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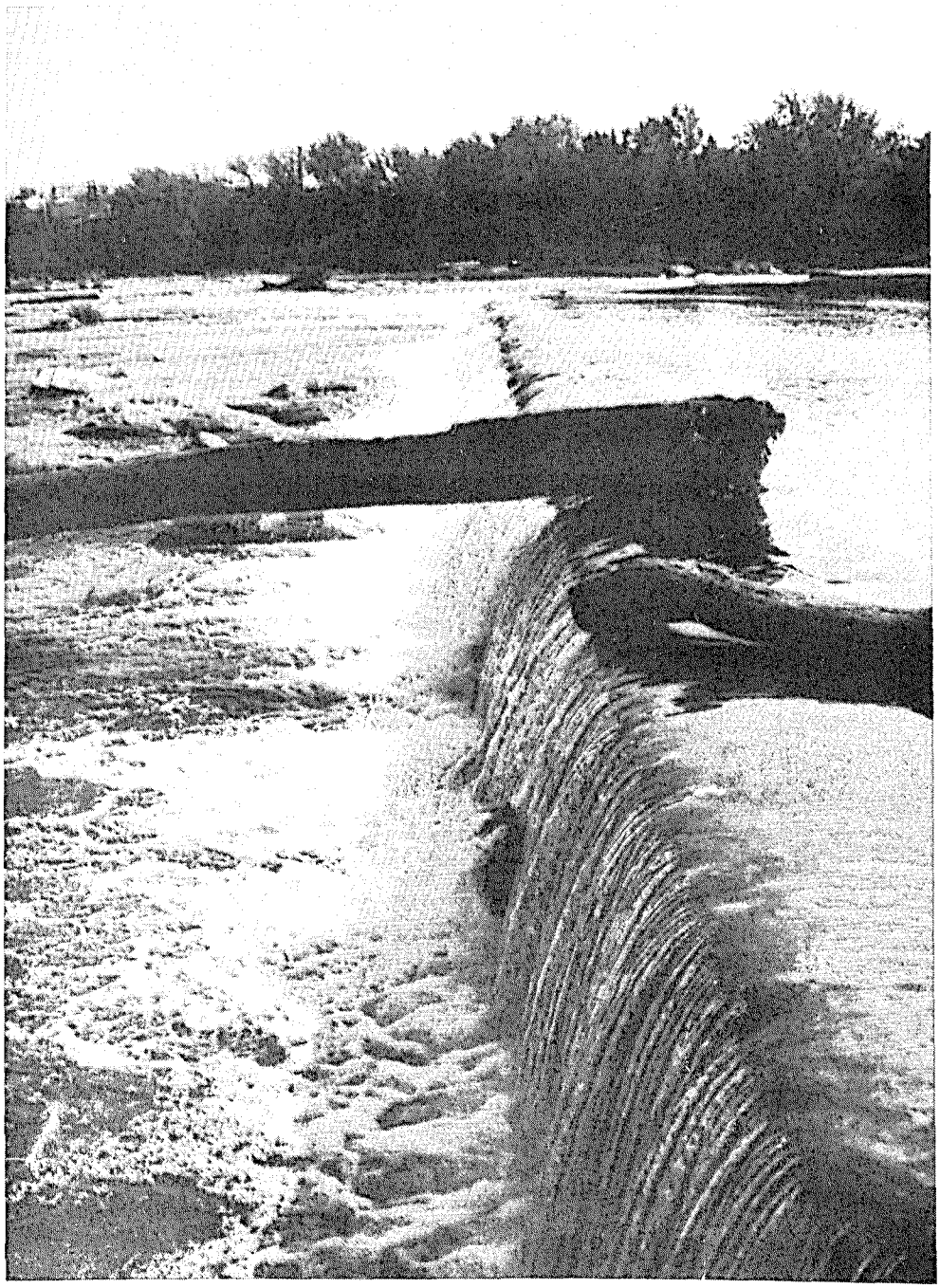
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FEASIBILITY STUDY OF FISH PASSAGE FACILITIES IN THE JAMES RIVER, RICHMOND, VIRGINIA

FINAL REPORT



Prepared For
Virginia Commission of Game and Inland Fisheries

by

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Job Completion Report

For

Virginia Dingell-Johnson Project F-30-P
Study V, Job 5

Feasibility Study of Fish Passage Facilities In the James River, Richmond, Virginia

Period Covered

November 15, 1980 - October 15, 1982

Report Submitted December, 1983

Job Leader
Joseph G. Loesch, VIMS

Assistant Job Leader
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With Appendix

By

Ben Rizzo, U.S. Fish & Wildlife Service

VIMS Special Report Number 269
In
Applied Marine Science and Ocean Engineering

PREFACE

This report is a direct consequence of House Joint Resolution No. 233 agreed to by the Virginia House of Delegates and the Senate in February, 1981 (Table 1). The resolution directed appropriate State agencies and local political subdivisions to conduct a feasibility study of the construction and maintenance of fish passage facilities in the Richmond area of the James River. Additionally, the resolution directed that the assistance of appropriate Federal agencies be sought. In response to the resolution, the James River Fish Passage Facilities Committee was formed. It consists of representation from the Virginia Commission of Game and Inland Fisheries, the Virginia Institute of Marine Science, the Virginia Marine Resources Commission, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service.

The Committee during its second meeting on 14 July 1981 defined the scope of the investigation as the following tasks:

1. Life History Synopses
    a. Construction of life history for each anadromous species of concern.
2. Status of Stocks
    a. Historical state of the stocks and expressed concerns.
    b. Present state of the stocks and concerns.
3. Description of the Physical Problems
    a. Dams in the Richmond area.
    b. James River-Kanawha Canal.

4. Feasibility of Restoration Programs

   a. Description of other restoration programs.

   b. Virginia: James River.

5. Expected Benefits

6. Estimated Costs

7. Potential Funding Sources

The Commission of Game and Inland Fisheries financed the study with support from the U.S. Fish and Wildlife Service; in turn, the study was conducted by Messrs. Steven M. Atran and William H. Kriete, Jr. and Dr. Joseph G. Loesch. Additionally, a major input to the study was made by a U.S. Fish and Wildlife Service Hydraulic Engineer, Mr. Ben Rizzo. His report, enclosed herein as an Appendix, specifically addresses tasks 3, 4b and 6. The ultimate goal was to produce a study report that the Committee, via the Commission of Game and Inland Fisheries, will present to the Virginia state legislators and the Governor.

A comprehensive summary, in which many sections were taken verbatim from this report, was produced as a separate printing; it is available upon request from:

Commission of Game and Inland Fisheries
4010 West Broad Street
P.O. Box 11104
Richmond, VA 23230

To avoid a sizable redundancy, a more succinct summary is given herein.

SUMMARY

1. There has been a dramatic decline in Virginia landings of striped bass, American shad, alewife, blueback herring, and hickory shad since the early 1970's.

2. In contrast to the low levels of anadromous stocks in Virginia, stocks have been greatly enhanced or reintroduced after long absences in the New England region. These successes are due to the construction of fish passage facilities and stocking of fish upstream of the obstructions.

3. Based on the asthetic, social and economic rewards realized in other restoration programs, the construction of fish passage facilities on the five low head dams in the Richmond area of the James River is warranted. Benefits expected from the fish passage facilities are: 1) increased spawning and nursery habitat, thereby enhancing the anadromous stocks; 2) increased density of forage species for resident species; 3) enhancement of sport fisheries and support businesses; 4) enhancement of commercial fisheries and support businesses; and 5) enhancement of city park fishing activities and associate interpretive programs in the Richmond area.

4. It is estimated that about 600,000 shad and 3,000,000 river herring (alewife and blueback herring) would eventually be passed over the Bosher Dam. Striped bass and sturgeon would also be passed upriver, but their number and size would be a function of the types of facilities constructed.

5. Preliminary total cost estimates for fish passage facilities on all five dams range from $2.5 million to $7.5 million. The actual cost will depend on the nature of the facilities built and whether or not hydropower is redeveloped at the Manchester and Twelfth Street plants. The cost of a single facility elsewhere where dams are much higher has often exceeded the total estimated costs for all five dams on the James River.

6. Virginia Code section 29-151 requires any person owning or having control of any dam or other obstruction which may interfere with the free passage of fish to provide and maintain a suitable fish ladder. Although parts of some river systems are exempted from section 29-151, the Richmond area of the James is not. The City of Richmond owns the Williams Island Dam, the Hollywood/Belle Island Dam, the Brown's Island Dam, and the Manchester Dam. In addition, the City assumed the responsibility for the operation and maintenance of the Bosher Dam and Kanawha Canal when it acquired the water rights in 1973. If the hydroplants are rehabilitated at the Brown's Island Dam and the Manchester Dam by a party other than the City of Richmond the responsibilities, presumably will be passed to the leaseholder.

7. Provisions of the Fish and Wildlife Coordination Act, and the National Environmenal Policy Act require evaluation of impacts on fish and wildlife by non-Federal hydroelectric power projects. The Federal Energy Regulatory Commission (FERC) can use such impact evaluations as the basis for modifying, conditioning, or denying a license.

8. Federal funding for fish passage facilities is available on a matching fund basis under the Federal Aid and Sport Fish Restoration Act (1950) and the Anadromous Fish Conservation Act (1965). These funds may be used for the construction or renovation of fish passage facilities, and the operation and maintenance of the facilities. However, such funding cannot be obtained for projects subject to the FERC mandate; thus these funds could be sought for only the Williams Island Dam.

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INTRODUCTION

The James River is the longest and the largest river in Virginia, draining over 25% of the state. It begins in the Appalachian Plateau, crosses the Valley of Virginia, breaks through the Blue Ridge, winds through the Piedmont, and drops down to the Coastal Plains. The river from its headwaters to Hampton Roads is shown in Plate 1 (Appendix). Major tributaries include the Jackson River, the Cowpasture River, the Maury River, the Tyge River, and Rivanna River, and the Appomattox River (Corbett 1977). It has been called the "backbone... of the water system of the state" (Va. Comm. Fish. 1875). The first permanent English settlement in America was established in 1607 at Jamestown, about 35 miles above the mouth of the James River. Even before Jamestown, it's possible that the Spanish explorer, Ayallon, may have tried to establish a settlement, in 1526, called San Miguel de Gualdape, on the same site that was later to become Jamestown (Wilstach 1929).

The James River can lay claim to many "firsts" besides that of the first permanent English settlement. The first English legislative assembly met at Jamestown in 1619, and Jamestown continued to serve as the colonial capitol until 1699, when it was moved to Williamsburg (Wilstach 1929). At Falling Creek, a few miles below Richmond, on the south side of the river, the first iron works in America were set up. One hundred and fifty skilled workmen were transported and established there. The iron works were wiped off the map by an Indian massacre in 1622 (Earle 1924). In 1632 the oldest Protestant church in the new

world, the church of St. Luke, was built near Smithfield in Isle of Wight County (Wilstach 1929). Near the mouth of the James River, the Monitor and the Merrimac met during the Civil War to engage in the first battle between ironclad ships.

Before the coming of the English settlers, the James River had been called the Powhatan River by the Indians, after their great Indian king, Powhatan, who ruled at that time. The English settlers named the river the James, in honor of their king, but this was not to be the last time the name of the river would be changed. When Queen Anne was the queen of England, she curtailed some of the glories of King James. The James River above the mouth of the Rivanna River was renamed "Fluvanna", and this name continued to be used in statutes and deeds until the beginning of the nineteenth century (Va. Comm. Fish. 1875).

The falls of the James River at Richmond were the limit of navigation and colonization in the early 1600's. The James River valley above Richmond was rapidly settled once the land in the Tidewater area was exhausted or became unavailable. Charlottesville, Lexington, Buchanan, Lynchburg and Covington became major centers of commerce and the river provided the transportation necessary to carry their products downstream and to bring finished goods upstream. Great barges, 50 to 90 feet long, propelled by a crew of three, made the trip from Lynchburg to Roanoke. Over 500 of these barges/batteaux plied the James River between these two cities, taking a week to go downstream and ten days to return (Corbett 1977).

The need for a canal system along the James River was recognized by the colonists, and a canal was proposed within the House of Burgesses in 1774. It was 1785, however, before the James River Company was organized to open the river for navigation above Richmond. George Washington was the company's first president, and he was an avid supporter of canals/waterways to the west. By 1840, there were 146 miles of canal open between Richmond and Lynchburg and by 1851 the section from Lynchburg to Buchanan was operating. Over 195 freight boats made three trips a week between Lynchburg and Richmond; there were daily departures for passengers between these cities. An extension from Buchanan to Covington was begun, using slackwater navigation (like most of the river from Glasgow to Buchanan), but this upper section was not completed (Corbett 1977). An incident of high drama involving a canal boat in Rockbridge County and the heroic behavior of a slave was described by Corbett (1977).

"It was on the Balcony Falls section in 1854 that a canal boat with over 40 crewmen/passengers broke loose from a tow line on the North (Maury) River during high water. The canal boat, the Clinton, washed over the Mountain Dam, as the river was too deep for the poles of the crewmen to touch bottom. The boat did not capsize when it ran over the dam, but the unfortunate souls on the boat still had the worse to face. It was at White Rock, just above Balcony Falls, that the captain and five people jumped from the boat to the rocks in midstream. Then the Clinton washed downstream through all of the rapids and, by some miracle, lodged gently on a rock near Snowden without damage or loss of life. A rescue of the people on the rock

was undertaken, and a slave, Frank Padgett, lost his life making two attempts to remove the men from the rock during freezing weather on a flooded river. There is a monument alongside the C&O railroad to Frank Padgett's memory."

The Virginia Commission of Fisheries in the late 1800's was enthusiastic about the fishing potential of the James River, and concerned about dams being built on it. The first annual report published by the Commission after its creation in 1875 stated of the James:

> "It possesses every advantage for the production of an immense quantity of fish of various kinds, all of which advantages are lost by the great number of dams which bar its course above the tide."..."Dams, also, besides arresting the ascent of anadromous fish and withholding that 'providential succor' from all the people on the stream, tend to denude the rivers of all their native fishes. With the first fresh in the fall, the largest and best of these dams prevent their reascent next spring. In this way the James River has been stripped, and for its volume and extent, is perhaps, the poorest stream in fish on the continent."

Prior to the obstruction of the James River by dam-building, shad and river herring reportedly ascended as far upriver as Covington in Alleghany County, and far up all the principal tributaries (Va. Comm. Fish. 1875). Striped bass ascended at least as far as Swift Island at Lynchburg (Table 2), about 102 river miles above Richmond, and perhaps as far as Balcony Falls, just below the confluence of the James and Maury rivers in Rockbridge County (Va. Comm. Fish. 1875). These fish runs were of great importance to the people living near the James River, as evidenced by this statement from the Virginia Commission of Fisheries annual report for 1875:

> "We are informed that in former times, when James river was unobstructed, and the shad had free access to its upper waters, the people, for twenty-five miles on both sides the main stem and on its tributaries, were wont to obtain and salt enough fish for consumption during the six warm months, when it was the most wholesome of diets--in fact, that it amounted to half a hog crop for the entire population of the basin of the James..."

Concern for the protection of the fishery resources has long been evident in Virginia's laws. As early as 1680, a law was passed which prohibited the striking of fish with "giggs and harping-irons" in the waters of Gloucester, Middlesex and Lancaster counties. Beginning about 1740, Virginians became concerned about the depletion of the fish stocks, and from that time until the Revolutionary War, many laws were passed in Virginia requiring the removal of the obstructions or the building of fish passages. A typical example of this is an act, passed in 1761, concerning a dam built on Rockfish River, a tributary of the James River in Nelson County, formerly part of Amherst County (Va. Comm. Fish. 1875):

> "It being represented that Allan Howard, a gentleman, hath erected a mill on Rockfish river in Amherst Co, the dam whereof hath entirely obstructed the passage of fish up said river, to the great loss and prejudice of the inhabitants on the same,"..."said Howard should in two months pull down and destroy his said mill-dam and mill-house"..."and that no dam on said river below the forks near Sam Morril's should be lawful."

Many of the early fish passages were unsuccessful in passing fish. In 1771, an act was passed defining exactly the type of fish passages to be built and the times when they were to be kept open (Va. Comm. Fish. 1875):

> "That a gap be cut in the top of the dam contiguous to the deepest part of the water below the dam, in which shall be set a slope ten feet wide, and so deep that

> the water may run through it eighteen inches before it will through the waste, or over the dam; that the direction of the said slope be so, as with a perpendicular, to be dropped from the top of the dam, will form an angle of at least seventy-five degrees, and to continue in the direction to the bottom of the river, below the dam, to be planked up the sides two feet high; that there be pits or basins built in the bottom, at eight feet distance, the width of the said slope, and to be twelve inches deep, and that the whole be tight and strong; which said slope shall be kept open from the tenth day of February to the last day of May, annually, and any owner not complying to forfeit five pounds tobacco a day."

Due to the onset of the Revolutionary War, this law was never enforced and the fish passage design was not tested. In the Virginia Code of 1849, the legislature reaffirmed its right to restrict the building of dams (Va. Fish. Comm. 1875):

> "Whatever power is reserved to the legislature by any act heretofore passed, to abate any dam or other works in a water-course, or improve its navigation, shall continue in full force."

It appears that the Virginia legislature of 1870-71 began, and then aborted, a project to alleviate the problem of obstructions on the rivers. In a letter dated October 2, 1872, and published by the U.S. Commission of Fish and Fisheries, McKennie (1873) wrote concerning obstructions on the rivers in Virginia:

> "I have been much interested in the question for several years, but I fear that little can be done until some cunning leech is able to apply some plaster to our people which shall arouse them to a sense of their duty to themselves and their children. The project started in a small way by the legislature of 1870-'71 was dropped by that of 1871-'72."

In 1875 there were 21 dams with an average height of 14.5 feet on the James River from Richmond to Buchanan [in] (Botetourt County), a

distance of 196.5 miles (Va. Comm. Fish. 1875); by 1882 the number had increased to 23 (Va. Comm. Fish. 1882). These dams had been the property of the James River and Kanawha Canal Company, but ownership was transferred by the Virginia Assembly to the Richmond and Alleghany Railroad, subject to the construction by the railroad of suitable fishways for the passage of shad over all the dams maintained by them. In 1882 only one fishway had been constructed, that over Bosher's dam, and it was incomplete (Va. Comm. Fish. 1882).

In 1930 the General Assembly enacted Virginia Code section 29-151, requiring the owners of dams and other obstructions which may interfere with the free passage of fish to provide a suitable fish ladder. The act was amended in 1942, 1950, and again in 1958, and currently reads as follows:

> 29-151. Dams and fish ladders; inspection of.--Any dam or other thing in a watercourse, which obstructs navigation or the passage of fish, shall be deemed a nuisance, unless it be to work a mill, manufactory or other machine or engine useful to the public, and is allowed by law or order of court. Any person owning or having control of any dam or other obstruction in any of the streams of this State above tidewater which may interfere with the free passage of fish, shall provide every such dam or other obstruction with a suitable fish ladder, so that fish may have free passage up and down the streams during the months of March, April, May and June of each year, and maintain and keep the same in good repair, and restore it in case of destruction; provided, however, that this section shall not apply to the Meherrin river within the counties of Brunswick and Greenville, nor the Meherrin river within or between the counties of Lunenburg and Mecklenburg, nor to the Nottoway river between the counties of Lunenburg and Nottoway, nor to Abram's creek in Shawnee district, Frederick County, nor to the James River between the counties of Bedford and Amherst, nor any streams within the counties of Augusta, Lunenburg, Mecklenburg, Louisa, Buckingham, Halifax, Montgomery, Pulaski, Franklin, Russell, Tazewell, Giles, Bland, Craig,

> Wythe, Carroll and Grayson, nor to that part of any stream that forms a part of the boundary of Halifax and Franklin counties; provided however, that no fish ladders shall be required on dams twenty feet or more in height or on such dams as the Commission may deem it unnecessary on which to have ladders. Any person failing to comply with this provision shall be fined one dollar for each day's failure; and the circuit court of the county or the corporation court of the city in which the dam is situated, after reasonable notice, by rule or otherwise, to the parties or party interested and upon satisfactory proof of the failure, shall cause the fishway to be constructed, or put in good repair as the case may be, at the expense of the owner of the dam or other obstruction. It shall be the duty of the game warden to make a personal inspection of dams and rivers in his respective county or city in the months of April and October of each year and report to the circuit court of the county or the corporation court of the city any violation of this section. (1930, p. 651; Michie Code 1942, 3305(42); 1950, p. 891; 1958, c. 607.)

Today, the James River is an important part of Virginia's economy. Ships navigate the river as far up as Richmond. Downriver from Richmond is Hopewell, a city created during World War I for the manufacture of ammunition (Wilstach 1929). Anadromous fishes presently migrate upstream through the tidal section of the James River to the Richmond area. Much of their historical spawning ground, however, is no longer accessible to them, the result of dams and obstructions. The Richmond dams on the James River are described in the Appendix; dams further upriver from Lynchburg to Glasgow, Virginia have been described by Corbett (1977).

STRIPED BASS

HISTORICAL PERSPECTIVE

Striped bass, Morone saxatilis, have been caught in Virginia waters since before the arrival of the earliest settlers. Shell heaps and other archaeological detritus indicate that they were known by the East Coast Indian tribes (Cole 1978). Striped bass were also caught by the early settlers in Virginia. Captain John Smith, in 1607, included them in a list of fishes in Virginia (Wharton 1957). The early settlers captured striped bass by stretching long seines and weirs across coastal streams at high tide. When the water ebbed from the creeks, the stranded fish were trapped, often in far greater quantities than the fishermen could haul to land (Pearson 1938).

Until about 1885 the striped bass population seems to have held up well despite great demands (Raney 1952). In 1874, 1500 striped bass were taken at a single set of seine near Norfolk, Virginia. A few years earlier, a single seine had yielded 600 fish averaging 80 lb. each (Goode 1887). In 1875, the Virginia Commission of Fisheries stated that, next to (river) herring and (American) shad, striped bass were the most abundant and valuable fish in Virginia's waters.

In 1887, the first year for which reliable statistics are available, striped bass ranked twelfth in Virginia in landings with 896 tons, and eighth in value with $32,758. Since 1887, striped bass landings in Virginia have undergone great fluctuations, ranging from 145 tons in 1929 to 1,443 tons in 1973. From its 1973 high, Virginia

striped bass landings have declined precipitously to 197 tons in 1981, the smallest annual landings since 1934 and the fourth smallest on record (Fig. 1).

LIFE HISTORY

Adults

The striped bass ranges on the Atlantic and Gulf coasts from the St. Lawrence River, Canada, to the Tchefuncta River, Louisiana. It was introduced in the Pacific in 1879 and 1882, and is now found on the Pacific coast from the Columbia River, Washington, to Los Angeles County, California (Pearson 1938).

Striped bass in the Chesapeake Bay begin to mature when the females are four years old, and the males are two years old. Nearly all males above 10 inches in length are mature, as are practically all females by age 5 (Vladykov and Wallace 1952).

Once a female becomes mature, spawning may occur annually for approximately five years (Jackson and Tiller 1952). Fish over ten years old, however, are not necessarily annual spawners. Jackson and Tiller (1952) found indications of curtailed spawning in one third of all specimens examined over ten years of age from the Chesapeake Bay.

The spawning season for striped bass along the Atlantic coast generally runs from April through June, the exact time being dependent upon latitude and temperature (Pearson 1938). In the Rappahannock River, Virginia in 1951, striped bass eggs were collected from

mid-April to mid-May (Massmann et al. 1952). Rinaldo (1971) also concluded that spawning in the York-Pamunkey River occurred from mid-April to mid-May, based on the occurrence and distribution of eggs and prolarvae.

Kohlenstein (1981) reported that the migrating segment of the population moves northward along the coast in the early spring. Those fish that do not spawn move before or during the spawning season, while the spawners follow later. In May and June the striped bass move along the south shore of Long Island. Some of the fish continue on to New England; others remain scattered along the coast for the summer. In the fall the bass migrate southward and spend the winter in the coastal waters from New Jersey to North Carolina. Those fish which do not undertake coastal migrations overwinter in the deeper waters of the Chesapeake Bay and its tributaries.

In the spring, the spawners return to their natal waters to spawn, while the immature fish remain downstream of the spawning area. There is some evidence from tagging studies that immature females in the migrating stock do not return to their natal waters until they are ready to spawn (Kohlenstein 1981).

The diet of adult striped bass is quite varied and includes alewife, herring, menhaden, mummichogs, mullet, rock eels, sculpin, shad, silver hake, silversides, smelt, tomcod, weakfish, white perch, lobsters, crabs, shrimp, isopods, gammarid crustaceans, worms, squid, clams, and mussels (Smith and Wells 1977). Small bass feed mainly on crustaceans and marine worms, but after reaching a size of about

3 inches, other fishes become their primary prey (Raney 1952). When prey is plentiful, striped bass are likely to gorge themselves on one particular prey item, ignoring other food items, then cease feeding to digest, and then gorge themselves again (Bigelow and Schroeder 1953).

The spawning migration, which takes place several weeks before the actual spawning (Raney 1952), begins when the water temperature ranges from about 43 to 46°F (Merriman 1941). The males apparently reach the spawning grounds first, and are always more numerous than females (Raney 1952).

Spawning occurs in large, swift flowing streams (Merriman 1941) where the salinity is less than 10 ppt, usually lower than 1 ppt, and at temperatures of 50 to 77°F with a mean temperature of 62.5°F at peak spawning (Morgan et al. 1981). In Virginia, striped bass spawn in April and May (Massmann et al. 1952, Rinaldo 1971).

The spawning grounds in Virginia have been identified by Tresselt (1952) and Rinaldo (1971). Rinaldo found that the striped bass spawning area on the York-Pamunkey river system extended from 35 to 60 miles upstream from the mouth of the York River and was centered at about 40 miles upriver. Tresselt surveyed the Pamunkey, Mattaponi, Chickahominy, James, and Rappahannock rivers, and found that in all of these rivers, most of the spawning occurs within the first 25 miles of freshwater. However, only in the Mattaponi River did he collect eggs in appreciable numbers. After spawning, the striped bass remain in the rivers, and appear to leave the freshwater during the summer (Massmann et al. 1952).

The act of spawning has been observed by Woodhull (1947) and Morgan and Gerlach (1950), and summarized by Raney (1952). According to Woodhull, groups of from 5 to 30 bass appear, with the males greatly outnumbering the females. After milling about for a few moments each group heads upstream or downstream, the fish rolling over on their sides at about a 45° angle and splashing water in all directions with their caudal fins. Each group remains at the surface for several minutes, mainly in the shallower portions of the river. Spawning occurs throughout the day, but appears to be most common in the late afternoon and early evening, especially on the flood tide.

The fecundity of the females increases with age and size, ranging from approximately 65,000 eggs in a four-year-old to 4,500,000 eggs in a thirteen- or fourteen-year-old (Jackson and Tiller 1952). It is not known if egg viability decreases with age. The eggs are kept suspended by water currents created by stream flow and/or tidal action (Talbot 1966). Raney (1952) reported that time to hatching ranges from 30 hours at 72°F to 74 hours at 52°F.

The migration range of the striped bass depends strongly on both sex and age (Kohlenstein 1981). Not all of the bass undertake coastal migrations, but of those that do, nearly 90% are female (Mansueti 1961a). From the Chesapeake Bay stock, this constitutes approximately 50% of the age 3 females and smaller proportions of age 2 and age 4 females (Kohlenstein 1981). Mansueti (1961a) reported that the average distance traveled by striped bass is a linear function of size.

Juveniles

Striped bass eggs average 0.13 inch in diameter after water hardening (Mansueti 1958a). The density of the eggs exceeds the density of column water, therefore the eggs depend upon currents to stay suspended in the water column (Talbot 1966). At hatching, the prolarvae range in size from 0.08 to 0.14 inch total length (Mansueti 1958a). In three to four weeks the young striped bass grow to a size of 1.4 inches, have scales and fully developed fins and rays, and are shaped like the adult (Raney 1952). After one year, the striped bass have reached a fork length of about 4 inches; after two years, 10 inches; and after three years, 14 inches (Talbot 1966). Both sexes grow at about the same rate for the first three years. Beginning at age four, the growth rate of males is consistently lower than that of females (Mansueti 1961a).

Usually, just after hatching, the larval striped bass drift with the current into the lower and often saline section of the stream (Talbot 1966). The larvae remain in fresh or slightly brackish water until they are about 0.5 to 0.6 inch long, when they move in small schools toward the shallow protected shorelines. In the winter, they move to the deep waters of the rivers (Smith and Wells 1977).

During their second summer, the juvenile striped bass move down river from their parent streams to low salinity bays or sounds (Smith and Wells 1977). Massmann and Pacheco (1961) reported that most striped bass remain in a single river system until they reach a length of 12 inches, after which they move into the Chesapeake Bay or along

the Atlantic Coast. Tagging studies by Massmann and Pacheco (1961) and Vladykov and Wallace (1952) indicate that striped bass from the James River migrate less than striped bass from other Virginia river systems. Tagging studies conducted by the Virginia Institute of Marine Science (VIMS) in 1968 (Grant 1970) also appear to support the hypothesis that James River striped bass migrate less than those from other river systems. However, the James River fish that were tagged were smaller than those tagged in the other river systems, and since younger fish do not migrate from the river, this finding is to be expected. In contrast, in a 1969 VIMS study, fish tagged in the James River were comparable in size to those from the other river systems, and the percentage of fish migrating from the James River was substantially larger than in previous observations (Grant 1970).

Striped bass larvae absorb their yolk sac and begin feeding within two weeks after hatching. Kernehan et al. (1981) reported that late yolk-sac and early post yolk-sac larvae from the vicinity of the Chesapeake & Delaware Canal, Delaware have a strong positive selection for immature cladocerans of the genus Bosmina while older stages are more opportunistic. Boynton et al. (1981) found that juveniles of 1 to 4 inches were flexible, nonselective feeders consuming mostly insect larvae, polychaetes, larval fish, mysids, and amphipods.

Mortality of striped bass larvae is dominated so greatly by environmental factors that year-class strength is determined independently of parent-stock potential (Polgar 1982). Within a nursery area, decreasing availability of preferred prey in the

downstream direction seems to be associated with increasing mortality of the larval fish (Polgar 1982). He found that on the Potomac River, recruitment levels of striped bass could best be explained by the formula:

$$R = 1239*P*\exp(-0.26\ DT - 0.59\ AT)$$

where R = computed mature female recruits, P = computed mature female spawning stock, DT = December air temperature in °C, and AT = April temperature in °C. This density-independent model explained 81% of the variability in recruitment in the Potomac River over the last 25 years.

FISHERIES

Gear Types

Gill nets and pound nets are the principal types of gear used in the commercial striped bass fishery. In 1976 anchor, set and stake gill nets accounted for 69% of the commercial landings, drift gill nets accounted for 9% of the catch, and pound nets accounted for 13%. The remaining 9% of the landings was taken with a variety of gear including haul seines, otter trawls, fyke and hoop nets, pots and traps, and hand lines (Nat. Mar. Fish. Serv. 1980).

Richards and Zaborski (1978) reviewed the types of fishing for striped bass in Virginia. Pound nets fished at permanent locations are the most consistent gear used; the nets are lifted only for cleaning, to prevent possible ice damage, or because of nuisance factors such as jellyfish. Fyke nets are usually located farther

upstream than pound nets. Trawling is limited to offshore fishing by law. Therefore, striped bass are available to this gear only in winter months, when they are migrating up the coast. Haul seines are used sporadically throughout the warmer months, but most effectively in the spring. Gill nets are fished in a variety of methods and mesh sizes. Small mesh "spot and perch nets" of 2.87- to 3.5-inch stretched mesh are anchored in the summer and staked from late fall to winter. Large mesh "shad nets" of 5.5-inch stretched mesh) are staked or drifted in late winter and spring. In recent years, because of the paucity of American shad, many fishermen early in the shad season switch to a larger mesh to catch the equally scarce, but more valuable, striped bass (Loesch et al. 1979).

A sport fishery for striped bass exists from the mouth of the Chesapeake Bay to the freshwater regions of major river systems from March through December. Sport fishing is especially intensive along the Chesapeake Bay Bridge-Tunnel in spring and fall (Grant 1974). Sport fishing methods generally consist of deep trolling with weighted lures, spincast jigging of "feathers" and other small "bucktail" lines, night fishing under lights with live baitfish or "feathers," and bait casting from shore or boat with peeler crabs at high tide (Richards and Zaborski 1978).

The recreational catch of striped bass in the Chesapeake Bay region is probably substantial, but no program exists for estimating the catch or for gathering long-term catch-and-effort statistics. Jones and Loesch (1982) suggested the institution of a recreational

fishing license for tidal waters of Chesapeake Bay. The requirement of a license would identify the number of the marine recreational fishermen and would facilitate a monitoring program to collect catch-effort statistics from them.

Status of Stocks

The record of commercial striped bass landings in Virginia, which extends from 1887 to the present, is one of great fluctuations. The smallest recorded catch, about 145 tons, occurred in 1929, and the largest, 1,444 tons was in 1973.

Striped bass taken in Virginia estuarine waters by the sport and commercial fisheries are predominantly Age II unless a strong year class makes large numbers of Age I fish available. Older fish are taken by all segments of the fishery in Virginia, but beyond 4 years of age their incidence is low (Merriner and Hoagman 1973).

In Maryland, commercial landings appear to show a cyclic pattern, with alternation of high and low landings occurring at fairly regular intervals of about six years (Koo 1970). Landings in Virginia showed a similar cycle with intervals of about every three years, from 1957 to 1973 (Merriner and Hoagman 1973). However, Grant (1974) states that the six-year cycle observed by Koo is not apparent in the Virginia landings, perhaps being obscured or eliminated by the occurrence of additional strong year-classes in Virginia which were absent in Maryland. Van Winkle et al. (1979) examined the Atlantic Coast striped bass commercial catch data using autocorrelation and

spectral analysis techniques and found no support for the hypothesis of a six-year or any other cycle of year-class dominance. Since 1973, striped bass landings have declined dramatically. In 1973 the catch was 1,444 tons, 477 tons in 1976 and 234 tons in 1979. In 1981, 197 tons were landed.

The recent decline in striped bass landings since 1973 (Fig. 1) has occurred along the entire East Coast. To a large degree, this decline is due to poor reproductive success in the Chesapeake Bay region, which is the major contributor to the Atlantic coastal stocks from Maine to North Carolina (Texas Instruments 1976, Berggren and Lieberman 1978). Thus, a concern about the state of the Chesapeake Bay stock of striped bass is more than a parochial interest.

Possible Reasons for Decline

Environmental factors which can affect striped bass reproduction and recruitment include stream flows and winter temperatures (Setzler et al. 1980). High river flows and low winter temperatures have been associated with successful spawns by a number of researchers (Merriman 1941, Van Cleve 1945, Vladykov and Wallace 1952, Hassler 1958, Heinle et al. 1976, Chadwick et al. 1977, Polgar 1982). Chadwick et al. (1977) determined that in the San Joaquin Delta, California, the success of a striped bass year class is determined within the first 2 months of life.

With increased industrialization and urbanization in the Chesapeake Bay area and its tributaries, there is concern that

man-induced stresses superimposed on natural environmental stresses have greatly diminished the resiliency of the Chesapeake stock of striped bass. Talbot (1966) and Mansueti (1961a) noted that sedimentation, pollution from agricultural, industrial, and domestic sources, wetland reclamation, dams, pesticides, radioactivity, and heavy expoloitation may have had deleterious effects on striped bass populations. Mansueti (1961b) also suggested that fertilization of the waters by domestic sewage may be indirectly responsible for an increase in striped bass production in Chesapeake Bay. However, in light of the recent declines in striped bass populations, this hypothesis does not appear to be valid. Loesch et al. (1982a) reported the presence of Kepone in young-of-the-year striped bass in the Mattaponi and Pamunkey rivers. They suggested that the "export" of Kepone from the James River system was due to wind transport.

Among the factors which have historically controlled striped bass abundance are availability of spawning and nursery grounds. Talbot (1966) considered the loss of spawning grounds through dam construction as probably the most immediate threat to striped bass populations. Dams may also have an adverse effect on hatching success if stream flow is reduced below the minimum rate necessary to keep eggs and larvae from settling to the bottom (Talbot 1966). Reduced flows can also intensify siltation and pollution problems (Ulrich et al. 1979).

Environmental factors appear to influence survival of larval stages of striped bass so greatly that year-class strength is

determined independently of parent-stock size (Cooper and Polgar 1981, Polgar 1982). A spawner-recruit relationship probably exists, particularly at low levels of stock, but the relationship may be obscured by environmental variations (Sissenwine et al. 1978).

MANAGEMENT

Jurisdiction for Virginia's striped bass fisheries in tidal waters is charged to the Virginia Marine Resources Commission (VMRC) (Va. law sec. 28.1-3) except in the Potomac River, where the Potomac River Fisheries Commission (PRFC) has jurisdiction (Va. law sec. 28.1-203; PRFC 1983). In freshwater above the fall line, the Virginia Game and Inland Fish Commission has jurisdiction (Va. law sec. 29-11).

Except as otherwise provided by regulation, the minimum and maximum size limits for the taking of striped bass in Virginia are 14 inches and 40 inches total length, respectively. No person, firm, or corporation may possess during any one day more than two striped bass over the maximum size, or more than 5% or two by count, whichever is greater, of any striped bass less than the minimum size (Va. law sec. 28.1-50).

On the Potomac River, striped bass may not be caught which are less than 12 inches in length or more than 15 lb. in weight (PRFC Reg. III, Sec. 11, 1983).

The remaining laws affecting striped bass consist of gear restrictions. It is unlawful to use a pound net, head, or picket (under 600 feet long) having less than a 2-inch, stretched mesh. Haul

seines may not be longer than 1,000 yards in length, and if over 200 yards long, shall not have less than a 3 inch, stretched mesh (Va. law sec. 28.1-51).

It is unlawful to use a snatch hook, grab hook, or gang hook to take fish in the Rappahannock River below the Downing Bridge at Tappahannock between January 1 and March 15 (Va. law sec. 28.1-51.1). Trawls, trawl nets and drag nets are prohibited in Virginia waters, except that trawling is permitted within the three-mile limit of the Virginia Atlantic shoreline, north of Cape Charles to the Maryland line during the year except for September and October. Trawling is also permitted off the Virginia Beach coast (Cape Henry to 36° 40' north latitude) between October 1 and May 1, and from 36° 40' north latitude to the North Carolina line at any time (Va. law sec. 28.1-67 and 28.1-69.1).

On the Potomac river, the PRFC restricts the size of pound, seine, fyke, and hoop nets to 1.5-inch stretched mesh. Gill nets must be at least 3.5 inch stretched mesh from March 15 to June 1, and 2.5-inch stretched mesh at all other times (PRFC Reg. III, sec. 8b, 1983).

For the 1983 fishing season, the VMRC has adopted regulations affecting closed areas, season, and gear limitations for the striped bass spawning areas, and minimum size limits for striped bass taken in the Territorial Sea. Under Regulation XXIX, Pertaining to the Taking of Striped Bass (VMRC 1982), the striped bass spawning reaches of the James, Pamunkey, Mattaponi, and Rappahannock rivers are closed to

anchor and stake gill net fishing from April 10 to May 21. During this period striped bass taken by any other means in the spawning reaches must be returned immediately to the water. In the Territorial Sea, a minimum size limit of 24 inches is imposed on all striped bass with the following exceptions. If the striped bass are caught by hook and line, no more than four fish between 14 and 24 inches may be retained; however, if the fish are caught by net, no more than 5% of a total daily catch may be in this length interval.

In the Potomac River, minimum mesh sizes are set by the PRFC as follows (Reg. III, sec. 10, 1983): pound net 1.5 inches, haul seine 2.5 inches, fyke or hoop net 2 inches, and gill net 2.5 inches.

The objectives of management of striped bass in Virginia were outlined by Liquori (1978). The generalized goal is to achieve optimal utilization and fair allocation of the resources among commercial and recreational users.

Recommendations for management strategy for striped bass were recently put forth by the striped bass Scientific and Statistics (S&S) Committee (Austin 1980) for the Northeast Marine Fisheries Board of the State-Federal Fisheries Management Program. The committee recommended a strategy of reducing variability of the catch by increasing the mean age of the stock. Increasing the mean age would increase the stock size of five- to seven-year-old females, the ideal age/abundance ration for maximum viable egg production. Specific methods of implementation suggested by the committee included: 1) adjusting minimum mesh and/or size regulations, 2) geographic and

seasonal restictions on catch to protect particular sex or size groups (e.g., no fishing on spawning grounds during spawning season), 3) establishing geographic/seasonal recreational creel limits and age/size quotas for the commercial catch, and 4) regulation of effort by season, time of day, location, or gear.

In addition, the S&S committee recommended a research and monitoring program to develop and implement a reliable annual young-of-the-year index, and a program for the collection of catch-and-effort data.

Cooper and Polgar (1981) have proposed an alternate strategy of dominant year-class management for striped bass stocks. They suggest that management strategies which use maximum sustainable yield as their basis are inappropriate for striped bass. The concept of maximum sustainable yield management has evolved from and is only consistent with the dynamics of populations with density-dependent recruitment. Striped bass year-class strength appears to be predominantly environment-dependent rather than density-dependent, which can result in large year-to-year fluctuations, and the possibility of a dominant year class being produced by a low parent stock. Using juvenile indices as forecasting variables, managers could identify dominant year classes, and could then increase biomass yields from those year classes by selectively limiting the harvests of younger fish. Delaying maximum fishing pressures in order to harvest older fish would also protect the reproductive potential of the stocks somewhat, although improved recruitment would not be assured.

Regulations under this strategy would be flexible and not uniform from year to year or from one jurisdiction to another because of age and sex differences in migratory patterns.

AMERICAN SHAD

HISTORICAL PERSPECTIVE

Before the colonists came to Virginia, the Indians caught American shad (Alosa sapidissima) in the rivers and streams in large quantities using a seine made of bushes, called a bush net (Walburg and Nichols 1967). Fish were so plentiful that children would spear them with pointed sticks as they swam on the flats (Va. Comm. Fish. 1875). The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, however, fish were becoming scarce due to dams, seines, traps, and other devices which depleted the stock or prevented the fish from reaching their spawning grounds. The colonists, concerned about the scarcity of fish and obstructions to their passage, passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (Va. Comm. Fish. 1875).

The early fish passages failed to pass fish, and so in 1771, the Virginia Assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to the last day of May. Due to the approach of the Revolutionary War, however, this law was never enforced (Va. Comm. Fish. 1875).

Many of those involved in the early shad fisheries were large plantation owners. Thomas Jefferson brought shad to Monticello. George Washington ran a shad fishing business, and also leased fishing

rights and privileges on his land on the Potomac River (Mansueti and Kolb 1953).

In the early days, haul seines were used almost exclusively, but about 1835 gill nets were introduced, and have since become an important gear for capturing shad in the Chesapeake Bay area (Walburg and Nichols 1967). Pound nets were introduced to the area in 1858, and reached their peak in use in 1930 (Kriete and Merriner 1978).

The shad fishery of Chesapeake Bay became important about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and stake gill nets (Walburg and Nichols 1967). The fishery again became depleted and reached a low in 1878. An artificial hatching program was begun in 1875 by the U.S. Fish Commission and Virginia Commission of Fisheries, and in 1879 the fishery began to improve. This increase led biologists to believe that the shad fishery was largely dependent upon artificial propagation, and resulted in an expanded hatchery program. Later studies, however, showed that the upsurge could not be correlated with the output from artificial stocking. In the early 1900's a decline began in the numbers of shad harvested despite improved hatching methods and increased numbers of shad fry released (Mansueti and Kolb 1953).

In 1880 the tributaries of the Chesapeake Bay yielded more than 2,500 tons of shad. In 1896 Virginia ranked second to New Jersey in shad production with 5,501 tons. Usually Virginia ranked first or second in shad production. In 1908, Virginia's shad catch of 3,650

tons made it the most important fish caught in Virginia and comprised about one fourth of all shad taken in the United States; in contrast, shad landings in Virginia in 1981 were only about 7% of the 1908 catch. The main types of fishing gear used in 1908 included drift gill nets, pound nets, stake gill nets, and seines (Walburg and Nichols 1967). Today the primary gear is stake gill nets and drift gill nets, and to a lesser extent, pound nets (Va. Mar. Res. Comm. 1980).

LIFE HISTORY

Adults

The American shad, ranges on the Atlantic coast from the Gulf of St. Lawrence to Florida, but is most abundant from Connecticut to North Carolina (Mansueti and Kolb 1953). It was introduced on the Pacific coast in 1871, where it has spread to southern California and Alaska (Leim and Scott 1966).

Most shad spawn for the first time when they are four or five years old. Males mature and begin spawning at an earlier age than females (Walburg and Nichols 1967). Data reported by Walburg and Nichols (1967) indicated that the age of spawning shad in Virginia rivers ranged from 2 to 8 years, with most of the shad at 4 or 5 years of age. More than 73% of the shad were first-time spawners, and less than 9% had spawned more than once. Loesch et al. (1979) reported that the modal age for spawning shad in Virginia was 6 years in 1979 and 1978, and 5 years in 1977. However, the authors noted that these

estimates were based on samples from the commercial gillnet fishery, which is selective for larger and older fish.

American shad ascend rivers and streams in the spring to spawn. The time of migration is related to the water temperature, and occurs when the temperature is from 41 to 73°F but the peak movement occurs about 55 to 61°F (Walburg and Nichols 1967). In Chesapeake Bay, the migration begins in mid-February or March and the shad are gone by early June (Hildebrand and Schroeder 1928; Walburg and Nichols 1967).

Davis et al. (1970) compiled a list of known or probable spawning areas of Alosa species in the river systems of Virginia including the Potomac River. Although it is part of Maryland, many of the fish caught in the Potomac River are landed in Virginia, and therefore, it is included in this discussion. The physical characteristics of the spawning grounds for American shad include waters of less than 1 part per thousand (ppt) salinity, and usually freshwater (Davis et al. 1970). The shad may spawn anywhere but prefer the shallow sandy flats which border the streams, and the sand bars found up in the tidal freshwater section of the mainstream (Mansueti and Kolb 1953; Davis et al. 1970). Shad also appear to spawn in larger tributary streams to some extent (Davis et al. 1970). Spawning takes place between sundown and midnight (Mansueti and Kolb 1953). The spawning shad swim close to the surface, occasionally breaking the surface and making splashing sounds, referred to as "washing" by some fishermen. In the act of spawning, the two sexes run along together from the channel toward the shore, ejecting eggs and milt simultaneously. Females, depending on

size, produce about 200,000 to 280,000 eggs. Leim (1924) reported that hatching occurs in 6 to 8 days at about 63°F, and in 12 to 15 days at 54°F.

According to Neves and Despres (1979), adult shad, after spawning, return to the sea and migrate to the Gulf of Maine or to an area south of Nantucket shoals, where they remain during the summer and early autumn. Their movements are limited to areas and depths with near-bottom temperatures between 37 and 59°F. They migrate vertically during this time, following the diel movements of zooplankton, on which they feed. During the daylight hours, the shad appear to be closer to the bottom.

In the autumn, with declining water temperature, most shad leave the Gulf of Maine and congregate offshore for the winter, between southern Long Island and Nantucket shoals. In the winter and early spring, the adults move into coastal waters along the Middle Altantic coast and migrate to their spawning rivers (Neves and Despres 1979).

Juveniles

Juvenile (young-of-the-year) American shad, in the Chesapeake region, spend their first summer in the tidal, freshwater sections of the rivers. Loesch and Kriete (1980) reported that young shad tend to move upriver in mid-summer, possibly due to the lessening of freshwater runoff and the ensuing encroachment of saline water.

Juvenile shad also undergo diel verticial migrations. Loesch et al. (1982b) found that catches of shad by bottom trawl were

signifigantly greater during the day than at night, and conversely, catches of shad by surface trawl were greater at night than during the day. Gear avoidance in daylight could account for the significant differences in the surface trawl catches but it would not explain the differences in the bottom trawl catches. This day-night vertical migration could result in very inaccurate sampling data if the choice of sampling gear is made without regard to the time of sampling.

American shad have a protracted spawning period which builds to a maximum and then decreases, extending over about a three-month period. When first hatched the shad fry are less than 0.4 inch in length, but they grow rapidly. In the Potomac River they reach an average total length of about 1.8 inches during the first half of July, 2.6 inches by the last half of August, and 2.8 inches by the last half of October (Hildebrand and Schroeder 1928). Within the York River system, lengths of shad in the Pamunkey River have been found to be consistently higher than in the Mattaponi River. Possibly this is due to a lesser food supply in the Mattaponi as indicated by the greater clarity of the water (Loesch and Kriete 1980).

Absolute growth is difficult to measure. Marcy (1976) showed that there was a tendency for the larger juvenile shad to migrate downstream; similarly, Loesch (1969) reported a downstream drift for large juvenile blueback herring. The measurement of growth is also affected by uneven recruitment. Anadromous Alosa spawning is protracted; however, each species has a shorter period in which the bulk of spawning occurs. Peak recruitment to the sampling gear at

some time after the initiation of sampling may result in an apparent negative growth rate; the rate is again positive after the period of peak recruitment. This phenomenon is apparent in the juvenile American shad data reported by Marcy (1976; his Fig. 46); it has also been reported for blueback herring (Loesch 1969), and for juvenile alewife and blueback herring in Virginia waters (Loesch and Kriete 1980). Because of the problems of migration and recruitment, growth is best measured from daily increments to the otoliths.

Instantaneous daily mortality for Amerian shad in the Mattaponi and Pamunkey rivers in 1979 was estimated at 0.056 and 0.079, respectively (Loesch and Kriete 1980). The survival of juvenile shad is dependent on many factors including the abundance of prey organisms, the abundance of predators, and physical parameters such as turbidity, salinity, and temperature.

Walburg and Nichols (1967) reported that the major migration of juvenile shad from the rivers begins in the fall, usually after the water temperature has decreased to less than 60°F. It is not until near the end of November or the beginning of December, however, that all of the young shad have left the fresh waters in the Chesapeake region (Hildebrand and Schroeder 1928). Most of these young shad probably spend the winter with the adults in the middle Atlantic area (Walburg and Nichols 1967), but a few spend their first winter in the saline waters of the rivers and Chesapeake Bay (Hildebrand and Schroeder 1928).

FISHERIES

Gear Types

The American shad in Virginia are fished commercially with stake gill nets, and to a lesser extent, pound nets and drift gill nets as the primary gear. Other types of gear which have been used include fyke nets and haul seines. The bulk of the fisheries takes place in the rivers between the river mouths and spawning grounds.

Data collected from the James, York, and Rappahannock River systems show that in 1979 stake gill nets accounted for 96% of the catch, 3.8% of the catch was with pound nets, and drift gill nets accounted for the remainder (Loesch et al. 1979). In 1980, 448 stake gill net stands totaling about 58 miles of net, with 44 miles of net fished primarily for American shad, landed an estimated 754 tons of shad. Pound nets, which reached a peak of 272 active nets in late May, landed 11 tons of shad. In the Potomac River, 7 tons of shad were landed by stake, anchor, and drift gill nets combined, and in the James River, 0.4 ton were landed by fyke nets, which reached a peak of 23 nets in April and May (Loesch and Kriete 1980). Although the Potomac River is part of Maryland, many of the fish are landed in Virginia, and therefore it is included in this discussion. Sport fishermen also fish for shad, casting from shore or boats with artificial lures (Kriete and Merriner 1978).

Status of Stocks

Catch-per-unit-of-effort (CPUE) has been used to monitor the status of the stocks rather than catch alone because changes in total

catch may be the result of changes in stock density and/or fishing effort (Loesch and Kriete 1976). CPUE must be viewed with caution because of subtle changes that may take place in the fishery. For example, prior to 1977 all stake gill nets were assumed to have been set for American shad. However, in 1977 all of the nets on the Rappahannock River above mile 40 and 40% of the nets downstream were large-mesh nets set primarily to capture striped bass which have a higher market value than American shad (Loesch et. al 1979).

The CPUE of American shad caught by stake gill nets increased from 1969 to 1972, then decreased from 1972 to 1975. In 1976 it rose sharply (Loesch and Kriete 1976). These CPUE's were based on the assumption that all the stake gill nets were set for American shad.

From 1977 to 1979, the CPUE's oscillated in the James and Rappahannock rivers, but increased continually in the York River (Loesch et al. 1979). In 1980, the CPUE increased in the James River and, except for the CPUE of males in the Rappahannock River, declined in the York and Rappahannock rivers (Loesch and Kriete 1980).

No general trend appears from the CPUE data for the American shad stocks in Virginia. Catch data alone show a continuing decline (Fig. 2), but do not reflect changes in effort, as some fishermen have shifted their effort from shad to more valuable species, or have shortened their active fishing periods due to adverse weather conditions or large numbers of blue crabs becoming entangled in the nets. Where CPUE exhibits an increase during years of low yield, this might be indicative not of an improvement in the stock, but rather a

removal of marginal or inefficient fishing gear, leaving only the most efficient gear.

Possible Reasons for Decline

In previous years concern over heavy fishing of the shad stocks had been an issue in Virginia. The U.S. Fish and Wildlife Service in the past contended that Virginia fishermen were depleting the shad supply by not permitting a sufficient number of fish to escape the nets and continue on to the spawning grounds (Mansueti and Kolb 1953). However, the Virginia Fisheries Commission opposed this view, contending that the available information was not adequate to arrive at such a conclusion (Marshall 1949).

In recent years the fishing effort for American shad has decreased. Because of the paucity of shad, many fishermen early in the shad season will switch to larger mesh to catch the equally scarce, but more valuable striped bass.

In 1972, Tropical Storm Agnes hit Virginia when larvae, post-larvae, and juveniles were present in the tidal freshwater nursery zones. The failure of the 1972 river herring year class to recruit in 1976 was attributed to Tropical Storm Agnes, possibly as a result of eggs and juveniles being physically damaged by the highly turbid conditions, and heavy river flows sweeping them seaward where osmotic imbalance would cause large mortalities (Loesch and Kriete 1976). American shad catch data are biased due to the selective nature of the fishing gear used; however, trends in mean age and

distribution in the late 1970's paralleled the finding derived from the unbiased data for alewives and blueback herring. Thus, it is possible that Tropical Storm Agnes also affected the 1972 year class of shad.

Dams built in the 1800's block the upstream passage of anadromous fishes and substantially reduce the amount of available spawning grounds. On the James River, the American shad originally migrated 335 miles upstream. Today, because of Bosher Dam, the limit is about 105 miles. On the Chickahominy River, a tributary of the James River, a low head dam was built in 1943 at Walker, about 22 miles above the mouth of the tributary. In 1896, before the dam had been built, the Chickahominy River contributed 30% of the total shad catch on the James River watershed; in 1960 it contributed only 13% (Walburg and Nichols 1967), and there is no shad fishing on the Chickahominy River today. The area below Walker's Dam had been the lower limit of shad spawning on the Chickahominy River before the dam was built; now it is the major spawning area.

Contamination of the spawning and nursery grounds must also be suspected as a factor in the decline of anadromous stocks in Virginia. Kepone, for example, was reported in juvenile American shad and blueback herring in the Mattaponi River (Loesch et al. 1982a). The effects of various contaminants upon the survival rate of Alosa eggs, larvae and juveniles is largely unknown, but it is reasonable to assume that contaminants do not enhance survival.

RIVER HERRING

HISTORICAL PERSPECTIVE

River herring is a collective term for two anadromous herring species, the alewife (Alosa pseudoharengus) and blueback herring (Alosa aestivalis). The two species are very similar in appearance, and the commercial landings are simply reported as alewives. However, there are significant behavioral differences (Loesch and Lund 1977; Loesch et al. 1982b). These species have long been a important part of Virginia's fisheries. As long ago as 1588, Thomas Hariot wrote that during the months of February through May, herring were "most plentiful, and in best season, which we found to be most delicate and pleasant meat" (de Bry 1590). In the latter half of the 18th century, a decline in abundance of river herring, along with all anadromous fish, prompted the Virginia Assembly to pass laws requiring that dams be removed or fish passages built.

River herring, along with shad, were considered the most valuable food fishes in Virginia in 1875. Their ability to keep well when salted added immensely to their value (Va. Comm. Fish. 1875). However, the fisheries suffered a decline, and by 1879 were no longer profitable (Va. Comm. Fish. 1879). Artificial propagation was considered to be impractical for river herring due to the glutinous character of the eggs. Instead, measures recommended by the Virginia Fish Commission included a closed season to permit a proportion of the fish to escape upriver and spawn, and a tax on fishing in order to

discourage occasional fishermen and entrepreneurs from entering the fishery and causing fluctuations in production and prices.

In 1920, river herring in Virginia ranked first in quantity and fourth in value, with a catch of about 8,000 tons worth 253 thousand dollars. As late as 1969 river herring in Virginia ranked third in quantity and fifth in value, with a catch of 15,000 tons worth 608 thousand dollars (Nat. Mar. Fish. Serv. 1972). Since the early 1970's, however, the fishery has dramatically declined (Fig. 3).

In the early days, haul seines were used to catch the river herring. In 1976, however, more than 99% of the catch was made with pound nets. Other types of gear used include stake gill nets and drift gill nets.

LIFE HISTORY

Alewife

Adults

Alewives are distributed along the Atlantic coast from Newfoundland to North Carolina, and in streams and lakes as far inland as the Great Lakes. In the Great Lakes and many other inland lakes they are landlocked.

Data reported by Loesch et al. (1979) show that from 1977 to 1979 the age of spawning ranged from 3 to 9 years, with the modal age at 4 to 6 years. The higher modal values are few, and associated with years of extremely poor recruitment. The males dominate the younger

age classes, but in the older age classes females, which mature at a later age and have greater longevity, are more abundant (Loesch et al. 1979).

The alewife spawning migration occurs in the early spring, and is related to water temperature. It occurs three or four weeks earlier than that of blueback herring, and also precedes the first run of American shad. In the Chesapeake Bay, alewives usually arrive sometime in March (Hildebrand and Schroeder 1928). Bigelow and Schroeder (1953) state that spawning ordinarily occurs at water temperaturs of 55 to 60°F. In the act of spawning, two or more fish swim rapidly in tight circles 8 to 12 inches in diameter with sides touching, spiraling upward from the depths to the surface (Edsall 1964). Kissil (1974) reported that, depending on the length, female sea-run alewives produced from about 48,000 to 360,000 eggs, with a mean of 229,000. The eggs are demersal and somewhat adhesive immediately after being laid. Incubation period is dependent upon water temperature. The time to hatching was reported by Rounsefell and Stringer (1943) range from two to four days at 72°F, to six days at 60°F.

Neves (1981) reported that alewives in the ocean move north to the Nantucket Shoals, Georges Bank, and coastal Gulf of Maine areas during the summer and early fall, and then return south to the mid-Atlantic area in winter and early spring. He found alewives at depths ranging from about 65 to 960 feet, but primarily in water depths of less than 328 feet, which corresponds to the occurrence of

major zooplankton concentrations, upon which these fish feed. Alewives appear to prefer deeper depths than blueback herring. Neves (1981) noted that the alewife has a slightly larger eye than the blueback, a feature generally associated with existence at greater depths; also, the dorsum of the alewife is green, a color which generally penetrates deeper into the continental shelf waters than blue, the color of the blueback's dorsum.

Juveniles

Young alewives spend their first summer in freshwater. Few juvenile alewives have been captured in recent years in the James River, but previous sampling data (Davis et al. 1970) indicate the nursery zone was from about mile 45 to 70. Other major nursery areas for the alewives in Virginia are approximately mile 34 to 81 in the Pamunkey River, mile 34 to 71 in the Mattaponi River, mile 40 to 104 in the Rappahannock River, and mile 69 to 109 in the Potomac River (Loesch and Kriete 1980). Although the Potomac River is part of Maryland, many of the fish are landed in Virginia and therefore, are included in this discussion.

The juvenile alewives begin a seaward migration with the approach of cool weather. This migration is very gradual. In the Potomac River, alewives have been caught as late as December 3 (Hildebrand and Schroeder 1928). From the Chesapeake Bay the majority of the young migrate directly to the ocean, but at least some of them stay in the Chesapeake Bay until they are 1 or 2 years old (Hildebrand and Schroeder 1928).

Loesch et al. (1982b) reported a vertical segregation of juvenile alewives and bluebacks in tidal freshwater. Both species exhibited a diel vertical migration. In simultaneous samples with bottom and surface trawls, most alewives were caught during daytime in bottom samples; conversely, most blueback herring were captured at night with the surface trawl. Loesch et al. (1982b) suggested that this separation could serve to reduce feeding competition between the two species since their reported diets are identical. Because of the vertical migration and vertical separation of species, care must be used when selecting sampling gear and time. Conflicting measures of relative abundance can result from an inappropriate choice of sampling, and from the effects of varied light intensity when surface waters are sampled (Loesch et al. 1982b).

Mansueti and Hardy (1967) reported the total length of alewives when hatched ranges from 0.14 to 0.20 inch. They grow rapidly, reaching a size of 2.2 inches by July, 2.6 inches by September, and about 2.8 inches by December in the Chesapeake region (Hildebrand and Schroeder 1928). Loesch and Kriete (1980) presented growth curves for juvenile Alosa, and discussed aspects of Alosa behavior that affect such estimates.

Estimates of instantaneous daily mortality rates of alewives in Virginia rivers ranged from 0.033 to 0.040, with a mean of 0.036 in 1980 (Loesch and Kriete 1980).

LIFE HISTORY

Blueback herring

Adults

The blueback herring is found from Nova Scotia to the St. Johns River, Florida (Hildebrand and Schroeder 1928).

The age of blueback herring sampled in Virginia rivers ranged from 3 to 9. Prior to 1976, age 4 blueback herring were the modal age groups for both virgin spawners and all spawners. Because of successive years of poor recruitment, the proportions of age 4 fish in the commercial fisheries have been substantially reduced. Males dominate the younger age classes, while females are more abundant in the older classes. (Loesch et al. 1979).

The blueback herring spawning migration generally begins in the lower Chesapeake region during the first half of April and in the upper reaches of the bay during the last half of April (Hildebrand and Schroeder 1928). By June 1, only stragglers are left. They are reported to use the same general area as alewives, but are more selective, preferring sites with fast-flowing water and the associated hard substrate (Loesch and Lund 1977). However, in southern North Carolina and further south, where alewives do not occur, blueback herring utilize lentic waters. This suggests that differential selection of spawning grounds is a clinal-like phenomenon, and spatial isolation where the two species occur would reduce competition for spawning sites. Bigelow and Welsh (1925) reported that blueback

herring spawning occurred when water temperatures were about 70 to 75°F. However, Loesch and Lund (1977) found that this range in water temperature did not occur until about midway through the spawning season in Connecticut. The spawning behavior of blueback herring was described by Loesch and Lund (1977) and is similar to that of American shad as reported by Medcof (1957).

Estimates of egg production and post-spawning retention in blueback herring are facilitated by: 1) the reliability of using a subsample of the ovary to determine eggs per unit weight, 2) the independence of eggs per unit weight and total ovary weight and, 3) the nonsignificance of observed differences in eggs per unit weight for paired left and right ovaries (Loesch and Lund 1977). Additionally, a strong linear relation between left and right ovary weights permits the prediction of the weight of one member of a pair from the other member with little loss of precision (Loesch 1981).

Loesch and Lund (1977) reported that variation in ova production for individual fish ranged from 45,800 (9.4-inch fish [total weight]) to 349,700 (12.2-inch fish). The range for eggs retained in an ovary pair after spawning was 9,300 (10-inch fish) to 107,600 (11.7-inch fish).

The ocean movements of blueback herring are similar to those for alewives, except that bluebacks do not tend to occur as deep in the water column as alewives (Neves 1981).

Juveniles

The juvenile blueback herring in Virginia spend their first summer in the tidal freshwater sections of the rivers. The nursery areas for bluebacks in Virginia extend from about mile 46 to 92 on the James River, mile 0 to 23 on the Chickahominy River, mile 34 to 81 on the Pamunkey River, mile 34 to 71 on the Mattaponi River, mile 46 to 104 on the Rappahannock River, and mile 69 to 109 on the Potomac River (Loesch and Kriete 1980). Although they use the same part of the river for a nursery ground as alewives, bluebacks are higher up in the water column than alewives. Possibly this reduces feeding competition between the two species. The river herring migrate vertically, moving deeper in the water during the day than at night, and changing position in the water column in association with available light, suggesting negative phototropism. The vertical migrations of these fish must be considered when selecting sampling gear and time of sampling or conflicting measures of abundance may result (Loesch et al. 1982b).

The young blueback herring are about 0.14 inch long when hatched (Kuntz and Radcliffe 1918). They grow rapidly, reaching an average length of 1.1 inches by July, 1.8 inches by September, and 2.5 inches by December (Hildebrand and Schroeder 1928).

The growth rate of alosids is greater in the Pamunkey River than in the Mattaponi, both of which drain into the York River. This may be due to a lesser food supply in the Mattaponi. Growth rates of blueback herring in the Chickahominy River have also been found to be

relatively slow. However, the Chickahominy River has a relatively small nursery zone length, approxmimately 43 miles, and the apparent slow growth could be due to emigration of larger juveniles into the James River, where juveniles exhibit a relatively high growth rate (Loesch and Kriete 1980).

The estimated daily mortality of juvenile bluebacks in Virginia in 1980, excluding the Chickahominy River, ranged from 0.034 to 0.048 with a mean of 0.040. The estimate for the Chickahominy River was much higher, 0.067, but this statistic could be due to emigration of larger juveniles (Loesch and Kriete 1980).

With the approach of cool water, October and November in the Chesapeake Bay area, the blueback herring leave the freshwater (Hildebrand 1963). Most pass through Chesapeake Bay and migrate out to sea, but some stop in the deeper waters of the bay during their first winter, and a few apparently remain through their second winter (Hildebrand and Schroeder 1928).

FISHERIES

Gear Types

Pound nets are the primary gear used to catch river herring commercially. Other types of gear used include haul seines, stake gill nets, drift gill nets, and fyke nets, but in 1976 these methods accounted for less than 1% of the total river herring catch in Virginia (Nat. Mar. Fish. Serv. 1980).

Sport fishermen collect river herring during the spawning run with dip nets. The dip net fishery in Virginia begins in March and continues into May. In 1977 and 1978, the daily catch by dip net fishermen ranged from 30 to 400 fish per fishermen, depending upon time and location of fishing effort (Loesch et al. 1979).

Status of Stocks

Since 1970 there has been a general decline in Virginia landings of river herring (Fig. 3). In 1970, 9,522 tons of river herring were landed in Virginia. By 1975 only 2,027 tons were landed, and in 1976, the landings dropped sharply to 694 tons. In 1980, 592 tons were landed (Loesch and Kriete 1980) and for 1981 the estimated landings declined to 260 tons (Va. Mar. Res. Comm. 1981).

Catch per unit effort has shown an increase since 1977 on the York River, it has oscillated on the Rappahannock River, and has decreased since 1975 on the Potomac River except for 1978, when it showed a large increase (Loesch et al. 1979).

Loesch et al. (1979) reported that the annual percentage of blueback herring relative to alewife was significantly greater in the Virginia commercial catches from 1974 to 1979. In addition, the authors noted that the data indicated a six-year trend of increasing dominance of blueback herring over alewife. Thus, as the Virginia river herring stock declined since the early 1970's, the rate of decline for alewife appears to have been greater than the rate for blueback herring.

Possible Reasons for Decline

In 1969 the reported landings of river herring by foreign fishing fleets, primarily the USSR, East Germany, Bulgaria, and Poland, increased relative to previous years (Hoagman and Kriete 1975). These fleets operated east of the Virginia Capes and the Delmarva Peninsula from January to May, and harvested river herring that would have otherwise spawned in rivers of the mid-Atlantic states. The 1969 river herring landings for Virginia were about 26,791 tons, but in 1970 the landings decreased to 9,522 tons, and from 1971 to 1975 averaged about 5,512 tons.

Since 1973 the catch by offshore foreign fishing fleets has been relatively low as a result of agreements between the USA and foreign countries, and enactment of the 200-mile limit (PL 94-265). However, the continued lack of strong recruitment has resulted in a continued decline of the stocks (Loesch et al. 1979).

In 1976 there was a further decline in catch resulting from the near absence of the 1972 year class of river herring, which is believed to have been decimated by the occurrence of Tropical Storm Agnes that year. Eggs and young-of-the-year may have been physically damaged by the highly turbid conditions. Also, heavy river flows may have swept them seaward where large mortalities would have occurred because of osmotic imbalance (Loesch and Kriete 1976).

Over the longer period of time, the creation of impoundments on Virginia rivers has resulted in a loss of spawning grounds for river

herring. Loesch and Kriete (1980) theorized that impoundments could have a greater impact on alewives than on blueback herring. Alewives prefer spawning grounds in slow moving water or lentic environments, while bluebacks prefer fast-flowing water, and could spawn in the rapid flow below the impoundments. Except for Walker's Dam on the Chickahominy River, which was built in 1943 (Walburg and Nichols 1967), there has been no dam construction since 1897 on large waterways in Virginia. However, impoundments have been constructed on small streams which exclude river herring from former spawning grounds. The contribution of these exclusions to the present decline in river herring stocks is not known.

Contamination from pesticides and the increased application of herbicides used in conjunction with no-till farming may also have contributed to the decline of the river herring stock. The agrichemical contamination may have had a greater effect on alewives spawning in minor tributaries, where the contamination would be more concentrated, than on blueback herring spawning in the larger main streams, where the contamination would be more diluted. This could result in the differing rates of decline for alewives and blueback herring (Loesch and Kriete 1980).

HICKORY SHAD

HISTORICAL PERSPECTIVE

One of the first fish to be caught in the spring, hickory shad (Alosa mediocris) in the late 19th and 20th centuries were caught in pound nets and often sold in the cities as American shad to people who were not well-informed. The market for them would soon cease, after which they would be sold as fertilizer with river herring, at twice the value of river herring (McDonald 1884, Jordan and Evermann 1937). The market for hickory shad today continues to exist primarily in the spring before the American shad arrive.

Hickory shad is of minor importance as a foodfish, mainly because the meat is bony and considered inferior in flavor to the American shad (Hildebrand 1963). However, hickory shad roe is often considered superior to that of American shad.

LIFE HISTORY

Adults

Hickory shad, are found on the Atlantic coast from Maine to Florida. They are rare north of Cape Cod, are apparently more numerous in southern New England than in the Middle Atlantic States, and are most abundant in Virginia and North Carolina (Hildebrand 1963).

Hickory shad generally mature at three to five years (Mansueti 1958b), but a few of both sexes mature at 2 years (Pate 1972). They

spend most of their lives in the sea, returning to streams and tributaries to spawn. Hildebrand and Schroeder (1928) reported that there was a definite spring run and a somewhat less definite fall run of hickory shad in the Chesapeake Bay. They have been reported in Virginia rivers as early as February and have been found on the spawning grounds until late May (Davis et al. 1970). The fall run occurs from November until at least December (Hildebrand and Schroeder 1928).

Hickory shad swim as far upstream as possible and spawn below the first insurmountable barrier encountered (Davis et al. 1970). They found shad in running-ripe and spent condition in both tributary streams and mainstreams in Virginia. Pate (1972), however, working on the Neuse River, North Carolina, was only able to collect hickory shad eggs and larvae from tributary creeks and not from the mainstream.

Pate (1972) found hickory shad eggs and larvae in flooded swamps and sloughs located off the main channels of the creeks. The eggs are apparently broadcast at random. They tend to be bouyant and are slightly adhesive (Mansueti and Hardy 1967). The number of eggs per female has been found to range from 43,556 eggs in a 12.8-inch, 3-year-old female to 347,610 eggs in a 17-inch, 6-year-old female (Pate 1972). Mansueti (1962) found that the eggs hatch in two or three days at 65 to 70°F.

The adult hickory shad, after spawning, returns to an area near the sea, and in the fall moves back into the lower estuaries before moving out to sea (Mansueti 1958b). A small number of hickory shad

are found almost every month of the year, under a wide variety of estuarine conditions (Mansueti 1962). No information is available concerning the movements of hickory shad in the ocean.

Juveniles

The nurseries of the hickory shad in Virginia are in the fresh tidal sections of the James River, Pamunkey River, Mattaponi River, Rappahannock River, and Potomac River (Davis et al. 1970). Massmann (1953) reported that hickory shad migrate into salt water much earlier than American shad, alewives, or blueback herring. Mansueti (1958b) stated that the shad spends about 6 to 10 months in brackish water after hatching before going to sea. However, Pate (1972), working on the Neuse River, North Carolina, suggested that the young hickory shad may migrate to a more saline environment without utilizing the oligohaline portion of the estuary as a nursery area. He noted that the freshwater zone which forms on the scales of anadromous clupeids was far less evident on scales of adult hickory shad.

Bottom trawls conducted by the Virginia Institute of Marine Science (VIMS) in the Rappahannock River during 1968 and 1969 captured juvenile hickory shad at river mile 35 in September, 1968, mile 20 in October, 1968, and mile 35 to 40 in July and August, 1969.

Hickory shad larvae average 0.24 inch in length when hatched (Mansueti 1962). The growth rate of young hickory shad is much greater than that of other Alosa species. Juveniles collected during VIMS surveys in the Rappahannock River during 1968 and 1969 ranged in

length from 2.6 to 3.1 inches with a mean of 2.9 inches in July and August, 1969. On September 18, 1968 they averaged 4.6 inches, and one hickory shad caught on October 20, 1968 measured 5.4 inches. By contrast, alewives reach an average length of 2.6 inches by September, blueback herring reach an average length of 1.8 inches by September, and American shad reach an average length of 2.8 inches by the last half of October (Hildebrand and Schroeder 1928).

No information is available concerning the mortality rates of juvenile hickory shad in Virginia.

FISHERIES

Gear Types

The principal gear for catching hickory shad is stake gill nets, accounting for 71% of the hickory shad landed in 1976. Pound nets were second, with 26% and drift gill nets caught 3%. Other types of gear which have been used include haul seines, fyke nets, and slat traps (Nat. Mar. Fish. Serv. 1980, Power 1960). In 1981, most of the hickory shad caught commercially on the Rappahannock River were taken by stake and anchor gill net fishermen using 4-inch and 4.5-inch mesh net. Other gill net fishermen using 5-inch mesh net caught no hickory shad, and pound net fishermen took them only in small numbers (J. C. Owens, Virginia Institute of Marine Science; personal communication).

A sport fishery exists for hickory shad near the spawning grounds beyond the influence of the tide. Sport fishermen take hickory shad

by casting for them with shad darts, spoons, and spinners (Kriete and Merriner 1978).

Status of Stocks

The peak recorded catch of hickory shad in Virginia since 1920 occurred in 1925 when 118 tons were landed. In 1970 the catch was 12 tons, and from 1970 to 1975 it ranged from 5.5 to 28 tons. In 1976 there was a sharp decrease to 1.8 tons, and a further decrease to 0.7 ton in 1977. Since 1977, the catch has remained low (Fig. 4).

Possible Reasons for Decline

The hickory shad is not an abundant commercial fish in Virginia. It is one of the first fish caught in the spring and one of the last to be caught in the fall in considerable quantities, but relatively few are caught during the summer (Hildebrand and Schroeder 1928). The fishery is not intense enough to greatly affect their abundance (Hildebrand 1963).

As is believed to be the case with other Alosa species in Virginia, Tropical storm Agnes probably decimated the 1972 year class of hickory shad.

It is difficult to assess the impact of impoundments on spawning hickory shad. Prior to 1962, a dispute existed between scientists as to whether hickory shad even spawned in freshwater or whether they returned to sea to spawn. Mansueti (1962) determined that hickory shad do spawn in freshwater in Maryland. In Virginia, anadromous fish

studies conducted at the VIMS show that juvenile hickory shad have been caught in the tidal, freshwater sections of the Virginia rivers. Davis et al. (1970) reported that spawning hickory shad swim upstream until they encounter an insummountable barrier. They have been found below the dam on the Rappahannock river at Fredericksburg, at Walker's Dam on the Chickahominy River, and below the first dam at Richmond on the James River. They have also been found in several tributary streams in these rivers. Pate (1972) found that a low-head dam in the Neuse River, North Carolina hampered the progress of the hickory shad, although some were able to negotiate a fishway at the dam. It is likely, therefore, that the construction of impoundments in Virginia Rivers has resulted in a loss of spawning grounds.

Contamination of rivers with pesticides and herbicides used in conjunction with no-till farming may also have contributed to the decline of hickory shad.

MANAGEMENT - *ALOSA* FISHERIES

Virginia has traditionally been very conservative in applying new regulations to its fisheries. Former director of the Virginia Fisheries Laboratory, Nelson Marshall, wrote in 1949, "Extreme caution should be exercised in the adoption of measures restricting, in the name of conservation, the methods of fishing and the size and quantity of fish taken."

Management of Virginia's fisheries in tidal waters is charged to the Virginia Marine Resources Commission (VMRC) except in the Potomac

River, where the Potomac River Fisheries Commission (PRFC) has jurisdiction. The VMRC is authorized to adopt such regulations as it deems necessary to protect and promote the industry (Va. Mar. Res. Comm. 1980). The PRFC may, by regulation, prescribe the type, size, and description of all species of finfish and shellfish which may be taken or caught within its jurisdiction, the places where they may be caught or taken, and the manner of catching or taking (Va. law sec. 28.1-203).

An Interstate Fisheries Management Program is presently being developed by state participants from Maine to Georgia. At present, however, there are few laws regulating the Alosa fisheries in Virginia. Those laws which affect the fishery are primarily directed toward regulating the fishing gear, as follows:

Pound nets must have a minimum stretched mesh size of 2 inches. The maximum length of haul seines is 1,000 yards long, and when more than 200 yards long, they must have at least a 3-inch stretched mesh (Va. law sec. 28.1-5.1).

The maximum length of any fishing structure in Chespeake Bay is 400 yards. There must be at least 200 ft. between successive fishing structures and 300 yards between adjoining rows of structures (Va. law sec. 28.1-52).

No net may be set across any river, bay, estuary, creek, or inlet which is longer than one fourth the width of the body of water, and

the net shall not be set or fished more than one half the distance across the channel of the water (Va. law sec. 28.1-53).

Except in the James River, there are no regulations concerning the size, number, or season for catching Alosa fishes in Virginia waters. In the James River, a regulation by the Virginia State Water Control Board prohibits fishing when they determine that the Kepone contamination levels are greater than 0.3 ppm.

Management of the offshore foreign fishing fleet operating within the 200 mile Fishery Conservation Zone is provided for by the Magnusen Fishery Conservation and Management Act (PL 94-265).

The Virginia Institute of Marine Science (VIMS) has been actively engaged in research of the anadromous Alosa since 1965. Based on recent data, VIMS management recommendations included a reduction in the river herring by-catch of foreign fishing vessels to 110 tons or less, and the development of a contingency management plan by the VMRC that would provide for increased escapement of river herring from the fishery until the advent of stronger recruitment (Loesch et al. 1979).

ATLANTIC STURGEON

HISTORICAL PERSPECTIVE

Sturgeon have been important fish to Virginians since the time of the first colonists. The early settlers at Jamestown, familiar with the valuable sturgeon roe or caviar in Europe, saw potential riches from the sturgeon in America. Within a few months of their arrival in 1607, a sturgeon fishery had become economically important (Pearson 1942). In 1609, Captain Samual Argall sailed from England to Virginia to fish for sturgeon, prompted by the desire of English merchants to be free of Baltic domination of the sturgeon market. Pickled sturgeon were sent to England, where the air bladder was used to make isinglass, and the roe to make caviar. Unfortunately, in the hot Virginia summers, sturgeon spoiled quickly, and sturgeon products did not keep well on the voyage to England. By 1626, the sturgeon fishery still had not become profitable, and colonists began turning their attention toward more productive efforts such as tobacco growing, and shad and river herring fishing for local consumption (Pearson 1942). At one time sturgeons were considered worthless, and were destroyed in large numbers by fishermen, who regarded them as pests (Hildebrand and Schroeder 1928).

Toward the end of the 19th century, however, sturgeon again became important, and a special fishery was inaugurated. In 1890, about 407 tons of sturgeon were landed in Virginia. A great decrease in the sturgeon catch occurred after 1897, and again after 1904 (Hildebrand and Schroeder 1928). By 1914, the Virginia legislature,

in an effort to protect the species, had enacted a minimum size limit of 48 inches for sturgeon (Va. Comm. Fish. 1915). In 1915, a bill was introduced in the Virginia General Assembly which would have prohibited the taking of sturgeon for a period of ten years, but it failed to pass (Va. Comm. Fish. 1916).

After continued declines in the landings in the 1970's, it became illegal to catch sturgeon after 1977. Today the Atlantic sturgeon is designated as a threatened species by the state of Virginia.

LIFE HISTORY

Adults

Atlantic sturgeon are found along the east coast of North America and in the Gulf of Mexico. They are divided into two subspecies, the Atlantic sturgeon, Acipenser oxyrhynchus oxyrhynchus, and the Gulf of Mexico sturgeon, Acipenser oxyrhynchus desotoi (Vladykov 1955). The range of the Atlantic subspecies is from the St. Lawrence River, Quebec (Sloterdijk 1978) to the St. Johns River, Florida (Vladykov and Greeley 1963), while the Gulf subspecies is limited to the Gulf of Mexico, northern coast of South America, and possibly Bermuda (Huff 1975). All further references to Atlantic sturgeon in this paper will apply to both subspecies, although only the former occurs in Virginia waters.

Sturgeons are long-lived fishes whose lifespans may exceed 60 years (Murawski and Pacheco 1977). The time until sexual maturity is also quite long, and appears to vary with latitude and with sex. In

Florida, Huff (1975) found, by microscopic examination of gonad tissue, mature females ranging in age from 8 to 17 years and males from 7 to 21. However, spawning may be delayed by several years because behavioral and hormonal development may not be sufficient to elicit spawning. By examination of the spawning marks in fin rays, Huff determined the mean age of first spawning for his Florida specimens to be 16.8 years for females and 12.2 years for males. In the St. Lawrence River, Canada, sexual maturity is achieved by males at 22 to 24 years and by females at 27 to 28 years. This corresponds to an approximate total length of 65 inches for males and 75 inches for females (Scott and Crossman 1973). No female has been reported as being ready to spawn before reaching a weight of at least 150 lb. and an age of about 10 years (Vladykov and Greeley 1963). In Chesapeake Bay, sexual maturity is believed to occur when a length of about 48 inches has been attained (Hildebrand and Schroeder 1928). This is the size at which the species loses its juvenile characteristics (Scott and Crossman 1973).

It is not known whether female Atlantic sturgeon spawn every year. However, Vladykov and Greeley (1963) observed that, even during the spawning season, large individuals with immature ovaries are found among fully mature female Atlantic sturgeon. They suggested that this may be explained by the fact that the fish, after the first spawning, may spawn only at intervals of two or even three years. Roussow (1957) showed that the lake sturgeon, Acipenser fulvescens, requires 3 to 6 years of gonadal development before spawning, and 1 to 2 years to

recover to a resting state, resulting in spawning only every 4 to 7 years.

The Atlantic sturgeon appear to enter the Chesapeake Bay prior to spawning during April, and later move into the rivers where the spawn is deposited (Hildebrand and Schroeder 1928). Huff (1975) found that the overall sex ratio during the spawning migration was 1:1, but that there were significant differences in the sex ratios between spring and fall. He concluded that this indicated differential migration routes chosen by pre- and post-spawning sturgeon, with females actively seeking shallow water during spring and deep water during fall.

The spawning locations in Virginia have not been identified. In the St. Lawrence River the sturgeon apparently move upstream through deep channels that are kept free of nets because of navigation (Vladykov and Greeley 1963). Dees (1961) reported that sturgeon almost cease feeding while swimming upstream and that they move to a spawning area beyond the reach of the tide. However, Dale and O'Conner (1981) reported that studies of sturgeon movements in the Hudson River by Dovel indicated that Atlantic sturgeon spawn in oligohaline waters (0.5-5 ppt). Spawning locations have been described as being over hard bottom in running water (shoals) and in pools below waterfalls, typically in and below bends, often with a rugged bathymetry varying as much as 19.7 ft (Huff 1975); and in running water as much as 9.8 ft deep over small rubble or gravel (Dees 1961). Borodin (1925) reported spawning to occur in water

temperatures of 56 to 64°F. Smith et al. (1980) induced spawning with pituitary injections in freshwater tanks at water temperatures of about 55 to 63°F.

The females appear to expel their eggs by rubbing their bellies against hard places on the river bottom, or against the bodies of males (Ryder 1890). The spawning activities of Atlantic sturgeon have not been observed; however, the blood red appearance of the bellies of females caught in rivers has been considered evidence that the fish were caught in the act of spawning (Borodin 1925).

The fecundity of the females ranges from 800,000 to 3,755,745 eggs (Vladykov and Greeley 1963). The fertilized eggs are 0.08 to 0.11 inch in diameter, and are slate-grey or light to dark brown (Jones et al. 1978). They are demersal and adhesive (Vladykov and Greeley 1963) and become firmly attached to substrate within 20 minutes (Jones et al. 1978).

After spawning the spent fish gradually return to the sea from September through December. They undertake coastal migrations as long as 870 miles along the coast at depths less than 66 ft. Possibly they spend the winter along the North Carolina coast (Jenkins and Musick 1980).

The food of the Atlantic sturgeon varies with habitat. It is a bottom feeder, rooting in the substrate with its snout, and sucking up its food along with considerable amounts of mud (Vladykov and Greeley 1963). The stomach contents of sturgeon taken from the Hudson River

have been found to contain mud along with plant and animal matter including sludgeworms, chironomid larvae, isopods, amphipods, and small bivalve molluscs. The stomachs of sturgeon taken in salt water have been found to contain polychaete worms, marine gastropods, shrimp, amphipods, and isopods. Large sturgeon feed on molluscs and other bottom organisms (Vladykov and Greeley 1963).

Juveniles

Atlantic sturgeon eggs hatch in about 94 hours at 68°F, about 168 hours at 64°F (Jones et al. 1978), and 121 to 140 hours at 61 to 66°F (Smith et al. 1980). The fry average 0.28 inch total length at hatching. They absorb their yolk sacs in about 11 days at which time they average 0.5 inch total length (Smith et al. 1980). Dale and O'Conner (1981) collected sturgeon larvae in the Hudson River at depths ranging from 30 to 65 ft., water temperatures between 59 and 76°F, and salinities of 0 to 2.2 ppt. The larvae were collected only in bottom samples, and no eggs were collected. The collections were made from 1972 to 1979 during May, June, and July, and total length ranged from 0.33 to 1.4 inches. Smith et al. (1980) reported that sturgeon under culture conditions grew to an average total length of 0.78 inch after 20 days and 4.5 inches after 131 days.

Young sturgeon may spend as long as three or four years in freshwater before migrating to sea (Murawski and Pacheco 1977). During this time they remain in the lower tidal reaches of rivers (Dees 1961).

FISHERIES

Gear Types

In 1976, the last year in which a sturgeon fishery was allowed and years prior to 1976, otter trawl fishing in the Atlantic was the primary gear used to capture the fish. Smaller catches were reported with pound nets, fyke and hoop nets, drift gill nets, and anchor, set and stake gillnets.

Status of Stocks

Atlantic sturgeon are a protected species in Virginia (Va. law sec. 28.1-49.1) and are fished neither commercially nor by sport fishermen. Nevertheless, a few sturgeon are still landed annually in Virginia as a result of a provision in the law allowing fishermen to keep dead or obviously injured fish (Jenkins and Musick 1980).

There are no commercial catch data available for assessing the currents status of the sturgeon stocks in Virginia. However, in 1978 and 1979, the Virginia Institute of Marine Science (VIMS) conducted a general pilot study of sturgeon in Virginia waters (Loesch et al. 1979). Logbooks were placed with cooperating pound net and gill net fishermen, and catch-per-unit-of-effort calculated for the sturgeon caught and released by these fishermen. From the total average pound net or gill net effort in the sampling area an estimate of the total biomass of sturgeon caught and released was obtained. In 1978 the James, York, Pamunkey, Mattaponi, and Rappahannock rivers were sampled. An estimated 2.8 tons of sturgeon were caught and released

in these rivers with the James River accounting for 64% of the catch. In 1979 only the James, York and Rappahannock rivers were sampled. The estimated catch was 5.7 tons, with 79% caught in the James River.

Sturgeon are scarce today in comparison to historical catch data. In 1880, the catch was 54.4 tons from the James River alone (Hildebrand and Schroeder 1928); the total Virginia landings of sturgeon that year was 206 tons. These figures include both Atlantic sturgeon and shortnose sturgeon, Acipenser brevirostrum. Shortnose sturgeon were taken commercially until declared an endangered species after 1973. However, the shortnose sturgeon have always been rare in Virginia waters. Only one specimen has been collected in Chesapeake Bay and that was in 1876 from the Potomac River (Jenkins and Musick 1980).

The sturgeon catch declined sharply after 1898, from 316 tons in 1898 to about 91.5 tons in 1901, and again after 1904, when it dropped from 90.5 tons in 1904 to 11 tons in 1920. In the mid-1970's the catch declined further, from about 9 tons in 1973 to 1.4 tons in 1976.

After 1973 shortnose sturgeon could no longer be caught, and in 1977 it became unlawful to catch Atlantic sturgeon in Virginia waters unless injured or dead. Although Atlantic sturgeon are protected in Virginia, the stocks are commercially exploited in North Carolina during their oceanic migrations, and substantial landings are still reported (Jenkins and Musick 1980).

Possible Reasons for Decline

Overfishing is a major factor in the decline of sturgeon stocks. Because of their large size and sluggish behavior, sturgeon are easily captured. When they became a valuable fishery around 1870 (Murawski and Pacheco 1977), they were caught in great numbers, with the aggregate catch becoming smaller each year (Hildebrand and Schroeder 1928). At the turn of the century, fishing was so intensive that few mature fish were able to reach the spawning grounds (Vladykov and Greeley 1963). In addition, young sturgeon were killed by shad fishermen when they became entangled in the nets (Murawski and Pacheco 1977).

Pollution has also contributed to the decline of sturgeon. Sturgeon are strictly bottom feeders, and destruction of their food supply by pollution has had an adverse impact on the stocks. Pollution has been considered the principal cause for the elimination of sturgeon runs in the Sampit and Lynches rivers, South Carolina, and for the decline of sturgeon stocks in the Delaware River, Delaware (Murawski and Pacheco 1977).

Dam construction is another potential contributor to the decline of sturgeon. Dams have been reported to block passage of sturgeon in the Merrimac River, New Hampshire, and Peedee, Wateree, Congaree and Savannah rivers, South Carolina (Murawski and Pacheco 1977). Dam construction on the lower Susquehanna River in Maryland, and possibly those dams associated with navigation canals in Virginia may have reduced the spawning ground available to sturgeon (Jenkins and Musick 1980).

MANAGEMENT

Currently, fishing for sturgeon is not allowed in Virginia waters. Prior to the banning of sturgeon fishing in 1977, a law passed by 1914 had allowed sturgeon to be caught, provided they were at least 48 inches in length (Va. Comm. Fish. 1915).

Jenkins and Musick (1980) have proposed that tagging studies should be initiated to determine whether Virginia sturgeon are being taken by North Carolina winter fisheries. If so, consideration should be given to protecting sturgeon from the coastal fisheries, allowing estuarine and riverine fisheries only in those states where stocks are adequate to support a fishery.

FEASIBILITY OF RESTORATION PROGRAMS

SUCCESSFUL RESTORATION PROGRAMS

Fish passage facilities over dams have been successful on both the east and west coasts of the United States. Examples of successful structures, and current plans for future facilities are as follows:

Columbia River (Washington, Oregon and British Columbia, Canada)

American shad (descendants of East Coast fry stocked in the late 19th century) have utilized fish ladders on the Columbia River for many years. While the shad is an exotic species to the area, its use of ladders built for Pacific salmon is another example of the value of fishways in a restoration program. American shad presently migrate over 430 miles up the Columbia and Snake rivers in Washington and Oregon. To complete this journey the shad must negotiate fish passage facilities at eight hydrodams. Since 1968 over 90% of the shad passing the Bonneville Dam (mile 145 on the Columbia River) have also passed the Dalles Dam, about 46 miles upstream. In 1981, approximately 1.1 million American shad passed over the Dalles Dam, about 528 thousand over the John Day Dam (mile 216), 193 thousand over the McNary Dam (mile 292), and 21 thousand over the Priest Rapids Dam (mile 397).

Maine

The Department of Marine Resources in Maine has had a very active fish ladder construction program since the late 1960's to enhance

sea-run fish populations for commercial and recreational users (Lewis N. Flagg and Thomas S. Squiers, Maine Department of Marine Resources; personal communications). Some of the completed projects are shown in Figure 5. Future sites under consideration for fish passage facilities or stream improvement include the St. George, upper Royal, Orange, and Marsh rivers, and West Harbor Pond. Presently, there is also an active restoration program for alewife, American shad and Atlantic salmon in the St. Croix River, the boundary between Maine and New Brunswick, Canada. Alewife and landlocked Atlantic salmon movement in the St. Croix River has been verified at Grand Falls Dam, the third of five dams on the main stream.

New Hampshire

During the 1960's and 1970's fish ladders were constructed in New Hampshire's major coastal rivers. River herring were also stocked above stream barriers. The result of these efforts has been, in general, a major increase in river herring in the Lamprey, Exeter, Oyster, Cocheco, Taylor, and Winnicut rivers; e.g., in the Lamprey River the river herring run has increased from about 1,400 fish in 1973 to over 50,000 in 1981 (Jonathan C. Greenwood, New Hampshire Fish and Game Department; personal communication). Presently, there is also an active American shad stocking program. This effort is expected to reintroduce this species in rivers where it was eliminated by the construction of dams for the textile industry in the mid-1800's.

Connecticut River (Connecticut, Massachusetts, New Hampshire and Vermont)

Presently, Atlantic salmon, American shad, blueback herring and striped bass move upstream to a fish lift at the Holyoke Dam, Massachusetts (mile 86). The lift became operational in 1955 and has been modified seven times, with each modification improving the efficiency or capacity (Moffitt et al. 1982). The additions of a tailrace in 1975 and a spillway lift in 1976 are believed to be the major resons for the relatively large returns of fish in subsequent years (Table 3). In 1981, a total of 319 Atlantic salmon were passed over the Holyoke Dam along with approximately 420,000 blueback herring, 380,000 American shad and 570 striped bass. Most of the salmon were collected for breeding but some, together with the shad, moved upriver to the Turners Fall Dam (mile 123). In turn, fish of both species moved to a Vernon, New Hampshire fish trap (mile 142); subsequently salmon were transported upriver by hatchery trucks beyond Bellow Falls Dam (mile 174) where the fish were released to spawn naturally.

Massachusetts

In addition to the fish lifts at Holyoke, a new lift in the Commonwealth of Massachusetts became operational on 9 May 1983 at the Essex Dam on the Merrimack River in Lawrence. As of 25 May, 660 American shad, 2,375 river herring, and 8 Atlantic salmon were passed upriver (Ben Rizzo, U.S. Fish and Wildlife Service, Newton Cornor, Massachusetts; personal communication). Additionally, 19 new Denil

ladders were installed, and about 70 of the older weir-pool type ladders have been replaced or repaired, or modified since 1969 (Joseph S. DiCarlo, Massachusetts Division of Marine Fisheries; personal communication).

Rhode Island

The Rhode Island Division of Fish and Wildlife in 1980 reported that American shad had returned to the Pawcatuck River after a total absence of nearly 100 years. The reestablishment of the run was due to the construction of a fish ladder and the stocking of shad upstream of the dam. A total of 165 American shad were counted at the Potter Hill Fish Ladder in 1980. These fish were mostly four-year-olds and were the progeny of approximately 2,500 adult shad transported from the Connecticut River and stocked into the Pawcatuck River during the Spring of 1976. This is believed to be the first time a depleted American shad run has been successfully restored when no remnant of the original run remained (John F. O'Brian, Rhode Island Division of Fish and Wildlife; personal communication). An average of 800 adult shad returned in the years 1981 and 1982 (Table 4). Some of the other activities relative to the restoration of anadromous runs in Rhode Island are summarized in Table 5.

Pennsylvania

The city of Philadelphia funded the construction of a fish ladder within the city limits on Fairmont Dam on the Schuylkill River in 1979. This site is within city limits and contains a public viewing

chamber which provides urban entertainment and stimulates public interest in fishery projects. Only a few shad were observed in 1981, but it is expected that their numbers will increase. Other fishways are required before anadromous species can totally utilize all the historical spawning habitat in the Schuylkill River.

Susquehanna River (Maryland, Pennsylvania and New York)

A cooperative program for restoring historical runs of anadromous species to the Susquehanna River has been in progress since the 1960's. There are four dams that will require fishways, the Conowingo (95 ft), Holtwood (55 ft), Safe Harbor (55 ft) and York Haven (several, 6 to 22 ft), to permit these fishes access to over 250 miles of suitable spawning and rearing habitat in the main stem and over 200 miles in the tributaries. The American shad was once an important commercial species in the Susquehanna River and migrated upstream to at least Binghamton, New York (mile 330) during its spawning runs (Stevenson 1897). Striped bass have been documented at mile 160 (Pa. State Comm. Fish. 1886). Alewife, blueback herring and American eel are additional sea-run species that formerly utilized the Susquehanna River, but now encounter the Conowingo Dam at river mile 10.

Other Activities

The states of Maryland, Virginia, North Carolina, South Carolina, and Georgia (in addition to many of the states discussed above) annually collect statistics on the anadromous species in their respective waters. Catch and effort, sex ratio, age structure, size,

and relative abundance data are collected in most of the programs for adult fishes; an index of relative abundance is generally determined for the young-of-the-year. These baseline data are essential for rational management of the stocks.

Virginia: James River

A description of the dams in the Richmond area of the James River, the feasibility of retrofitting fish passage facilities to the dams, the types of facilities, and preliminary estimates of cost are presented in the Appendix.

EXPECTED BENEFITS

All anadromous stocks in Virginia waters have declined in the last century, some have exhibited dramatic decreases within the last decade. The passage of fish upstream of Bosher Dam would extend the migratory route of anadromous fishes to Coleman Falls Dam, Virginia, approximately, an additional 100 miles. Benefits expected from the fish passage facilities are: 1) increased spawning and nursery habitat, thereby enhancing the anadromous stocks; 2) increased density of forage species (Alosa) for resident species; 3) enhancement of sport fisheries and support businesses; 4) enhancement of commercial fisheries and support businesses; and 5) enhancement of city park fishing activities and associate interpretive programs in the Richmond area.

Mr. Rizzo's design estimate for 600,000 American shad to eventually be passed above the Bosher Dam (Appendix) is based on the

assumption of 50 spawning adults per acre. This value (50/acre) was originally used in testimony pertaining to a shad restoration program in the Susquehanna system; the testimony was submittd by Richard S. St. Pierre (U.S. Fish and Wildlife Service, Harrisburg, PA) to the Federal Energy Regulatory Commission, Docket No. EL80-38. Mr. St. Pierre derived the constant from long-term estimates of the annual number of American shad in the Connecticut River and the amount of spawning habitat available. The potential population of 3,000,000 river herring to be passed above the Bosher Dam is based on an estimate of the river herring to American shad ratio in the Connecticut River. Both of these estimates of expected number to be passed over the Bosher Dam are probably conservative. Estimates of the annual number of American shad in the Connecticut River were recently adjusted upward for the years 1965 through 1981 to account for gill net selectivity; also, juvenile surveys in the years 1979, 1980, and 1981 indicated that the relative abundance of just the blueback herring was ten times greater than that of the American shad (Victor Crecco, Connecticut Department of Natural Resources; personal communication). In an earlier investigation of juveniles in the Connecticut River in the years 1966, 1967 and 1968, the relative abundance of blueback herring was also much greater than that for alewife and American shad (Loesch 1969). Striped bass and sturgeon would also be passed upriver, but their number and size would be a function of the types of facilities constructed. Fish lifts and locks in the New England region have been found to be much more efficient

than fish ladders for passing striped bass greater than about 15 inches.

Based on the documented success of other restoration programs, we believe our stated expected benefits are reasonably conceived. In the Connecticut River drainage basin, a group of utility companies, collectively Northeast Utilities (NU), proudly proclaim the results of their restoration efforts, and their cooperation with the Committee for Fisheries Management of the Connecticut River Basin. The Holyoke Water Power Company lays claim to the first successful shad fishway on the Atlantifc coast, the Holyoke Dam fish lift. At the Turner Falls facility NU has provided viewing areas and welcomes the public. Each spring, a "shad derby" sponsored by the Holyoke Water Power Company brings thousands of anglers to the river below the dam. An NU brochure states that sport fishermen catch over 10,000 American shad in the Connecticut River, and, altogether, spend about $270 thousand. Additionally, the value of the commercial catch from the river mouth to just below Hartford (approximately mile 45) averages about $500 thousand annually.

The estimated economic worth associated with the restoration of American shad runs in the Susquehanna River is between $45 million and $185 million (McConnell and Strand 1981). The investigators, for several reasons, also considered their estimates to be conservative, e.g., American shad was the only species considered, and the New York State portion of the river was not included in their economic models.

In a 1982 Sport Fishing Institute Bulletin it was stated that the importance of opportunities for recreational fisheries in urban areas is apparent when we recognize that 70% of the cities in the United States with a population of 50,000 or more, and about 30% of the cities having a population between 25,000 and 50,000 are located on a river, lake, estuary or ocean. There is a rapidly growing awareness of the aesthetic and social importance of urban fishing programs by urban planners, developers, and city officials, as well as by fishery professionals. The American Fisheries Society, in recognition of the unique needs and problems encountered in the development of urban fisheries, has organized an international symposium entitled "Creating Fishing Opportunities in the Urban Environment" (Grand Rapids, MI, October 1983).

The Commonwealth of Massachusetts and the State of New York are two of our nearest "neighbors" that have instituted urban fishery programs because of the high social value of water-related receation. Their programs address the planning, implementation, and information and education aspects of urban recreational fisheries. Some of the basic goals in the Massachusetts Urban Angler program are:

1. Demonstrate ways to catch, prepare, cook and preserve the abundant, but underutilized, fish species present in Massachusetts waters.
2. Provide residents with a healthy, inexpensive, life-long outdoor recreation which can be pursued close to home.

3. Develop an increased awareness of man's impact on the aquatic environment, and an awareness of how this environment relates to their lives.
4. Aid in the emotional, intellectual, and physical development of the participants.

It is hoped that these goals will be obtained by teaching basic fishing skills through local workshops, (Ilo Howard, Massachusetts Division of Fisheries and Wildlife; personal communication). A special effort is being made to attract children, women, and senior citizens to the program; e.g., a study was conducted to compile a profile of the "average" woman angler, in Massachusetts (Howard 1979).

Private industry and concerned citizens are also involved in promoting urban fisheries. A television station in Washington, D.C. (TV-7) will host its third annual Fishing Derby this year in the Potomac River. Additionally a TV-7 Fishing Clinic is being sponsored in cooperation with Safeway Stores, Schlitz Beer and Outdoor Life Unlimited. A citizen's group, The Fishing Committee of the Washington Area Waterfront Action Group is coordinating both events. A decade ago, prior to the initiation of a massive clean-up effort which started several years ago, the debased condition of the Potomac River precluded such recreational activities.

The present high activity in water reclamation projects for public recreation, the involvement of industry and the public in fish restoration projects, and the growing popularity of urban fishery programs indicate that the aesthetic and social rewards of such

endeavors are, at the least, no less important than the monetary considerations. No state or municipality can expect other sovereignties to provide a wholesome environment for their enjoyment while they, for whatever purpose, degrade their own. Perhaps it was a similar thought that prompted Henry Thoreau to write[1]

> Such is beauty ever -- neither here nor there, now nor then -- neither in Rome nor in Athens, but wherever there is a soul to admire. If I seek her elsewhere because I do not find her at home, my search will prove a fruitless one.

We recommend the installation of facilities that would insure upstream passage for anadromous species, and, subsequently, the successful downstream return of adults and juveniles. Access to historical spawning grounds above Bosher Dam will enlarge the anadromous populations. All Virginians would benefit from this enhancement, and in particular, the cities and other municipalities from Richmond to Lynchburg would have a unique oportunity to enrich their aesthetic, social and economic posture.

EXPECTED COSTS

The preliminary cost estimates for fish passage facilities at each of the five dams are presented in the Appendix. Total cost estimates range from $2.5 million to $7.5 million, depending upon the nature of the facilities and whether or not VEPCO redevelops hydropower at the Manchester and Twelfth Street plants. Although

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[1] Thoreau on Man and Nature: A compilation by A. G. Volkman (1960).

these estimates are substantial sums, the values, particularly for any individual facility, pale when compared to many such investments elsewhere. Northeast Utilities spent $2.1 million in the period 1974-1976 just for modifications (spillway and an additional lift) to the Holyoke Dam facilities. Since 1955, about $5 million have been spent at the Holyoke site; in terms of 1983 dollars, the sum would be considerably greater. Northeast Utilities also spent $12.5 million for three fish ladders that were completed in 1980 at the Turners Falls Dam, Massachusetts. New England Electric Company financed the construction of two fish ladders at dams in the Connecticut River in Vermont. The ladder at Vernon Dam was completed in 1981 at a cost of $9.5 million; the other ladder at Bellows Falls Dam, scheduled to open later this year, will cost about $7 million. A private investment firm, Lawrence Hydroelectric Associates, which sells electrical power to Northeast Utilities, earlier this year opened a new fish lift at the Essex Dam on the Merrimack River in Lawrence, Massachusetts at a cost of $2.3 million.

The construction of fish passage facilities for the five dams in the Richmond area of the James River is a practicable undertaking. The costs are long-term amortizations, while enhanced fish stocks are an annually renewable resource with a large potential for very positive socio-economic ramifications.

POTENTIAL FUNDING SOURCES

In 1930 the General Assembly enacted Virginia Code section 29-151, requiring any person owning or having control of any dam or other obstruction which may interfere with the free passage of fish to

provide and maintain a suitable fish ladder. Although parts of some river systems are exempted from section 29-151, the Richmond area of the James River is not. (See pages 8-9 for Section 29-151.) Title to the Bosher Dam and Kanawha Canal are vested in the C&O Railroad. The City of Richmond, however, assumed the responsibility for the operation and maintenance of these facilities when it acquired the water rights in 1973. In addition, the City of Richmond owns the Williams Island Dam, the Hollywood/Belle Island Dam, the Brown's Island Dam, and the Manchester Dam.

Under the Federal Power Act (FPA), 16 U.S.C. Sec. 791 (a) et seq., the Federal Energy Regulatory Commission (FERC; formerly the Federal Power Commission [FPC]) is authorized to issue licenses for non-Federal hydroelectric power projects.

After a review of a project application, FERC may issue a license to the applicant for a term of up to 50 years, if the Commission finds that the project will be best adapted to a comprehensive plan:

1. for improving or developing a waterway for the use or benefit of interstate or foreign commerce;
2. for the improvement and utilization of water-power development;
3. and for other beneficial water uses, including recreational purposes. (Section 10[a].)

The last standard, requiring consideration of "other beneficial uses, including recreational purposes" has been interpreted by the Federal courts to require evaluation of impacts to fish and wildlife,

conservation of natural resources, the maintenance of natural beauty, and the presevation of historic sites.

The consideration which must be given under the FPA to impacts on fish and wildlife from a hydroelectric project is further strengthened by the provisions of Fish and Wildlife Coordination Act, 16 U.S.C. Sec. 661 et seq., and the National Environmental Policy Act, 42 U.S.C. Sec. 4321 et seq. Both statutes require evaluation of fish and wildlife impacts, and can serve as the basis for modifying, conditioning, or denying a FERC license. When requested by appropriate state agencies, and the U.S. Fish and Wildlife Service and/or the U.S. National Marine Fisheries Service, FERC has generally included construction of a passage facility by an applicant as a condition for granting a license. In Section 18 of the FPA it is stated that "The Commissioner shall require the construction, maintenance, and operation by a licensee and its own expense of such lights and signals..., and such fishways as may be prescribed by the Secretary of Commerce." The authority of FERC has been confirmed by the U.S. Supreme Court, e.g., see Udall vs. FPC, 387 U.S. 428 (1966).

The Virginia Electric and Power Company (VEPCO) was issued a preliminary permit by FERC in 1981 for the rehabilitation of the Twelfth Street Hydroplant including the Brown's Island Dam. In 1982, VEPCO obtained a similar permit for the Manchester Hydroplant. If these facilities eventually become operational, FERC could require VEPCO to construct, operate, and maintain fish passage facilities at each site.

Federal funding for fish passage facilities is available under the Federal Aid and Sport Fish Restoration Act (1950) and the Anadromous Fish Conservation Act (1965). Under the former act, Federal reimbursement is 75% of the cost, while under the latter, reimbursement is generally 50%. These funds may be used for the construction or renovation of fish passage facilities, and the operation and maintenance of the facilities. However, such funding cannot be obtained for projects subject to the FERC mandate; thus these funds could be sought for only the Williams Island Dam.

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LD6388154

Table 1.

HOUSE JOINT RESOLUTION NO. 233

Offered January 15, 1981

Requesting certain State and federal agencies to determine a need for and coordinate efforts in regard to the placement of fish ladders along the James River.

Patrons--Axselle and Thomas

Referred to the Committee on Conservation and Natural Resources

---

WHEREAS, the stocks of anadromous striped bass, American shad, hickory shad, alewife, blueback herring, and Atlantic sturgeon have seriously declined in the Chesapeake Bay and its tributaries; and

WHEREAS, the James River and its tributaries have sustained this loss of anadromous fishes; and

WHEREAS, anadromous fishes are prevented by low profile dams at Richmond, Virginia, from moving upstream to their historical spawning and rearing areas; and

WHEREAS, the placement of devices to overcome obstructions to upstream movement of anadromous fishes to historical spawning and rearing areas is permitted pursuant to § 29-151 of the Virginia Code; and

WHEREAS, a significant problem exists with the stocks of anadromous fish in Virginia waters; now, therefore, be it

RESOLVED by the House of Delegates, the Senate concurring, That the Commission of Game and Inland Fisheries is requested, in coordination with the Marine Resources Commission, the Virginia Institute of Marine Science, and local political subdivisions to determine such need, from both a technological and an economic point of view, as may exist for the construction and maintenance of devices to pass fish along the James River and subject to availability of adequate federal matching funds, to take such action as may be feasible and effective in providing access for anadromous fishes to their historical spawning and rearing sites; and, be it

RESOLVED FURTHER, That the efforts of the Commission of Game and Inland Fisheries and other State agencies be, to the extent practicable, assisted by the United States Fish and Wildlife Service and the National Marine Fisheries Service; and, be it

RESOLVED FINALLY, That the Clerk of the House of Delegates forward a copy of this resolution to the United States Fish and Wildlife Service and to the National Marine Fisheries Service so as to apprise them of the sense of this body.

Table 2. Historical catches of shad and striped bass in the James River in Nelson County recorded in the diaries of Col. William Cabell and Col. William Cabell, Jr.

Year	Norwood Island		Swift Island	
	Shad	Striped Bass	Shad	Striped Bass
1769		100+		
1770	1+			
1771	1+			
1774		1+		
1775	128			
1777	1+			
1778	1+			
1779	2222	24+		
1780	73	2		
1781	3219+			
1784	40			
1785	76			
1786	2563		3676	
1787	151	1	709	
1788			18	
1789	64		1039	
1790	1+			
1791	1+			
1792	1217		100	
1793	70			1
1795	1+			

Table 3. Anadromous fish passage recorded at the Holyoke Dam lift since 1955.

Year	American Shad	Blueback Herring	Atlantic Salmon	Striped Bass
1955	4,900	0	0	0
1956	7,700	0	0	0
1957	8,800	16	1	0
1958	5,700	29	1	0
1959	15,000	20	0	0
1960	15,000	796	2	0
1961	23,000	1,200	0	0
1962	21,000	19	0	0
1963	30,000	32	0	0
1964	35,000	13	0	0
1965	34,000	53	0	0
1966	16,000	54	0	0
1967	19,000	356	0	0
1968	25,000	a	0	0
1969	45,000	10,000b	0	0
1970	66,000	1,900	0	0
1971	53,000	302	0	0
1972	26,000	188	0	0
1973	25,000	302	0	0
1974	53,000	504	0	0
1975	110,000	1,600	1	0
1976	350,000	4,700	1	0
1977	200,000	33,000	2	0
1978	140,000	38,000	23	0
1979	260,000	40,000	19	103c
1980	380,000	198,000	118	139c
1981	380,000	420,000	319	510

a not counted
b estimated
c all immature

Source: Moffitt et al. (1982)

Table 4. Summary of American shad adults and cultured fingerlings released into the Pawcatuck River, RI, and subsequent returns to the Potter Hill fish ladder, 1976-1982.

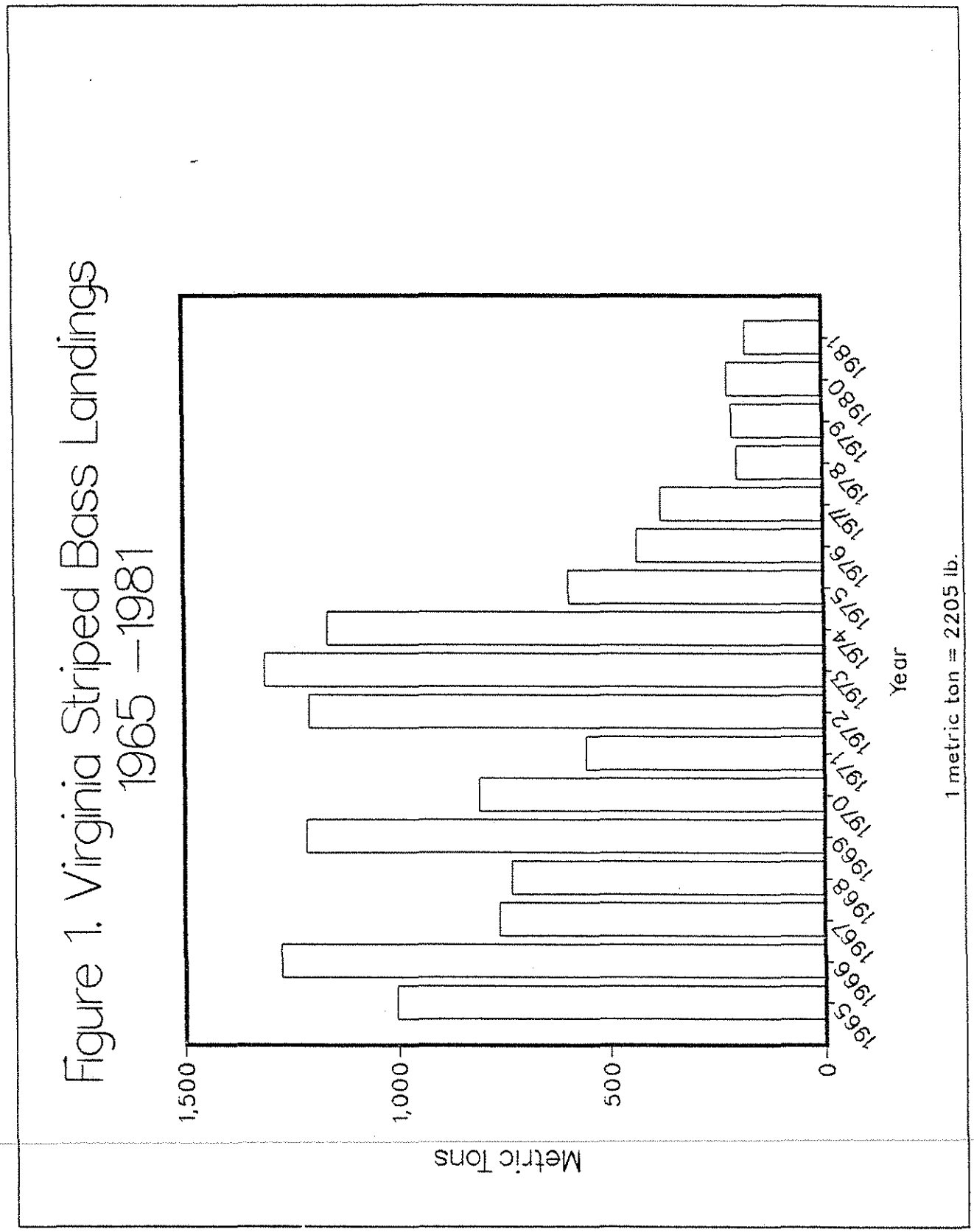
Year	Releases		Returns
	Fingerlings	Adults	
1976	40,000	2,500	
1977	75,000	2,000	
1978	94,000	2,100	
1979	97,000	3,500	5
1980	40,000	4,700	175
1981		2,500	900
1982		1,500	700

Source: John F. O'Brien, Rhode Island Division of Fish and Wildlife (personal communication).

Table 5. Summary of some anadromous fish projects in Rhode Island, 1968-1975.

Location	Date	Cost	Information (as of 1976)
Hamilton ladder	1968	$34,000	Alewife run now exceeding 300,000 established.
Peacedale ladder	1969	52,730	Alewife run established; 300,000 potential.
Wakefield ladder	1970	38,000	Same as Peacedale.
Bellville ladder	1971	41,000	Same as Hamilton.
Nonquit ladder	1972	26,710	Alewife run of 50,000 established, 200,000 potential.
Potter Hill ladder	1973	45,419	Alewife run of 300,000 established; 1,000,000 potential.
Forge Road ladder	1975	39,000	Alewife run of 40,000 established; 200,000 potential.

Source: John F. O'Brien, Rhode Island Division of Fish and Wildlife (personal communication).


Figure 1. Virginia Striped Bass Landings
1965 – 1981
Metric Tons
1,500
1,000
500
0
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
Year
1 metric ton = 2205 lb.

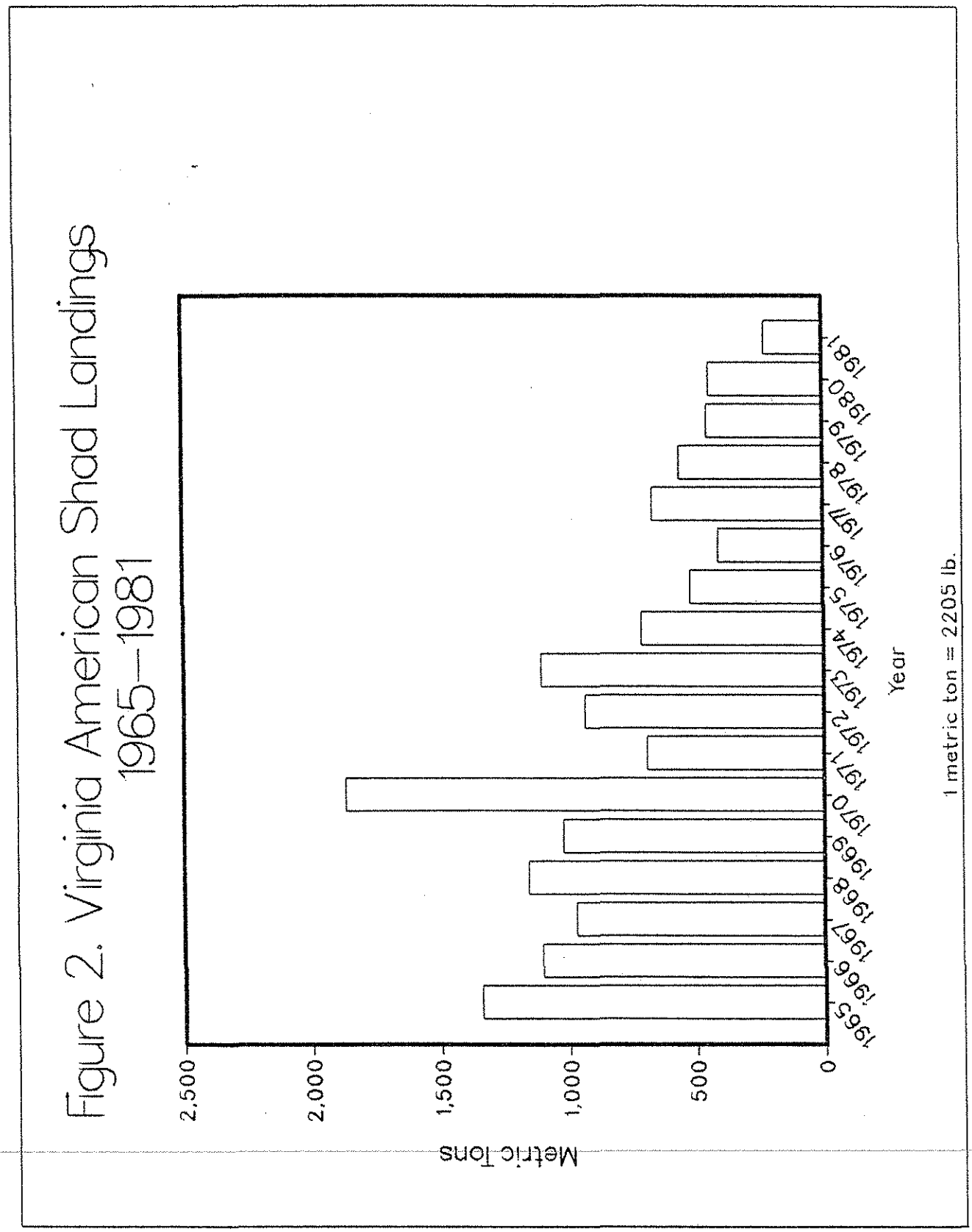
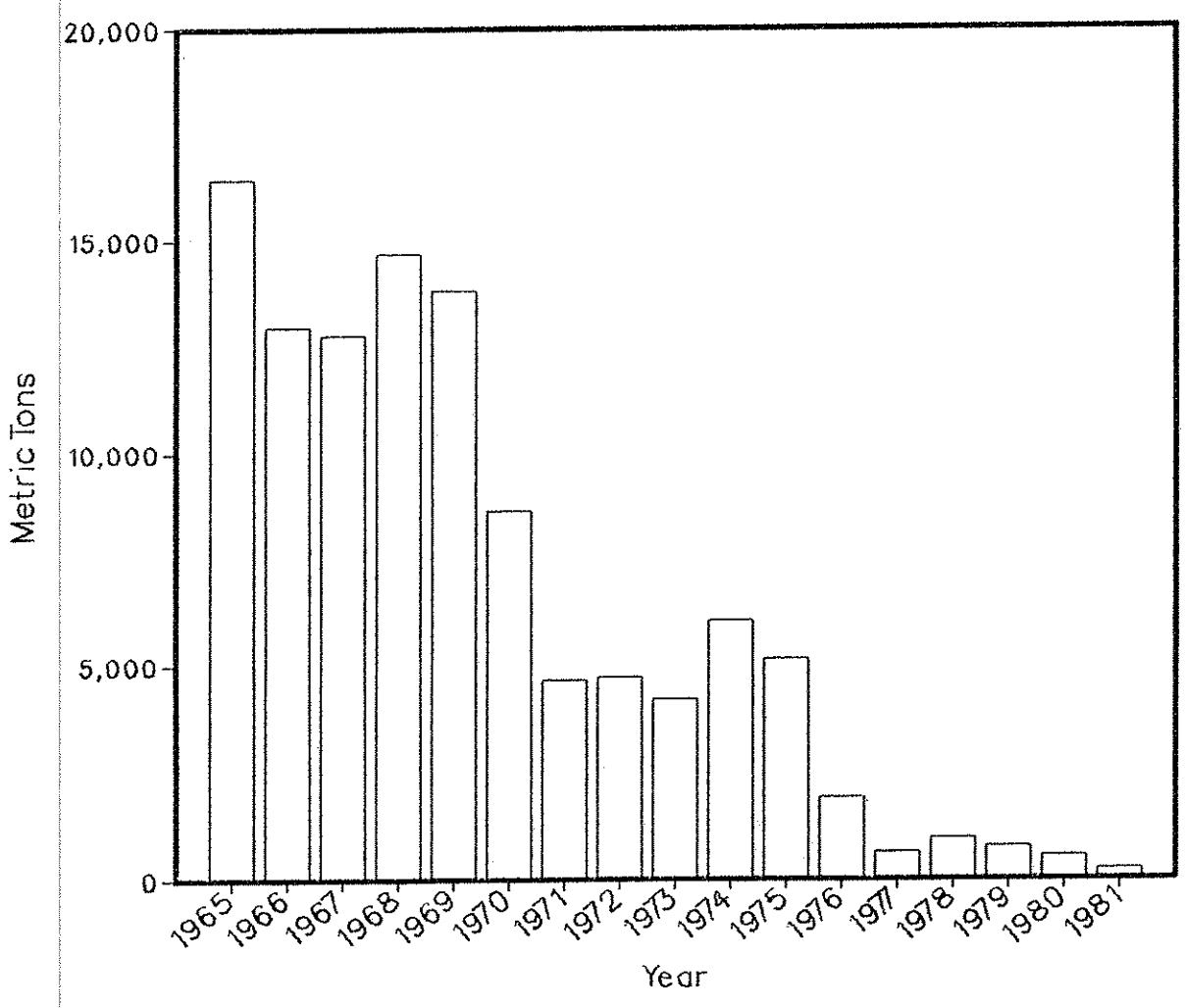

Figure 2. Virginia American Shad Landings
1965—1981
Metric Tons
2,500
2,000
1,500
1,000
500
0
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
Year
1 metric ton = 2205 lb.

Figure 3. Virginia River Herring Landings 1965–1981



1 metric ton = 2205 lb.

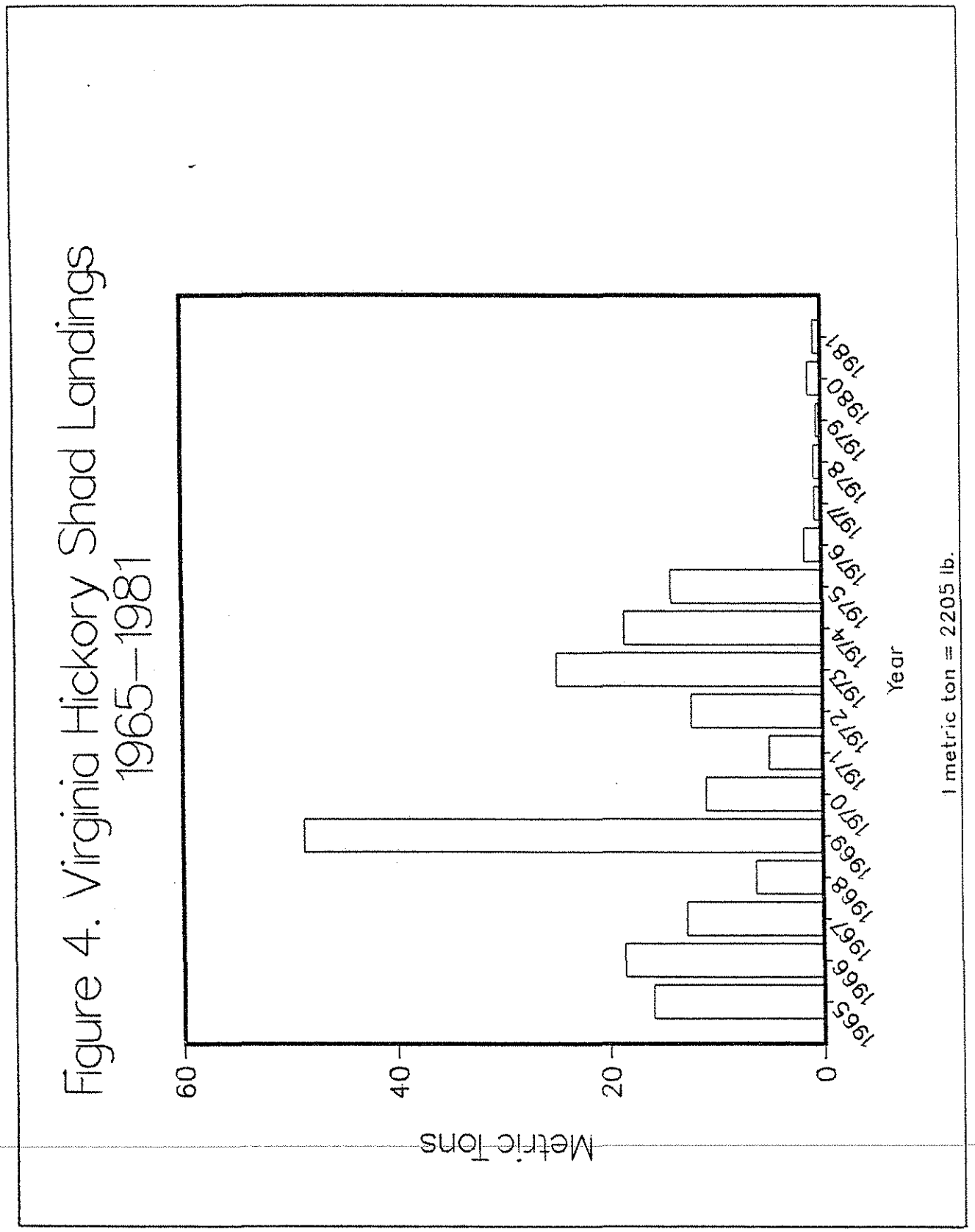
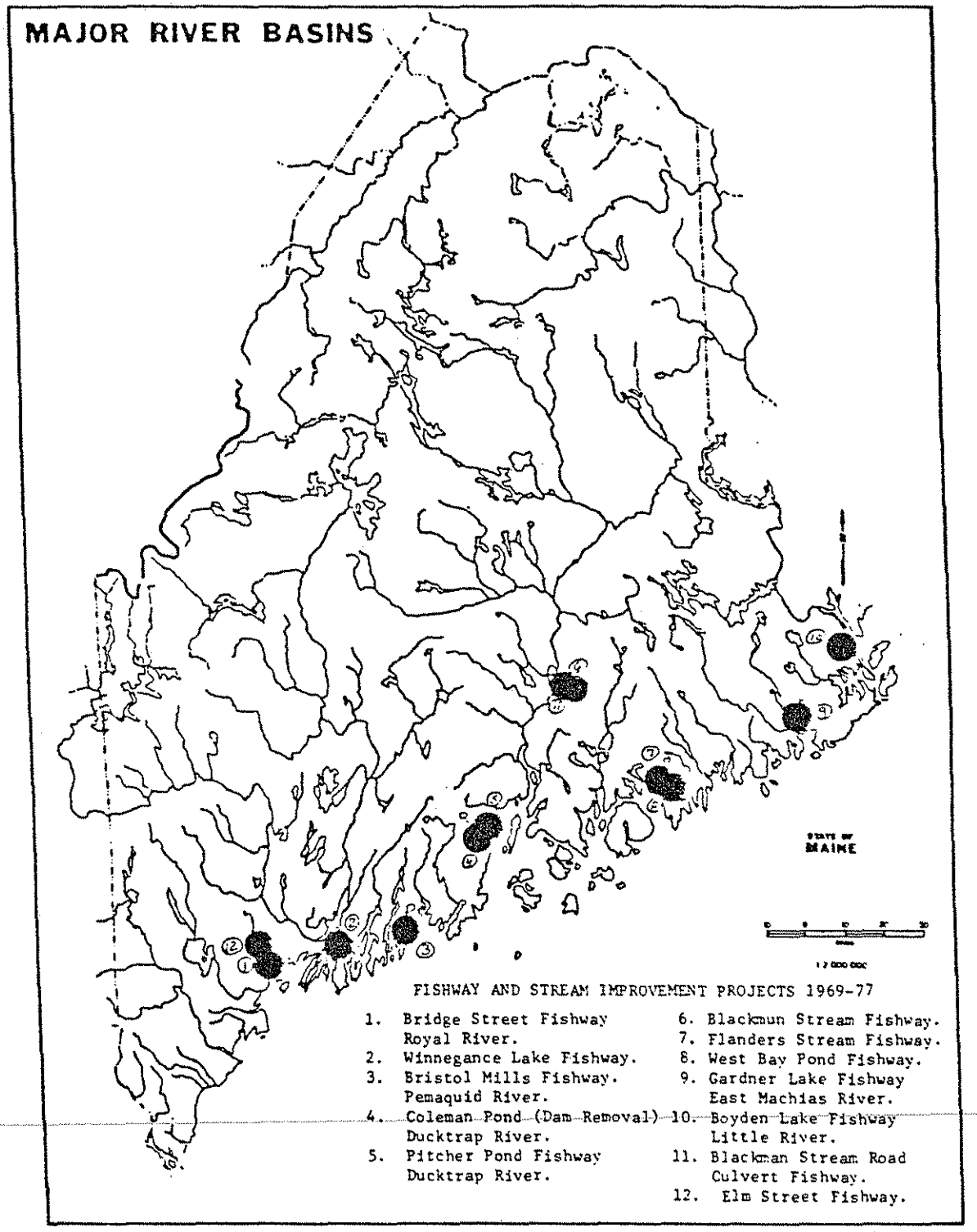

Figure 4. Virginia Hickory Shad Landings
1965–1981
Metric Tons
60
40
20
0
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
Year
1 metric ton = 2205 lb.

Figure 5. Fishway and stream improvement projects conducted by the Maine Department of Marine Resources.



APPENDIX

PRELIMINARY REPORT ON THE FEASIBILITY OF CONSTRUCTING FISH PASSAGE FACILITIES AT DAMS ON THE JAMES RIVER IN RICHMOND VIRGINIA

By

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U.S. FISH AND WILDLIFE SERVICE
NEWTON, MASSACHUSETTS

MARCH 1983

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1.0 INTRODUCTION

The purpose of this report is to investigate the feasibility of constructing fish passage facilities for various species of anadromous fish at five existing low head dams on the James River in Richmond, Virginia. The approximate cost and conceptual layout of facilities for both upstream and downstream migrants are presented.

Historically, the James was an important spawning river for several species of anadromous fish. American and Hickory shad, Alewives, Blueback herring and Striped bass all may have made spawning migrations up to and above Lynchburg, Virginia. A series of dams constructed in the Richmond area starting in 1804 has blocked the migration of these fish to upstream spawning and rearing habitat. Richmond is approximately 100 miles above the mouth of the James River.

Anadromous fish restoration programs have been underway for over a decade on other major East Coast rivers such as the Penobscot, Androscoggin, St. Croix, Connecticut and Merrimack in New England and the Susquehanna in Chesapeake Bay. As part of these programs, modern fish passage facilities have been constructed or are planned at many existing dams on each river.

A similar anadromous fish restoration program requiring the construction of adequate fish passage facilities at existing dams is planned for the James River above Richmond. The primary target species include American and Hickory shad, Alewife, Blueback herring and American eel. Atlantic sturgeon and Striped bass may also benefit from this program. All of these species presently exist in the river below Richmond.

2.0 JAMES RIVER

The James River is formed by the confluence of two tributaries, the Jackson and Cowpasture Rivers near Clifton Forge, Virginia. It flows in a southeasterly direction and after falling approximately 990 feet over a distance of 340 miles, it empties into Chesapeake Bay at Hampton Roads. The James River Basin has a drainage area of approximately 10,000 square miles, which is equivalent to 25% of the total area of Virginia. (See Plate 1).

Richmond is located at the fall line, approximately 100 miles above the mouth of the river. In the Richmond area the river bed is primarily exposed bedrock and boulders with a fairly steep gradient, here the river gradient drops over 100 feet to tidewater levels over a distance of eight miles. This reach has many small islands and varies in width from 500 to 2500 feet.

The U.S. Geological Survey and the Virginia State Water Control Board maintain stream flow data for the river via a series of gaging stations. The lowermost gaging station is in Richmond, approximately 1.7 miles downsteam from the Bosher Dam. This

station which has been in operation since 1934 has a drainage area of 6,758 square miles and an average discharge of approximately 7,500 cubic feet per second (cfs). Mean monthly discharge values for this station are shown on Table 1, mean daily discharges for the 1981 water year which was relatively dry are shown on Table 2. The minimum recorded daily flow of the James River below the City of Richmond's Hollywood Hydroplant was 370 cfs on September 13, 1966 and the maximum discharge was 313,000 cfs which occurred on June 23, 1972, as a result of floods from Hurricane Agnes.

3.0 DESCRIPTION OF DAMS AND HYDROPOWER OPERATIONS

The project site is an eight mile reach of the James River in Richmond. This reach includes five low head dams, the James River and Kanawha Canal, two operating hydroplants owned by the City, two abandoned hydroplants formerly operated by the Virginia Electric and Power Company (VEPCo) which plans to reactivate both, and the Richmond Water Works. (See Plate 2).

Following is a brief description of the five dams and related facilities in downstream order, commencing with the Bosher Dam:

3.1 BOSHER DAM

This dam is located approximatley two miles upstream from the Huguenot Memorial Bridge in Richmond. It is the highest of the five dams, having a normal head of approximately ten feet and a spillway length of 904 feet from bank to bank. The dam is a stone masonry gravity type spillway with a crest elevation of 113 feet (MSL). It was constructed prior to 1837 by the James River

and Kanawha Canal Company to divert water into the navigation canal and lock system traversing the falls in the river. It was later purchased by the C&O Railroad Company (the Chessie System) and a railroad line was laid in the old tow path of the canal. The City of Richmond subsequently acquired the water rights to the dam and canal system and bears the responsibility for the operation and maintenance of these facilities. Title to the dam and canal remain vested in the C&O Railroad.

The dam has been used since 1924 by the City of Richmond to divert up to 1,000 cfs into the James River and Kanawha Canal to their Byrd Park Hydroplant (FERC #3029) and Hollywood Hydroplant (FERC #3024), located approximately six and eight miles respectively downstream from the Bosher Dam. Both of these projects were issued Federal Energy Regulatory Commission (FERC) licenses in August 1982 for a period of 20 years. The James River and Kanawha Canal is listed on the National Register of Historic Places.

When the flow in the James River at Bosher Dam drops to approximately 1,000 cfs, the city has the option of diverting all or a portion of the flow to either the canal or the river.

3.2 WILLIAMS ISLAND DAM

This dam is located approximately three miles downstream from the Bosher Dam. The dam is owned by the City of Richmond and consists of two segments connecting to Williams Island. The northern segment was constructed in 1905 and is approximately 500 feet long x 7 feet high. The southern segment was constructed in 1932 and is

approximately 700 feet long x 4 feet high. The dam is used to divert from 33 to 62 cfs into the Richmond Water Works via a gated intake canal for treatment and ultimate distribution throughout the city. The intake canal is approximately 2000 feet long and is located adjacent to the north bank of the river.

3.3 HOLLYWOOD/BELLE ISLE DAM

The first dam was constructed at this site around 1830 to supply water for the city. Sometime prior to 1909 the present concrete dam was constructed to provide water to the Hollywood hydroplant. This dam consits of two segments connecting to Belle Isle and varies in height from 4 to 16 feet. The northern segment is approximately 2,400 feet in length and has a crest elevation of 55.0 feet (MSL). The segment south of Belle Isle is approximately 1,450 feet long and has a crest elevation approximately 2.5 feet higher than the northern segment. The southern segment of the dam was formerly used to divert water to a hydroplant on Belle Isle which has been abandoned for some time. The northern segment contains two breaches each approximately 40-60 feet in width, these breaches have existed for a few years.

Presently, approximately 1,600 cfs is diverted from the river at the dam to the city owned Hollywood Hydroplant via a gated intake canal (600 feet long x 50 feet wide) located adjacent to the north bank of the river.

3.4 BROWN'S ISLAND DAM

This abandoned dam is located immediately upstream from the Manchester Dam and approximately 3,000 feet downstream from the Hollywood Hydroplant. It was constructed in 1901 and is approximately 1,700 feet long and formerly had a crest height approximately nine feet above the riverbed. The dam formerly had a total of thirty gated openings and thirteen fixed crest openings spanning concrete piers. The gated openings previously had timber taintor gates, each approximately 36 feet long x 5 feet high.

The dam was used to divert up to 5,500 cfs to the now abandoned Twelfth Street Hydroplant and adjacent steam electric plant owned by VEPCo. The flow was diverted to these generating facilities via a gated intake canal 2,240 feet long x 12 feet deep x 48 feet average width. VEPCo ceased power generation at both stations in 1968.

Flood flows in the James River primarily from Hurricanes Camille in August, 1969 and Agnes in June, 1972, destroyed the timber taintor gates at the dam. The concrete piers and fixed crest portion of dam were not damaged. The dam, intake canal and generating stations are presently not used. In 1974 the City of Richmond obtained ownership to both this dam and the Manchester Dam immediately downstream.

In March, 1981 VEPCo was issued a preliminary permit by FERC (#3504) for the rehabilitation of the Twelfth Street Hydroplant including the Brown's Island Dam, intake canal and other appertenances that were formerly used for hydropower generation. VEPCo will

also investigate reducing the number of gated openings in the rehabilitated dam and replace these with fixed crest overflow sections. It is anticipated that VEPCo will file a license application for this project in the near future. The turbine flow capacity of the redeveloped Twelfth Street Hydroplant will be approximately 6,300 cfs.

3.5 MANCHESTER DAM

This dam is the lowermost dam on the James River and is immediately downstream from the Brown's Island Dam.

A wing dam was constructed at this site prior to 1804, to supply water for milling operations. The dam was later extended across the entire river. A hydroelectric station was constructed in about 1886 on the Manchester canal on the south side of the dam. This generating facility was upgraded in 1924 and then retired by VEPCo in 1965.

The present dam is a stone masonry structure approximately 2,300 feet long with a maximum height of six feet and runs diagonally across the river from the Manchester Canal on the south bank to the Brown's Island Dam on the north bank. The dam was deeded to its present owner the City of Richmond in 1974 together with the Brown's Island Dam. VEPCo retained ownership of the Manchester Hydroplant and the the 5,000 foot long intake canal.

In late 1982, VEPCo was issued a preliminary permit by FERC (#6480) for the rehabilitation of the Manchester Hydroplant. This project would be developed in conjunction with the Twelfth Street Project. The rehabiliated Manchester plant would have a single

turbine having a normal discharge capacity of 1,500 cfs and generate 1,300 KW. No modifications are proposed to the existing dam

4.0 PRIOR FISHWAYS AT JAMES RIVER DAMS

Non-functional pool type fishways were constructed at the three lower dams on the James River, namely the Manchester Dam, Brown's Island Dam and on the southern segment of the Hollywood/Belle Isle Dam. The fishways were constructed in the middle portion of each spillway. Apparently no fishways were constructed at the Williams Island or Bosher Dams. The fishways at the three lower dams were probably constructed in the early 1900's and are typical of the deficient fishway designs of that era. Similar fishways were constructed prior to 1950 at many dams on eastern coastal rivers, especially in New England. Very few of these early fishways were successful in passing anadromous fish, especially American shad. Many of these useless fishways have since been replaced by successful modern day fish passage facilities similar to those being proposed in this report for the James River dams.

The fishway at the Brown's Island Dam no longer exists and the other two fishways have been severely damaged by the past floods and age. They probably passed very few anadromous fish when they were operable due to the following design and location deficiencies:

1. Probably the worst location for a fishway is in the middle of an inaccessable spillway. Fishways in this location are subjected to the undesirable turbulent flow of spillway

discharges and clogging from the water borne debris, which cannot be removed due to inaccessability of the fishway.

2. Fish passage facilities should always be readily accessible for inspection, debris removal and maintenance — the best location is at the shore end of a spillway and/or powerhouse.

3. The fishway entrance is located too far downstream from spillway.

4. A weir type fishway with fixed crest weirs is a poor design at spillways with fluctuating headpond levels. High pond levels cause high velocity and excessive turbulence in the fishway pools

5. Insufficient attraction flow provided at the fishway entrance to compete with spillway flow.

6. The fishway entrance becomes submerged at high river flows making it difficult for fish to locate.

5.0 PRESENT FISH PASSAGE CONDITIONS AT DAMS

Since the removal of the gated sections of the Brown's Island Dam in 1969-72, some anadromous fish may have ascended the river to the Bosher Dam. Under high river flow conditions, some fish may be passing over submerged portions or small breaks in the four lower dams. We estimate this limited passage would probably have to occur at river flows greater than 10,000 cfs, since at flows less than this both the Manchester Dam and the south segment of the Williams Island Dam appear to be barriers to upstream fish migration. Presently, only two of the

five dams are partially negotiable by anadromous fish at practically all river flows. They are the Brown's Island Dam and the breached portions of the Belle Isle Dam.

The very limited upstream passage of anadromous fish discussed in this section has not been documented, nor is it sufficient to sustain any significant spawning or juvenile production above the Manchester Dam. Certainly, had additional breaches been provided at the Manchester Dam, Brown Island Dam and south segment of the Williams Island Dam, many more fish would have ascended upstream to the Bosher Dam and under a greater range of flow conditions. However, since the major spawning and rearing habitat for shad and river herring is above the Bosher Dam, the key is to provide passage over the Bosher Dam -- this requires the construction of new fish passage facilities.

6.0 INSTREAM FLOWS

Adequate instream flows must be maintained in the river channel during the migration period to insure suitable passage conditions for anadromous fish. This matter will become critical during relatively dry years like 1981, especially if VEPCo reactivates the Manchester and Twelfth Street hydroplants which have the capacity of diverting up to 7,800 cfs from the river. Some channel modifications may be required to concentrate low river flows. In addition, hydropower generation may have to be curtailed at these two plants during critical periods. Further studies will be required to ascertain appropriate minimum instream flow values. However, we anticipate a flow no less than 2,000 cfs may be required in the river channel for fish passage purposes.

7.0 TARGET SPECIES DESIGN POPULATION

The estimated design populations of target species to be passed above the Bosher Dam are designated below. Estimated periods of migration are shown on Table 3.

	Estimated Design Population
American shad	600,000
Hickory shad	200,000
Blueback herring & Alewife	3,000,000
American eel (elvers)	-
Striped bass	-
Atlantic Sturgeon	-

8.0 PROPOSED FISH PASSAGE FACILITIES

To provide passage for the designated target species past the five dams and associated intake canals and hydropower projects, both upstream and downstream passage facilities are proposed. The upstream passage facilities include fishways or fish locks at four of the five dams and possibly at the rehabiliated Twelfth Street hydroplant if VEPCo reactivates this facility. Some trapping and trucking of fish will also be undertaken during the early stages of the restoration program.

Downstream passage facilities will be required to provide safe downstream passage for post-spawned adult and juvenile anadromous fish past hydropower and water supply intakes in the project area. These facilities would consist of physical screening devices and bypass conduits to guide and pass downstream migrants around these potential sources of injury and mortality.

The location and preliminary design features of proposed fish passage facilities are shown on Plates 3-5 and Table 4. The type, size and location of those facilities ultimately selected for final design and construction will be determined by subsequent engineering and biological studies to be undertaken by the licensees in cooperation with the State and Federal fishery agencies.

8.1 UPSTREAM PASSAGE FACILITIES

A pool type fishway with vertical slot baffles (vertical slot fishway) would provide suitable upstream passage at the designated dams for resident fish and all but two of the target species listed in section 7.0. The author could not locate any documentation indicating the successful passage of spawning size adult Striped bass or Atlantic sturgeon through any conventional pool or chute type fishway. Some passage of immature Striped bass has been documented at some projects, however these fish were all generally under twenty inches in length.

In a vertical slot fishway, upstream migrants would swim of their own volition upstream through a series of pools separated by concrete baffles. Each baffle has a vertical slot opening (12-20 inches wide) extending the full height of the baffle through which upstream migrants would pass. The drop per fishway pool ranges from 6-12 inches. This type fishway is self-regulating under variable river flow conditions and does not require operating personnel other than for routine maintenance or for fish counting/trapping activities.

If it is necessary to pass spawning size Striped bass and Atlantic sturgeon above the Bosher Dam, the most effective fish passage facility for these two species would be a fish lock or fish elevator.

A fish lock would operate in a manner similar to a navigation lock. Fish would be attracted into the lock by flows discharging from its entrance at the base of the dam. After a period of time (approximately 10-30 minutes), the water in the lock would be raised to the pond level above the dam and the fish collected over that period would be crowded out of the lock by a crowding device, into the river above the dam, to continue their migration upstream. A fish lock would also pass the other target species plus resident fish.

A fish lock system is an electro-mechanical device which although it can be automated, typically requires operating personnel to be present during operating periods. The construction cost as well as operating and maintenance costs for fish locks would be higher than those for vertical slot fishways.

Spillway crest gates will be required adjacent to the proposed fishways or fish locks to create suitable flow patterns and to provide attraction water for upstream fish passage under the variable river flow conditions anticipated. These crest gates can also be utilized to provide downstream fish passage during low flow periods at unregulated spillways.

Some limited trapping and trucking of certain fish species to areas above the Bosher Dam may be undertaken to expedite the restoration program on the James River. Similar trapping and trucking operations (primarily American shad) have been undertaken on other east coast rivers. Initially fish could be trapped from the fish passage facility proposed at the Brown's Island/Manchester Dams and/or suitable sites on the river below these dams. The progeny from these trucked fish would be imprinted to sites above

the Bosher Dam and would as returning adults, have a strong desire to home to these upstream sites to spawn. We do not recommend that trapping and trucking of anadromous fish be considered as a long term solution to fish passage on the James River. The limited time available for migration, logistics and the anticipated mortality of trucking large numbers of fish preclude trapping and trucking as a viable fish passage alternative.

Following is a brief description of the upstream passage facilities proposed at each dam:

1. MANCHESTER DAM

Scheme A - If hydropower is not redeveloped at the Manchester Hydroplant, two breaches in the existing dam are proposed. Each breach should be at least 100 feet wide and be located near each end of the spillway.

Scheme B - If hydropower is redeveloped at the existing Manchester Hydroplant as proposed by VEPCo, a relocation of the north or upstream end of the Manchester Dam is proposed. The new terminus of the dam would be located at one of the existing concrete piers of the Brown's Island Dam, approximately three spillway bays south from the C and O Railroad Bridge. The existing Manchester Dam downstream from these three bays of the Brown's Island Dam would be removed (See Plate 4).

2. BROWN'S ISLAND DAM

Scheme A - If hydropower is not redeveloped at the Twelfth Street Hydroplant, two breaches are proposed between the existing concrete piers at each end of the dam. Each breach should be at least 100 feet wide and would consist of removing

the concrete sills between the existing piers. The piers would not be removed.

Scheme B - If hydropower is redeveloped at the Twelfth Street Hydroplant as proposed by VEPCo, the proposed fish passage facilities would include a fish lock or fishway constructed at the north side of the Brown Island Dam. This facility would be located in the spillway bay on the south side of the railroad bridge (See Plate 4).

Under this scheme a minimum spillway discharge of at least 2,000 cfs, or the flow designated by the Fishery Agencies would be released from the dam during the upstream migration period. This flow would be discharged from gated spillway bays adjacent to the fish passage facility.

Scheme C - An alternate to Scheme B is to construct the fish passage facility at the Brown's Island Dam as proposed in Scheme B plus a second fish lock or fish elevator at the Twelfth Street Hydroplant. The passage facility at the powerhouse would operate primarily during periods of lower river flows and would pass fish upstream via the intake canal. Under this scheme, less flow could be discharged from the dam during non spill periods. However, major problems associated with this scheme include the high flow velocity anticipated in the intake canal (approximately 10.5 fps at 6,000 cfs), possible modifications required at canal head gates to eliminate submerged gate openings and high construction costs.

3. HOLLYWOOD/BELLE ISLE DAM

A. Construct a breach approximately 50 feet wide at the apex (most upstream portion) of the dam on the north side of Belle Isle. Two breaches presently exist in this segment of the dam, one of these existing breaches can be repaired, if necessary.

B. Construct a fishway or fish lock on the shore side of the dam segment located south of Belle Isle (near the existing fishway). This passage facility would operate primarily during periods of spill from this higher segment of the dam.

4. WILLIAMS ISLAND DAM

Construct a fishway or fish lock at the shore side of each of the two dam segments on either side of Williams Island. Two passage facilities are proposed.

5. BOSHER DAM

Initially construct a fishway or fish lock at the north side of the dam. As the restoration program succeeds and the fish runs build to a pre-designated population, a second passage facility would be constructed on the opposite side of the dam, at a future date.

8.2 DOWNSTREAM PASSAGE FACILITIES

Downstream passage facilities are proposed to provide safe passage downstream for post spawned adult and juvenile anadromous fish past hydropower and water supply intakes. These facilities

would include fish screening devices, fish bypass conduits or sluiceways, trash booms and possibly some immersed pipe electrodes to create an electric field to repel fish. These facilities would operate only during the downstream migration period. Portable side scan sonar units can be utilized to determine the presence of downstream migrants at hydropower intakes.

Fish screening devices would consist of metal screen panels, vertical bar racks or louvers having a maximum clear spacing between vertical members of 1½-2 inches. Mesh screens (1" x 1" mesh) may also be required at certain locations especially during the fall migration of juvenile clupeids. Most of these screening devices would be angled (20 degrees - 40 degrees) with the current and would guide downstream migrants to a fish by-pass structure and discharge conduit located at the downstream end of the angled screening facility. Fish collected in the by-pass conduit would be sluiced to the tailrace level to continue their downstream migration. The operating flows for the by-pass structures would be approximately 20-30 cfs.

Electric barriers consisting of cable suspended pipe electrodes immersed in the water column may also be utilized in certain areas to repel fish from intakes by inducing a mild electric shock. However, these devices present safety hazards which may limit their use.

Following is a list of tentative locations where downstream passage facilities are recommended (See Plate 3). Further evaluation will be required to determine the best location and type of screening device.

1. JAMES RIVER AND KANAWHA CANAL

Flows ranging up to 1,000 cfs are diverted from the James River immediately above the Bosher Dam, into the James River and Kanawha Canal, primarily for hydropower generation at the Byrd Park and Hollywood hydroplants. To prevent downstream migrants from entering the canal a fish screening facility is proposed at the upstream end of the canal, located approximately 1,200 feet upstream from the Bosher Dam.

An alternate location for an angled screening facility in the canal, is in the vicinity of Williams Island where the canal is in close proximity to the river. A fish by-pass structure and conduit would also be required at this latter site to bypass fish back into the river.

2. RICHMOND WATER WORKS INTAKE CANAL

Flows ranging up to 90 cfs are diverted from the James River at the Williams Island Dam into a gated intake canal for purification and distribution by the Richmond Water Works, located downstream of the dam. Although this is not a major flow diversion, a fish screening device or pipe electrodes are recommended at the canal intake to prevent downstream migrants from entering the canal and water supply sedimentation ponds.

3. HOLLYWOOD HYDROPLANT INTAKE CANAL

Flows ranging up to 1,600 cfs are diverted from the James River at the Hollywood Plant, via a gated intake canal. An angled fish screening and by-pass facility is proposed in the intake canal upstream from or at the Hollywood Hydroplant. Downstream migrants would be bypassed into the river below the dam.

4. TWELFTH STREET HYDROPLANT INTAKE CANAL

If VEPCo redevelops hydropower at the Twelfth Street Plant as presently proposed, flows ranging up to 6,300 cfs will be diverted from the James River into a gated canal at the Brown's Island Dam for this purpose. The Twelfth Street Hydroplant is located at the downstream end of the canal on the north side of the river. An angled fish screening and by-pass device is proposed in the intake canal upstream from or at the Twelfth Street Plant. The spare turbine bays at the powerhouse can possibly be modified and utilized for downstream fish passage.

If hydropower is not redeveloped at this site, no downstream passage facilities are contemplated.

5. MANCHESTER HYDROPLANT INTAKE CANAL

If VEPCo redevelops hydropower at the Manchester Plant as proposed, flows ranging up to 1,500 cfs will be diverted from the James River into a gated canal located on the south side of the Manchester Dam for this purpose. An angled fish screening and by-pass device is proposed in the intake canal upstream from or at the Manchester powerhouse.

If hydropower is not developed at this site, no downstream passage facilities are contemplated.

9.0 CONSTRUCTION COST DATA

The estimated costs of constructing both upstream and downstream fish passage facilities at the five dams and associated water diversions are provided below. Please note that these are

preliminary estimates and include construction and engineering costs only. The estimates are based on 1983 price levels. More reliable cost estimates should be made when the preliminary design of the various facilities is undertaken.

9.1 UPSTREAM PASSAGE FACILITIES COST ESTIMATE

	Estimated 1983 Construction Cost
Manchester Dam	
Scheme A - Breach portion of dam	$ 40,000
Scheme B - Breach plus new terminus	160,000
Brown's Island Dam	
Scheme A - Breach portion of dam	60,000
Scheme B - Fishway at north bank	980,000
Fishlock " " "	1,020,000
Scheme C - Scheme B fishway plus fish lock at Twelfth Street Hydroplant	$ 2,280,000
Scheme B fishlock plus fish lock at Twelfth Street Hydroplant	2,320,000
Hollywood/Belle Isle Dam	
Breach at north segment of dam	60,000
Fishway at south segment of dam	550,000
Fishlock at south segment of dam	755,000
Williams Island Dam	
Fishway at north segment of dam	510,000
Fishlock at north segment of dam	725,000
Fishway at south segment of dam	343,000
Fishlock at south segment of dam	615,000

Bosher Dam

Fishway at north bank	595,000
Fishlock at north bank	880,000
Fishway at south bank	595,000
Fish lock at south bank	880,000

9.2 DOWNSTREAM PASSAGE FACILITIES COST ESTIMATE

	Estimated 1983 Construction Cost
James River and Kanawha Canal fish screening and bypass facility	$ 110,000
Richmond Water Works Intake Canal fish screening facility	50,000
Hollywood Hydroplant and Intake Canal fish screening and bypass facility	$ 175,000
Twelfth Street Hydroplant and Intake Canal fish screening and bypass facility	200,000 to 650,000
Manchester Hydroplant and Intake Canal fish screening and bypass facility	165,000

9.3 COST SUMMARY

The total construction cost (1983) of providing both upstream and downstream fish passage at the five dams and intake canals is summarized below:

A. Estimated total construction cost assuming hydropower is not re-developed at both the Manchester and Twelfth Street Hydroplants. Both the Manchester and Brown Island Dams would be breached and a single fish passage facility would be provided at the Bosher Dam.

$ 2.5 million with fishways

$ 3.5 million with fishlocks

B. Estimated total construction cost assuming hydropower is re-developed at both the Manchester and Twelfth Street Hydroplants and fish passage facilities are provided at all dams including two passage facilities at each end ofthe Bosher Dam.

$ 4.9 million with fishways

$ 6.2 million with fishlocks

C. Same conditions as item B above plus the construction of separate upstream passage facilities at the Twelfth Street Hydroplants.

$ 6.2 million with fishways

$ 7.5 million with fishlocks

TABLE 1

ESTIMATED MEAN MONTHLY FLOW OF JAMES RIVER AT RICHMOND, VIRGINIA

(Does not include flow in James River and Kanawha Canal)

(cubic feet per second)

(1934-1981)

MONTH	MINIMUM	MEDIAN	MAXIMUM
January	840	8,200	22,500
February	3,240	10,270	20,750
March	5,690	11,510	25,900
April	2,770	10,050	22,760
May	2,430	6,130	16,990
June	900	3,660	30,910
July	80	2,270	11,300
August	150	1,820	21,710
September	130	1,350	16,730
October	180	1,680	18,670
November	540	3,180	19,710
December	450	4,610	20,160

TABLE 2

JAMES RIVER BASIN

02037500 JAMES RIVER NEAR RICHMOND, VA

LOCATION.--Lat 37°33'47", long 77°32'50", Henrico County, Hydrologic Unit 02080205, on left bank 0.1 mi (0.2 km) upstream from Huguenot Memorial Bridge, 0.5 mi (0.8 km) west of city limits of Richmond, 1.7 mi (2.7 km) downstream from Bosher Dam, 3.3 mi (5.3 km) upstream from Powhite Creek, and at mile 116.60 (187.61 km).
DRAINAGE AREA.--6,758 mi^2 (17,503 km^2).
PERIOD OF RECORD.--October 1934 to current year. Gage-height records collected in vicinity of Mayo's Bridge, at mile 109.5 (176.2 km), 1876-1956, and at mile 108.7 (174.9 km) since 1957, are contained in reports of the National Weather Service.
REVISED RECORDS.--WSP 972: 1936(M). WSP 1433: 1951(M). WSP 2104: Drainage area.
GAGE.--Water-stage recorder. Control is Williams Island dams which divert flow for city of Richmond water supply. Datum of gage is 98.82 ft (30.120 m) National Geodetic Vertical Datum of 1929.
REMARKS.--Records good. City of Richmond takes from 40 ft^3/s (1.13 m^3/s) to 90 ft^3/s (2.55 m^3/s) for water supply from river below gage except during periods of low flow when supply is obtained from James River and Kanawha Canal. Flow regulated by powerplants above station. Above 18.2 ft (5.55 m) stage there is interchange of flow with James River and Kanawha Canal. Records of daily discharge include diversion by city of Richmond but do not include flow in James River and Kanawha Canal (station 02037000) which diverts around station. National Weather Service telemeter at station. Several observations of water temperature were made during the year. Water-quality records for some prior periods have been collected at this location.
COOPERATION.--Records computed and furnished by the Virginia State Water Control Board.
AVERAGE DISCHARGE.--47 years, 7,511 ft^3/s (212.7 m^3/s), 15.09 in/yr (383 mm/yr), includes flow in James River and Kanawha Canal.
EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 313,000 ft^3/s (8,860 m^3/s), includes canal flow, June 23, 1972, gage height, 28.62 ft (8.723 m); minimum daily, about 10 ft^3/s (0.28 m^3/s) Sept. 8-15, 1966, Sept. 30, Oct. 5, 6, 1968, Oct. 8-10, 1970; minimum daily discharge of James River and James River and Kanawha Canal combined, 370 ft^3/s (10.5 m^3/s) Sept. 13, 1966.
EXTREMES OUTSIDE PERIOD OF RECORD.--Probable minimum daily discharge, since 1899, of James River and James River and Kanawha Canal combined, about 350 ft^3/s (9.9 m^3/s) in October 1930.
EXTREMES FOR CURRENT YEAR.--Maximum discharge, 25,700 ft^3/s (728 m^3/s) May 30, gage height, 9.85 ft (3.002 m), no peak above base of 50,000 ft^3/s (1,400 m^3/s); minimum, 182 ft^3/s (5.15 m^3/s) Sept. 30, gage height, 3.13 ft (0.954 m).

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1290	1820	2480	1270	1070	4750	2500	3040	12500	490	1190	490
2	1290	1540	2260	1340	1140	4370	3500	2770	9430	615	940	490
3	1700	1680	2450	1450	1400	4000	3500	2740	8780	865	565	915
4	1860	1630	2820	1320	1590	3740	3370	2740	12500	2330	740	865
5	1560	1590	2140	1160	2120	3870	3370	2600	15800	4540	540	690
6	1660	1660	1320	1270	1860	4240	5150	2570	15000	6290	465	1520
7	1400	1680	1400	955	2330	4240	5020	2700	11600	6880	490	2850
8	1380	1800	1770	955	2000	3740	4620	2700	9000	6940	1260	6450
9	1380	1680	1980	1180	1910	3500	4240	2190	7880	5060	8090	5300
10	1320	1680	1660	865	1910	3500	4000	1800	7720	3990	4950	3990
11	1400	1610	1340	735	2020	3500	3740	1770	6590	3600	3130	3050
12	1380	1500	1520	715	3760	3370	3620	3370	5650	3600	2250	2090
13	1270	1180	1660	715	7070	3300	3500	3500	4720	3730	2510	1560
14	1220	865	1540	820	6760	2970	3370	3000	4430	2770	3080	1360
15	1110	1450	1400	1180	6600	2940	4000	2500	3960	2400	2480	1160
16	1110	1110	1450	1340	5290	2870	4120	2140	3730	2250	1690	1120
17	1160	955	1360	1430	4120	2550	3870	1980	3960	1790	1140	940
18	1270	1000	1380	1320	3870	2400	3500	2070	3960	1620	865	1340
19	1360	1220	1360	1000	3500	2430	3340	3220	2790	1440	715	1620
20	1380	1960	1160	1020	4370	2400	3240	5290	2250	1360	640	1440
21	1500	1800	1250	1290	8690	2310	3370	5290	1990	1220	490	1190
22	1320	1860	1110	1450	9170	2240	3740	4370	1660	790	390	990
23	1320	1930	1500	1380	7400	2190	4000	7730	1620	865	390	765
24	1380	1980	1360	1380	7400	2140	4120	7070	1660	965	290	790
25	1750	2310	1220	1400	6300	2160	4000	5860	1840	790	244	540
26	1890	2380	1140	1520	5290	2240	4000	4500	1440	940	212	440
27	1980	2820	955	1430	5430	2210	3740	3870	1090	1920	259	340
28	2140	2480	888	1820	5290	2120	3370	3500	890	1840	290	290
29	1860	2550	1220	1820	---	2090	3340	3300	890	1460	365	244
30	1700	2770	1450	1770	---	2070	3270	13400	765	1160	690	197
31	1910	---	1380	1380	---	2190	---	20300	---	1220	690	---
TOTAL	46250	52490	47923	38830	119660	92640	112520	133880	166095	75730	42040	45026
MEAN	1492	1750	1546	1254	4274	2988	3751	4319	5537	2443	1356	1501
MAX	2140	2820	2820	1820	9170	4750	5150	20300	15800	6940	8090	6450
MIN	1110	865	888	715	1070	2070	2500	1770	765	490	212	197
(*)	.60	315	422	423	396	448	503	660	818	758	649	681
MEAN*	1493	2065	1968	1677	4670	3436	4254	4979	6355	3201	2005	2182
CFSM*	.22	.31	.29	.25	.69	.51	.63	.74	.94	.47	.30	.32
IN*	.25	.35	.33	.29	.72	.59	.70	.85	1.05	.54	.35	.36

CAL YR 1980 TOTAL 2572853 MEAN 7030 MAX 59800 MIN 865 MEAN* 7092 CFSM* 1.05 IN* 14.25
WTR YR 1981 TOTAL 973134 MEAN 2666 MAX 20300 MIN 197 MEAN* 3172 CFSM* .47 IN* 6.38

* Diversion, in cubic feet per second, by James River and Kanawha Canal.
* Adjusted for diversion.

TABLE 3

ESTIMATED PERIODS OF FISH MIGRATION

JAMES RIVER DAMS, RICHMOND, VIRGINIA

Species	Migration	Period
American shad	Adults Upstream	March - May
	Adults Downstream	April - May
	Juveniles	June - September
Hickory shad	Adults Upstream	March - May
	Adults Downstream	April - May
	Juveniles Downstream	June - September
Blueback herring	Adults Upstream	April - May
	Adults Downstream	May - June
	Juveniles Downstream	June - October
Alewife	Adults Upstream	March - April
	Adults Downstream	April - May
	Juveniles Downstream	June - September
Striped bass	Adults Upstream	March - May
	Adults Downstream	April - June
	Juveniles Downstream	October - January
Atlantic sturgeon	Adults Upstream	April - May
	Adults Downstream	May - July
	Juveniles Downstream	September - October

TABLE 4

PROPOSED UPSTREAM PASSAGE FACILITIES DESIGN DATA

Dam	Proposed Upstream Passage Facility	Number Req'd	Location	Size
Bosher	Vertical Slot fishway	2	At each end of spillway	10'Wx12'L Pools
	Fish Lock	2		10'Wx80'L
Williams Island	Vertical Slot Fishway	2	At shore end of each spillway	10'Wx12'L Pools
	Fish Lock	2		10'Wx80'L
Hollywood/ Belle Isle	Breach	1	At apex of north spillway	50' Wide
	Vertical Slot Fishway	1	At south end of south spillway	10'Wx12'L Pools
	Fish Lock	1		10'Wx80'L
Brown Island	Vertical Slot Fishway	1	At north end of spillway	16'Wx12'L Pools
	Fish Lock	1		16'Wx80'L
	Fish Elevator or Lock	1	At Twelfth Street Hydroplant	10'Wx180'L
Manchester	Breaches proposed	Scheme A	At both ends of dam	100'W
	" "	Scheme B	At north end of dam	100'W

TABLE 5

HYDROPLANT DESIGN DATA

Byrd Park Hydroplant

Owner	City of Richmond
Number of units	2
Rated head	20 feet
Turbine flow (2 units)	966 cfs
Turbine speed	200 rpm
Turbine type	Vertical Francis
Generating capacity (2 units)	1,125 KW
FERC License	#3029
Expiration Date	2002

Hollywood Hydroplant

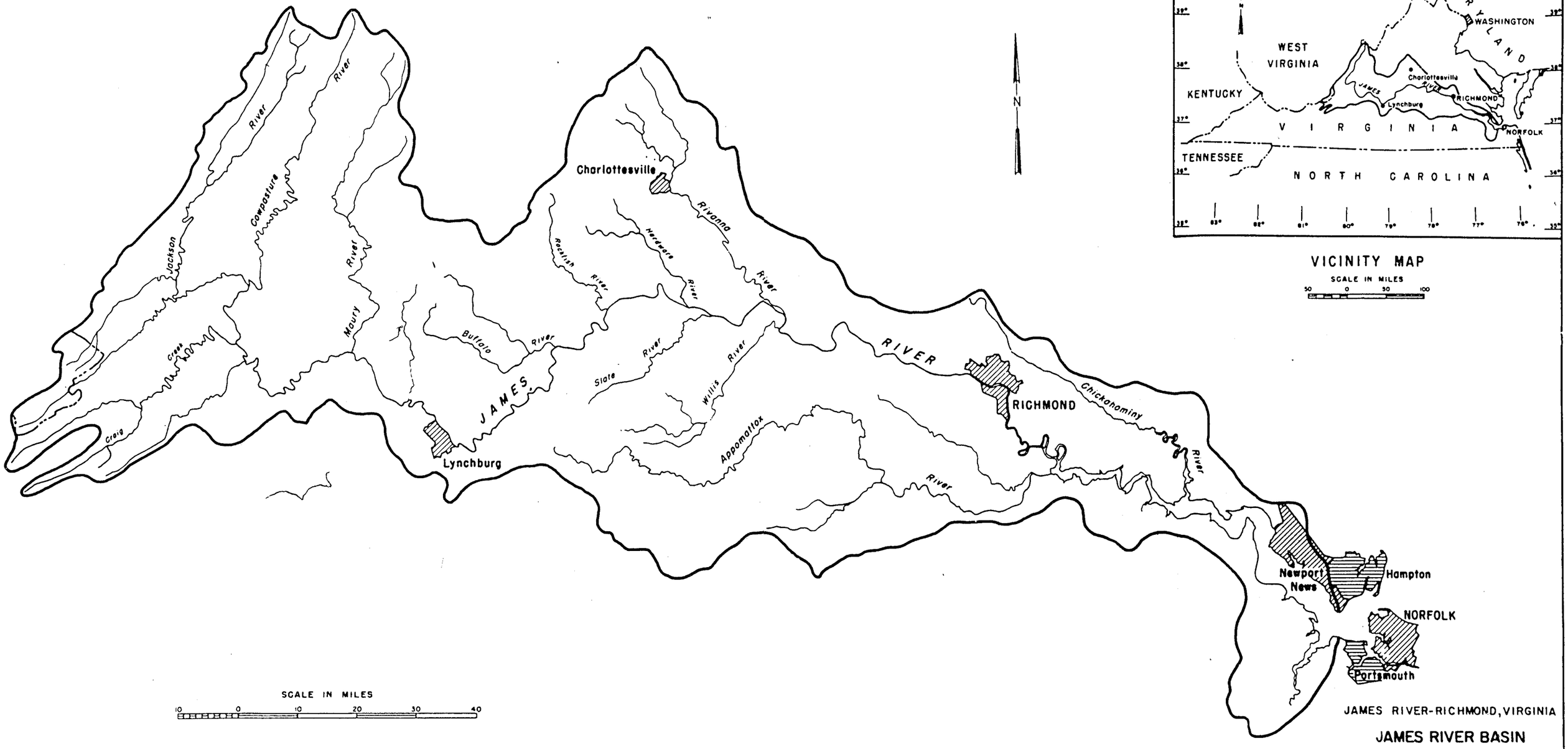
Owner	City of Richmond
Number of units	6
Rated head - Units #1-4	19 feet
#5	17 feet
#6	45 feet
Turbine flow (6 units)	1,680 cfs
Turbine speed Units #1-4	150 rpm
#5	200 rpm
#6	720 rpm
Turbine type Units #1-4	Horizontal Francis
Units #5&6	Vertical Francis
Generating capacity (6 units)	2,025 KW
(Future Unit)	
Generating capacity (1 unit)	3,100 KW
Rated head	45 feet
Turbine flow	1,000 cfs
FERC License	#3024
Expiration date	2002

12th Street Hydroplant

Owner	Virginia Electric and Power Co.
Number of units	-
Rated head	24 feet
Turbine flow (all units)	6,300 cfs
Turbine speed	-
Turbine type	-
Generating capacity	-
FERC License	#3504 (Pending)

Manchester Dam

Owner	Virginia Electric and Power Co.
Number of units	1
Rated head	20 feet
Turbine flow	1,500 cfs
Turbine speed	-
Turbine type	-
Generating capacity	1,300 KW
FERC License	#6480 (Pending)



VICINITY MAP

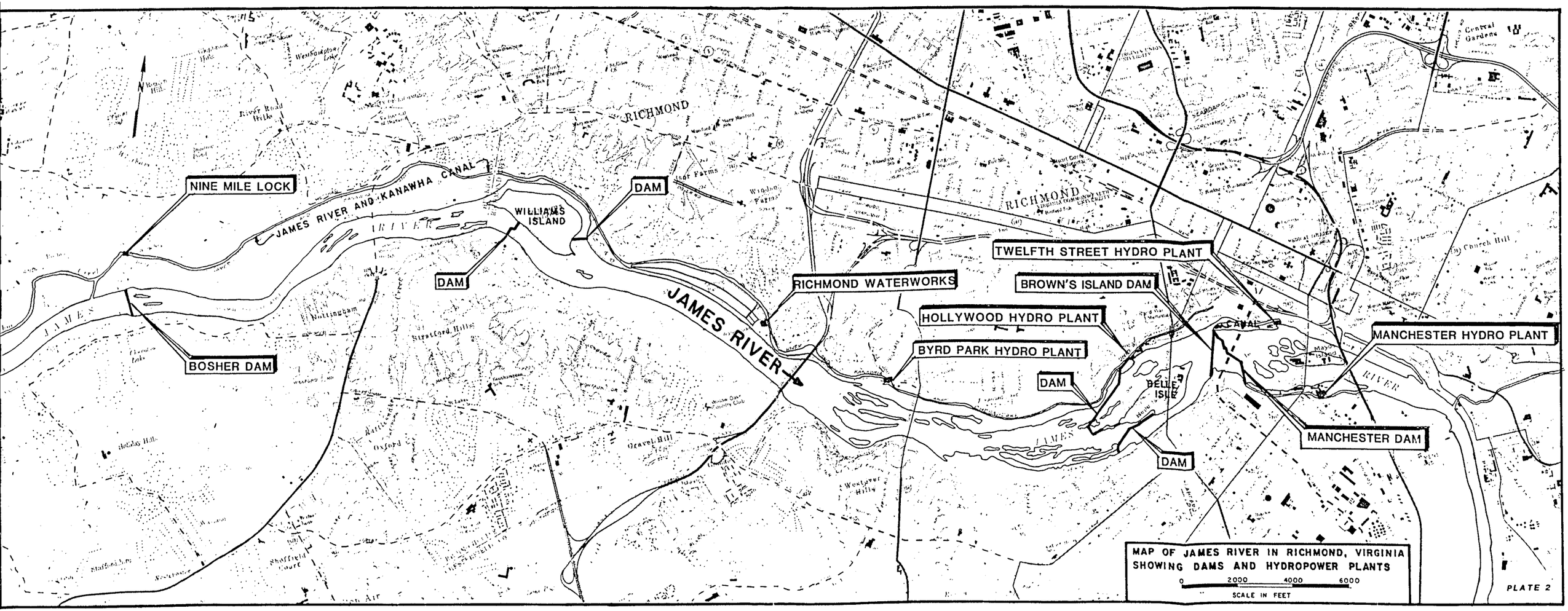
SCALE IN MILES

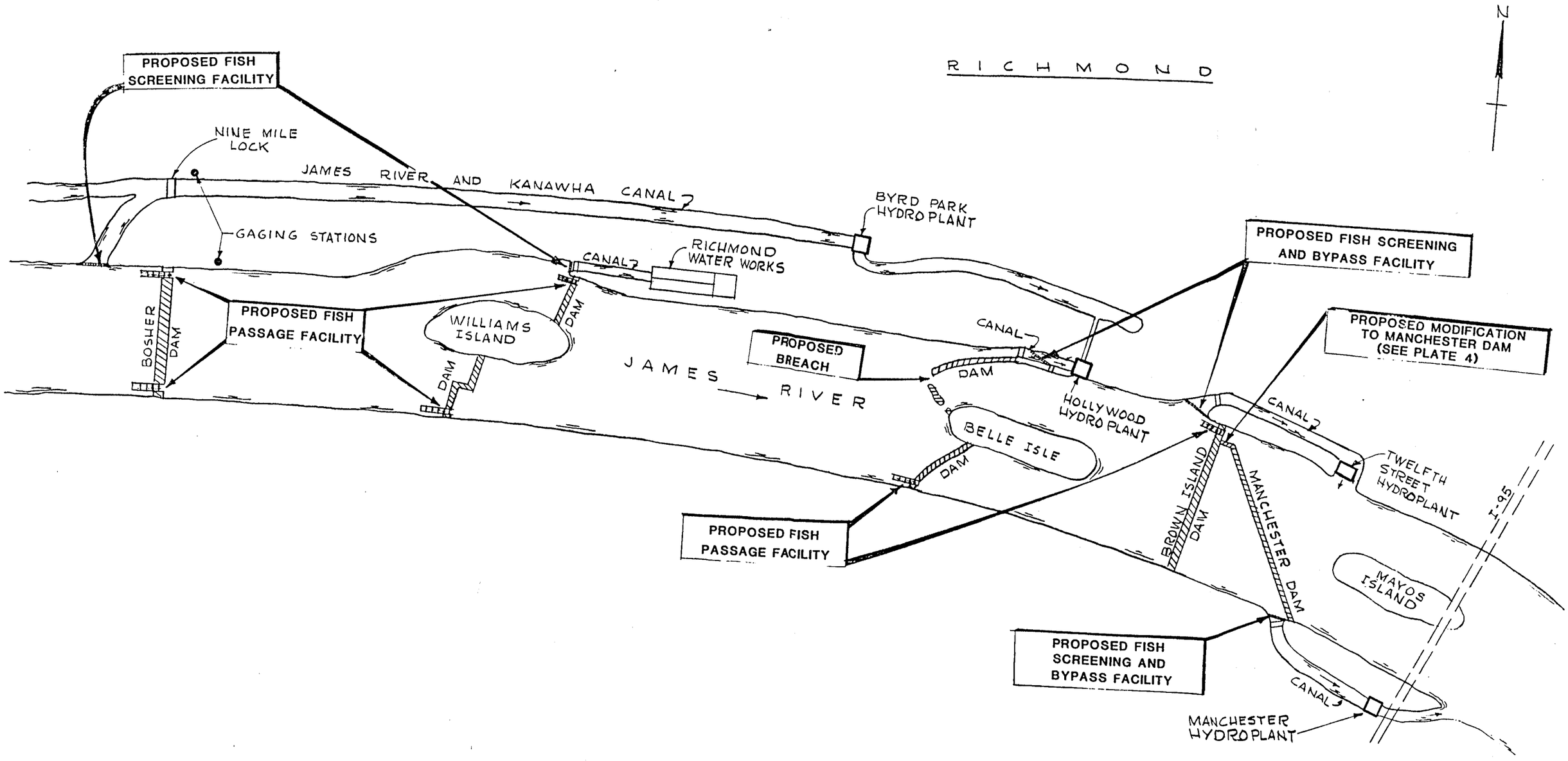
50 0 50 100

JAMES RIVER-RICHMOND, VIRGINIA

JAMES RIVER BASIN

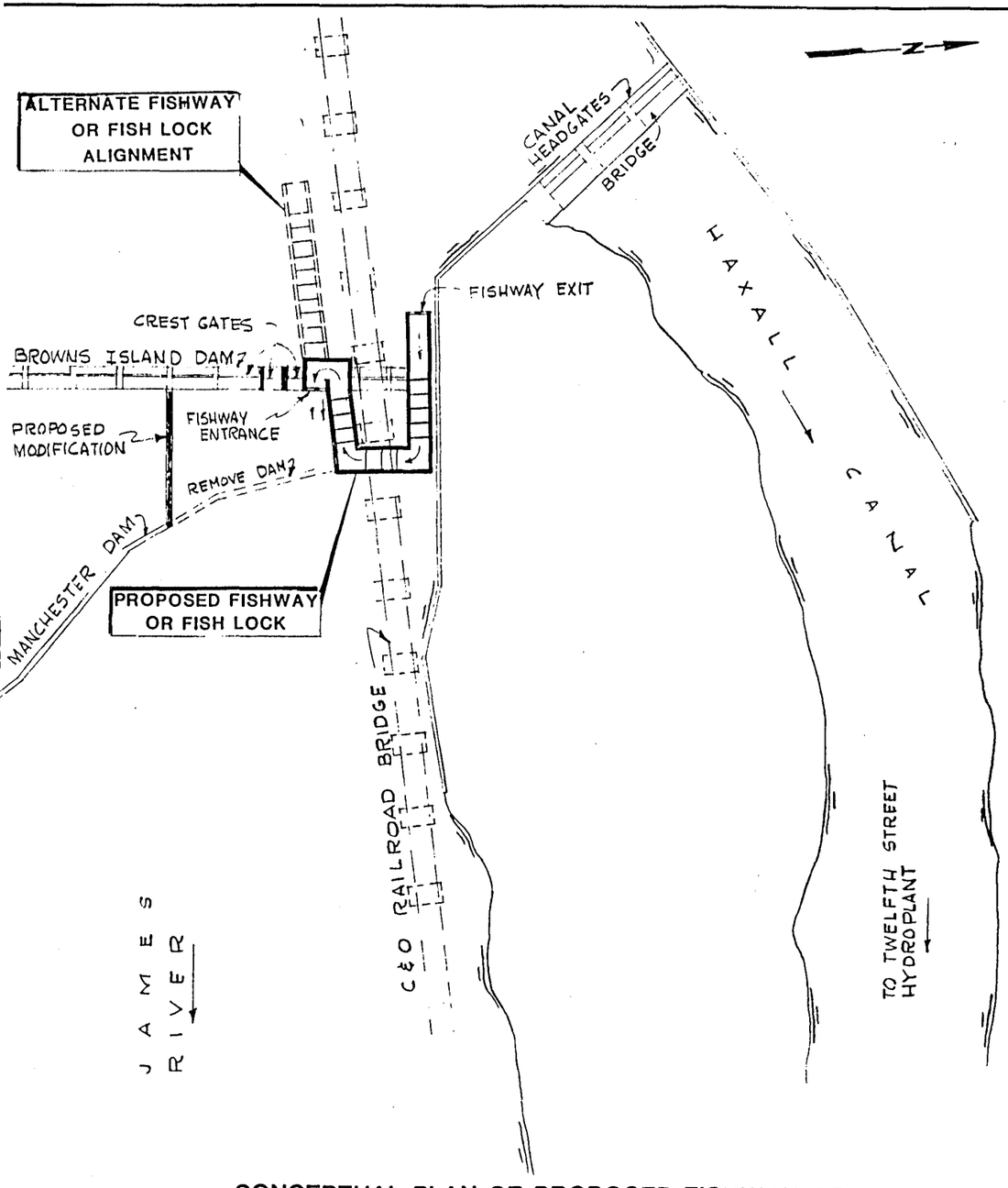
PLATE 1


NINE MILE LOCK
JAMES RIVER AND KANAWHA CANAL
DAM
WILLIAMS ISLAND
DAM
BOSHER DAM
RICHMOND
RICHMOND WATERWORKS
JAMES RIVER
TWELFTH STREET HYDRO PLANT
BROWN'S ISLAND DAM
HOLLYWOOD HYDRO PLANT
BYRD PARK HYDRO PLANT
DAM
BELLE ISLE
DAM
CANAL
MANCHESTER HYDRO PLANT
MANCHESTER DAM
RIVER
MAP OF JAMES RIVER IN RICHMOND, VIRGINIA
SHOWING DAMS AND HYDROPOWER PLANTS
0 2000 4000 6000
SCALE IN FEET
PLATE 2



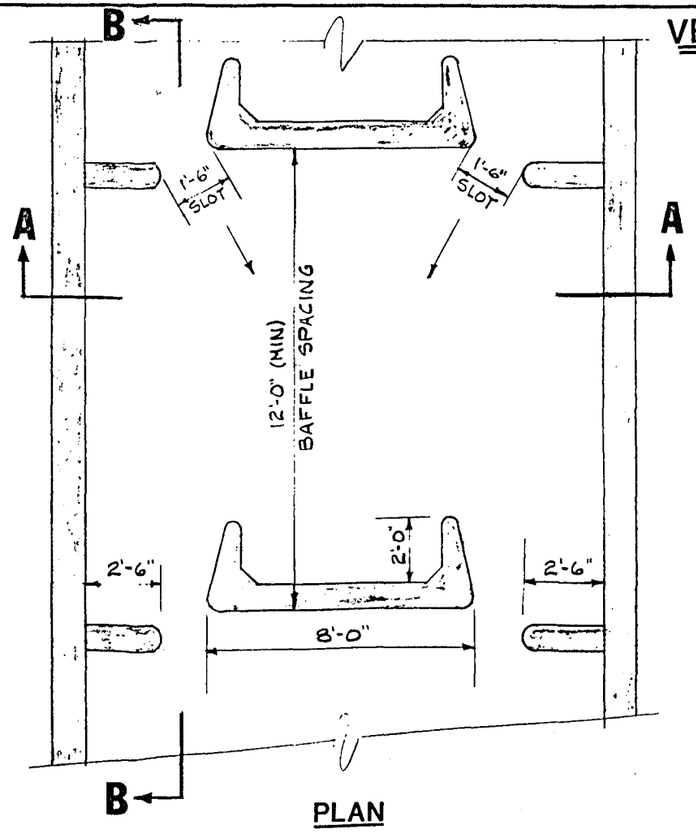
CONCEPTUAL PLAN OF JAMES RIVER DAMS
SHOWING LOCATION OF PROPOSED
FISH PASSAGE AND SCREENING FACILITIES

PLATE 3



CONCEPTUAL PLAN OF PROPOSED FISHWAY AT BROWN'S ISLAND DAM -SCHEME B

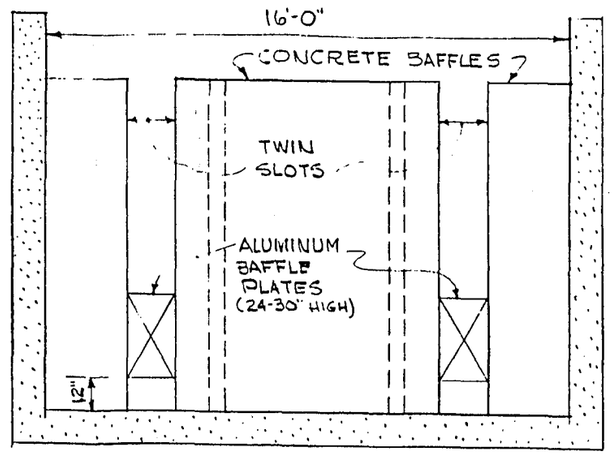
SCALE: 1"=50' (APPROX.)



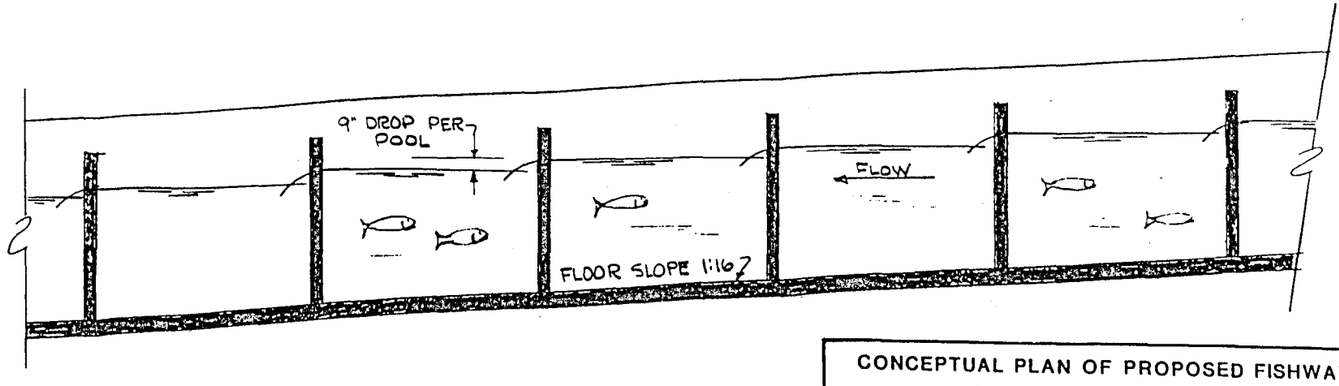
PLAN

SCALE: 1/4"=1'-0"

VERTICAL SLOT FISHWAY POOL DETAILS AT BROWN'S ISLAND DAM



SECTION AA



SECTION BB FISHWAY PROFILE

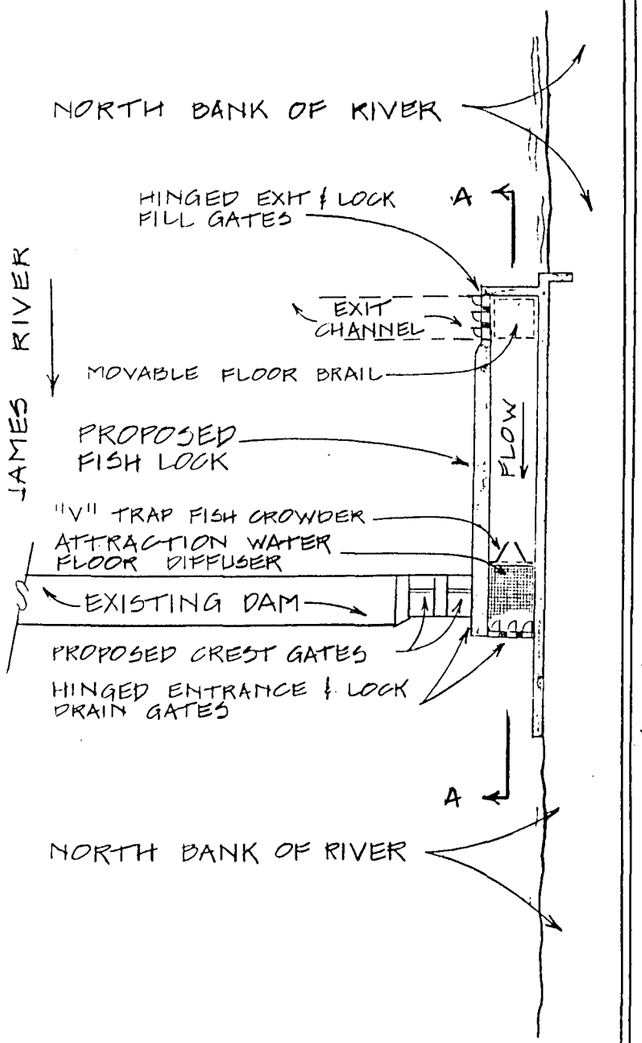
N.T.S.

CONCEPTUAL PLAN OF PROPOSED FISHWAY

AT BROWNS ISLAND DAM

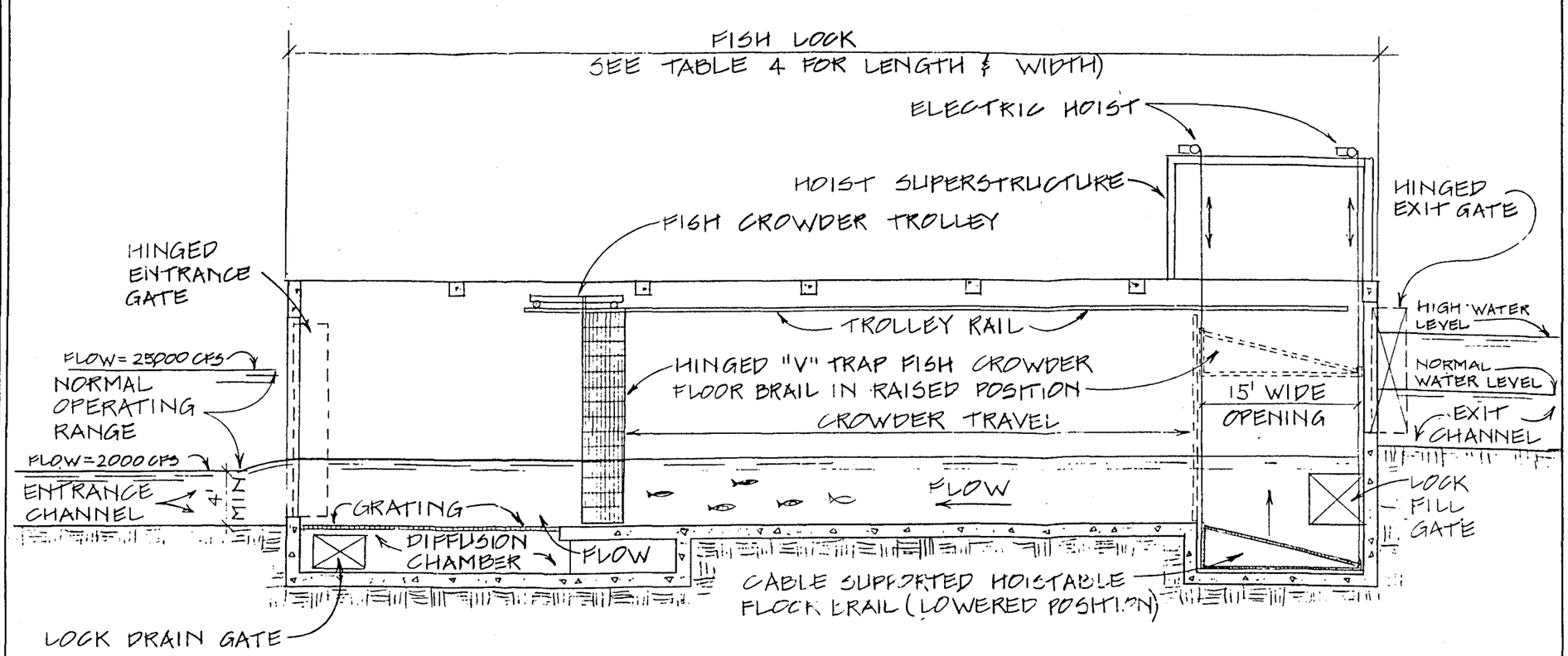
JAMES RIVER RICHMOND, VIRGINIA

PLATE 4



TYPICAL LAYOUT OF FISH LOCK

N.T.S.



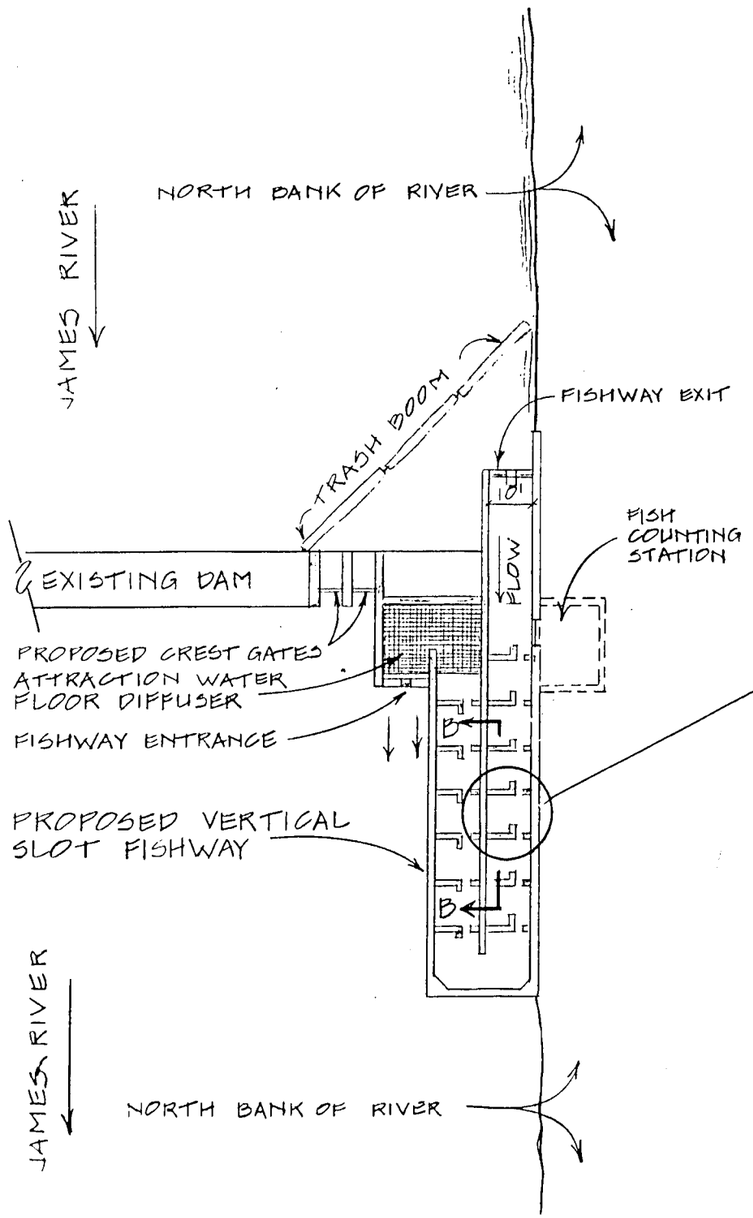
SECTION AA

SCHEMATIC SECTION THROUGH FISH LOCK

NO SCALE

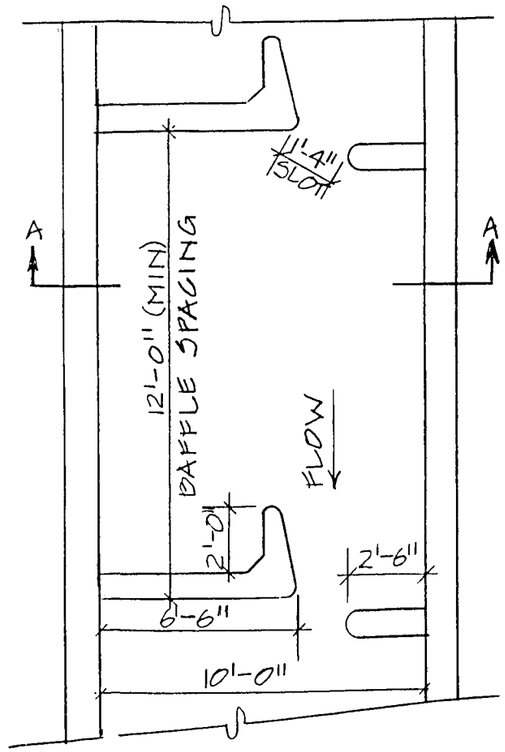
CONCEPTUAL PLAN OF PROPOSED
FISH LOCK SYSTEM
AT JAMES RIVER DAMS
RICHMOND, VIRGINIA

PLATE 5



TYPICAL LAYOUT OF VERTICAL SLOT FISHWAY AT BOSHEF, WILLIAMS ISLAND & HOLLYWOOD DAMS

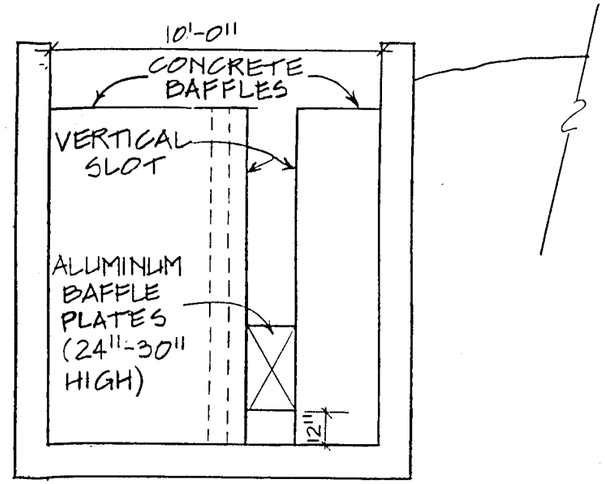
N.T.S.



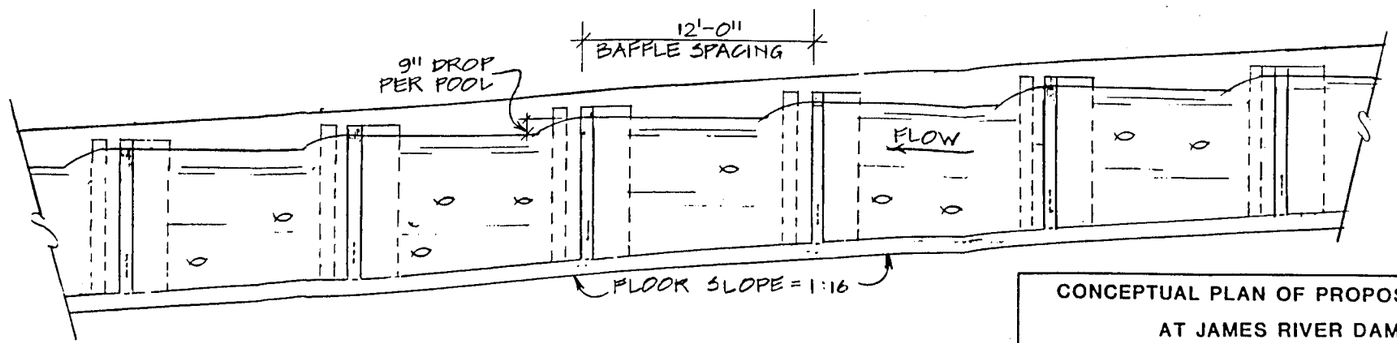
PLAN

SCALE: 1/4"=1'-0"

VERTICAL SLOT FISHWAY DETAILS AT BOSHER, WILLIAMS ISLAND AND HOLLYWOOD DAMS



SECTION A-A



SECTION B-B FISHWAY PROFILE

N.T.S.

CONCEPTUAL PLAN OF PROPOSED FISHWAYS
AT JAMES RIVER DAMS
RICHMOND, VIRGINIA

PLATE 6