	X	X
ENGRAULIDAE - anchovies			
Anchoa mitchilli	bay anchovy	-	X
CYPRINIDAE - carps and minnows			
Carassius auratus	goldfish	X	X
Cyprinella analostana	satinfin shiner	X	X
Cyprinella spiloptera	spotfin shiner	X	X
Cyprinus carpio	common carp	X	X
Hybognathus regius	eastern silvery minnow	X	X
Luxilus cornutus	common shiner	-	-
Notemigonus crysoleucas	golden shiner	X	X
Notropis amoenus	comely shiner	X	-
Notropis bifrenatus	bridle shiner	X	-
Notropis hudsonius	spottail shiner	X	X
Notropis procne	swallowtail shiner	X	X
Pimephales notatus	bluntnose minnow	-	X
Rhinichthys atratulus	blacknose dace	X	X
Semotilus atromaculatus	creek chub	X	-
Semotilus corporalis	fallfish	X	X
CATOSTOMIDAE - suckers			
Carpiodes cyprinus	quillback	X	X
Catostomus commersoni	white sucker	X	X
Erimyzon oblongus	creek chubsucker	X	X
ICTALURIDAE - bullhead catfishes			
Ameiurus catus	white catfish	X	X
Ameiurus natalis	yellow bullhead	-	X
Ameiurus nebulosus	brown bullhead	X	X
Ictalurus punctatus	channel catfish	X	X
Noturus gyrinus	tadpole madtom	X	-
Noturus insignis	margined madtom	-	X

Appendix 9-2, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
ESOCIDAE - pikes			
Esox americanus americanus	redfin pickerel	X	X
Esox lucius x E. masquinongy	tiger muskellunge	-	X
Esox niger	chain pickerel	X	X
UMBRIDAE - mudminnows			
Umbra pygmaea	eastern mudminnow	X	-
OSMERIDAE - smelts			
Osmerus mordax	rainbow smelt	X	-
APHREDODERIDAE - pirate perches			
Aphredoderus sayanus	pirate perch	X	-
BELONIDAE - needlefishes			
Strongylura marina	Atlantic needlefish	X	-
CYPRINODONTIDAE - killifishes			
Fundulus diaphanus	banded killifish	X	X
Fundulus heteroclitus	mummichog	X	X
Fundulus majalis	striped killifish	-	-
ATHERINIDAE - silversides			
Membras martinica	rough silverside	-	X
Menidia beryllina	inland silverside	X	X
Menidia menidia	Atlantic silverside	-	X
GASTEROSTEIDAE - sticklebacks			
Apeltes quadracus	fourspine stickleback	X	X
Gasterosteus aculeatus	threespine stickleback	-	X
PERCICHTHYIDAE - temperate basses			
Morone americana	white perch	X	X
Morone saxatilis	striped bass	X	X
Morone saxatilis x M. chrysops	striped bass hybrid	-	-

Appendix 9-2, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
CENTRARCHIDAE - sunfishes			
Ambloplites rupestris	rock bass	-	X
Enneacanthus chaetodon	blackbanded sunfish	X	-
Enneacanthus gloriosus	bluespotted sunfish	X	-
Enneacanthus obesus	banded sunfish	X	-
Lepomis auritus	redbreast sunfish	X	X
Lepomis cyanellus	green sunfish	X	X
Lepomis gibbosus	pumpkinseed	X	X
Lepomis macrochirus	bluegill	X	X
Micropterus dolomieu	smallmouth bass	X	X
Micropterus salmoides	largemouth bass	X	X
Pomoxis annularis	white crappie	X	X
Pomoxis nigromaculatus	black crappie	X	X
PERCIDAE - perches			
Etheostoma olmstedi	tessellated darter	X	X
Perca flavescens	yellow perch	X	X
Stizostedion vitreum	walleye	X	X
SCIAENIDAE - drums			
Leiostomus xanthurus	spot	-	X
Micropogonias undulatus	Atlantic croaker	-	X
Pogonias cromis	black drum	-	-
GOBIIDAE - gobies			
Gobiosoma bosc	naked goby	X	X
SOLEIDAE - soles			
Trinectes maculatus	hogchoker	-	X

Appendix 9-3. Comparison of historical and recent faunas of the mainstem Delaware River between Trenton, New Jersey and the Chesapeake and Delaware Canal in DRBC WQZ 3.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
PETROMYZONTIDAE - lampreys			
Petromyzon marinus	sea lamprey	-	X
ACIPENSERIDAE - sturgeons			
Acipenser brevirostrum	shortnose sturgeon	X	X
Acipenser oxyrhynchus	Atlantic sturgeon	X	X
AMIIDAE - bowfins			
Amia calva	bowfin	X	-
ELOPIDAE - tarpons			
Elops saurus	ladyfish	-	X
ANGUILLIDAE - freshwater eels			
Anguilla rostrata	American eel	X	X
CLUPEIDAE - herrings			
Alosa aestivalis	blueback herring	X	X
Alosa mediocris	hickory shad	X	X
Alosa pseudoharengus	alewife	X	X
Alosa sapidissima	American shad	X	X
Brevoortia tyrannus	Atlantic menhaden	X	X
Dorosoma cepedianum	gizzard shad	X	X
ENGRAULIDAE - anchovies			
Anchoa mitchilli	bay anchovy	X	X
CYPRINIDAE - carps and minnows			
Carassius auratus	goldfish	X	X
Cyprinella spiloptera	spotfin shiner	-	X
Cyprinus carpio	common carp	X	X
Hybognathus regius	eastern silvery minnow	X	X
Notemigonus crysoleucas	golden shiner	X	X
Notropis bifrenatus	bridle shiner	X	-
Notropis hudsonius	spottail shiner	X	X
Notropis procne	swallowtail shiner	X	X
CATOSTOMIDAE - suckers			
Catostomus commersoni	white sucker	X	X
ICTALURIDAE - bullhead catfishes			
Ameiurus catus	white catfish	X	X
Ameiurus natalis	yellow bullhead	-	-
Ameiurus nebulosus	brown bullhead	X	X
Ictalurus punctatus	channel catfish	X	X
Noturus gyrinus	tadpole madtom	-	-
Noturus insignis	margined madtom	-	-

Appendix 9-3, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
ESOCIDAE - pikes			
Esox lucius x E. masquinongy	tiger muskellunge	-	X
Esox niger	chain pickerel	-	X
APHREDODERIDAE - pirate perches			
Aphredoderus sayanus	pirate perch	X	-
BELONIDAE - needlefishes			
Strongylura marina	Atlantic needlefish	X	-
CYPRINODONTIDAE - killifishes			
Fundulus diaphanus	banded killifish	X	X
Fundulus heteroclitus	mummichog	X	X
ATHERINIDAE - silversides			
Membras martinica	rough silverside	X	X
Menidia beryllina	inland silverside	X	X
Menidia menidia	Atlantic silverside	X	X
GASTEROSTEIDAE - sticklebacks			
Apeltes quadracus	fourspine stickleback	X	-
PERCICHTHYIDAE - temperate basses			
Morone americana	white perch	X	X
Morone saxatilis	striped bass	X	X
Morone saxatilis x M. chrysops	striped bass hybrid	-	X

Appendix 9-3, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
CENTRARCHIDAE - sunfishes			
Enneacanthus chaetodon	blackbanded sunfish	X	-
Lepomis auritus	redbreast sunfish	-	X
Lepomis cyanellus	green sunfish	-	X
Lepomis gibbosus	pumpkinseed	X	X
Lepomis macrochirus	bluegill	X	X
Micropterus dolomieu	smallmouth bass	-	X
Micropterus salmoides	largemouth bass	X	X
Pomoxis annularis	white crappie	X	X
Pomoxis nigromaculatus	black crappie	X	X
PERCIDAE - perches			
Etheostoma olmstedi	tessellated darter	X	X
Perca flavescens	yellow perch	X	-
POMATOMIDAE - bluefishes			
Pomatomus saltatrix	bluefish	-	X
SCIAENIDAE - drums			
Cynoscion regalis	weakfish	X	-
Leiostomus xanthurus	spot	X	X
Micropogonias undulatus	Atlantic croaker	-	X
MUGILIDAE - mullets			
Mugil cephalus	striped mullet	-	X
GOBIIDAE - gobies			
Gobiosoma bosc	naked goby	X	X
BOTHIDAE - lefteye flounders			
Paralichthys dentatus	summer flounder	-	X
SOLEIDAE - soles			
Trinectes maculatus	hogchoker	X	X

Appendix 9-4. Comparison of historical and recent faunas of the mainstem Delaware River between Trenton, New Jersey and the Chesapeake and Delaware Canal in DRBC WQZ 4.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
PETROMYZONTIDAE - lampreys			
Petromyzon marinus	sea lamprey	X	X
ACIPENSERIDAE - sturgeons			
Acipenser brevirostrum	shortnose sturgeon	-	X
Acipenser oxyrhynchus	Atlantic sturgeon	X	X
AMIIDAE - bowfins			
Amia calva	bowfin	X	-
ANGUILLIDAE - freshwater eels			
Anguilla rostrata	American eel	X	X
CLUPEIDAE - herrings			
Alosa aestivalis	blueback herring	X	X
Alosa mediocris	hickory shad	X	X
Alosa pseudoharengus	alewife	X	X
Alosa sapidissima	American shad	X	X
Brevoortia tyrannus	Atlantic menhaden	X	X
Clupea harengus harengus	Atlantic herring	-	X
Dorosoma cepedianum	gizzard shad	X	X
ENGRAULIDAE - anchovies			
Anchoa hepsetus	striped anchovy	-	X
Anchoa mitchilli	bay anchovy	X	X
CYPRINIDAE - carps and minnows			
Carassius auratus	goldfish	X	-
Cyprinella analostana	satinfin shiner	X	X
Cyprinella spiloptera	spotfin shiner	X	X
Cyprinus carpio	common carp	X	X
Hybognathus regius	eastern silvery minnow	X	X
Luxilus cornutus	common shiner	X	-
Notemigonus crysoleucas	golden shiner	X	X
Notropis bifrenatus	bridle shiner	X	-
Notropis hudsonius	spottail shiner	X	X
Notropis procne	swallowtail shiner	X	-
Pimephales notatus	bluntnose minnow	X	-
Pimephales promelas	fathead minnow	X	-
Semotilus corporalis	fallfish	X	-
CATOSTOMIDAE - suckers			
Carpiodes cyprinus	quillback	X	-
Catostomus commersoni	white sucker	X	X
Erimyzon oblongus	creek chubsucker	X	-
ICTALURIDAE - bullhead catfishes			
Ameiurus catus	white catfish	X	X
Ameiurus natalis	yellow bullhead	-	X
Ameiurus nebulosus	brown bullhead	X	X
Ictalurus punctatus	channel catfish	X	X

Appendix 9-4, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
ESOCIDAE - pikes			
Esox americanus americanus	redfin pickerel	X	-
Esox lucius x E. masquinongy	tiger muskellunge	-	X
Esox niger	chain pickerel	X	-
UMBRIDAE - mudminnows			
Umbra pygmaea	eastern mudminnow	X	-
SYNODONTIDAE - lizardfishes			
Synodus foetens	inshore lizardfish	-	X
APHREDODERIDAE - pirate perches			
Aphredoderus sayanus	pirate perch	X	-
GADIDAE - codfishes			
Merluccius bilinearis	silver hake	-	X
OPHIDIIDAE - cusk-eels			
Ophidion marginatum	striped cusk-eel	-	X
BELONIDAE - needlefishes			
Strongylura marina	Atlantic needlefish	X	X
CYPRINODONTIDAE - killifishes			
Fundulus diaphanus	banded killifish	X	X
Fundulus heteroclitus	mummichog	X	X
ATHERINIDAE - silversides			
Membras martinica	rough silverside	X	X
Menidia beryllina	inland silverside	X	X
Menidia menidia	Atlantic silverside	X	X
GASTEROSTEIDAE - sticklebacks			
Apeltes quadracus	fourspine stickleback	X	-
Gasterosteus aculeatus	threespine stickleback	X	-
PERCICHTHYIDAE - temperate basses			
Morone americana	white perch	X	X
Morone saxatilis	striped bass	X	X
Morone saxatilis x M. chrysops	striped bass hybrid	-	X

Appendix 9-4, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
CENTRARCHIDAE - sunfishes			
Ambloplites rupestris	rock bass	-	X
Enneacanthus obesus	banded sunfish	X	-
Lepomis auritus	redbreast sunfish	X	X
Lepomis cyanellus	green sunfish	X	-
Lepomis gibbosus	pumpkinseed	X	X
Lepomis macrochirus	bluegill	X	X
Micropterus dolomieu	smallmouth bass	X	X
Micropterus salmoides	largemouth bass	X	X
Pomoxis annularis	white crappie	X	X
Pomoxis nigromaculatus	black crappie	X	X
PERCIDAE - perches			
Etheostoma olmstedi	tessellated darter	X	X
Perca flavescens	yellow perch	X	X
POMATOMIDAE - bluefishes			
Pomatomus saltatrix	bluefish	X	X
CARANGIDAE - jacks			
Caranx hippos	crevalle jack	-	X
SCIAENIDAE - drums			
Cynoscion regalis	weakfish	X	X
Leiostomus xanthurus	spot	X	X
Menticirrhus saxatilis	northern kingfish	-	X
Micropogonias undulatus	Atlantic croaker	X	X
Pogonias cromis	black drum	-	X
MUGILIDAE - mullets			
Mugil cephalus	striped mullet	-	X
GOBIIDAE - gobies			
Gobiosoma bosc	naked goby	X	X
BOTHIDAE - lefteye flounders			
Etropus microstomus	smallmouth flounder	-	X
Paralichthys dentatus	summer flounder	-	X
SOLEIDAE - soles			
Trinectes maculatus	hogchoker	X	X

Appendix 9-5, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
CENTRARCHIDAE - sunfishes			
Lepomis gibbosus	pumpkinseed	X	X
Lepomis macrochirus	bluegill	X	X
Micropterus salmoides	largemouth bass	X	-
Pomoxis annularis	white crappie	X	X
Pomoxis nigromaculatus	black crappie	X	X
PERCIDAE - perches			
Etheostoma olmstedi	tessellated darter	X	X
Perca flavescens	yellow perch	X	X
POMATOMIDAE - bluefishes			
Pomatomus saltatrix	bluefish	X	X
CARANGIDAE - jacks			
Caranx hippos	crevalle jack	X	X
SCIAENIDAE - drums			
Bairdiella chrysoura	silver perch	X	X
Cynoscion regalis	weakfish	X	X
Leiostomus xanthurus	spot	X	X
Menticirrhus saxatilis	northern kingfish	-	X
Micropogonias undulatus	Atlantic croaker	X	X
Pogonias cromis	black drum	X	X
MUGILIDAE - mullets			
Mugil cephalus	striped mullet	-	X
URANOSCOPIDAE - stargazers			
Astroscopus guttatus	northern stargazer	-	X
GOBIIDAE - gobies			
Gobiosoma bosc	naked goby	X	X
SCOMBRIDAE - mackerels			
Scomberomorus maculatus	Spanish mackerel	-	X
STROMATEIDAE - butterfishes			
Peprilus alepidotus	harvestfish	-	X
Peprilus triacanthus	butterfish	-	X
BOTHIDAE - lefteye flounders			
Etropus microstomus	smallmouth flounder	-	X
Paralichthys dentatus	summer flounder	X	X
Scophthalmus aquosus	windowpane	-	X
PLEURONECTIDAE - righteye flounders			
Pleuronectes americanus	winter flounder	X	X
SOLEIDAE - soles			
Trinectes maculatus	hogchoker	X	X
TETRAODONTIDAE - puffers			
Sphaeroides maculatus	northern puffer	X	X

Appendix 9-5, continued.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
ESOCIDAE - pikes			
Esox americanus americanus	redfin pickerel	X	-
OSMERIDAE - smelts			
Osmerus mordax	rainbow smelt	X	-
GADIDAE - codfishes			
Urophycis regia	spotted hake	X	-
OPHIDIIDAE - cusk-eels			
Ophidion marginatum	striped cusk-eel	-	X
BELONIDAE - needlefishes			
Strongylura marina	Atlantic needlefish	X	X
CYPRINODONTIDAE - killifishes			
Fundulus diaphanus	banded killifish	X	X
Fundulus heteroclitus	mummichog	X	X
Fundulus majalis	striped killifish	-	X
ATHERINIDAE - silversides			
Membras martinica	rough silverside	X	X
Menidia beryllina	inland silverside	X	X
Menidia menidia	Atlantic silverside	X	X
SYNGNATHIDAE - pipefishes			
Syngnathus fuscus	northern pipefish	X	X
TRIGLIDAE - searobins			
Prionotus evolans	striped searobin	-	X
PERCICHTHYIDAE - temperate basses			
Morone americana	white perch	X	X
Morone saxatilis	striped bass	X	X
Morone saxatilis x M. chrysops	striped bass hybrid	-	X
SERRANIDAE - sea basses			
Centropristis striata	black sea bass	-	X

Appendix 9-5. Comparison of historical and recent faunas of the mainstem Delaware River between Trenton, New Jersey and the Chesapeake and Delaware Canal in DRBC WQZ 5.

Species	Common name	Historic fauna (pre-1980)	Recent (1980 - present) fauna from all sources
PETROMYZONTIDAE - lampreys			
Petromyzon marinus	sea lamprey	X	X
ACIPENSERIDAE - sturgeons			
Acipenser brevirostrum	shortnose sturgeon	X	X
Acipenser oxyrhynchus	Atlantic sturgeon	X	X
ANGUILLIDAE - freshwater eels			
Anguilla rostrata	American eel	X	X
CONGRIDAE - marine eels			
Conger oceanicus	conger eel	-	X
CLUPEIDAE - herrings			
Alosa aestivalis	blueback herring	X	X
Alosa mediocris	hickory shad	X	X
Alosa pseudoharengus	alewife	X	X
Alosa sapidissima	American shad	X	X
Brevoortia tyrannus	Atlantic menhaden	X	X
Dorosoma cepedianum	gizzard shad	X	X
ENGRAULIDAE - anchovies			
Anchoa hepsetus	striped anchovy	-	X
Anchoa mitchilli	bay anchovy	X	X
CYPRINIDAE - carps and minnows			
Carassius auratus	goldfish	X	X
Cyprinella analostana	satinfin shiner	X	-
Cyprinus carpio	common carp	X	X
Exoglossum maxillingua	cutlips minnow	-	X
Hybognathus regius	eastern silvery minnow	X	X
Notemigonus crysoleucas	golden shiner	X	X
Notropis bifrenatus	bridle shiner	X	-
Notropis hudsonius	spottail shiner	X	X
CATOSTOMIDAE - suckers			
Catostomus commersoni	white sucker	-	X
ICTALURIDAE - bullhead catfishes			
Ameiurus catus	white catfish	X	X
Ameiurus nebulosus	brown bullhead	X	X
Ictalurus punctatus	channel catfish	X	X