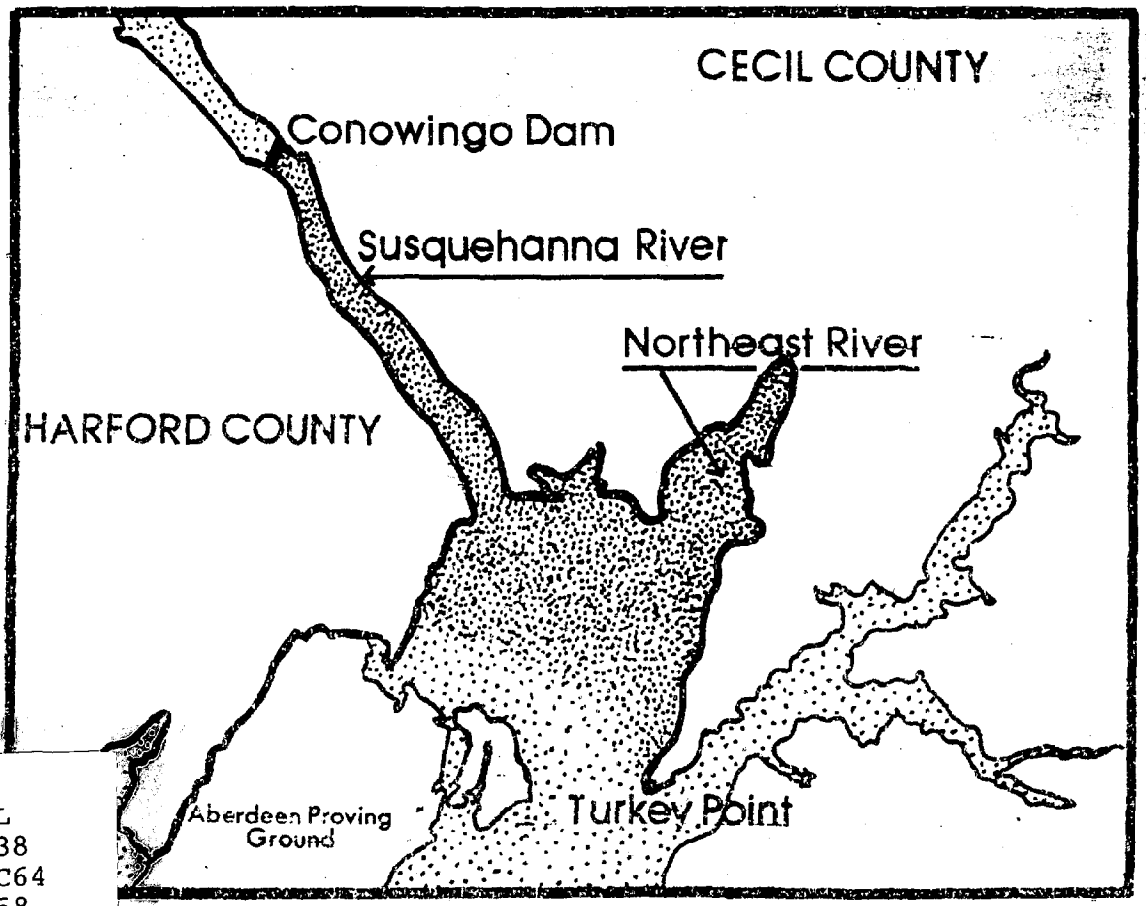
INVESTIGATION OF AMERICAN SHAD IN THE UPPER CHESAPEAKE BAY 1980

COASTAL ZONE
INFORMATION CENTER

DALE R. WEINRICH MARY ELLEN DORE W. R. CARTER III



QL
638
.C64
I58
1984

Tidewater Administration
MARYLAND DEPARTMENT OF NATURAL RESOURCES
SEPTEMBER 1981

Appendix IV

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

UNITED STATES

DEPARTMENT OF INTERIOR

FISH AND WILDLIFE SERVICE

FEDERAL AID REPORT

State: MARYLAND

Project No.: F-37-R

Project Title: Investigation of American shad in the Upper Chesapeake Bay

Status: Annual Report

Period Covered: January 1, 1980 to December 31, 1980

Prepared By: Dale R. Weinrich, Project Leader

Mary Ellen Dore, Staff Biologist

W. R. Carter, III, Program Leader

Date: Sept.2, 1981

Approved By: _____

Date: 9/2/81

William P. Jensen, Director
Tidal Fisheries Division,
Maryland Tidewater Administration

_____

Date: 9/2/81

Howard J. King, Federal Aid Coordinator
Tidal Fisheries Division,
Maryland Tidewater Administration

Property of CSC Library

U.S. DEPARTMENT OF COMMERCE NOAA
COASTAL SERVICES CENTER
2234 SOUTH HOBSON AVENUE
CHARLESTON, SC 29405-2413

QL638.C64 I58 1984
6758856
JAN 15 1997

ABSTRACT

During 1980, adult American shad (Alosa sapidissima) were collected at the head-of-the-Chesapeake Bay with various commercial fishing gears. Of the 399 fish observed, 147 were successfully tagged and released. Based on 13 recaptures, a population estimate of 2,675 American shad (UL=4,740, LL=1,607 @ 95% CL) was made utilizing Chapman's modification of the Petersen formula. Analysis of length, weight, sex ratios, age, and spawning history indicated that the 1979 and 1980 head-of-the-Bay shad runs were similar and could be characterized as a population supported by two remnant age classes with approximately 11% repeat spawners. Major differences were noted with other east coast shad stocks particularly the stable and increasing runs on the Delaware and Connecticut Rivers. Only one American shad was reported captured during the 1980 Susquehanna River sport fishing survey. 1980 sport catches for other clupeid species were also well below previous reported levels. White perch, channel catfish, and striped bass made up 81% of the estimated sport angling harvest in 1980. No young-of-the-year American shad were captured by haul seine or otter trawl from 10 upper Chesapeake Bay sampling stations in 1980. Severe declines in numbers and standing crop for all Alosa species from the late 1960's through 1980 in the Susquehanna estuary was noted. An American shad literature review was initiated to broaden Maryland's biological and management data base. Comparison of this state's present situation with the successful management practices of other areas was undertaken in hopes of restoring the severely depleted shad stocks to levels allowing for the perpetuation of the species and eventual consumptive use of the resource.

ACKNOWLEDGEMENTS

We would like to acknowledge the assistance of Bill Hogans and Tim Sughrue who provided tireless field help under arduous conditions. Thanks are due those people who also helped as creel clerks; John Foster, Mike Burch, Howard King, Rudy Lukacovic, John Williams, and Bob Lunsford. We extend our gratitude to Captains Frank and Henry Pratt, Howard Sexton, and Alvin Price and their respective crews in helping us obtain adult American shad for tagging. Special thanks are due Nick Carter, Harley Speir, and Steve Early for their field help and acute editorial assistance. We also thank Rose Safford for typing the manuscript.

TABLE OF CONTENTS

	Page
Introduction	1
Job I. Tagging And Population Estimation	2
Job II. Population Characterization	16
Job III. Creel Census	37
Job IV. Juvenile Recruitment Survey	50
Job V. Literature Review And Survey.	112
Conclusions And Recommendations	119
Literature Cited	123

LIST OF TABLES

1.	Capture-recapture dates, locations, and gear types for thirteen recaptures of tagged American shad during 1980.	11
2.	Comparison of total catch, number tagged, number lost, and % net mortality by location and gear type for American shad captured in the Susquehanna River, Susquehanna Flats, and Northeast River during 1980.	12
3.	Population estimate of adult American shad utilizing the Susquehanna River, Susquehanna Flats, and Northeast River for 1980.	13
4.	Age composition of Susquehanna River American shad collected by the Conowingo Dam Fish Lift and by sport anglers from 1972 through 1979.	24
5.	Mean fork length (mm), mean weight (kg), and length and weight ranges by sex and age class for American shad collected from the Susquehanna drainage during 1979 and 1980 by various gear types.	26
6.	Age frequency, number, and percent repeat spawners by sex for American shad collected from the Susquehanna drainage during 1979 and 1980 by various gear types.	28

		Page
7.	Age frequency, number, and percent repeat spawners by sex for American shad collected from selected east coast rivers during 1978 and 1979 by various gear types.	30
8.	Mean fork length (cm) and length ranges by sex and age classes for American shad collected from the Connecticut and Delaware Rivers during 1979.	34
9.	Access points and comparison of associated sampling probabilities for the lower Susquehanna River Creel Surveys, 1970, 1979, and 1980.	42
10.	Time blocks, time units, and associated sampling probabilities for creel census of the lower Susquehanna River, May-June, 1980.	43
11.	Comparison and characterization of data collected from the 1970, 1979, and 1980 Susquehanna River Sport Fishing Surveys.	44
12.	Catch per angler hour for selected species caught during the 1970, 1979, and 1980 Susquehanna River Sport Fishing Surveys.	45
13.	Comparison of the species composition and harvest of finfish caught by sport anglers during the 1979 and 1980 Susquehanna River Sport Fishing Surveys.	46
14.	Sampling periods during the 1980 Juvenile Recruitment Survey.	63
15.	Station numbers, names, locations, and mode of sampling during the 1980 Juvenile Recruitment Survey.	64
16.	Trawl station number, name, location, and compass bearings during the 1980 Juvenile Recruitment Survey.	65
17.	Number of seine hauls and trawl runs by period and site during the 1980 Juvenile Recruitment Survey.	66
18.	Number of hauls and area swept by haul seine for each sampling period during the 1980 Juvenile Recruitment Survey.	67
19.	Area swept by otter trawl for each sampling period by site during the 1980 Juvenile Recruitment Survey.	68
20.	Area swept by haul seine and otter trawl, number of hauls taken and trawl runs completed, and total area swept during the 1980 Juvenile Recruitment Survey.	69
21.	Species caught during the 1980 Juvenile Recruitment Survey.	70

		Page
22.	Species and numbers of individual finfish collected by haul seine during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	72
23.	Species and numbers of individual finfish collected by otter trawl during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	74
24.	Species and number of individual finfish collected by haul seine at ten sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	76
25.	Species and number of individual finfish collected by otter trawl at six sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	78
26.	Species and weight (grams) of finfish collected by haul seine during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	80
27.	Species and weight (grams) of finfish collected by otter trawl during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	82
28.	Species and weight (grams) of finfish collected by haul seine at ten sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	84
29.	Species and weight (grams) of finfish collected by otter trawl at six sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.	86
30.	Total numbers collected, total area swept, and standing crop in numbers per hectare for all species combined for each gear type by sampling period during the 1980 Juvenile Recruitment Survey.	88
31.	Total area swept, total weight of species collected, and standing crop in kilograms per hectare for all species combined for each gear type by period during the 1980 Juvenile Recruitment Survey.	89
32.	Total numbers collected, total area swept, and standing crop in numbers per hectare for all species combined for each gear type by station during the 1980 Juvenile Recruitment Survey.	90

		Page
33.	Total area swept, total weight of species collected, and standing crop in kilograms per hectare for all species combined for each gear type by station during the 1980 Juvenile Recruitment Survey.	91
34.	Numbers caught and catch-per-unit-effort (CPUE) by sampling period, total catch, and total CPUE for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana for haul seine and otter trawl during the 1980 Juvenile Recruitment Survey.	92
35.	Numbers caught and catch-per-unit-effort (CPUE) by sampling station, total catch, and total CPUE for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana by haul seine and otter trawl during the 1980 Juvenile Recruitment Survey.	93
36.	Standing crop as numbers per hectare for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana collected by haul seine and otter trawl in each sampling period during the 1980 Juvenile Recruitment Survey.	94
37.	Standing crop as numbers per hectare for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana collected by haul seine and otter trawl at each sampling station during the 1980 Juvenile Recruitment Survey.	95
38.	Reported commercial catch as pounds caught of American shad and alewife/blueback herring combined from the Susquehanna River, Susquehanna Flats, and the Northeast River from 1968 through 1980.	96
39.	Species and number of individual finfish collected by haul seine during six sampling periods for the 1979 Juvenile Recruitment Survey.	97
40.	Species and number of individual finfish collected by haul seine at ten sampling stations during the 1979 Juvenile Recruitment Survey.	99
41.	Species and weight (grams) of finfish collected by haul seine during six sampling periods for the 1979 Juvenile Recruitment Survey.	101
42.	Species and weight (grams) of finfish collected by haul seine at ten sampling stations during the 1979 Juvenile Recruitment Survey.	103

		Page
43.	Total catch and catch per haul by haul seine by sampling period for young-of-the-year Alosa sapidissima, Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana during the 1979 Juvenile Recruitment Survey.	104
44.	Total catch and catch per haul by sampling station for young-of-the-year Alosa sapidissima, Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana during the 1979 Juvenile Recruitment Survey.	106
45.	Comparison of the population density (numbers per hectare) of young-of-the-year American shad, alewife herring, and blueback herring captured by haul seine and otter trawl from the Susquehanna drainage during 1968, 1969, and 1980.	107
46.	Reported commercial catch of American shad from all waters in Florida, Georgia, South Carolina, North Carolina, Virginia, Maryland, and the Delaware, Hudson, and Connecticut Rivers from 1962 through 1980.	118

LIST OF FIGURES

I.	Gear and locations utilized in tagging adult American shad during 1980.	14
II.	Numbers of American shad caught for tagging by all gear types and by date from the Susquehanna River, Susquehanna Flats, and Northeast River during 1980.	15
III.	Length frequency distribution for male American shad collected from the Susquehanna System in 1980.	35
IV.	Length frequency distribution for female American shad collected from the Susquehanna System in 1980.	36
V.	Interview sites for the 1980 Susquehanna River Sport Fishing Survey.	47
VI.	Interview form for the 1980 Susquehanna River Sport Fishing Survey.	48
VII.	Survey stations for the 1980 American shad Juvenile Recruitment Survey.	108
VIII.	Numbers of young-of-the-year Alosa aestivalis and Alosa pseudoharengus caught by haul seine per sampling period during the 1980 Juvenile Recruitment Survey.	109

		Page
IX.	Numbers of young-of-the-year Alosa aestivalis and Alosa pseudoharengus caught by otter trawl per sampling period during the 1980 Juvenile Recruitment Survey.	110
X.	Numbers of young-of-the-year Alosa aestivalis and Alosa pseudoahrengus caught by haul seine per sampling station during the 1980 Juvenile Recruitment Survey.	111
XI.	Numbers of young-of-the-year Alosa aestivalis and Alosa pseudoharengus caught by otter trawl per sampling station during the 1980 Juvenile Recruitment Survey.	112

INTRODUCTION

Historically, the principal shad river in Maryland has been the Susquehanna (Mansueti and Kolb 1953). Prior to 1980, a commercial shad fishery had existed there for over 200 years. Similarly, a successful sport fishery had existed in this region since the early 1930's. Because of the sharp, continuous statewide decline in the numbers of adults harvested since the early 1970's the 1980 Maryland shad season was closed. The most precipituous decline occurred in the Susquehanna drainage: The 1971 reported commercial catch of American shad from the Susquehanna River and Flats combined was 184,221 pounds while the reported 1979 catch for this same area was 14,319 pounds (Maryland Tidewater Administration MTA in-file data).

Concerned by the seriousness of this situation, the Tidewater Administration of Maryland's Department of Natural Resources proposed a long term investigation of American shad in the upper Chesapeake Bay. The primary objective of this study is to assess the status of head-of-the-Bay shad stocks, specifically those utilizing the Susquehanna River drainage. The information obtained will be used to formulate management policies to restore American shad to stable, harvestable levels. To meet the primary objective, five separate jobs were initiated: tagging and population estimate, population characterization, creel census, juvenile recruitment survey, literature review and survey. The five year project, initiated in February, 1980, is funded under The Federal Aid in Fish Restoration Act, PL 81-691, and the Power Plant Siting Program of the Maryland Department of Natural Resources.

JOB I. TAGGING AND POPULATION ESTIMATION

INTRODUCTION

A prerequisite to effectively manage an exploited fish stock is to determine how many individuals comprise the population under investigation. Since 1965, the state of Connecticut has been utilizing a mark-recapture program in estimating the numbers of American shad ascending the Connecticut River each spring to spawn (Crecco 1979). The data accumulated from this procedure has been one of the major factors in that state's efforts to effectively manage their shad stocks. Similar efforts on the Delaware River by New Jersey and Delaware state conservation personnel have also aided in effective management of that river's American shad stocks (Lupine 1980).

Few population estimates for American shad in Maryland waters have been made. Walburg (1954) estimated the American shad population (in pounds) in Maryland waters from 1944 to 1952 based on a single tagging experiment conducted in 1952 and the commercial catch records from 1944 to 1952. These estimates appear below:

YEAR	COMMERCIAL CATCH (lbs.)	ESTIMATED POPULATION (lbs.)
1944	661,005	2,412,427
1945	556,141	1,951,372
1946	653,868	1,841,882
1947	768,830	1,800,539
1948	892,852	1,988,535
1949	949,690	2,168,242
1950	1,342,401	3,274,149
1951	1,486,616	3,046,344
1952	1,487,085	2,836,193

St. Pierre (1978) estimated the average annual population of American shad in the Susquehanna River and the extreme northern portion of Chesapeake Bay from 1890 to 1904 to be

1,790,000 fish. This computation was based on the average annual commercial harvest for this 15 year period plus the estimate that approximately 24% of the total population was harvested during this time.

Because of the time lag between past and present population estimates of American shad and the inadequacies of previous efforts, a tagging experiment was undertaken to determine the numbers of American shad utilizing the Susquehanna River, Susquehanna Flats, and Northeast River to spawn. An extensive population evaluation would aid the Maryland Department of Natural Resources in its attempts to monitor the American shad in what was historically its most important spawning/nursery area, and in using the accrued data for future management decisions.

METHODS AND MATERIALS

Tagging of adult American shad was undertaken at various sites within the Susquehanna River, Susquehanna Flats, and Northeast River between April 22 and May 31, 1980 during the peak of the spawning run for this species (Figure I, p. 14). Fish were captured in commercially operated pound nets and anchor gill nets. Drift gill nets were also employed but were unsuccessful in catching shad. Three pound net sites were located along the shore of the Northeast River at its juncture with the Susquehanna Flats. A fourth pound net site was located at the mouth of the Susquehanna River near Perryville. Drift gill nets were fished along the east shore of the Northeast River and in the Susquehanna River near Port Deposit and Havre-de-Grace. Gill net dimensions (both anchor and drift) were 1,000' x 6' and ranged from five to five and one half inch stretched mesh. All gill net sampling was done between 12:00 AM and 6:00 AM. Pound nets were sampled every day from 6:00 AM to 12:00 PM. All tagging was done with a Dennison Floy Tagging Gun, Model # FD-67, using plastic anchor tags four inches in length.

Fish were taken from the nets, measured for length, scale samples taken, sex determined, and tagged as expeditiously as conditions would allow. Under certain circumstances, to minimize stress, the fish were only tagged and immediately returned to the water. Data from dead shad found in the nets, including weights, was also collected. Tags were inserted into the dorsal musculature posterior to the dorsal fin at an angle conducive to streamlining. Tag retention appeared to be satisfactory and did not seem to affect tag return data. A $5.00 reward was offered for each tag returned.

RESULTS

A total of 399 American shad were examined during the 40 days of sampling. Breakdown of collection by gear types is presented in Table 2, p. 12. Figure II, p.15 illustrates the time frame in which pound net and gill net captures were made. Of the 399 fish examined, 147 were tagged successfully and released from the four pound nets and two anchor gill nets. Stress among captured fish may have caused some post-release mortality. Fish taken from the four pound nets were tagged and released with good success and did not seem to exhibit the degree of stress that was observed in fish captured by, tagged, and released from the anchor gill nets. Mortality for fish captured in the anchor gill nets appeared to be higher than those captured in the pound nets.

Another problem encountered with the use of the anchor gill nets was that of immediate recapture of the newly marked fish from the same net. Fish were initially released on the downstream side of the gill net but since this gear is fished under no flow river conditions there was no current to carry the tagged fish downstream away from the nets. The use of a holding tank to transfer the newly marked fish to deeper water away from the tagging area was moderately successful.

Initially, population estimates were to be made using multivariate population models such as the Jolly-Seber stochastic and Bailey triple catch deterministic models (Ricker 1975). However, since there were only thirteen recaptures, these population models could not be utilized. An estimate for the adult spawning population of American shad in this area was attained, to an acceptable degree, by using Chapman's version of the standard Petersen estimate (Chapman 1951). Appropriate confidence limits were set by using tabulated limits for a Poisson distribution as set forth by Ricker (1975). These computations are presented in Table 3 while recapture data is summarized below:

Of the 13 recaptures-

a) 10 were made by commercial fishermen
2 were made by sport anglers
1 was made by the Conowingo Dam Fish Lift

b) 9 were originally tagged from pound nets
4 were originally tagged from anchor gill nets

c) 5 fish were recaptured from the same location
5 fish were recaptured upstream from their tagging locations
3 fish were recaptured downstream from their tagging locations

d) shortest recovery 1 day
longest recovery 21 days
average recovery 6.4 days

Of the three shad recaptured downstream of their tagging location, two were recaptured one day after tagging by a commercial fisherman from Rock Hall, Maryland, approximately 30 nautical miles south of their tagging location. Leggett (1976) found that a majority of the American shad he tagged with ultrasonic tags (both internal and external) on the Connecticut River initially moved downriver as a possible

result of physiological shock and disorientation related to capture and tagging. The third downstream recovery was that of a spent individual tagged 19 days previously and recaptured at the most southerly pound net, possibly indicating it was returning to the ocean. Specific information concerning each of the 13 recaptures is presented in Table 1, p. 11.

DISCUSSION

Several problems were encountered in both collecting and analyzing the data needed to estimate the number of American shad in the head of Chesapeake Bay.

1. A lack of sufficient capture sites within the specific spawning area combined with a lack of time synchrony between netting effort and adult fish spawning waves caused the number of fish captured to fall below what was originally anticipated. Anchor gill nets, which ultimately caught a majority of the fish, were not successfully used until the latter part of the run. American shad are not as hardy as other fish and it was feared that those caught in the anchor gill nets would be unfit for tagging. Pound nets on the other hand, permit the continuous movement of captured American shad thus minimizing much of the stressing conditions imposed on gill net caught fish. As a result of trial and error, however, it was found that by fishing only one or two boxes of gill net at a time, continuously checking the nets for fish, and using an aerated holding tank this gear would be used to collect shad for tagging. The majority of the shad lost in the anchor gill nets occurred before these techniques were employed and perfected, and most of the fish captured by this gear during the latter part of the run were successfully tagged and returned to the water. Of the 31 fish lost in the pound nets, 19 were the result of the late arrival of the tagging team to the pound nets on April 22. Table 2 presents a comparison of gear types employed to catch American shad and their relative success.

2. As stated previously, the lack of sufficient numbers of recaptures eliminated the use of multivariate population models such as the Jolly-Seber which are specifically designed for use with open populations that are subject to immigration and emmigration. Ricker (1975) states that if the number of recaptures is small, say less than four for any of the several recapture periods (ie. one week) the population estimate is subject to bias.

3. A number of problems were associated with the use of a Petersen population estimate. Ricker (1975) notes six conditions that should be satisfied to obtain a valid Petersen estimate;

   a. the marked fish suffer the same natural mortality as the unmarked fish
   b. the marked and unmarked fish are equally vulnerable to fishing
   c. the marked fish do not lose their marks
   d. the marked fish become randomly mixed with the unmarked fish
   e. all marks are recognized and reported on recovery
   f. there is only negligible recruitment to the catchable population during the time the recoveries are being made.

   Tagging equipment and procedures were quite similar to those employed on the Delaware (Lupine 1980) and on several rivers in South Carolina (Crochet et al. 1976). Data from these studies indicated little tag induced mortality and good tag retention. Because of the thinness of the spagetti tag used and its placement at a streamlined angle, tag-induced excess fishing mortality from these areas was found to be virtually non-existent. These same observations were also noted for the 1980 Susquehanna tagging operation. It would be difficult to prove or disprove whether the tagged fish become randomly distributed with the untagged individuals but it seems reasonable to

assume that if the tagged fish were released in good physical condition their ability to keep up with the untagged fish should not be impaired. No mention of this problem was made in other shad tagging studies (Crochet et al. 1976, Minta et al.1980, Lupine 1980). The offering of a $5.00 reward for each tag returned was thought to provide sufficient incentive for reporting the recapture of American shad during the present study.

Violation of assumption f interjects a source of bias into the Petersen estimate. Since American shad enter their natal rivers in several spawning waves or pushes, they are not all available for possible capture, tagging and recapture at one time. The general trend on the Susquehanna River during previous years has been for the shad run to begin during the last two weeks of April and continue until the end of May, depending on water temperatures and river conditions. Figure II indicates that during the course of the 1980 tagging experiment possibly three different spawning pushes were noted. Ricker's assumption f may possibly be met if one considers the fact that once the migrating American shad reach the Susquehanna area they can go nowhere else because of the presence of the Conowingo Dam. Since all of the fish that were observed and collected by the various gear types were fish homing to this area, one is dealing with only Susquehanna fish regardless of the time frame in which they were observed. This problem of timing with respect to the various spawning pushes does not seem to deter the use of the Petersen statistic in estimating populations of American shad in other east coast rivers (Lupine 1980, Crecco 1979).

Ricker (1975) states that the violation of assumption f will produce a population estimate that is too high assuming that the other five assumptions are satisfied. It seems probable then, that using the modified Petersen formula

overestimated the 1980 spawning population of American shad in the Susquehanna drainage. Since the estimated population was only 2,675 spawning adults, the overestimated figure further emphasizes the severely depleted shad stocks utilizing the upper Chesapeake Bay.

4. Another source of bias associated with a Petersen estimate is the low number of recaptures. Bailey (1951) states that a large scale recapture effort may be necessary to make a reliable population estimate. Ricker (1975) noted that lower numbers of recaptures cause the Petersen estimate to become biased and, therefore, less reliable, although some confidence is gained through the use of a Poisson distribution as was done for the Susquehanna data (Table 3, p. 13).

   The sources of recaptures during the 1980 study were to have been the local sport and commercial fisheries. However, the progresive, drastic decline in the spawning stocks of American shad necessitated a statewide closure of Maryland waters for the 1980 season. Because of this closure, the incidental sport and commercial fishing effort for American shad produced a limited number of returns, with the bulk coming from commercial watermen specifically hired by the Department of Natural Resources to capture fish for tagging. Admittedly, this made for a somewhat limited population estimate, but in analyzing the current situation the Department considered the protection of the remaining brood stocks to be of greater importance than extreme precision of estimates. Although overall stock size is greatly reduced, sufficient numbers of American shad may be present in this area to allow for a more reliable population estimate, provided the number of recaptures increases. This will be attempted in 1981 through greater utilization of local commercial watermen in an effort to improve sampling techniques and timing. It is hoped that these changes will increase data reliability and allow the use of more sophisticated statistical techniques to provide more accurate information.

SUMMARY

1. Of the 399 American shad collected at the Head-of-the-Bay, 147 were tagged and released. Thirteen of these were recaptured.
2. A population estimate of 2,675 American shad was made utilizing the Petersen formula.
3. Stress and mortality problems associated with the use of anchor gill nets to capture shad for tagging were encountered. After corrective measures were implemented, these problems were reduced, allowing for the successful tagging of gill net caught shad.
4. Increased tagging and recapture efficiency may permit the use of more accurate population models in estimating future Susquehanna shad populations.

TABLE 1. Capture-recapture dates, locations and gear types for thirteen recaptures of tagged American shad during 1980.

Date Tagged	Date Recaptured	Tagging Location	Gear Type	Recapture Location	Gear Type
4-22-80	5-7-80	NE River	PN	Perryville	GN
4-25-80	4-30-80	NE River	PN	NE River	PN
4-29-80	4-30-80	NE River	PN	Rock Hall	GN
4-29-80	4-30-80	NE River	PN	Rock Hall	GN
5-7-80	5-13-80	Susq. River	GN	Susq. River	GN
5-12-80	5-13-80	Susq. Flats	PN	Susq. River	GN
5-8-80	5-13-80	Susq. River	GN	Susq. River	GN
5-12-80	5-14-80	Susq. River	GN	Susq. River	GN
5-12-80	5-14-80	Susq. River	GN	Susq. River	GN
5-6-80	5-11-80	Susq. Flats	PN	Con. Te.	HL
5-10-80	5-23-80	Susq. Flats	PN	Con. Te.	FL
4-23-80	5-14-80	NE River	PN	Con. Te.	HL
5-12-80	5-31-80	Susq. Flats	PN	NE River	PN

Gear Type Abbreviations

GN = gill net
PN = pound net
HL = hook & line
FL = fish lift

Location Abbreviations

Con. = Conowingo Dam
NE = Northeast River
Con. Te. = tailrace

TABLE 2. Comparison of total catch, number tagged, number lost, and % net mortality by location and gear type for American shad captured in the Susquehanna River, Susquehanna Flats, and Northeast River during 1980.

		Location	Total Catch	No. Tagged	No. Lost	% Net Mortality
A.	Pound Nets	TP	50	29	21	
		CC I	8	7	1	
		CC II	17	16	1	
		PP	45	37	8	
	Sub Totals		120	89	31	26
B.	Anchor Gill Nets	NE R.	0	0	0	
		Sus. R.	144	65	79	
	Sub Totals		144	65	79	55
C.	Conowingo Fish Lift	Dam	135	0	?	
D.	Drift Gill Nets	NE R.	0	0	0	
		Sus. R.	0	0	0	
E.	Grand Totals		399	154*	110	42**

* # tagged used in Petersen estimate = 147: 7 fish were recaptured in anchor gill nets immediately after tagging, died, and were not included in number tagged but as lost in population estimate.

** figure based on pound net and anchor gill net totals only

TABLE 3. Population estimate of adult American shad utilizing the Susquehanna River, Susquehanna Flats, and Northeast River for 1980.

FROM CHAPMAN (1951):

$$N = \frac{(M + 1)\ \ (C + 1)}{R + 1}$$

where: N = population estimate
C = number of fish examined for marks
R = number of fish recaptured
M = number of fish marked

For the 1980 Survey -

C = 252
R = 13
M = 147

Therefore -

$$N = \frac{(147 + 1)\ \ (252 + 1)}{13 + 1}$$

$$= \frac{148 \times 253}{14}$$

$$= \frac{37,444}{14}$$

$$= 2,675$$

FROM RICKER (1975): Calculation of sampling error using recapture numbers in conjunction with a Poisson distribution approximation and acceptable confidence limits.

Using Chapman (1951) -

$$N^* = \frac{(M + 1)\ \ (C + 1)}{R_t + 1}$$

where: R = tabular value (from Ricker p343)

$$\text{Upper } N^* = \frac{(147 + 1)\ \ (252 + 1)}{6.9 + 1} = 4,740 \text{ @ } 95\% \text{ confidence limits}$$

$$\text{Lower } N^* = \frac{(147 + 1)\ (252 + 1)}{22.3 + 1} = 1,607 \text{ @ } 95\% \text{ confidence limits}$$

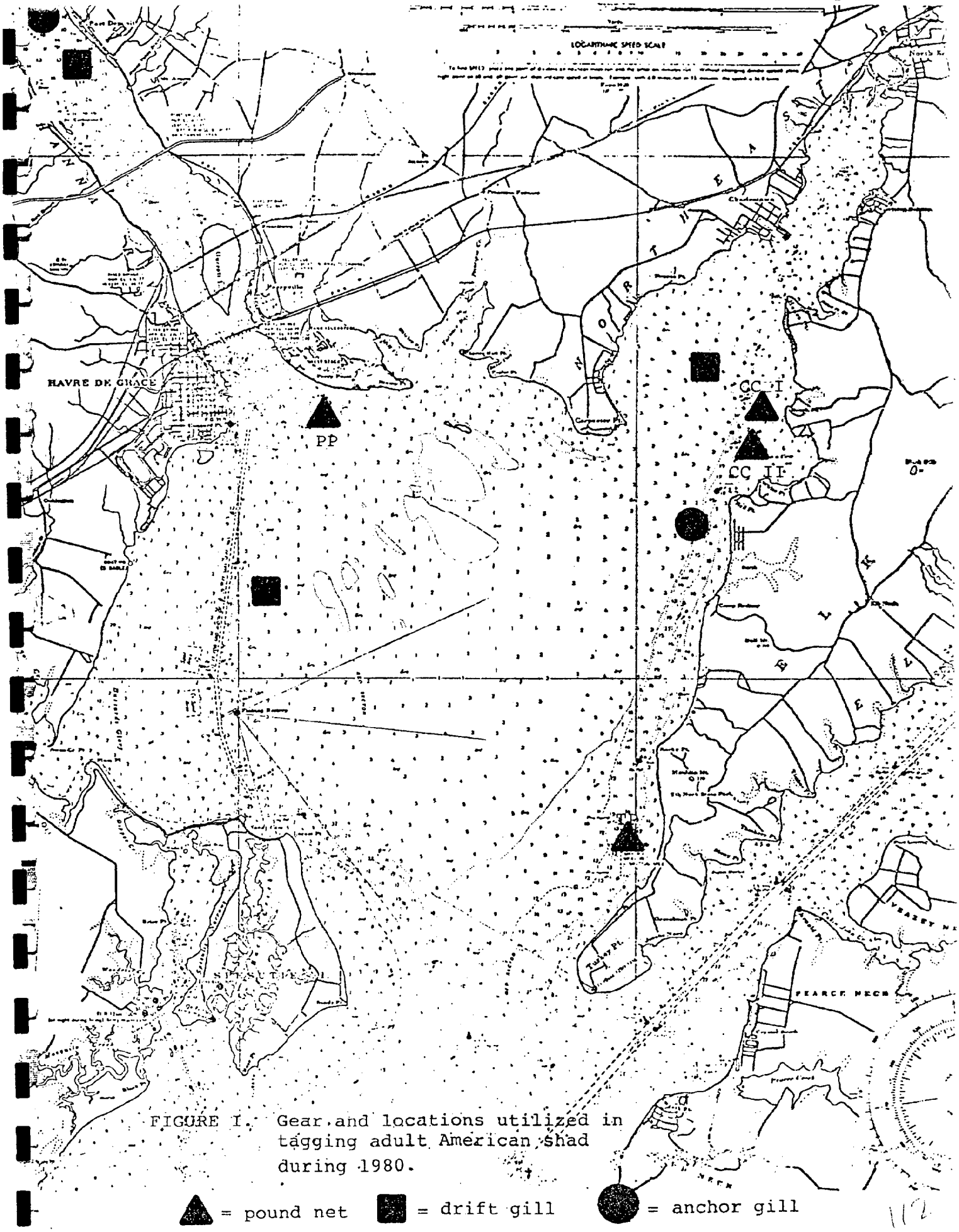


FIGURE I. Gear and locations utilized in tagging adult American shad during 1980.

▲ = pound net ■ = drift gill ● = anchor gill

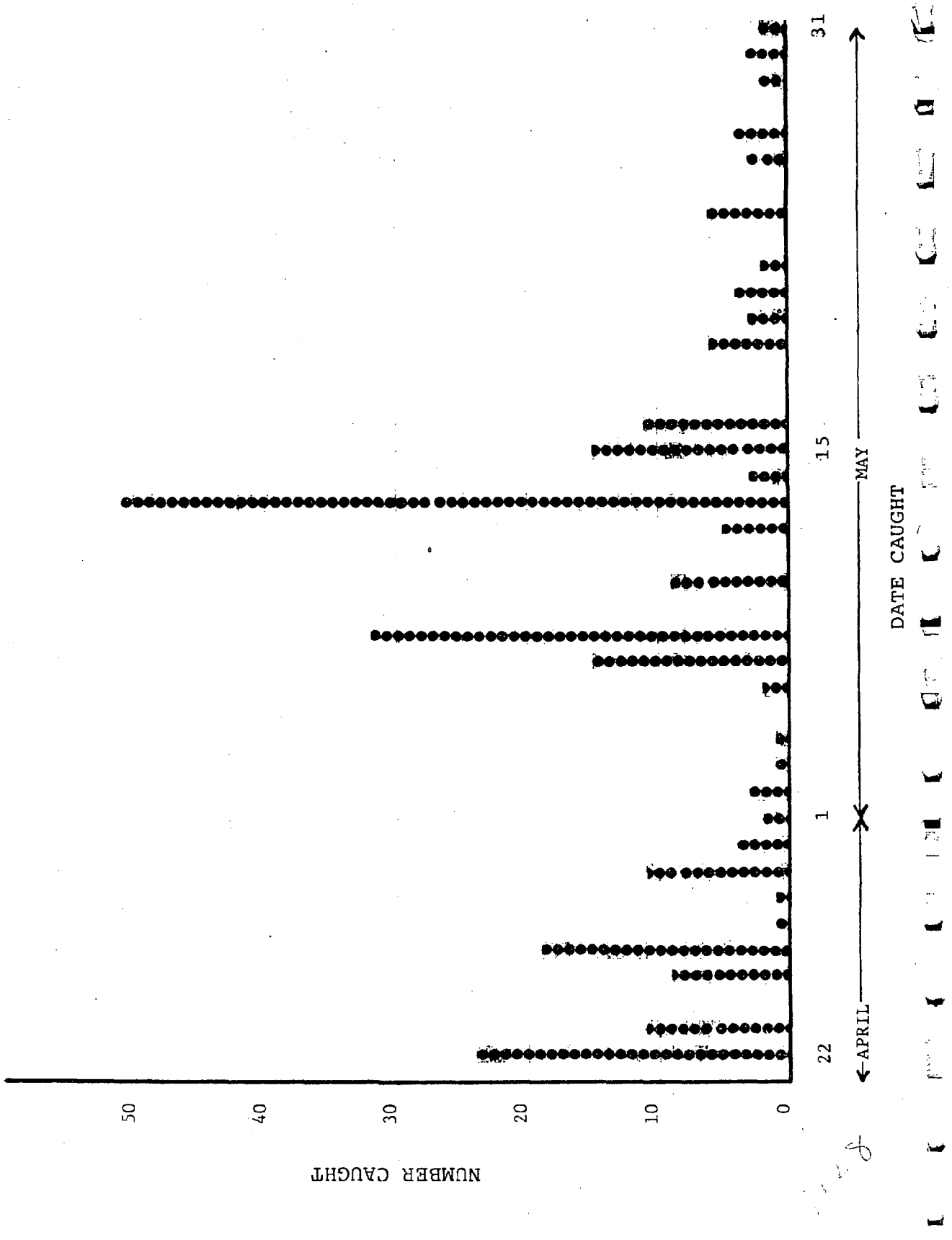


FIGURE II. Numbers of American shad caught for tagging by all gear types and by date from the Susquehanna River, Susquehanna Flats, and Northeast River during 1980.

JOB II. POPULATION CHARACTERIZATION

INTRODUCTION

Effective management policies can only be implemented when an extensive data base exists from which to draw information. Such a data base exists in Connecticut where the population characteristics of American shad have been monitored for many years (Fredin 1954, Judy 1961, Jones et al. 1976, Leggett 1976, Crecco 1979, Minta et al. 1980). In this system such parameters as growth and survival rates, total, fishing and natural mortality rates, and annual fishing rates have been determined from length and weight frequencies, sex and age composition, adult spawning history, and commercial and sport fishing data since 1966 (Crecco 1979). Other estimates made for Connecticut River shad include recruitment, escapement, and return per spawner based on adult age structure. The accumulated data are then utilized for determining different yields associated with changes in fishing effort for the exploited shad fishery. A stable shad population has been the result of this research and subsequent management which allows sufficient escapement while permitting a viable economic harvest.

Most of the literature concerning Maryland American shad stocks discusses historical overviews of the commercial fishery, catch records, and catch-per-unit-effort (CPUE) estimates of those landings (Mansueti and Kolb 1953, Walburg 1955, Mansueti 1958, Walburg and Nichols 1967, Forester and Reagan 1977, St. Pierre 1978). Very little is known about the fluctuations in American shad stocks for the Susquehanna River other than these historical reviews. There has been no long term monitoring program of the population characteristics of Susquehanna River American shad. La Pointe (1958) presented sex ratios, age class, spawning history and length data for Susquehanna shad. RMC (1979) summarized sex and age composition data for shad collected at the Conowingo Dam fishlift and from sport anglers between

1972 and 1979. In that eight year period, however, only 451 fish were examined, and in one year, as few as six fish were collected (Table 4, p. 24).

In 1979, a pilot study of Susquehanna River American shad stocks was made. The study, designed to gather information concerning population characteristics of upper-Bay shad, was expanded in 1980 to measure length and weight frequency distributions, sex and age composition, and adult spawning history data for five years. This will allow estimation of the parameters needed for effective management of Maryland shad stocks. For example, since the gear used by upper Chesapeake Bay shad fishermen is highly size selective, accumulation of length-weight data would allow the Department of Natural Resources to better protect a safe number of virgin spawners who make up the majority of the adult population and older, more fecund repeat spawning individuals through limitations in net mesh sizes.

METHODS

American shad were collected at various locations in the Susquehanna system as described in JOB I. A sample of approximately 12 or more scales was taken midway between the dorsal fin and the midline on the left side of each fish and placed in a scale envelope. The date and location of capture, net type, fork length (mm), sex, and weight (grams) were recorded on each envelope. Weight measurements were taken from dead fish only. On occasions when it appeared that a fish was stressed due to handling or confinement in the sampling gear, scale samples were not taken so as to minimize handling and possible mortality, since the fish were being tagged for use in a population estimate.

Scale samples were prepared for age and spawning history determinations by selecting 4 to 6 non-regenerated scales from each envelope and cleaning each one thoroughly with soap and

water. Clean scales were impressed on 25 mm by 76 mm acetate slides with a roller press. The slides were then placed in a microprojector and read at 2.5X magnification. Two biologists read each scale for age and spawning marks according to the techniques developed by Cating (1953). If the two readers were in disagreement, the slide was set aside to be re-read later. If agreement could not be reached after reading the slide a second time, that sample was discarded. Age was determined by the number of true annuli present plus the outer edge of the scale (Cating 1953). Spawning history was indicated by the presence or absence of a spawning mark near the scale periphery.

RESULTS

To reduce stress-induced mortality of captured American shad, not all physical measurements were taken for each fish collected. Consequently, sampling sizes for such measured parameters as length, weight, age and spawning marks are not equal. The sample sizes for sex, length, weight, and age of male, female, and spent shad are presented below:

	SAMPLE SIZE		
Variable	Female	Male	Spent
Sex	160	97	
Length	124	69	5
Weight	57	16	
Age	117	67	4

The sex ratio of 257 shad examined was 1.6:1, female to male (Table 6, p. 28). The mean fork length for females was 461 mm, while that for males was 428 mm (Table 5, p. 26). The mean weights for female and male shad were 1,580 grams and 1,240 grams, respectively (Table 5, p. 26). Figures III and IV present the length frequency distributions by sex for adult shad.

There were 196 scale samples collected for age structure data and spawning history. Because some scale samples were discarded as unusable, there were 188 slides from which age and spawning history could be determined. Table 6, p. 28, presents scale analysis data. The dominant age class, age IV, comprised 57.4% of the shad examined, while age V individuals made up 33% of all shad collected. Only 11.7% were determined to be repeat spawners (Table 6). The percentage of male shad which were virgin fish was 83.6%, while the female population consisted of 90.6% virgin recruits.

DISCUSSION

Tables 6, 7, and 8 (p. 28, 30, and 34) present characterization data collected from Susquehanna American shad captured in 1979 and 1980, and for other east coast shad rivers. Of note are the following:

1. Little age structure change was noted for upper Chesapeake Bay shad captured in 1979 and 1980; the dominant age class for both years was IV. The incidence of repeat spawners increased slightly in 1980, although this level was far below the 37% reported by LaPointe (1958) for Susquehanna River American shad. Slight increases were noted in mean length for both males and females in 1980 while length at age ranges were similar for both years. The most noticeable change between the two year's catch was in the sex ratio which changed from strongly female in 1979 to slightly female in 1980. During 1979, approximately 90% of the American shad examined from the Susquehanna River and Flats were collected by gill nets. In 1980, nearly 50% of the fish sampled were taken from commercial pound nets, a less selective gear. This change in sex ratios appears to be an artifact of the various sampling gears employed for the two years.
2. 1978 sex ratios for Chesapeake Bay shad stocks from the York, James, Rappahannock, and Pamunkey Rivers, Virginia were similar to 1979 Susquehanna sex ratios. This similarity may, again, be due to the fact that fish collected

in all the Virginia rivers in 1978 and from the Susquehanna in 1979 were taken with size selective gill nets. Age structure, however, appears to be different between the two with age class VI individuals dominating the Virginia runs as opposed to age IV for the upper Chesapeake Bay population. Few age III and IV individuals were collected from these Virginia rivers in 1978. No data on repeat spawning was available from these Virginia caught fish.

3. Age structure of 1978 caught shad from Albemarle Sound North Carolina was similar to age structure of Virginia shad. However, certain differences between the two were noted: a) the dominant age class for the North Carolina fish was V instead of VI, b) the numbers of younger age classes (III and IV) was much greater for North Carolina shad. Sex ratios of Albemarle Sound fish were quite different from Maryland and Virginia Chesapeake Bay stocks and more closely represented the 1:1 ratio reported by Leggett (1976). The percentage of repeat spawners for 1978 Albemarle Sound fish was lower than for Susquehanna shad. This agrees with the findings of Leggett and Carscadden (1978) who concluded that the incidence of repeat spawners decreased with decreasing latitudes and was virtually non-existent in South Carolina, Georgia, and Florida.

4. Delaware River American shad captured in 1978 and 1979 exhibited a similar age structure to upper Chesapeake Bay fish with age IV individuals dominating. Beginning in 1978, however, an influx of three year old males occurred on the Delaware which increased greatly in 1979. Both mean length and length ranges at age were usually greater for 1979 Delaware shad as opposed to their 1979 and 1980 Susquehanna counterparts (Table 6, p. 28). Numbers of repeat spawners were significantly less for Delaware River shad due primarily to adult mortality during seaward migration (Sykes and Lehman 1957, Chittenden 1969).

113

5. Mean length and length ranges by age for both male and female Connecticut River American shad collected in 1979 were greater than 1979 and 1980 Susquehanna fish. However, the differences between 1979 Connecticut and 1979 Susquehanna shad were very slight for all age groups. The 1979 Connecticut River sex ratio was also quite similar to that found for 1980 Susquehanna fish. The greatest difference between the two stocks appears to be in the spawning history. The percentage of repeat spawners utilizing the Connecticut River in 1979 was 20%, with a 15 year average (1965-1979) of 36% (Minta et al. 1980). Susquehanna River American shad exhibited only a 10.4% and 11.7% incidence of repeat spawning during 1979 and 1980, respectively.

The data presented in Tables 6, 7, and 8 and summarized above were from American shad collected with various commercial gear types; therefore, some degree of sampling bias has been introduced. Measured parameters reflect characteristics of the commercially harvested sample and not the entire spawning population. The mesh size of commercial gill nets fished in the non-Maryland areas is unknown. However, it seems reasonable to assume that the mesh size employed by each system's commercial fishermen does not drastically change within that system. This is because a river's watermen are all fishing on the same stocks. Upper Chesapeake Bay gill net fishermen select large net sizes (5¼ to 5 3/4 inch stretch mesh) designed to capture the larger, more robust shad. Males, which are normally smaller than females at any given age are less likely to be captured by these larger mesh nets. An extra economic incentive also exists for taking females because of their roe. Preliminary pound net samples from the Connecticut River (Minta et al. 1980) indicated that there were major differences in the sex ratios of pound net vs gill net captured American shad in 1980. Connecticut DEP personnel theorize that the probability of tagging and recapturing small adult shad was reduced by gill net fishing that is highly size selective. Adult collections of American shad from the Delaware River are made with less size selective haul seines (Friedersdorff and Baren 1978, Lofton 1979, Lupine

1980). The 1979 Delaware sex ratio, 53% males and 47% females is very similar to the 1:1 proportion as reported by Leggett (1976).

It would appear from analysis and comparison of the 1979 and 1980 Susquehanna shad data that this stock can be characterized as a run primarily supported by two very small, virgin age classes with relatively few repeat spawners. These conditions provide little buffering against man-induced and natural environmental problems. The situation on the Connecticut River is such that each year's run is supported by more than one large year class and a large number of more fecund repeat spawners. Consequently, this is the most stable shad fishery of all major east coast rivers. With few repeat spawners present, the recent increases in Delaware River shad runs are due primarily to the presence of several strong year classes that have successfully passed through the Philadelphia pollution zone. Chittenden (1975) found that large increases in the 1962 and 1963 Delaware shad runs were the result of extremely large year classes produced in 1958 and 1959. Chittenden noted a shift in the sex ratios from strongly female in 1960 to strongly male in 1961 and 1962. He concluded that since males tend to enter the fishery one year before females, a sudden large increase in the proportion of male fish appears to be a strong indicator of year class strength and hence run size for the following year(s) as the females return to spawn. The 1963 Delaware shad run was one of the largest in the previous 45 years. Similar increases in the proportion of males in 1978 and 1979 indicated strong year class production in 1974 and 1975. Subsequent Delaware River sport and commercial catches of American shad for the past four years have also increased dramatically.

As previously stated, the shift in the sex ratio of Susquehanna shad (Table 6) from 1979 to 1980 was probably due to changes in the gear types employed to capture adults. If an actual increase in male fish did take place a significant increase in 1980

Susquehanna age III male fish should have occurred as it did on the Delaware in 1978 and 1979. However, this did not happen on the Susquehanna and it appears that two very reduced, virgin age classes, with little help from stronger year classes and more fecund repeat spawners will continue to support the already limited upper Chesapeake Bay American shad runs.

SUMMARY

1. General similarity was noted between 1979 and 1980 upper Chesapeake Bay American shad runs.
2. Although similarities existed for some characteristics, Susquehanna stocks exhibited definite differences with other east coast American shad populations.
3. The 1979-1980 upper Chesapeake Bay runs may be characterized as being supported by two remnant virgin age classes with a small percentage of repeat spawners.
4. Comparison with both Connecticut and Delaware River American shad runs indicates that with no significant increase in the numbers of virgin males, an indicator of increased year class strengths, and in the numbers of more fertile repeat spawners, the present reduced levels of American shad utilizing the head-of-Chesapeake Bay will continue for the forseeable future.

TABLE 4. Age composition of Susquehanna River American shad collected by the Conowingo Dam Fish Lift and by sport anglers from 1972 through 1979.

YEAR	AGE CLASS	FISH LIFT m	FISH LIFT f	SPORT ANGLERS m	SPORT ANGLERS f	TOTALS
1972	III	8	0	-	-	8
	IV	37	15	-	-	52
	V	10	19	-	-	29
	VI	0	9	-	-	9
	Total	55	43			98
1973	IV	1	0	-	-	1
	V	1	2	-	-	3
	VI	0	1	-	-	1
	VII	0	1	-	-	1
	Total	2	4			6
1974	III	1	0	4	0	5
	IV	2	1	7	14	24
	V	2	3	2	8	15
	VI	0	0	0	1	1
	Total	5	4	13	23	45
1975	IV	4	7	15	9	35
	V	0	2	4	8	14
	VI	0	0	1	1	2
	Total	4	9	20	18	51
1976	III	0	0	1	0	1
	IV	4	3	7	8	22
	V	2	8	2	8	20
	VI	2	1	1	0	4
	VII	0	1	0	0	1
	Total	8	13	11	16	48

TABLE 4 - continued.

YEAR	AGE CLASS	FISH LIFT m	FISH LIFT f	SPORT ANGLERS m	SPORT ANGLERS f	TOTALS
1977	III	0	0	2	0	2
	IV	2	6	18	5	31
	V	2	8	13	33	56
	VI	0	0	0	7	7
	Total	4	14	33	45	96
1978	V	2	1	8	6	17
	VI	0	2	4	12	18
	VII	0	2	1	1	4
	Total	2	5	13	19	39
1979	III	1	0	0	0	1
	IV	4	3	2	1	10
	V	7	17	3	7	34
	VI	6	8	1	4	19
	VII	2	1	0	1	4
	Total	20	29	6	13	68
TOTALS 1972 - 1979		100	121	96	134	451

TABLE 5. Mean fork length (mm), mean weight (kg), and length and weight ranges by sex and age class for American shad collected from the Susquehanna drainage during 1979 and 1980 by various gear types.

GILL NET					RANGE		POUND NET					RANGE	
AGE	SEX	VARIABLE	NO.	MEAN	MIN.	MAX.	AGE	SEX	VARIABLE	NO.	MEAN	MIN.	MAX.
A. 1979													
III	m	length	3	375	361	385							
		weight	3	0.72	0.68	0.74							
IV	m	length	29	420	375	457							
		weight	27	0.98	0.45	1.39							
	f	length	152	447	365	487							
		weight	152	1.47	0.74	2.16							
V	m	length	11	455	408	504							
		weight	9	1.27	0.91	1.59							
	f	length	126	461	420	522							
		weight	125	1.66	0.91	2.07							
VI	m	length	2	508	498	519							
		weight	2	1.76	1.71	1.81							
	f	length	3	495	470	520							
		weight	3	1.85	1.64	2.04							

TABLE 5 - continued.

		GILL NET			RANGE				POUND NET			RANGE	
AGE	SEX	VARIABLE	NO.	MEAN	MIN.	MAX.	AGE	SEX	VARIABLE	NO.	MEAN	MIN.	MAX.
B. 1980													
III	m	length	2	387	373	402	III	m	length	10	379	350	412
		weight	1	0.70	-	-			weight	1	1.80	-	-
IV	m	length	12	417	387	436	IV	m	length	23	429	408	459
		weight	4	0.97	0.80	1.10			weight	3	1.16	1.00	1.40
	f	length	32	445	398	475		f	length	37	446	415	483
		weight	21	1.39	0.90	2.30			weight	11	1.55	1.00	2.40
V	m	length	6	456	441	482	V	m	length	12	461	440	483
		weight	3	1.26	1.20	1.30			weight	1	1.50	-	-
	f	length	23	476	444	499		f	length	20	481	440	530
		weight	18	1.67	1.20	2.30			weight	3	2.03	1.80	2.40
VI	m	length	0	-	-	-	VI	m	length	2	495	487	503
		weight	0	-	-	-			weight	2	1.85	1.70	2.00
	f	length	1	537	-	-		f	length	2	527	527	528
		weight	1	2.00	-	-			weight	1	2.00	-	-
VII	f	length	1	524	-	-	VII	f	length	0	-	-	-
		weight	0	-	-	-			weight	0	-	-	-

TABLE 6. Age frequency, number, and percent repeat spawners by sex for American shad collected from the Susquehanna drainage during 1979 and 1980 by various gear types.

YEAR	GEAR TYPE	SEX	SEX RATIO	NO.	AGE CLASS III	IV	V	VI	VII	% REPEAT SPAWNERS
1979	gill net	m	14%	total= 45	3	29	11	2		
				repts= 15	0	7	6	2		33.0
		f	86%	total=281		152	126	3		
				repts= 19		2	14	3		6.8
	TOTALS			total=326	3	181	137	5		
				repts= 34	0	9	20	5		10.4
1980	gill net	m	26%	total= 20	2	12	6			
				repts= 2	0	0	2			10.0
		f	74%	total= 57		32	23	1	1	
				repts= 7		1	5	0	1	12.3
	TOTALS			total= 64	2	44	29	1	1	
				repts= 9	0	1	7	0	0	11.7
	pound net	m	44%	total= 47	10	23	12	2		
				repts= 9	0	8	1	0		19.1
		f	56%	total= 60		38	20	2		
				repts= 4		0	3	1		6.7

TABLE 6 - continued.

YEAR	GEAR TYPE	SEX	SEX RATIO	NO.	AGE CLASS III	IV	V	VI	VII	% REPEAT SPAWNERS
1980	pound net	sp		total= 4		3	1			
				repts= 0		0	0			0.0
	TOTALS			total=111	10	61	32	4		
				repts= 13	0	8	4	1		12.1

TABLE 7. Age frequency, number, and percent repeat spawners by sex for American shad collected from selected east coast rivers during 1978 and 1979 by various gear types.

YEAR	GEAR TYPE	SEX	SEX RATIO	NO.	AGE CLASS III	IV	V	VI	VII	VIII	% REPEAT SPAWNERS
A. Connecticut River[1]											
1979	gill net	m	32%	total=174	9	92	67	6			
				repts= 40		no individual data					23.0
		f	68%	total=374		147	205	19	2	1*	
				repts= 70		no individual data					10.0
	TOTALS			total=548	9	239	272	25	2	1	
				repts=180		no individual data					20.1
B. Delaware River											
1978[2]	haul seine	m	69%	total=407	48	245	112	2			
				repts= ?		no data available					NA
			31%	total=188	1	39	118	25	5		
				repts= ?		no data available					NA
	TOTALS			total=595	49	284	230	27	5		
				repts= ?		no data available					NA

TABLE 7 - continued.

YEAR	GEAR TYPE	SEX	SEX RATIO	NO.	AGE CLASS III	IV	V	VI	VII	VIII	% REPEAT SPAWNERS
1979[3]	haul seine	m	53%	total=429	115	260	51	3			
				repts= 10	no individual data						2.3
		f	47%	total=387	5	183	160	39			
				repts= 6	no individual data						1.5
	TOTALS			total=836	120	443	211	42			
				repts= 16	no individual data						1.9
C. Rappahannock River[4]											
1978	gill net	m	22%	total= 43		1	11	24	6	1	
				repts= ?	no data available						NA
		f	78%	total=149		1	34	102	12		
				repts= ?	no data available						NA
D. York River[4]											
1978	gill net	m	30%	total= 74			35	34	5		
				repts= ?	no data available						NA
		f	70%	total=172		1	39	123	9		
				repts= ?	no data available						NA

YEAR	GEAR TYPE	SEX	SEX RATIO	NO.	AGE CLASS III	IV	V	VI	VII	VIII	% REPEAT SPAWNERS
E. Pamunkey River[4]											
1978	gill net	m	17%	total= 30 repts= ?	1	1	9	17	2		 NA
					no data available						
		f	83%	total=149 repts= ?			36	101	12		 NA
					no data available						
F. James River[4]											
1978	gill net	m	28%	total= 39 repts= ?		1	12	26			 NA
					no data available						
		f	72%	total= 99 repts= ?		2	29	60	8		 NA
					no data available						
G. Albemarle Sound[4]											
1978	unkwn.	m	58	total=285 repts= 19	3	54	188	39	1		 6.7
					no individual data						
		f	42	total=205 repts= 11		9	110	78	8		 5.4
					no individual data						
	TOTALS			total=490 repts= 30	3	63	298	117	9		 6.1
					no individual data						

TABLE 7 - continued.

* fish was recorded as VII+ in original text (Minta. et al. 1980)

1 from Minta, et al. 1980

2 from Lofton 1979

3 from Lupine 1980

4 from Johnson, et al. 1978

TABLE 8. Mean fork length (cm) and length ranges by sex and age classes for American shad collected from the Connecticut and Delaware Rivers during 1979.

RIVER SYSTEM	YEAR	GEAR TYPE	SEX	VARIABLE	III	IV	V	VI	VII
Conn.[1]	1979	gill net	m	number	30	180	100	10	
				$\bar{x}$ length	39	43	46	48	
				range[2]	33-42	39-46	44-48	45-51	
			f	number	0	189	268	24	2
				$\bar{x}$ length		47	49	53	57
				range		40-50	45-52	50-55	55+
Del.[3]	1979	haul seine	m	number	115	260	51	3	
				$\bar{x}$ length	43	45	46	45	
				range	32-47	39-51	42-49	45-46	
			f	number	5	185	160	39	
				$\bar{x}$ length	45	49	50	51	
				range	43-48	43-54	43-55	47-58	

1 from Minta, et al. 1980

2 from Minta, personal communication

3 from Lupine 1980

FIGURE II. Length frequency distribution for male American shad collected in the Susquehanna System in 1980.

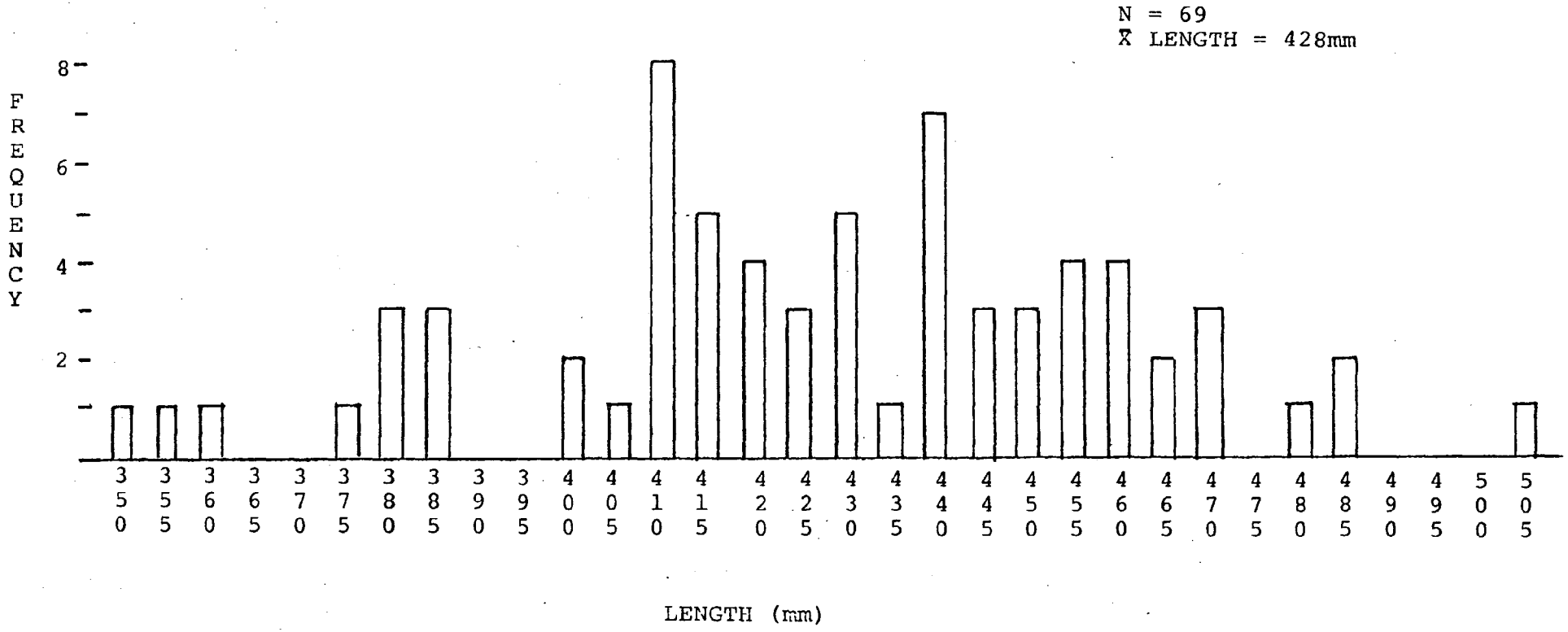
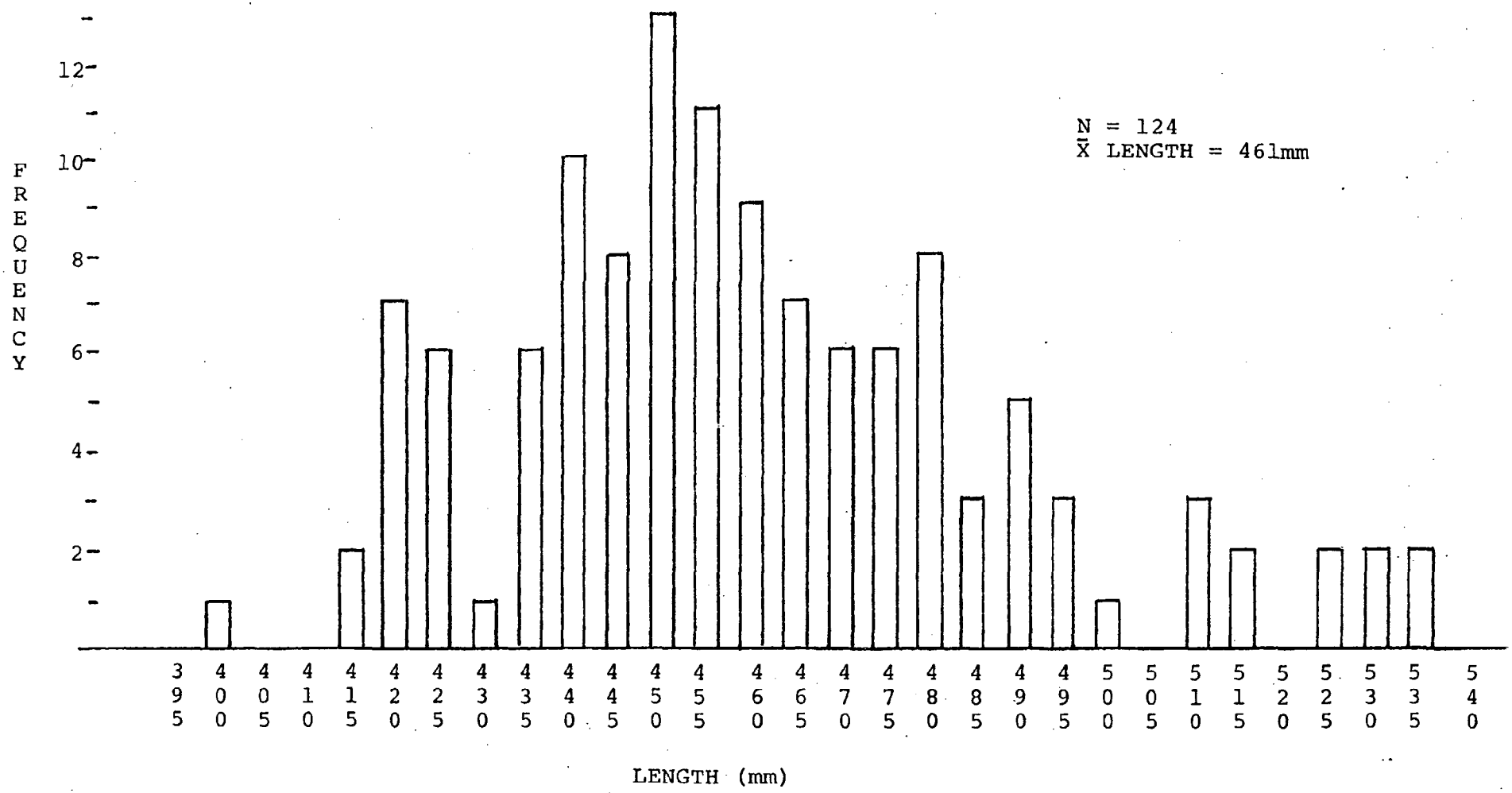


FIGURE III. Length frequency distribution for female American shad collected in Susquehanna System in 1980.



JOB III. SPORTFISHING SURVEY

INTRODUCTION

A non-uniform probability creel census (Pfeiffer 1966) was conducted from 3 May through 30 June 1980 in the area of the Susquehanna River from Conowingo Dam south to the river's mouth at Havre de Grace. The non-uniform probability sport angling survey makes use of prior fishing knowledge on a particular body of water, in this case the Susquehanna River (Whitney 1961, Carter 1973, RMC 1979). Selection of sampling probabilities, locations, and interview days and times is proportional to expected intensity as determined from these previous surveys. The non-uniform probability census also provides more reliable information with less expenditure of effort and money (Pfeiffer 1966). The purpose of this survey was to determine fishing pressure, catch per unit of effort, harvest, and catch composition. Data from this survey is compared with previous surveys (Carter, 1973; RMC, 1979) to assess trends that have taken place in the sport fishery of the lower Susquehanna River.

METHODS AND MATERIALS

Thirteen access points were utilized in the 1970 survey but the present survey dropped the Riverside site because of low fishermen usage (Fig. V). Probabilities for the twelve access points, time blocks, time units and associated sampling probabilities utilized in the 1980 survey are presented in Tables 9 and 10. The probabilities were the same as those used by RMC in 1979. The day and time probabilities were changed slightly to reflect the differences in fishing pressure during weekday holidays.

Interviews were conducted with fishermen who had completed their fishing trips during the assigned time interval at a

given access point. Anglers were canvassed concerning their mode of fishing, number in their party, state of residence, hours spent fishing, species catch composition and catch disposition. The survey questionnaire is presented as Figure VI. Observed angler catch was expanded using the assigned probabilities for day, time and location. The expanded values estimated number of anglers, angler hours, harvest (fish kept), and total catch for the Susquehanna River during the survey period.

Anglers were also asked their opinion of the possible construction of a fishway at the Conowingo Dam and of the 1980 American shad fishing closure.

RESULTS

A total of 314 party interviews, comprising 749 individual anglers, were conducted on 27 census days between 3 May through 30 June, 1980. Of these, 565 (75%) were Maryland residents and 184 (25%) nonresidents. The average party trip length was 5.0 hr with 2.5 anglers per party. Interviewed shore and boat anglers spent 3,668 hours fishing and caught 4,741 fish of 19 different species. Catch, harvest, and success rate data are presented in Table 11. Anglers kept approximately 40% of their total catch. The dominant species caught was white perch (Morone americana). Channel catfish (Ictalurus punctatus), striped bass (Morone saxatilis), and carp (Cyprinus carpio) were also commonly taken. Sixty-one percent of the carp caught were retained, and anglers kept twice as many striped bass as they released. However, twice as many white perch and channel catfish were released as were kept. American shad were released because of the closure of the commercial and sport shad fisheries by the Maryland Department of Natural Resources.

Catch per angler hour (CPUE) for selected species caught during this creel survey are found in Table 12. The CPUE for

white perch was 0.7375, while the CPUE for channel catfish and striped bass were 0.1892 and 0.1270, respectively. American shad CPUE was 0.0003.

Estimated harvest of fish kept for the survey period was 50,432 with nearly half consisting of white perch (Table 13). Striped bass comprised 18% of the estimated harvest while channel catfish and brown bullheads comprised 16.2% and 7.4%, respectively. The CPUE for boat fishermen was greater (1.38 fish caught per angler hour) than that experienced by shore anglers (1.21 fish caught per hour).

Of the 547 anglers responding to the opinion question, 68% favored construction of a fish ladder at Conowingo Dam while 30% had no opinion. Fifty-six percent of the anglers agreed with the imposed ban on commercial and sport fishing for American shad, while 38% offered no opinion.

DISCUSSION

Estimated sport fishing pressure in 1980 was similar to that observed in 1979 (RMC, 1979). There were 26,291 anglers in 1979 that fished 107,503 hours (Table 11). In 1980, the number of anglers (21,063) was 20% fewer than the previous year while the number of hours fished (109,764) increased by 21%. Susquehanna anglers caught 1.12 and 1.29 fish per hour during 1979 and 1980, respectively.

Estimated sport fishing pressure in 1970 was greater than in 1980 (Table11). There were fewer estimated anglers and less estimated fishing time expended in the present survey, but the success rate, a possible measure of angler satisfaction, was greater than that observed a decade earlier. There was a 62% decrease in hours fished between 1970 and 1980, and a 63% decrease in the number of anglers. However, the success rate for 1980 was 1.29, 38% greater than the 1970 survey success rate of 0.93.

Because sport anglers were required in 1980 to release all American shad caught, there was little data concerning sport angling for this species during the present survey. Only one shad was reported caught and subsequently released. It was rumored among anglers that more shad were taken from the Susquehanna River than were reported. However, there was no evidence to substantiate or refute this rumor. In 1970, the actual reported catch of American shad by sport anglers was 694. This comprised approximately 9% of the total sampled catch. In 1980, only one American shad was reported taken by hook and line which made up less than 1% of the entire sampled catch for this year.

Observed catch per angler hour (CPUE), and species composition, both observed and expanded, for white perch, striped bass, and channel catfish can be found in Tables 12 and 13.

Approximately half of all white perch landed by anglers were recorded from the Lapidum access point; 45% by boat anglers and 5% by bank fishermen. An additional 25% of the white perch landed were caught by shore anglers in Shures Landing. These percentages are not simply an artifact of sampling intensity or sampling probability. The boat angler CPUE was 1.46 white perch caught per hour at the Lapidum site, twice the total calculated CPUE for this species in the 1970 survey (Table 11). CPUE's for shore anglers at Lapidum and Shures Landing were 0.32 and 0.52 fish caught per hour, respectively. White perch CPUE for all sites experienced a 93% increase between 1970 and 1980, although there was a 15% decline in actual numbers of fish caught.

Forty-two percent of the striped bass were landed by bank fishermen utilizing Shures Landing. CPUE for striped bass at this site was 0.15 per hour. An additional 32% were caught by boat anglers (CPUE 0.17) who had launched from Lapidum. Catch per angler hour of striped bass in 1980 was approximately 214% and 147% greater than in 1970 and 1979, respectively. There were 3.1 striped bass caught per trip with 1.8 stripers

kept per angler per trip in the present survey. In 1979, only 0.3 striped bass were kept per angler per trip. For shore and boat anglers, respectively, striped bass success rates were 450% and 27% better than in 1979.

Seventy-six percent of the channel catfish caught during the present survey were caught by shore anglers at Shures Landing. The CPUE for channel catfish at this site was 0.40 fish caught per hour which was twice the CPUE calculated for this species for the present survey over all access points. The 1980 CPUE for channel catfish increased 219% over 1970 but decreased 27% since 1979. The boat angler success rate for channel catfish in 1980 was 0.06, a 65% decline from 1979, while the shore angler success rate for this species increased by 43% from 1979 to 1980.

SUMMARY

1. Seven hundred forty-nine individual anglers were interviewed on 27 census days between 3 May and 30 June.
2. Sampled anglers spent 3,668 hours fishing and caught 4,741 fish of 19 species.
3. The four most frequently caught species were white perch, channel catfish, striped bass, and carp.
4. An estimated 26,291 anglers fished 109,764 hours and harvested 50,432 fish from the Susquehanna River.
5. Only one American shad was reported caught during the 1980 creel survey.

Table 9. Access points and comparison of associated sampling probabilities for the lower Susquehanna River Creel surveys, 1970, 1979, and 1980.

Access Point	1970 May-June Probability	1979 Probability	1980 Probability
1. Shures Landing	0.16	0.17	0.17
2. Mouth of Deer Creek	0.03	0.03	0.03
3. Susquehanna State Park	0.05	0.03	0.03
4. Lapidum	0.30	0.32	0.32
5. Baldwins Dock	0.05	0.03	0.03
6. Tidewater Marina	0.03	0.02	0.05
7. Penn's Beach Marina	0.05	0.05	0.05
8. Tydings Park Marina	0.05	0.05	0.05
9. Riverside*	0.01	0.01	0.01
10. Spanglers Rock Run Marina	0.05	0.09	0.09
11. Port Deposit Marina	0.05	0.04	0.04
12. Logan's Wharf	0.11	0.11	0.11
13. Owens Fish House	0.06	0.05	0.05

*site dropped because of low fishermen usage.

Table 10. Time blocks, time units and associated sampling probabilities for creel census of lower Susquehanna River, May-June, 1980

Day	Time Block	Time Unit	Sampling Probability
Sunday	A	0800-1200	0.10
		1200-1600	0.50
		1600-2000	0.40
			1.00
Monday	B	0800-1200	0.02
		1200-1600	0.04
		1600-2000	0.07
Tuesday		0800-1200	0.02
		1200-1600	0.05
		1600-2000	0.12
Wednesday		0800-1200	0.02
		1200-1600	0.09
		1600-2000	0.11
Thursday		0800-1200	0.03
		1200-1600	0.05
		1600-2000	0.16
Friday		0800-1200	0.02
		1200-1600	0.04
		1600-2000	0.16
			1.00
Saturday	C	0800-1200	0.10
		1200-1600	0.50
		1600-2000	0.40
			1.00

Table 11. Comparison and characterization of data collected from the 1970, 1979, and 1980 Susquehanna River Sport Fishing Surveys.

A. NON-EXPANDED TOTALS	1970	1979	1980
Survey Dates	3/28-6/21	4/28-6/30	5/3-6/29
No. of Interview Days	34	29	27
No. of Anglers Interviewed	1,607	937	749
No. of Hours Fished	8,314	3,462	3,668
Mean Trip Length	5.17	4.10	5.03
Total Catch (in numbers of fish)	7,738	3,886	4,741
No. of Fish Kept (Harvest)	4,705	1,575	2,030
No. of Fish Released	3,033	2,311	2,711
No. of Fish Caught per Hour (success)	0.93	1.12	1.29
No. of Maryland Residents/ Non-residents	818/789	750/187*	565/184
B. EXPANDED TOTALS			
Total Anglers	56,977	26,291	21,062
Total Hours Fished	291,510	107,530	109,764
Total Harvest	205,280**	48,914	50,432
Total Catch	337,611	N/A	129,611
Trips	56,384	26,226	21,821

*Obtained by taking 80% of anglers interviewed (RMC 1979, p. 3).

**Obtained by multiplying the estimated total fish caught by the ratio of numbers of fish kept to total fish caught.

TABLE 12. Catch per angler hour for selected species caught during the 1970, 1979 and 1980 Susquehanna River Sport Fishing Surveys.

SPECIES	1970 CPUE[1]	1979 CPUE[2]	1980 CPUE
Morone americana	0.3830	0.6912	0.7375
Morone saxatilis	0.0404	0.0517	0.1270
Alosa pseudoharengus/ A. aestivalis	0.2609	0.0295	0.0016
Alosa sapadissima	0.0835	0.0043	0.0003
Ictalurus punctatus	0.0593	0.1944	0.1892

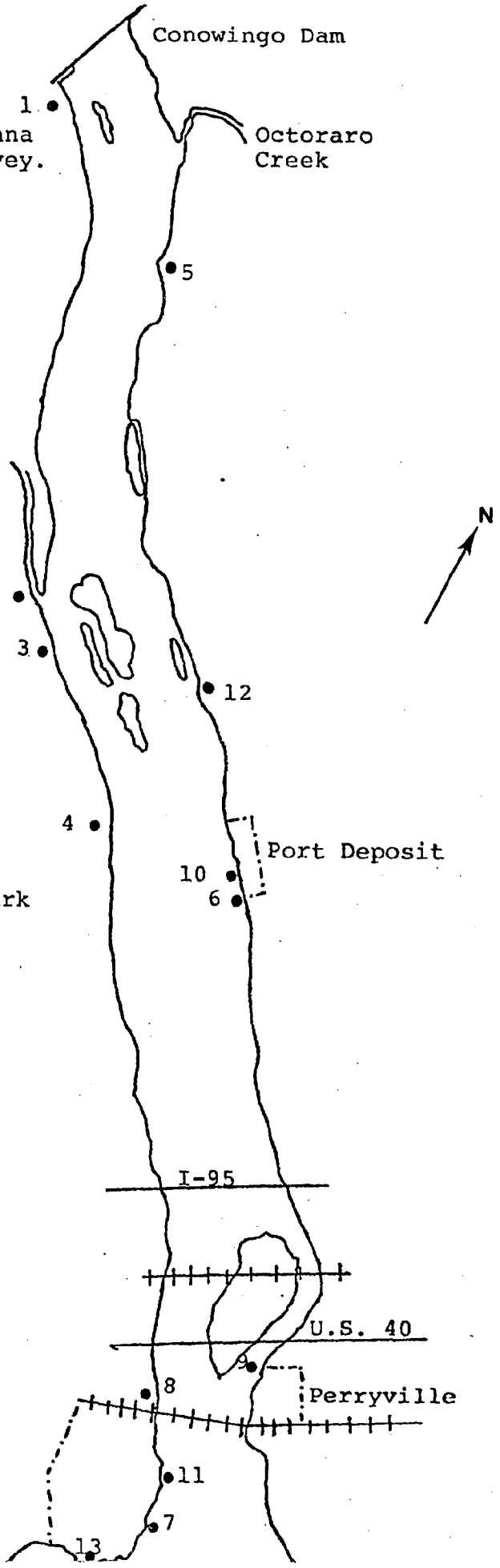
1. From Carter 1973.

2. From RMC 1979.

TABLE 13. Comparison of the species composition and harvest of finfish caught by sport anglers during the 1979 and 1980 Susquehanna River Sport Fishing Surveys.

Species	No. Kept		No. Released		Total Caught		Estimated Harvest		Percent of Est. Harvest	
	1979	1980	1979	1980	1979	1980	1979	1980	1979	1980
Morone americana	864	1,051	1,529	1,654	2,393	2,705	26,833	23,739	54.9	47.1
Ictalurus punctatus	356	276	317	418	673	694	11,056	8,184	22.6	16.2
Ictalurus nebulosus	-	120	-	146	-	266	-	3,724	-	7.4
Cyprinus carpio	108	193	96	80	204	273	3,354	3,267	6.9	6.5
Morone saxatilis	59	278	120	188	179	466	1.832	8,991	3.7	17.8
Alosa pseudoharengus/ A. aestivalis (combined)	48	0	54	6	102	6	1,491	0	3.0	0.0
Dorosoma cepedianum	47	17	56	54	103	71	1,460	265	3.0	0.5
Micropterus dolomieui	16	33	47	27	63	60	497	601	1.0	1.2
Perca flavescens	14	26	23	50	37	76	435	211	0.9	0.4
Alosa sapidissima	13	0	2	1	15	1	404	0	0.8	0.0
Pomoxis spp.	13	6	8	37	21	43	404	104	0.8	0.2
Lepomis macrochirus	8	11	12	15	20	26	248	535	0.5	1.1
Anguilla rostrata	7	2	25	6	32	8	217	91	0.4	0.2
Other spp.	22	17	22	29	44	46	683	720	1.4	1.4
TOTALS	1,575	2,030	2,311	2,711	3,886	4,741	48,914	50,432	99.9	100.0

FIGURE V. Interview sites for 1980 Susquehanna River Sport Fishing Survey.



1. Shure's Landing
2. Mouth of Deer Creek
3. Susquehanna State Park
4. Lapidum
5. Riverside*
6. Logan's Wharf
7. Penn's Beach
8. Baldwin's Dock
9. Owen's Fish House
10. Port Deposit Marina
11. Tidewater Marina
12. Spangler's Rock Run
13. Tydings Park Marina

* Dropped site.

FIGURE VI. INTERVIEW FORM FOR 1980 SUSQUEHANNA RIVER SPORT FISHING SURVEY.

1. Interviewer Code (1-2)

2. Month/Day/Year (3-8)

3. Site Code (9-10)

4. Total Number of Anglers Leaving Site (11-13)
(both those interviewed and not interviewed)

5. Interview Number (14-15)

6. Mode (16)

Boat, rod = 1

Bank, rod = 2

Dipnet = 3

7. Number of People in Party (17-18)

8. State of Residence (19-20)

Maryland	= MD
Pennsylvania	= PA
Delaware	= DL
Virginia	= VA
District of Columbia	= DC
Other	= OT

9. Party Hours Fished (21-22)

FIGURE VI, con't.

10. Catch Information: Species
Species code (see code sheet)
Disposition
Kept = 1
Thrown back = 2
Used for bait = 3
Number of fish for each disposition type

Species	Species Code	Disposition	No. of Fish	
_____	☐☐	☐	☐☐	(23-27)
_____	☐☐	☐	☐☐	(28-32)
_____	☐☐	☐	☐☐	(33-37)
_____	☐☐	☐	☐☐	(38-42)
_____	☐☐	☐	☐☐	(43-47)
_____	☐☐	☐	☐☐	(48-52)
_____	☐☐	☐	☐☐	(53-57)
_____	☐☐	☐	☐☐	(58-62)
_____	☐☐	☐	☐☐	(63-67)
_____	☐☐	☐	☐☐	(68-72)

11. Opinion of Fish Ladder at Conowingo Dam ☐ (76)
For = 1
Against = 2
Don't care = 3

12. Opinion of White Shad Fishing Closure ☐ (80)
For = 1
Against = 2
Don't care = 3

JOB IV. JUVENILE RECRUITMENT SURVEY

INTRODUCTION

Numerous authors have noted a possible significant relationship between numbers of juvenile American shad and the numbers of spawning adults three to five years later (Chittenden 1975, Marcy 1976, Minta, Crecco, and Jacobs 1980). Chittenden (1975) investigated year class strengths by studying age and sex composition data and comparative run sizes for adult populations of Delaware River American shad between 1963 and 1965. He back-calculated by age class to determine the year class which exerted the greatest influence on the adult population for a particular year. Marcy (1976) collected juvenile American shad from the Connecticut River and calculated their yearly abundance between 1967 and 1973. He then developed an equation which indicated a significant relationship between juvenile shad, adults potentially available to spawn, water temperature, and river flow. Marcy stated that this equation could be successfully used to predict juvenile shad production in a particular year. From data derived by Marcy (1976), Minta, et al. (1980) regressed the realtive young-of-the-year and adult abundances of Connecticut River American shad and noted a strong positive correlation indicating year class strength is established before the juvenile stage. From further analysis of Marcy's 1965-72 juvenile index data and corresponding numbers of age V virgin females collected between 1970 and 1977, Minta also noted the apparent influences that the juvenile year classes exerted upon yearly abundances of adult American shad. He concluded that relative young-of-the-year abundances could be a useful management tool in forecasting adult year class strength five years in advance. Management strategies can be developed from a historic data base; therefore, beginning in 1979 an extensive juvenile recruitment survey was initiated in the Susquehanna River, Susquehanna Flats, and Northeast Rivers to provide an adequate

juvenile data base for developing management policies for Maryland shad stocks.

METHODS AND MATERIALS

To measure the spawning success of clupeid species at the head-of-Chesapeake Bay during 1980 a detailed young-of-the-year sampling survey was conducted on the Susquehanna River, Susquehanna Flats, and Northeast River. Sampling was carried out on a bi-weekly schedule from late June through October (Table14).

Ten shallow water shore sites were sampled with one of two different haul seines during each sampling period. At seven locations below Port Deposit, a 200'x10'x1/2" stretch mesh haul seine was set by boat in a semi-circular shape. The area swept by this seine set was calculated to be 0.0591 hectares. Because of the rocky nature of the Susquehanna River above Port Deposit, the three upper river sites had to be sampled with a 100'x6'x1/2" stretch mesh haul seine. The corresponding area swept by this gear, also set in a semi-circular shape, was calculated to be 0.0148 hectares. Locations and descriptions for each seine site can be found in Figure VII and Table 15, respectively.

Six open water sampling stations were established in the Susquehanna Flats and Northeast River as close to their corresponding seine sites as water depths and the presence of bottom snags would permit (Figure VII, Table15). Open water sampling was done with a modified 16' headrope semi-balloon shrimp (otter) trawl with 1/2" stretch mesh open end, 1 1/2" stretch mesh cod end, and 1/2" stretch mesh cod end liner. The area swept by this gear was calculated as:

$$\frac{3.0175\ m^{*} \times \text{trawl run length (m)}}{10{,}000\ m^2} = \text{area swept in hectares}$$

*3.0175 m = effective trawl mouth opening

Starting and stopping points for each run were determined from compass sightings of nearby fixed shore and navigational structures. Appropriate compass bearings are found in Table 16.

Trawl and seine samples were collected nearly simultaneously with replicate seine pulls and trawl runs made at each station per sampling period except where precluded by inclement weather or equipment failure. Tables 17, 18, 19, and 20 present sampling effort data by site and period for all gear types.

RESULTS

A total of 182 seine hauls and 101 trawl runs were made at sampling stations on the Susquehanna River, Susquehanna Flats, and Northeast River from 24 June through 31 October 1980. This effort captured 44,321 fish of 33 species (Table 21). Numbers and weights for each species caught by gear type by period and station are presented in Tables 23through 29.

Calculations of standing crop arranged by period and station for each gear type for all species combined are detailed in Tables 30, 31, 32, and 33. Of note -

1. Standing crop for haul seine effort was greatest
   - during Periods II and VII for number and weight per unit area, respectively
   - at Station 2 for both number and weight per unit area
2. Standing crop for otter trawl effort was greatest
   - during Period V for both number and weight per unit area
   - at Station 2 for both number and weight per unit area
3. For the six common seine and trawl stations mean standing crop
   - was 49% greater (#/ha) for haul seine vs. otter trawl captures
   - was 18% greater (kg/ha) for otter trawl vs. haul seine captures

4. For the nine common seine and trawl sampling periods mean standing crop
   - was 40% greater (#/ha) for haul seine vs otter trawl captures
   - was 39% greater (kg/ha) for otter trawl vs haul seine captures

Young-of-the-year catch and catch per unit of effort for four important commercial and sport species, blueback herring (Alosa aestivalis), alewife herring (Alosa pseudoharengus), striped bass (Morone saxatilis), and white perch (Morone americana), by gear type, sampling period, and station are presented in Tables 34 and 35. General trends indicated by this data were:

1. The haul seine caught more juvenile alewife and blueback herring and striped bass than the otter trawl.
2. A large total catch and catch-per-unit-of-effort (CPUE) of young-of-the-year herring and striped bass by one gear type was generally not accompanied by a corresponding large catch by the other gear type.
3. The haul seine captured young-of-the-year blueback herring, striped bass, and white perch in all sampling periods except X.
4. Of the four species, only juvenile striped bass were captured upstream from Station 6.

In the Susquehanna River, standing crop calculations (numbers/ha only) by gear type, period, and station for these four species are presented in Tables 36 and 37. Each of these four species were generally more prevalent during the middle sampling periods. Both young-of-the-year blueback and alewife herring were more abundant at one particular station (Wild Duck Cove and Camp Rodney, respectively) while juvenile striped bass and white perch were concentrated in at least three different sampling locations.

No young-of-the-year American or hickory shad were captured during the 1980 Juvenile Recruitment Survey. However, a yearling

American shad was captured by otter trawl at Havre de Grace, Station 6 on 22 July 1980.

Of the 302 juvenile herring captured by haul seine, 64% (194) were alewife. The species ratio for otter trawl captures was 58% (38) alewife and 42% (27) blueback herring. Haul seine catches of blueback herring indicated a bi-modal capture distribution, for both total numbers caught and CPUE, with peaks in Periods I and VII/VIII (Figure VIII, Table 34). Following Period I, otter trawl catches of bluebacks, however, were greatly reduced (Figure IX, Table 34). Haul seine and otter trawl catches of alewife herring were concentrated more during the survey's middle periods, peaking in Period V for haul seine and Period VI for otter trawl captures (Figures VIII and IX, Table 34). Site specificity for haul seine catches of both herring species was also noted (Figures X and XI, Table 35). Station 4 had 66% of all alewife herring haul seine catches while Station 1 had 46% of all blueback herring captured by this gear type. Site specific differences in trend of catch by otter trawl for both species were less obvious due to the small numbers captured, although alewives appeared to be more evenly distributed over the open water stations than bluebacks.

DISCUSSION

No young-of-the-year American shad were captured during the 1980 juvenile survey. The failure of the two gear types employed to capture any juvenile shad could be due to a number of factors. These include poor sampling techniques (i.e., poor timing, improper sampling locations, etc.), insufficient sampling, and a general recruitment failure.

With regard to the first two, poor sampling techniques and inadequate sampling, the sampling design for the 1980 survey was based upon a study carried out in the late 1960's by Carter (1973) in the same Susquehanna region. Carter's conclusions

were that the sampling techniques and gear he used were effective in capturing juvenile American shad. Data gathered over the past twenty-two years by the Maryland Estuarine Fish Recruitment Survey, Federal Aid Project F-27-R-6, show that no young-of-the-year American shad have been captured from any of ten upper Bay stations since 1972 (Boone 1980). Four of these ten sites are located close to four of the 1980 survey sites. Boone found that prior to 1972, juvenile shad were frequently taken by haul seine and that catch rates had been as high as 17 juveniles per haul during years of good reproduction. During 1980, the Maryland Anadromous Fish Stream Survey Program (AFC-8) conducted extensive sampling in the Susquehanna area with a bow-mounted push trawl. This apparatus, developed by the Virginia Institute of Marine Science has proved successful in collecting juvenile American shad in Virginia waters (Kriete and Loesch 1980). Push trawl sampling on the Susquehanna was initiated in June and continued through September on a tri-weekly basis. All sampling was conducted at night. No young-of-the-year American shad were collected by this gear during 1980 although two juvenile hickory shad were captured at Station 4, Port Deposit, during June (MTA infile data).

It appears that the 1980 sampling in the Susquehanna region by these various projects was adequate in both technique and magnitude to note the presence of juvenile American shad. The lack of juveniles, then, is the result of a near total recruitment failure during the 1980 spawning season. This failure to reproduce may be the result of certain chemical, physical, and biological conditions, some of which are briefly discussed below.

Chemical contaminants from nearby locations and upstream in the Susquehanna watershed may derive from urban non-point source runoff, agricultural runoff, and sewage treatment plant (STP) discharges, particularly chlorine. Colston (1974) found that COD and BOD from urban non-point sources averaged 91% and 67%, respectively, that of raw sewage. He also noted that

concentrations of heavy metals were from two to fifty times greater than in raw sewage. Increased sedimentation as a result of greater agricultural and urban land use can be highly detrimental to fish eggs. Morgan et al. (1973) found that only 0.5 to 1.0 mm of sediment cover caused greater than 50% mortalities in white perch eggs and that 1.2 mm of deposited sediment resulted in 100% mortality. Concerning chlorine, Middaugh et. al. (1977) found that larval development in striped bass, white perch and blueback herring was inhibited by increased chlorine concentrations; the length of larval fish hatched decreased, and that the incidence of larval deformities also increased with increases in chlorine concentrations. A delay in hatching or a change in the number of eggs hatching or nearing hatch may be very detrimental to a larval population. A delay in hatching may cause changes in the distribution and density of larvae both in time and space, plus a possible desynchronizing of larval food availability. Deformed larvae are less able to capture food or avoid predation. In an attempt to mitigate some of these problems the Maryland Departments of Natural Resources and Health and Mental Hygiene have selected certain STP's in the upper Chesapeake Bay and asked that their chlorine discharges be reduced or eliminated during the spring spawning season.

A number of biological factors may be adversely affecting American shad reproduction. Contamination of the eggs and milt by pesticides, heavy metals, and PCB's through accumulation in the adults could result in abortion/reabsorption of eggs, production of non-fertile eggs and milt, and deformities in eggs and larvae. During 1979 the Maryland Department of Health and Mental Hygiene analyzed body tissue and gonadal samples from six adult American shad taken from the Susquehanna River. This testing showed generally low levels of metals, pesticides, or PCB's in either flesh or reproductive organs (MTA infile data). Also during 1979, in a controlled lab experiment, Susquehanna River shad eggs were artificially fertilized to determine egg viability and hatching success. Examination of both fertilized eggs and developing

larvae revealed no discernable physical deformities that suggested gonadal deficiencies. Although these data are not conclusive, they suggest that reproductive organ failure is not the major factor contributing to the lack of recruitment.

A second biological factor to consider is the problem of drastically reduced spawning stocks in the upper Bay area. Leggett (1969) estimated that survival for American shad from egg to adult was approximately one in 100,000 indicating tremendous mortality for eggs and larvae. Since 1974 the commercial catch of adult American shad from the Susquehanna area dropped precipitously (Table 38) resulting in the closure of the shad fishing season for 1980. The decline in spawning stock size, as indicated by declining commercial catch, was also mirrored by the juvenile survey work of Boone (1980) and this current study. These two trends are strong indications that the number of juveniles produced by the remaining adult stocks in the Susquehanna area are not sufficient to replace individuals lost to both natural and man-induced mortalities.

Conowingo Dam at river mile 10 physically affects reproduction of American shad in several ways.

1. The area available for finfish spawning in the Susquehanna River is severely limited. Prior to the dam's completion in 1928, other dams along the river periodically restricted shad migration which historically had been as far as Binghamton, New York at river mile 218. By contrast, the Connecticut River with fish passage facilities at both Holyoke and Turners Falls Dams has 120 miles of river open for spawning, while the Delaware has approximately 270 river miles available.

2. Conowingo Dam is designed as a peaking plant, with the volume of water discharged constantly changing depending upon power demand and available water. Because

of this change in demand water depths may fluctuate as much as 15 feet while river flow may range from 0 to 86,000 cfs. These drastic fluctuations create unstable and unsuitable spawning habitat and conditions. Also, reduced flows have led to dissolved oxygen depletions which have resulted in four major fish kills and numerous minor ones below the dam since 1965.

Either of these conditions could be causative factors in the reproductive failure of American shad in the Susquehanna Region and because of the possible interrelationships behind them elimination of one may not solve this problem.

During 1979, a preliminary juvenile recruitment survey was conducted in the head-of-the-Bay region with haul seine only. This sampling utilized the same ten stations as the 1980 survey, with each station being checked every two weeks. The 1979 survey, however, encompassed only six sampling periods, resulting in 115 seine hauls or 67 less than the following year. All other sampling techniques and equipment were identical for both year's work. Results of the 1979 survey appear in Tables 39 through 44.

The 1979 seine survey captured three juvenile American shad during the six sampling periods. Young-of-the-year were captured at the Cara Cove (#3) and the Camp Rodney (#4) stations on 7/24/79 and at the Robert Island station (#9) on 8/24/79. Catch per haul was calculated as 0.03. No juvenile American shad were captured during the 1980 survey.

Catch in 1980 of juvenile blueback and alewife herring was markedly different from the 1979 catch. The total seine catch of alewife in 1980 was 194 as compared to only 18 in 1979, a 10.4 fold increase. Catch per seine haul in 1980 was 1.07 as opposed to only 0.16 in 1979, a 669% increase. For bluebacks, however, the total catch and catch per haul decreased in 1980; total catch was down by 244 individuals (326%) and catch per haul was down from 3.06 to 0.59 fish per haul, a five fold decrease. The large increase in the alewife

herring juvenile CPUE in 1980 could have been due to the increase in numbers of yoy over 1979 (Tables 43 and 44).

Total catch and catch per unit effort for juvenile striped bass was down in 1980, with 33% fewer juveniles being captured. Catch by site for both numbers and rate were greatest at Station 1 during both years.

Data for juvenile white perch captures (Tables 43 and 44) indicated that even though 672 more young-of-the-year were taken in 1980, catch per haul in 1979 was 21.3 while catch per haul for 1980 was 22.1. This indicated similar young-of-the-year populations in both years. The greatest numbers were captured from late August until the end of the survey during both years. Similarity in juvenile captures by site was also noted for the two years with the greatest numbers and highest rates occurring at Station 2.

Data gathered by Carter (1973) in 1968 and 1969 provides an adequate data base from which to note changes in the clupeid catch. Procedures and techniques used by Carter for his earlier survey were utilized during 1980. Of the 12 sites sampled in 1968-69, seven sites were resurveyed in 1980. These common sites are listed below:

NAME	SITE CODE 68-69	1980
Wild Duck Cove	12	1
Seneca Point	9	2
Cara Cove	8	3
Camp Rodney	7	4
Fishing Battery	3	5
Tydings Park	2	6
Quarry	1*	7*

*haul seine only.

Summation and comparison of the seven common sampling stations for the two surveys noted that-

1. Additional computations from Carter 1973, Table 53, page 61, indicated that a total of 281 young-of-the-year shad were captured by haul seine in 1969* and that 95 were collected by otter trawl during 1968/1969. During this study, juvenile shad were taken by haul seine at two sampling stations, Cara Cove and the Quarry. Otter trawl captures of young-of-the-year American shad for 1968/1969** were from four different locations; Cara Cove, Camp Rodney, Battery Island, and Tydings Park. Estimates for standing crop of juvenile shad by gear type derived from Carter (1973, Table 53, page 61) were 103/ha for haul seine and 4/ha for otter trawl samplings. No juvenile American shad were captured during 1980.

2. During the 1968 and 1969 samplings (Carter, 1973, Table 53, page 61) a total of 233 and 1,476 young-of-the-year alewife herring were captured by haul seine and otter trawl, respectively. Alewife herring were captured at five of the seven seine sites and at all six otter trawl stations. Standing crop, derived from Carter's data (Table 53, page 61) for alewives was calculated to be 86/ha for haul seine in 1969 and 66/ha for otter trawl captures during 1968/1969. In 1980, 194 and 38 juvenile alewife herring were collected by the same two gear types respectively. Calculated standing crop for haul seine was 23/ha and 1.4/ha for otter trawl. During 1980 this species was collected at four sites by seine and at five sites by trawl.

---

* haul seine data for 1969 only

** 1968 and 1969 otter trawl data combined

3. For blueback herring, Carter (1973, Table 53, page 61) collected a total of 5,281 by haul seine in 1969 and 520 by otter trawl for both years combined. Bluebacks were collected at all surveyed stations by both gear types during the earlier survey. Standing crops calculated for the 1969 seine haul captures was 1,944/ha and 23/ha for the 1968/1969 otter trawl. The 1980 seine sampling captured 108 young-of-the-year blueback herring from five different stations while the otter trawl collected 27 from three separate sites. Numbers per hectare in 1980 were calculated to be 13 and 1 for haul seine and otter trawl captures, respectively.

Comparisons of the results of these two surveys indicate a drastic decline in abundance of American shad, alewife and blueback herring during the 1970s (Table 45). The magnitude and severity of this decline is also mirrored by the commercial catch of these three species from the Northeast and Susquehanna Rivers and the Susquehanna Flats combined for the previous 12 years (Table 38). The numbers of American shad upper bay brood stock may continue to decrease simply because there are not enough recruits to replace dying adults. This condition will necessitate further intensive management to insure that the number of mature adults does not fall below a level where natural recovery is impossible, a level that may have already been attained.

SUMMARY

1. One hundred eighty-two seine hauls and 101 trawl runs were made at 10 seine and six trawl stations on the Susquehanna River/Flats and Northeast River. There were 44,321 fish of 35 species captured.
2. No young-of-the-year American shad were captured in 1980.
3. Among the 35 species captured, juveniles from four important commercial and sport species were represented; blueback and alewife herrings, striped bass, and white perch.

4. Comparisons with previous studies indicate drastic declines in total numbers and standing crop of juvenile American shad and alewife and blueback herrings in the Head-of-the-Bay between the late 1960's through 1980.

TABLE 14. Sampling periods during the 1980 Juvenile Recruitment Survey.

SAMPLING PERIOD	DATES
Period I	June 23, 24, 25, July 1
Period II	July 7, 11, 12
Period III	July 21, 22, 23
Period IV	August 4, 5, 6
Period V	August 18, 19, 20
Period VI	September 2, 3, 4
Period VII	September 17, 18, 19
Period VIII	October 1, 2, 3
Period IX	October 15, 16, 17
Period X	October 30, 31

TABLE 15. Station numbers, names, locations, and mode of sampling during the 1980 Juvenile Recruitment Survey.

STATION No.	Name	SAMPLING MODE	LOCATION
1	Wild Duck Cove	seine & trawl	Susquehanna Flats
2	Seneca Point	seine & trawl	Northeast River
3	Cara Cove	seine & trawl	Northeast River
4	Camp Rodney	seine & trawl	Susquehanna Flats
5	Battery Island Spoil Island #1	trawl only seine only	Susquehanna Flats
6	Tydings Park	seine & trawl	Susquehanna Flats
7	Quarry	seine only	Susquehanna River
8	Spencer Island	seine only	Susquehanna River
9	Robert Island	seine only	Susquehanna River
10	Spangler's Rock Run	seine only	Susquehanna River

TABLE 16. Trawl station number, name, location, and compass bearings[1] during the 1980 Juvenile Recruitment Survey.

SITE #	STATION NAME & LOCATION	COMPASS BEARINGS (in degrees magnetic) Point of Reference	Start	Finish
1	Wild Duck Cove, Susq. Flats	Stump Pt. water tank	290	290
		Concord Pt. Lighthouse	274	272
		Carpenter Point	155	136
2	Seneca Pt., Northeast River	Microwave Tower	96	102
		311 Fire Tower	132	140
		Carpenter Point	205	218
3	Cara Cove, Northeast River	Red Flasher #6	264	222
		Red Marker #8	352	40
		Black Can #7	305	258
		Microwave Tower		60
		311 Fire Tower		110
4	Camp Rodney, Susq. Flats	Red Nun #4	12	257
		Red Channel Marker #2	210	206
5	Battery Island, Susq. Flats	Plum Pt. water tank	264	252
		Concord Pt. Lighthouse	7	12
6	Tydings Park, Susq. Flats	Concord Pt. Lighthouse	4	355
		Perryville Elev. water tank	33	39
		Black Can #15	190	192

1. Refer to NOAA National Ocean Survey Chart #12274, "Head of Chesapeake Bay"

TABLE 17. Number of seine hauls and trawl runs by period and site during the 1980 Juvenile Recruitment Survey.

A. Effort By Period

	No. of Hauls/Runs by Period									
Period	I	II	III	IV	V	VI	VII	VIII	IX	X
seine	20	20	20	20	20	20	18	18	18	14
trawl	12	11	11	9	12	12	11	11	12	0

B. Effort By Site

	No. of Hauls/Runs by Site									
Site	1	2	3	4	5	6	7	8	9	10
seine	20	20	20	20	20	20	20	10	16	16
trawl	17	18	17	13	18	18	0	0	0	0

TABLE 18. Number of hauls and area swept by haul seine for each sampling period during the 1980 Juvenile Recruitment Survey.

LOCATION	NO. OF HAULS	AREA SWEPT/HAUL (hectares)	TOTAL AREA SWEPT (hectares)
Period I	14	0.0591*	
	6	0.0148**	0.9162
Period II	14	0.0591	
	0	0.0148	0.8274
Period III	14	0.0591	
	6	0.0148	0.9162
Period IV	14	0.0591	
	6	0.0148	0.9162
Period V	14	0.0591	
	6	0.0148	0.9162
Period VI	14	0.0591	
	6	0.0148	0.9162
Period VII	14	0.0591	
	4	0.0148	0.8866
Period VIII	14	0.0591	
	4	0.0148	0.8866
Period IX	14	0.0591	
	4	0.0148	0.8866
Period X	14	0.0591	
	0	0.0148	0.8274
		Total	= 8.8956

* area swept by 200 ft. seine
** area swept by 100 ft. seine

TABLE 19. Area swept by otter trawl for each sampling period by site during the 1980 Juvenile Recruitment Survey.

PERIOD	AREA SWEPT BY SITE (ha) 1	2	3	4	5	6	TOTAL AREA SWEPT (ha)
I	0.4414	0.4690	0.5518	0.6070	0.5518	0.5518	3.1728
II	0.4414	0.4690	0.5518	0.3035	0.5518	0.5518	2.1728
III	0.2207	0.4690	0.5518	0.6070	0.5518	0.5518	2.9521
IV	0.4414	0.4690	0.2759	0.0000	0.5518	0.5518	2.2899
V	0.4414	0.4690	0.5518	0.6070	0.5518	0.5518	3.1728
VI	0.4414	0.4690	0.5518	0.6070	0.5518	0.5518	3.1728
VII	0.4414	0.4690	0.5518	0.3035	0.5518	0.5518	2.8693
VIII	0.4414	0.4690	0.5518	0.3035	0.5518	0.5518	2.8693
IX	0.4414	0.4690	0.5518	0.6070	0.5518	0.5518	3.1728
X	--	--	--	--	--	--	--

TOTAL = 26.5411

TABLE 20. Area swept by haul seine and otter trawl, number of hauls taken and trawl runs completed, and total area swept by site during the 1980 Juvenile Recruitment Survey.

LOCATION	NO. OF HAULS	AREA SWEPT (ha)	TOTAL AREA SWEPT (ha)
A. Haul Seine			
Site 1	20	0.0591	1.1820
Site 2	20	0.0591	1.1820
Site 3	20	0.0591	1.1820
Site 4	20	0.0591	1.1820
Site 5	20	0.0591	1.1820
Site 6	20	0.0591	1.1820
Site 7	20	0.0591	1.1820
Site 8	10	0.0148	0.1480
Site 9	16	0.0148	0.2368
Site 10	16	0.0148	0.2369
			TOTAL = 8.8956
B. Otter Trawl			
Site 1	17	0.2207	3.7519
Site 2	18	0.2345	4.2210
Site 3	17	0.2759	4.6903
Site 4	13	0.3035	3.9455
Site 5	18	0.2759	4.9662
Site 6	18	0.2759	4.9662
			TOTAL = 26.5411

TABLE 21. Species caught during the 1980 Juvenile Recruitment Survey.

SCIENTIFIC NAME	COMMON NAME
Alosa aestivalis	Blueback herring
Alosa pseudoharengus	Alewife herring
Alsoa sapidissima	American shad
Anchoa mitchilli	Bay anchovy
Anguilla rostrata	American eel
Brevoortia tyrannus	Atlantic menhaden
Carassius auratus	Goldfish
Carpiodes cyprinus	Quillback
Cyprinus carpio	Carp
Dorosoma cepedianum	Gizzard shad
Etheostoma olmstedi	Tesselated darter
Fundulus diaphanus	Banded killifish
Fundulus heteroclitus	Mummichog
Hybognathus nuchalis	Silvery minnow
Hypentilium nigricans	Northern hogsucker
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Leiostomus xanthurus	Spot
Lepomis auritus	Redbreasted sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish

TABLE 21 , con't.

SCIENTIFIC NAME	COMMON NAME
Membras martinica	Rough silverside
Menidia beryllina	Tidewater silverside
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Morone americana	White perch
Morone saxatilis	Striped bass
Notropis hudsonius	Spottail shiner
Notropis spilopterus	Spotfin shiner
Perca flavescens	Yellow perch
Pomatomus saltatrix	Bluefish
Pomoxis nigromaculatus	Black crappie
Strongylura marina	Atlantic needlefish
Trinectes maculatus	Hogchoker

TABLE 22. Species and numbers of individual finfish collected by haul seine during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS										TOTALS
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Alosa aestivalis	21	9	5	1	3	6	36	25	2		108
Alosa pseudoharengus	3	27	39	38	46	36	18	7			214
Alosa sapidissima											0
Anchoa mitchilli		2			3		21	181	4	2	213
Anguilla rostrata	3	3	6	2	3	8	2	3			30
Brevoortia tyrannus		2,097	588	252	227	40	755	986	74	328	5,347
Carassius auratus											0
Carpiodes cyprinus											0
Cyprinus carpio	4	6	1		4	2	5	1			23
Dorosoma cepedianum	4	5	44	101	1,051	35	246	214	31	981	2,712
Etheostoma olmstedi				1	3	9	6	14	36	10	79
Fundulus diaphanus	4		1			36	7	10	5	4	67
Fundulus heteroclitus	2	12	4	11	4				2	3	38
Hybognathus nuchalis	1				2	1					4
Hypentelium nigricans			1	1				1			3
Ictalurus nebulosus				1							1
Ictalurus punctatus	4	8	5	13	8	44	8	3	2		95
Leiostomus xanthurus	1		2	5	71	13	55	87			234
Lepomis auritus					2						2
Lepomis gibbosus		3	9	6	9	14	2	9			52
Lepomis macrochirus			1		17		1	8		1	28
Lepomis megalotis			2					1			3
Membras martinica	46	3	1	2	12	3					67
Menidia beryllina	71	42	23	15	8	60	170	160	44	56	649
Micropterus dolomieui			5	4	5		4				18
Micropterus salmoides		1			2					2	5
Morone americana	657	220	409	289	299	746	347	317	79	73	3,436
Morone saxatilis	1	12	5	5	16	11	21	4	1		76

TABLE 22, con't.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Notropis hudsonius	173	69	94	164	335	384	433	421	123	176	2,372
Notropis spilopterus	8										8
Perca flavescens	8	10	14	12	18	6	37	24	9	17	155
Pomatomus saltatrix							1				1
Pomoxis nigromaculatus		2			1		1				4
Strongylura marina						2	2				4
Trinectes maculatus	1	2	5	1							9
TOTALS Species	18	19	22	20	24	19	22	18	13	12	32/
Numbers	1,012	2,533	1,263	924	2,149	1,456	1,178	2,476	412	1,653	16,057

TABLE 23. Species and numbers of individual finfish collected by otter trawl during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS										TOTALS
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Alosa aestivalis	24	1		2							27
Alosa pseudoharengus	6	1	3	7	11	12	2	2			22
Alosa sapidissima			1								1
Anchoa mitchilli					50	35	75	5			166
Anguilla rostrata	85	6	35		4						130
Brevoortia tyrannus	38	15	15	1	1	5	5	22	24		120
Carassius auratus		1									1
Carpiodes cyprinus			2								2
Cyprinus carpio	19	9	17	5	5	3	2	2	2		64
Dorosoma cepedianum			2	17	72	207	71	64	28		461
Etheostoma olmstedi			1	1	2	1	3	6	5		19
Fundulus diaphanus											0
Fundulus heteroclitus											0
Hybognathus nuchalis											0
Hypentelium nigricans							1				1
Ictalurus nebulosus	6	15	5	1	3	1		3			34
Ictalurus punctatus	35	58	130	20	129	199	206	25	26		828
Leiostomus xanthurus		16	160	31	548	144	422	459	183		1,963
Lepomis auritus											0
Lepomis gibbosus	1	3	1			1	1	1	1		9
Lepomis macrochirus											0
Lepomis megalotis											0
Membras martinica											0
Menidia beryllina											0
Micropterus dolomieui											0
Micropterus salmoides											0
Morone americana	1,751	3,710	3,468	2,635	4,091	2,417	3,052	1,190	432		22,746
Morone saxatilis	3	12	3	1	3	4	1	5	2		34

TABLE 23, con't.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Notropis hudsonius	205	223	60	56	64	75	90	84	18		875
Notropis spilopterus											0
Perca flavescens	89	64	58	44	41	15	32	27	54		424
Pomatomus saltatrix											0
Strongylura marina											0
Trinectes maculatus	2	6	31		44	42	164	10	10		309
TOTALS Species	13	16	17	13	15	15	15	15	12		21/
Numbers	2,264	4,141	3,992	2,820	5,069	3,161	4,127	1,905	785		28,264

TABLE 24. Species and number of individual finfish collected by haul seine at ten sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS										TOTALS
	1	2	3	4	5	6	7	8	9	10	
Alosa aestivalis	50	23	13	8	9						108
Alosa pseudoharengus	53	2	30	120							214
Alosa sapidissima											0
Anchoa mitchilli	176	19	12	4	1	1					213
Anguilla rostrata	3	6	7	12	1		1				30
Brevoortia tyrannus	602	1,484	1,216	1,897	148						5,347
Carassius auratus											0
Carpiodes cyprinus											0
Cyprinus carpio	3	4	4	9		1	1			1	23
Dorosoma cepedianum	121	1,353	193	51	288	60	646				2,712
Etheostoma olmstedi	16	16	10	6	4	26	1				79
Fundulus diaphanus	20	23		1	14	15	4				67
Fundulus heteroclitus	5	2	2		20	8	1				38
Hybognathus nuchalis		1		1		1	1				4
Hypentelium nigricans										3	3
Ictalurus nebulosus					1						1
Ictalurus punctatus	1	35	36	15	2	3	3				95
Leiostomus xanthurus	22	35	14	11	53	99					234
Lepomis auritus									2		2
Lepomis gibbosus			8	4		1	11	5	13	10	52
Lepomis macrochirus			1			1	1	12	4	9	28
Lepomis megalotis							1	2			3
Membras martinica	1				54	12					67
Menidia beryllina	89	54	48	98	114	179	66			1	649
Micropterus dolomieui						1		8	4	5	18
Micropterus salmoides						3	2				5
Morone americana	313	914	438	1,128	302	325	15		1		3,436
Morone saxatilis	15	8	7	16	7	12	11				76

TABLE 24 , con't.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Notropis hudsonius	603	290	283	430	313	234	215			4	2,372
Notropis spilopterus								4	4		8
Perca flavescens	13	19	33	31	5	27	20	6	1		155
Pomatomus saltatrix				1							1
Pomoxis nigromaculatus		3						1			4
Strongylura marina				1	1	2					4
Trinectes maculatus		7					2				9
TOTALS Species	18	20	18	20	18	19	18	8	7	7	32/
Numbers	2,096	4,298	2,360	3,853	1,337	1,008	1,003	40	29	33	16,057

TABLE 25. Species and number of individual finfish collected by otter trawl at six sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS										TOTALS
	1	2	3	4	5	6	7	8	9	10	
Alosa aestivalis	6	20	1								27
Alosa pseudoharengus	12	9		3	9	11					44
Alosa sapidissima						1					1
Anchoa mitchilli	17	26		4	49	70					166
Anguilla rostrata	1	10	112	6		1					130
Brevoortia tyrannus	15	43	39	2	27						126
Carassius auratus	1										1
Carpiodes cyprinus		1				1					2
Cyprinus carpio	4	8	18	7	11	16					64
Dorosoma cepedianum	17	224	194	3	3	20					461
Etheostoma olmstedi	9	3	1	2	4						19
Fundulus diaphanus											0
Fundulus heteroclitus											0
Hybognathus nuchalis											0
Hypentelium nigricans	1										1
Ictalurus nebulosus		28	4		2						34
Ictalurus punctatus	24	73	94	468	46	123					828
Leiostomus xanthurus	410	291	249	277	519	217					1,963
Lepomis auritus											0
Lepomis gibbosus			7	1		1					9
Lepomis macrochirus											0
Lepomis megalotis											0
Membras martinica											0
Menidia beryllina											0
Micropterus dolomieui											0
Micropterus salmoides											0
Morone americana	3,395	6,024	5,935	2,042	2,692	2,658					22,746
Morone saxatilis	2	2	1	2	10	17					34

TABLE 25, con't.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Notropis hudsonius	200	84	252	68	95	176					875
Notropis spilopterus											0
Perca flavescens	60	178	122	9	29	26					424
Pomatomus saltatrix											0
Pomoxis nigromaculatus											0
Strongylura marina											0
Trinectes maculatus	21	4	17	233	12	22					309
TOTALS Species	17	17	15	15	14	15					21/
Numbers	4,195	7,028	7,046	3,127	3,508	3,360					28,264

TABLE 26. Species and weight (grams) of finfish collected by haul seine during ten sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS										TOTALS
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Alosa aestivalis	21	10	5	1	6	17	91	69	6		226
Alosa pseudoharengus	34	345	200	218	375	285	125	46			1,630
Alosa sapidissima											
Anchoa mitchilli		9			4		21	214	4	2	254
Anguilla rostrata	48	80	105	22	62	209	46	66			638
Brevoortia tyrannus		7,638	3,516	2,601	2,294	613	10,757	13,020	1,000	9,040	50,479
Carassius auratus											0
Carpiodes cyprinus											0
Cyprinus carpio	9,200	8,600			11,000		8,400	1,800			40,000
Dorosoma cepedianum	1,450	530	534	900	12,194	298	4,836	2,278	220	15,149	38,389
Etheostoma olmstedi				1	4	25	16	36	103	25	210
Fundulus diaphanus	12		2			154	35	41	22	15	281
Fundulus heteroclitus	9	50	26	60	18				4	7	174
Hybognathus nuchalis					34	10					62
Hypentelium nigricans			134	128				265			527
Ictalurus nebulosus				230							230
Ictalurus punctatus	486	2,090	478	27	242	365	27	12	9		3,736
Leiostomus xanthurus	12		47	138	1,437	409	1,162	1,961			5,166
Lepomis auritus					168						168
Lepomis gibbosus		115	427	360	442	480	223	429			2,476
Lepomis macrochirus			81		223		2	57		5	373
Lepomis megalotis			109					72			181
Membras martinica	180	14	3	10	60	15					282
Menidia beryllina	213	106	62	30	13	154	294	277	78	98	1,325
Micropterus dolomieui			272	280	185		317				1,054
Micropterus salmoides		94			4					102	200
Morone americana	14,095	4,253	6,737	2,694	3,943	8,226	5,046	3,107	575	862	49,538
Morone saxatilis	18	510	14	33	152	107	160	58	8		1,060

TABLE 26, con't.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Notropis hudsonius	2,790	684	483	501	2,199	2,090	2,207	3,351	606	1,173	16,084
Notropis spilopterus	52										52
Perca flavescens	283	245	461	211	588	116	923	474	171	586	4,058
Pomatomus saltatrix							140				140
Pomoxis nigromaculatus		90			44		100				234
Strongylura marina							19				19
Trinectes maculatus	1	5	10	2		26					44
TOTALS Species	18	19	22	20	24	19	22	20	13	12	32/
Numbers	28,922	25,468	13,706	8,447	35,696	13,599	35,947	27,635	2,806	27,064	219,290

TABLE 27. Species and weight (grams) of finfish collected by otter trawl during nine sampling periods from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	TOTALS
Alosa aestivalis	28	3		11						42
Alosa pseudoharengus	74	3	30	46	97	102	19	16		387
Alosa sapidissima			70							70
Anchoa mitchilli		3			147	29	52	5		236
Anguilla rostrata	6,520	278	1,624		281					8,703
Brevoortia tyrannus	151	68	81	5	16	45	40	336	315	1,057
Carassius auratus		750								750
Carpiodes cyprinus		1,500								1,500
Cyprinus carpio	37,250	1,300	26,850	8,400	13,200	3,800	7,300	2,500	4,400	105,000
Dorosoma cepedianum			14	135	687	1,155	951	1,030	745	4,717
Etheostoma olmstedi			3	4	12	2	12	18	12	63
Fundulus diaphanus										0
Fundulus heteroclitus										0
Hybognathus nuchalis										0
Hypentelium nigricans							104			104
Ictalurus nebulosus	650	1,552	322	310	245	86		332		3,497
Ictalurus punctatus	2,283	4,204	9,664	1,085	6,705	4,207	6,795	2,023	2,350	39,316
Leiostomus xanthurus		363	2,013	774	10,866	3,130	11,594	11,695	4,059	44,494
Lepomis auritus										
Lepomis gibbosus	65	109	35			38	35	36	55	373
Lepomis macrochirus										
Lepomis megalotis										
Membras martinica										
Menidia beryllina										
Micropterus dolomieui										
Micropterus salmoides										
Morone americana	34,332	82,408	85,806	83,895	156,316	79,108	89,515	27,759	10,111	649,300
Morone saxatilis	37	163	210	93	37	132	138	307	75	1,192

TABLE 27, con't.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	TOTALS
Notropis hudsonius	1,812	2,359	753	690	663	586	1,043	1,056	152	9,114
Notropis spilopterus										0
Perca flavescens	2,000	1,243	2,297	672	966	294	653	750	1,323	10,198
Pomatomus saltatrix										0
Pomoxis nigromaculatus										0
Strongylura marina										0
Trinectes maculatus	33	38	244		497	225	4,740	80	236	6,093
TOTALS Species	13	16	17	13	15	15	15	15	12	
Numbers	85,285	94,844	131,516	96,120	190,735	92,939	122,991	47,943	23,833	

TABLE 28. Species and weights (grams) of finfish collected by haul seine at ten sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS										TOTALS
	1	2	3	4	5	6	7	8	9	10	
Alosa aestivalis	131	52	25	9	9						226
Alosa pseudoharengus	616	17	159	838							1,630
Alosa sapidissima											0
Anchoa mitchilli	210	19	19	4	1	1					254
Anguilla rostrata	50	141	143	239	6		9				638
Brevoortia tyrannus	4,974	21,875	10,454	11,651	1,525						50,479
Carassius auratus											0
Carpiodes cyprinus											0
Cyprinus carpio	3,400	14,400	4,450	11,750		1,300	4,700				40,000
Dorosoma cepedianum	2,196	17,090	2,670	249	2,090	841	13,253				38,389
Etheostoma olmstedi	42	40	24	15	9	78	2				210
Fundulus diaphanus	47	73		2	83	67	9				281
Fundulus heteroclitus	13	10	7		97	45	2				174
Hybognathus nuchalis		19		18		10	15				62
Hypentelium nigricans										527	527
Ictalurus nebulosus					230						230
Ictalurus punctatus	28	799	376	2,193	3	80	257				3,736
Leiostomus xanthurus	706	706	540	292	837	2,085					5,166
Lepomis auritus									168		168
Lepomis gibbosus			342	294		8	373	203	706	550	2,476
Lepomis macrochirus			1			2	5	104	8	253	373
Lepomis megalotis							72	109			181
Membras martinica	8				214	60					282
Menidia beryllina	146	80	97	183	290	378	148			3	1,325
Micropterus dolomieui						1		109	495	449	1,054
Micropterus salmoides							196	4			200
Morone americana	3,985	10,720	6,199	19,416	4,261	4,452	459		46		49,538
Morone saxatilis	77	117	80	107	89	532	58				1,060

TABLE 28. Species and weights (grams) of finfish collected by haul seine at ten sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS										TOTALS
	1	2	3	4	5	6	7	8	9	10	
Alosa aestivalis	131	52	25	9	9						226
Alosa pseudoharengus	616	17	159	838							1,630
Alosa sapidissima											0
Anchoa mitchilli	210	19	19	4	1	1					254
Anguilla rostrata	50	141	143	239	6		9				638
Brevoortia tyrannus	4,974	21,875	10,454	11,651	1,525						50,479
Carassius auratus											0
Carpiodes cyprinus											0
Cyprinus carpio	3,400	14,400	4,450	11,750		1,300	4,700				40,000
Dorosoma cepedianum	2,196	17,090	2,670	249	2,090	841	13,253				38,389
Etheostoma olmstedi	42	40	24	15	9	78	2				210
Fundulus diaphanus	47	73		2	83	67	9				281
Fundulus heteroclitus	13	10	7		97	45	2				174
Hybognathus nuchalis		19		18		10	15				62
Hypentelium nigricans										527	527
Ictalurus nebulosus					230						230
Ictalurus punctatus	28	799	376	2,193	3	80	257				3,736
Leiostomus xanthurus	706	706	540	292	837	2,085					5,166
Lepomis auritus									168		168
Lepomis gibbosus			342	294		8	373	203	706	550	2,476
Lepomis macrochirus			1			2	5	104	8	253	373
Lepomis megalotis							72	109			181
Membras martinica	8				214	60					282
Menidia beryllina	146	80	97	183	290	378	148			3	1,325
Micropterus dolomieui						1		109	495	449	1,054
Micropterus salmoides							196	4			200
Morone americana	3,985	10,720	6,199	19,416	4,261	4,452	459		46		49,538
Morone saxatilis	77	117	80	107	89	532	58				1,060

TABLE 28, con't.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Notropis hudsonius	4,999	2,266	1,549	3,278	1,566	1,347	1,075			4	16,084
Notropis spilopterus								37	15		52
Perca flavescens	212	292	685	753	128	739	827	385	32		4,058
Pomatomus saltatrix				140							140
Pomoxis nigromaculatus		190						44			234
Strongylura marina						19					19
Trinectes maculatus		13		8	18		5				44
TOTALS Species	18	20	18	20	18	19	18	8	7	7	32/
Nummbers	21,840	68,924	27,820	51,489	11,456	12,045	21,465	995	1,470	1,786	219,290

TABLE 29. Species and weights (grams) of finfish collected by otter trawl at six sampling stations from 23 June through 31 October for the 1980 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Alosa aestivalis	12	29	1								42
Alosa pseudoharengus	98	45		80	59	105					387
Alosa sapidissima						70					70
Anchoa mitchilli	19	30		7	127	53					236
Anguilla rostrata	45	573	7,869	211		5					8,703
Brevoortia tyrannus	105	199	325	28	400						1,057
Carassius auratus	750										750
Carpiodes cyprinus		1,500									1,500
Cyprinus carpio	6,100	11,400	32,050	14,350	17,450	23,650					105,000
Dorosoma cepedianum	177	1,667	2,190	46	80	557					4,717
Etheostoma olmstedi	23	12	4	6	18						63
Fundulus diaphanus											0
Fundulus heteroclitus											0
Hybognathus nuchalis											0
Hypentelium nigricans	104										104
Ictalurus nebulosus		2,800	362		335						3,497
Ictalurus punctatus	1,476	4,207	8,599	17,956	2,303	4,775					39,316
Leiostomus xanthurus	8,491	7,230	6,163	5,882	11,119	5,609					44,494
Lepomis auritus											0
Lepomis gibbosus			272	65		36					373
Lepomis macrochirus											0
Lepomis megalotis											0
Membras martinica											0
Menidia beryllina											0
Micropterus dolomieui											0
Micropterus salmoides											0
Morone americana	87,927	176,190	158,845	63,239	74,364	88,735					649,300
Morone saxatilis	244	54	28	27	327	512					1,192

TABLE 29, con't.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Notropis hudsonius	2,090	737	2,622	645	964	2,056					9,114
Notorpis spilopterus											0
Perca flavescens	1,011	3,444	3,187	364	1,474	718					10,198
Pomatomus saltatrix											0
Pomoxis nigromaculatus											0
Strongylura marina											0
Trinectes maculatus	391	48	99	5,249	57	249					6,093
TOTALS Species	17	17	15	15	14	14					21/
Numbers	109,063	210,165	222,616	108,155	109,077	127,130					886,206

TABLE 30. Total numbers collected, total area swept, and standing crop in numbers per hectare for all species combined for each gear type by sampling period during the 1980 Juvenile Recruitment Survey.

PERIOD	TOTAL NUMBERS COLLECTED		NUMBERS/HECTARE	
	Seine	Trawl	Seine	Trawl
I	1,012	2,264	1,104.6	713.6
II	2,533	4,141	3,061.4	1,443.2
III	1,264	3,992	1,379.6	1,352.3
IV	924	2,821	1,008.5	1,231.9
V	2,149	5,058	2,345.6	1,594.2
VI	1,456	3,161	1,589.2	996.3
VII	2,178	4,127	2,456.7	1,438.3
VIII	2,476	1,905	2,790.4	663.9
IX	412	785	464.7	247.4
X	1,652	-	1,996.6	-
TOTALS	16,057	28,264		

TABLE 31. Total area swept, total weight of species collected, and standing crop in kilograms per hectare for all species combined for each gear type by period during the 1980 Juvenile Recruitment Survey.

PERIOD	TOTAL WEIGHT (kg) Seine	TOTAL WEIGHT (kg) Trawl	KILOGRAMS/HECTARE Seine	KILOGRAMS/HECTARE Trawl
I	28.922	85.285	31.567	26.880
II	25.468	94.844	30.780	33.054
III	13.706	131.516	14.959	44.549
IV	8.447	96.120	9.219	41.975
V	35.696	190.735	38.960	60.115
VI	13.599	92.939	14.842	29.292
VII	35.947	122.991	40.544	42.864
VIII	27.635	47.943	31.169	16.708
IX	2.806	23.833	3.167	7.511
X	27.064	-	32.709	-
TOTALS	219.290	886.206		

TABLE 32. Total numbers collected, total area swept, and standing crop in numbers per hectare for all species combined for each gear type by station during the 1980 Juvenile Recruitment Survey.

STATION	TOTAL NUMBERS COLLECTED		NUMBERS/HECTARE	
	Seine	Trawl	Seine	Trawl
1	2,095	4,195	1,772.4	1,118.1
2	4,298	7,028	3,636.2	1,665.0
3	2,360	7,046	1,996.6	1,502.2
4	3,853	3,127	3,259.7	792.5
5	1,337	3,508	1,131.1	706.4
6	1,008	3,360	852.8	676.6
7	1,003	-	847.7	-
8	40	-	270.3	-
9	29	-	122.5	-
10	33	-	139.4	-
TOTALS	16,057	28,264		

TABLE 33. Total area swept, total weight of species collected, and standing crop in kilograms per hectare for all species combined for each gear type by station during the 1980 Juvenile Recruitment Survey.

STATION	TOTAL WEIGHT (kg)		KILOGRAMS/HECTARE	
	Seine	Trawl	Seine	Trawl
1	21.840	109.063	18.477	29.068
2	68.924	210.165	58.311	49.790
3	27.820	222.616	25.536	47.463
4	51.489	108.155	43.560	27.412
5	11.456	109.077	9.962	21.831
6	12.045	127.130	10.190	25.445
7	21.465	-	18.159	-
8	0.995	-	6.722	-
9	1.470	-	6.207	-
10	1.786	-	7.542	-
TOTALS	219.290	886.206		

TABLE 34. Numbers caught and catch-per-unit-effort (CPUE*) by sampling period, total catch, and total CPUE for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana for haul seine and otter trawl during the 1980 Juvenile Recruitment Survey.

SPECIES	GEAR	SAMPLING PERIOD I	II	III	IV	V	VI	VII	VIII	IX	X	TOTAL
A. Total Catch By Gear Type												
Alosa aestivalis	hs	21	9	5	1	3	6	36	25	2	0	108
	ot	24	1	0	2	0	0	0	0	0	0	27
Alosa pseudoharengus	hs	2	10	39	38	44	36	18	7	0	0	194
	ot	1	1	2	7	11	12	2	2	0	0	38
Morone saxatilis	hs	0	4	5	4	11	10	17	3	1	1	55
	ot	0	4	0	0	1	1	0	1	1	0	8
Morone americana	hs	1	33	49	130	146	463	171	215	65	42	1,315
	ot	2	2	372	120	237	121	277	225	98	0	1,453
B. CPUE* By Gear Type												
Alosa aestivalis	hs	1.05	0.64	0.25	0.05	0.15	0.30	2.00	1.38	0.11	0.0	
	ot	2.00	0.09	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	
Alosa pseudoharengus	hs	0.10	0.71	1.95	1.90	2.20	1.80	1.00	0.38	0.0	0.0	
	ot	0.08	0.09	0.18	0.77	0.91	1.00	0.18	0.18	0.0	0.0	
Morone saxatilis	hs	0.0	0.29	0.25	0.20	0.55	0.56	0.94	0.17	0.06	0.0	
	ot	0.0	0.36	0.0	0.0	0.08	0.08	0.0	0.09	0.08	0.0	
Morone americana	hs	0.05	2.35	2.45	6.50	7.30	23.15	9.50	11.94	3.61	3.00	
	ot	0.16	0.18	33.81	13.33	19.75	10.08	25.18	20.45	8.16	0.0	

*CPUE: total number of a species/total number of hauls or runs

TABLE 35. Numbers caught and catch-per-unit-effort (CPUE*) by sampling station, total catch, and total CPUE for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana by haul seine and otter trawl during the 1980 Juvenile Recruitment Survey.

SPECIES	GEAR	SAMPLING STATION 1	2	3	4	5	6	7	8	9	10	TOTAL
A. Total Catch By Gear Type												
Alosa aestivalis	hs	50	23	18	8	9	0	0	0	0	0	108
	ot	6	20	1	0	0	0	0	0	0	0	27
Alosa pseudoharengus	hs	34	2	30	128	0	0	0	0	0	0	194
	ot	12	5	0	2	9	10	0	0	0	0	38
Morone saxatilis	hs	15	6	6	12	1	4	11	0	0	0	55
	ot	0	1	0	1	2	4	0	0	0	0	8
Morone americana	hs	127	441	172	312	121	142	0	0	0	0	1,315
	ot	339	505	402	20	73	115	0	0	0	0	1,453
B. CPUE* By Gear Type												
Alosa aestivalis	hs	2.50	1.15	0.90	0.40	0.45	0.0	0.0	0.0	0.0	0.0	
	ot	0.35	1.11	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Alosa pseudoharengus	hs	1.70	0.10	1.50	6.40	0.0	0.0	0.0	0.0	0.0	0.0	
	ot	0.70	0.27	0.0	0.15	0.50	0.55	0.0	0.0	0.0	0.0	
Morone saxatilis	hs	0.75	0.30	0.30	0.60	0.05	0.20	1.10	0.0	0.0	0.0	
	ot	0.0	0.60	0.0	0.08	0.11	.022	0.0	0.0	0.0	0.0	
Morone americana	hs	6.35	22.05	8.60	15.60	6.05	7.10	0.0	0.0	0.0	0.0	
	ot	19.94	28.05	23.64	1.53	4.05	6.38	0.0	0.0	0.0	0.0	

* CPUE: total number of a species/total number of hauls or runs

TABLE 36. Standing crop as numbers per hectare for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana collected by haul seine and otter trawl in each sampling period during the 1980 Juvenile Recruitment Survey

SPECIES	GEAR	SAMPLING PERIOD I	II	III	IV	V	VI	VII	VIII	IX	X
Alosa aestivalis	hs	23.0	11.0	5.0	1.0	3.0	7.0	41.0	28.0	2.0	0.0
	ot	8.0	0.4	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Alosa pseudoharengus	hs	2.0	12.0	43.0	41.0	48.0	39.0	6.0	9.0	0.0	0.0
	ot	0.3	0.4	0.7	3.0	3.0	4.0	0.7	0.7	0.0	0.0
Morone saxatilis	hs	0.0	5.0	5.0	4.0	12.0	11.0	19.0	3.0	0.0	0.0
	ot	0.0	1.0	0.0	0.0	0.3	0.3	0.0	0.3	0.3	0.0
Morone americana	hs	1.0	40.0	53.0	141.0	159.0	505.0	192.0	248.0	73.0	47.0
	ot	0.6	0.7	162.0	52.0	75.0	38.0	97.0	78.0	31.0	0.0

TABLE 37. Standing crop as numbers per hectare for young-of-the-year Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana collected by haul seine and otter trawl at each sampling station during the 1980 Juvenile Recruitment Survey.

SPECIES	GEAR	SAMPLING STATION 1	2	3	4	5	6	7	8	9	10
Alosa aestivalis	hs	42	19	15	7	8	0	0	0	0	0
	ot	2	5	0.2	0	0	0	0	0	0	0
Alosa pseudoharengus	hs	29	2	25	108	0	0	0	0	0	0
	ot	3	1	0	1	2	2	0	0	0	0
Morone saxatilis	hs	13	5	5	10	0.8	3	9	0	0	0
	ot	0	0.2	0	0.3	0.4	0.8	0	0	0	0
Morone americana	hs	107	373	146	364	102	120	0	0	0	0
	ot	90	120	86	5	15	23				

Recorded in whole numbers except when value less than one

TABLE 38. Reported commercial catch as pounds caught of American shad and alewife/blueback herring combined from the Susquehanna River, Susquehanna Flats, and the Northeast River* from 1968 through 1980.

YEAR	REPORTED CATCH	
	Shad	Herring**
1968	175,878	1,506,088
1969	200,321	937,612
1970	118,343	635,347
1971	228,585	1,112,000
1972	188,278	251,066
1973	179,105	1,132,437
1974	50,389	783,810
1975	22,668	161,759
1976	10,223	63,498
1977	8,025	44,048
1978	20,359	43,472
1979	2,321	34,647
1980	48	16,610

* Sum of NOAA statistical subareas 090, 089, and 064, respectively

** *Alosa aestivalis* and *Alosa pseudoharengus* catch combined

TABLE 39. Species and number of individual finfish collected by haul seine during six sampling periods for the 1979 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Alosa aestivalis	89	158	15	17	75						354
Alosa pseudoharengus	1	2	2		7	6					18
Alosa sapidissima		2		1							3
Anchoa mitchilli	1			4	1,129	32					1,166
Brevoortia tyrannus	394	1	96		772	39					1,302
Carpiodes cyprinus			1								1
Cyprinus carpio	10	11	6	7	4	2					40
Dorosoma cepedianum	5	3	570	1,354	427	383					2,742
Etheostoma olmstedi		1	1	1		5					8
Esox lucius			1								1
Fundulus diaphanus	36	5	8	3	3	7					62
Fundulus heteroclitus		21	6	4	7	2					40
Hybognathus nuchalis	8			2	1	1					12
Hypentelium nigricans				10							10
Ictalurus punctatus	1	7	8	5	15	2					38
Leiostomus xanthurus	8	76	22	44	19	5					174
Lepomis auritus		2		1	1	1					5
Lepomis gibbosus	2	7	7	6	5	12					39
Lepomis macrochirus	1	4	7	9	4						25
Membras martinica	9	23	7	4	2						45
Menidia beryllina	193	85	71	99	107	144					699
Micropterus dolomieui	1	4	1	2	1	1					10
Micropterus salmoides	1	3	6			1					11
Morone americana	390	463	460	392	449	282					2,436
Morone saxatilis	17	23	18	17	22	7					105
Morone saxatilis X chrysops					1						1
Notropis hudsonius	51	185	283	435	382	316					1,652
Notropis spilopterus	33	74	37	13	2	1					160

TABLE 39, con't.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Perca flavescens	43	18	14	33	5	27					140
Pomoxis annularis					1						1
Pomoxis nigromaculatus				1	1						2
Strongylura marina	1		1		1						3
Trinectes maculatus			1		1						2
TOTALS Species	22	24	24	24	27	21					33/
Numbers	1,295	1,179	1,649	2,464	3,444	1,276					11,307

TABLE 40. Species and numbers of individual finfish collected by haul seine at ten sampling stations during the 1979 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS										TOTALS
	1	2	3	4	5	6	7	8	9	10	
Alosa aestivalis	62	75	126	22	5	11	51				354
Alosa pseudoharengus			4	11	2					1	18
Alosa sapidissima			1	1					1		3
Anchoa mitchilli	3	1	34			1		229	575	323	1,166
Brevoortia tyrannus	2	668	620	12							1,302
Carpiodes cyprinus	1										1
Cyprinus carpio	1	5	12	13		3	1	2	1	2	40
Dorosoma cepedianum	527	1,360	405		29	29	174	19	29	170	2,742
Etheostoma olmstedi	2	3			1	1	1				8
Esox lucius							1				1
Fundulus diaphanus	19	1	1	1	1	11	25	3		1	62
Fundulus heteroclitus	6	3			22	7	2				40
Hybognathus nuchalis		2	7	1	1	1					12
Hypentelium nigricans										10	10
Ictalurus punctatus	4	6	5	5	3	2	10		1	2	38
Leiostomus xanthurus	10	80	3	1	38	33			8	1	174
Lepomis auritus							1	4			5
Lepomis gibbosus	3	2	14	1	1		10	4		4	39
Lepomis macrochirus							4	20		1	25
Membras martinica	23		3	6	4	7	2				45
Menidia beryllina	135	29	16	27	182	239	56	6	9		699
Micropterus dolomieui				1		1	3	2	3		10
Micropterus salmoides							1	10			11
Morone americana	456	537	142	329	341	583	2	2	3	41	2,436
Morone saxatilis	43	11	7	4	22	3	12	1	2		105
Morone saxatilis X chrysops										1	1
Notropis hudsonius	163	228	256	298	364	286	26	21	6	4	1,652
Notropis spilopterus	1						48		110	1	160

TABLE 40, con't.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Perca flavescens	2	20	18	19	9	39	33				140
Pomoxis annularis									1		1
Pomoxis nigromaculatus								1		1	2
Strongylura marina					1	1				1	3
Trinectes maculatus	1				1						2
TOTALS Species	20	17	18	17	18	18	20	13	14	16	33/
Numbers	1,464	3,031	1,674	752	1,037	1,272	441	321	750	565	11,307

TABLE 41. Species and weights (grams) of finfish collected by haul seine during six sampling periods for the 1979 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Alosa aestivalis	89	260	29	19	129						526
Alosa pseudoharengus	8	8	16		39	52					123
Alosa sapidissima		8		2							10
Anchoa mitchilli	4			7	3,690	21					3,722
Brevoortia tyrannus	2,812	1	1,585		13,480	608					18,486
Carpiodes cyprinus			1,500								1,500
Cyprinus carpio	16,042	13,530	12,150	12,700	7,400	2,170					63,992
Dorosoma cepedianum	1,056	74	5,719	12,273	7,487	6,076					32,685
Etheostoma olmstedi		1	1	2		13					17
Esox lucius			500								500
Fundulus diaphanus	191	20	26	12	10	24					283
Fundulus heteroclitus		115	23	15	27	8					188
Hybognathus nuchalis	70			38	18	13					139
Hypentelium nigricans				1,216							1,216
Ictalurus punctatus	76	289	1,921	324	945						3,561
Leiostomus xanthurus	96	1,632	499	874	524	76					3,706
Lepomis auritus		140		58	14	21					233
Lepomis gibbosus	62	189	128	195	140	374					1,088
Lepomis macrochirus	30	138	181	28	11						388
Membras martinica	38	108	36	16	8						206
Menidia beryllina	371	254	85	165	153	262					1,290
Micropterus dolomieui	14	302	60	44	126	5					550
Micropterus salmoides	454	7	9			4					474
Morone americana	7,403	10,274	9,608	7,198	6,625	1,545					42,653
Morone saxatilis	81	269	148	101	108	74					781
Morone saxatilis X chrysops					35						35
Notropis hudsonius	338	1,294	1,971	2,650	1,993	1,608					8,854
Notropis spilopterus	74	210	88	40	6	1					419

TABLE 41, con't.

SPECIES	SAMPLING PERIODS I	II	III	IV	V	VI	VII	VIII	IX	X	TOTALS
Perca flavescens	1,274	345	364	749	127	280					3,139
Pomoxis annularis					6						6
Pomoxis nigromaculatus				2	30						32
Strongylura marina	50		34		44						128
Trinectes maculatus		12			2						14
TOTALS Species	22	24	24	24	27	21				33/	
Numbers	30,633	29,485	36,681	38,728	43,177	13,240					191,944

TABLE 42. Species and weights (grams) of finfish collected by haul seine at ten sampling stations during the 1979 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS										TOTALS
	1	2	3	4	5	6	7	8	9	10	
Alosa aestivalis	85	102	169	47	5	11	105			2	526
Alosa pseudoharengus			14	84	13					12	123
Alosa sapidissima			4	4					2		10
Anchoa mitchilli	6	4	23			2		600	2,037	1,050	3,722
Brevoortia tyrannus	10	12,715	4,903	858							18,486
Carpiodes cyprinus	1,500										1,500
Cyprinus carpio	1,000	4,237	13,420	33,223		3,800	1,362	1,500	3,200	2,250	63,992
Dorosoma cepedianum	3,031	12,575	5,676		510	1,980	5,993	218	277	2,425	32,685
Etheostoma olmstedi	3	10			1	1	2				17
Esox lucius							500				500
Fundulus diaphanus	72	5	4	6	50	132	5		9		283
Fundulus heteroclitus	23	18			111	28	8				188
Hybognathus nuchalis		38	56	14	18	13					139
Hypentelium nigricans										1,216	1,216
Ictalurus punctatus	226	1,062	335	1,132	202	11	523		26	44	3,561
Leiostomus xanthurus	278	1,620	74	20	913	693			96	12	3,706
Lepomis auritus							58	175			233
Lepomis gibbosus	42	39	333	30	29		438	88		89	1,088
Lepomis macrochirus							161	156		71	388
Membras martinica	102		14	32	14	34	10				206
Menidia beryllina	135	39	24	49	447	529	40	6	21		1,290
Micropterus dolomieui				78		60	202	48	162		550
Micropterus salmoides							454	20			474
Morone americana	9,374	5,545	4,632	7,307	6,005	8,048	113	198	106	1,325	42,653
Morone saxatilis	175	137	69	21	279	12	63	21	4		781
Morone saxatilis X chrysops										35	35
Notropis hudsonius	514	1,648	1,309	2,445	1,740	1,928	49	160	37	24	9,854
Notropis spilopterus	4						121		292	2	419

TABLE 42, con't.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
Perca flavescens	26	146	348	418	198	834	1,169				3,139
Pomoxis annularis									6		6
Pomoxis nigromaculatus								2		30	32
Strongylura marina					44	50				34	128
Trinectes maculatus	12				2						14
TOTALS Species	20	17	18	17	18	18	20	13	14	16	33/
Numbers	16,618	39,940	31,407	45,768	10,581	18,166	11,376	3,192	6,275	8,621	191,944

TABLE 43. Total catch and catch per haul by haul seine by sampling period for young-of-the-year Alosa sapidissima, Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana during the 1979 Juvenile Recruitment Survey.

SPECIES	SAMPLING PERIODS 1	2	3	4	5	6	TOTALS
A. Total Catch							
Alosa sapidissima	0	2	0	1	0	0	3
Alosa aestivalis	89	158	15	17	73	0	352
Alosa pseudoharengus	1	2	2	0	7	6	18
Morone saxatilis	14	20	12	14	18	4	82
Morone americana	0	35	76	145	165	222	643
B. Catch Per Haul							
Alosa sapidissima	0.0	0.10	0.0	0.05	0.0	0.0	0.03
Alosa aestivalis	5.56	7.90	0.75	0.85	3.84	0.0	3.06
Alosa pseudoharengus	0.06	0.10	0.10	0.37	0.30	0.0	0.16
Morone saxatilis	0.88	1.00	0.60	0.70	0.95	0.20	0.71
Morone americana	0.0	1.75	3.80	7.25	8.68	11.10	5.40

TABLE 44. Total catch and catch per haul by haul seine by sampling station for young-of-the-year Alosa sapidissima, Alosa aestivalis, Alosa pseudoharengus, Morone saxatilis, and Morone americana during the 1979 Juvenile Recruitment Survey.

SPECIES	SAMPLING STATIONS 1	2	3	4	5	6	7	8	9	10	TOTALS
A. Total Catch											
Alosa sapidissima	0	0	1	0	0	0	0	0	1	0	1
Alosa aestivalis	62	75	126	22	5	11	51	0	0	0	352
Alosa pseudoharengus	0	0	4	10	2	0	0	0	0	2	18
Morone saxatilis	40	5	3	3	16	3	10	0	2	0	82
Morone americana	42	256	43	63	113	124	1	0	1	0	643
B. Catch Per Haul											
Alosa sapidissima	0.0	0.0	0.08	0.08	0.0	0.0	0.0	0.00	0.08	0.0	
Alosa aestivalis	5.17	6.25	10.50	1.83	0.42	1.00	4.25	0.0	0.0	0.0	
Alosa pseudoharengus	0.0	0.0	0.33	0.83	0.17	0.0	0.0	0.0	0.0	0.0	
Morone saxatilis	3.33	0.42	0.25	0.25	1.33	0.27	0.83	0.0	0.17	0.0	
Morone americana	3.50	21.33	3.58	5.25	9.42	11.27	0.08	0.0	0.08	0.0	

TABLE 45. Comparison of the population density (numbers per hectare) of young-of-the-year American shad, alewife herring, and blueback herring captured by haul seine and otter trawl from the Susquehanna drainage during 1968, 1969, and 1980.

SPECIES	SEASONAL AVERAGE (No./ha)			
	1969 Haul Seine	1968-1969 Otter Trawl	1980 Haul Seine	1980 Otter Trawl
American shad	103	4	0	0
Blueback herring	1,944	23	13	1
Alewife herring	86	66	23	1

FIGURE VII. Survey stations for the 1980 American Shad Juvenile Recruitment Survey.

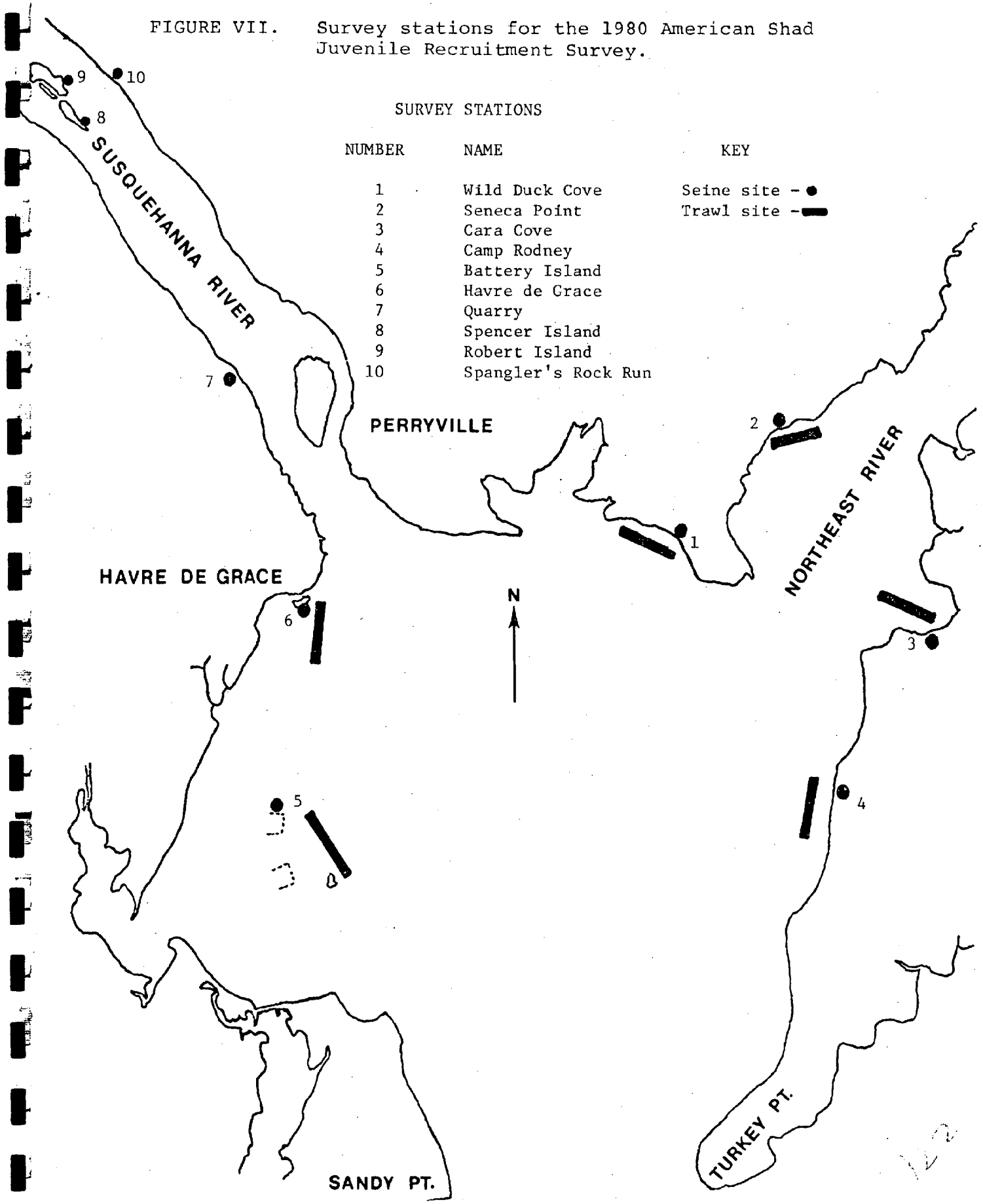


FIGURE VIII. Numbers of young-of-the-year Alsoa aestivalis (□) and Alosa pseudoharengus (▨) caught by haul seine per sampling period during the 1980 Juvenile Recruitment Survey.

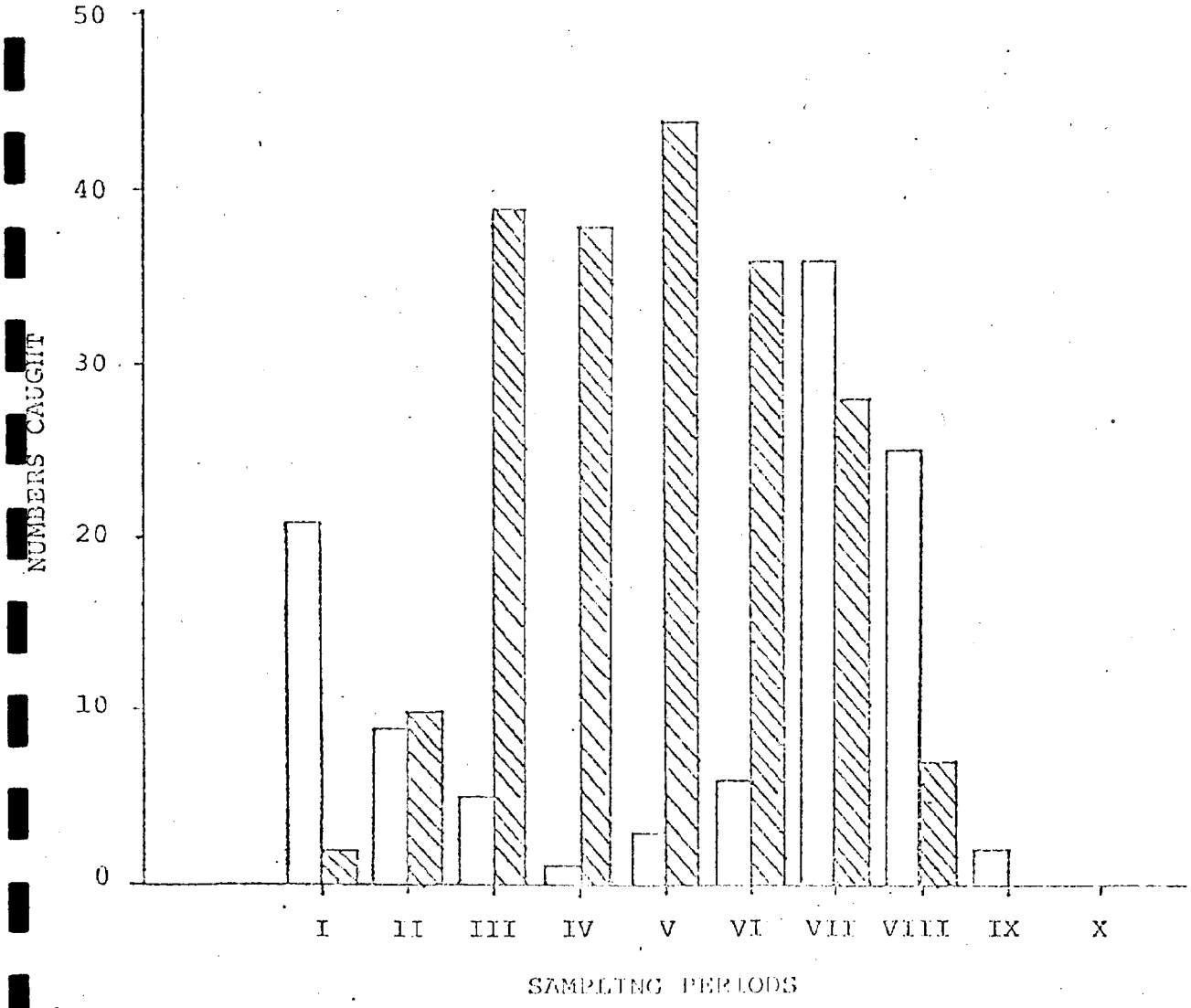


FIGURE IX. Numbers of young-of-the year Alosa aestivalis (□) and Alosa pseudoharengus (▨) caught by otter trawl per sampling period during the 1980 Juvenile Recruitment Survey.

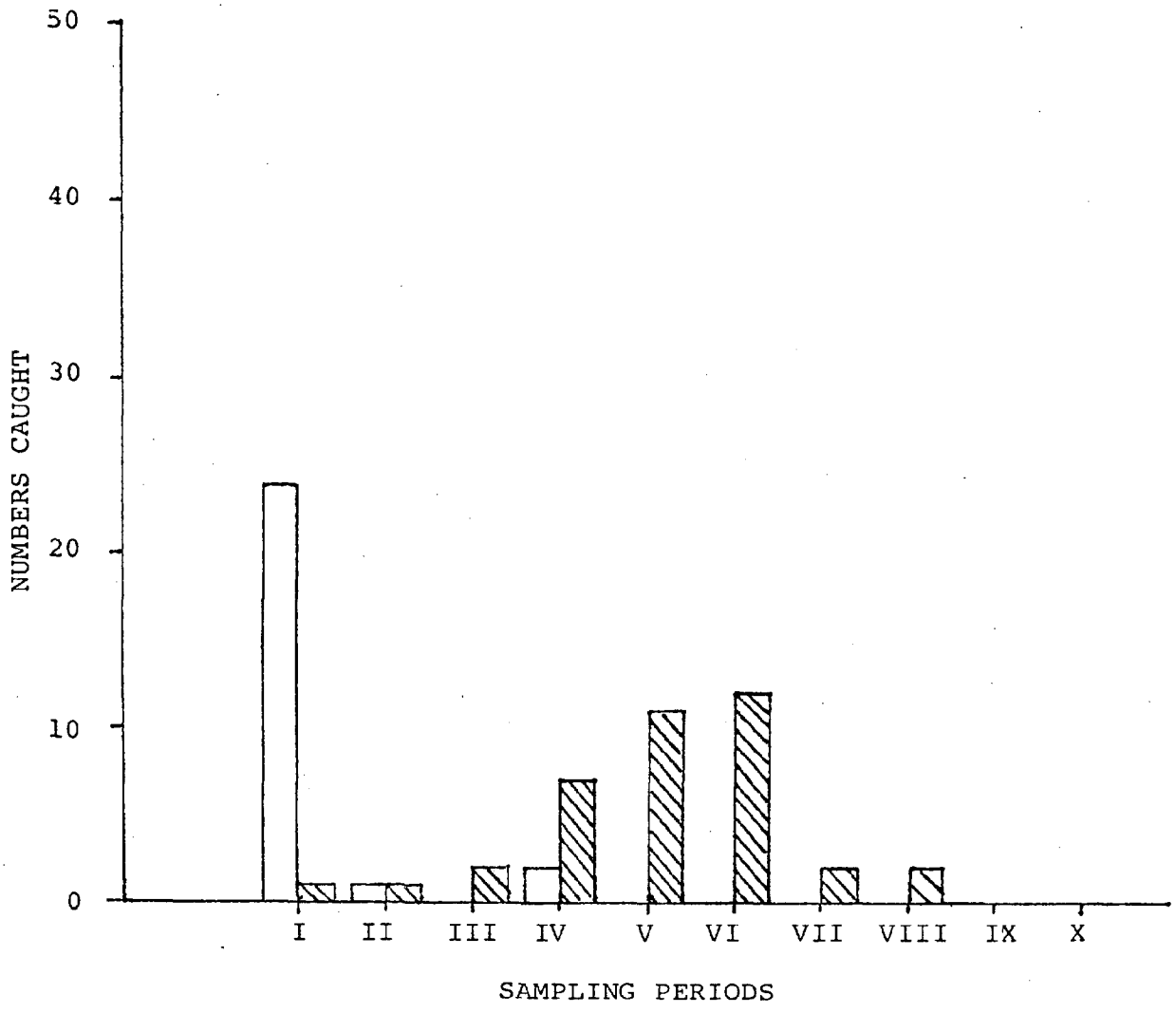


FIGURE X. Numbers of young-of-the-year Alosa aestivalis (□) and Alosa pseudoharengus (▨) caught by haul seine per sampling station during the 1980 Juvenile Recruitment Survey.

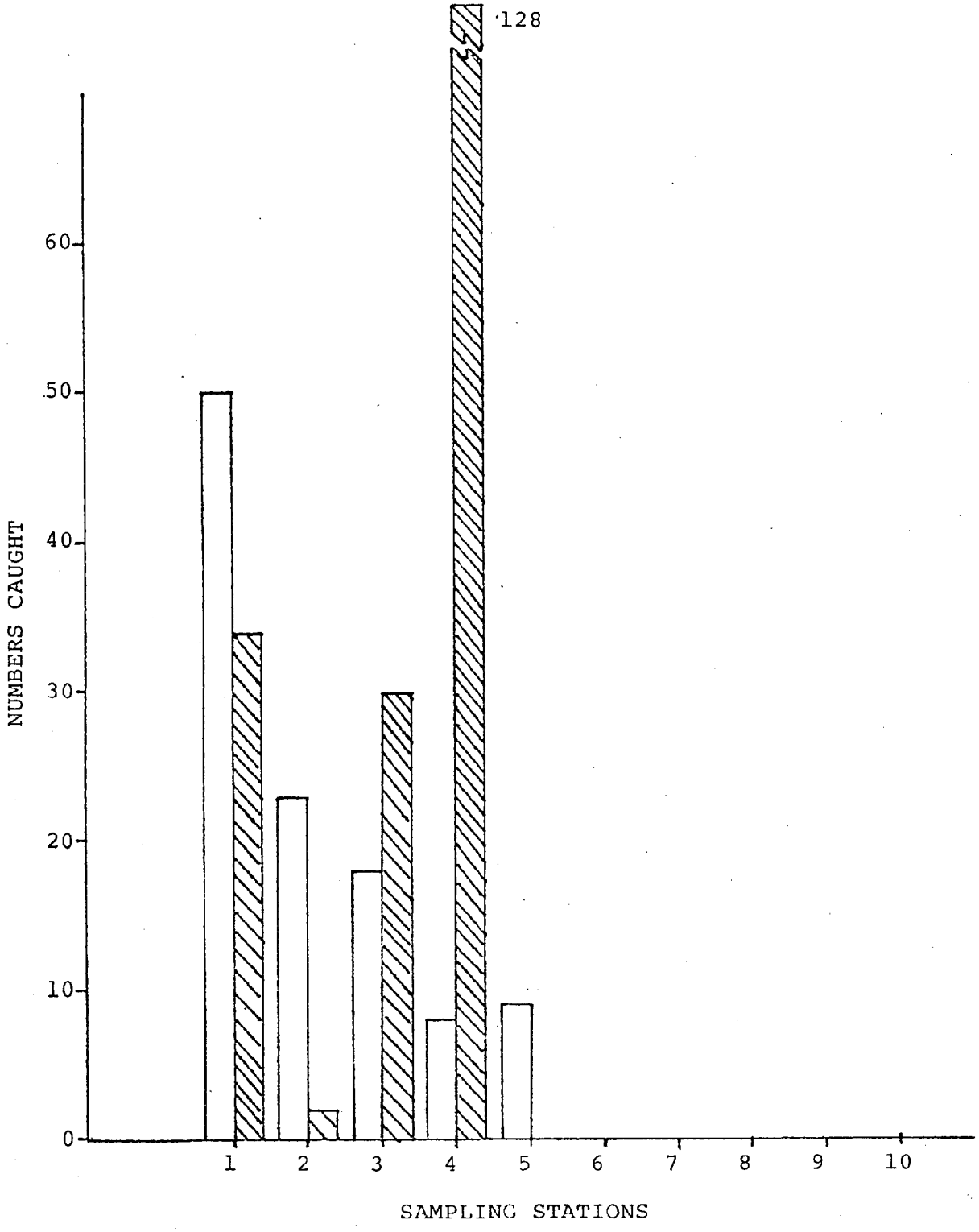
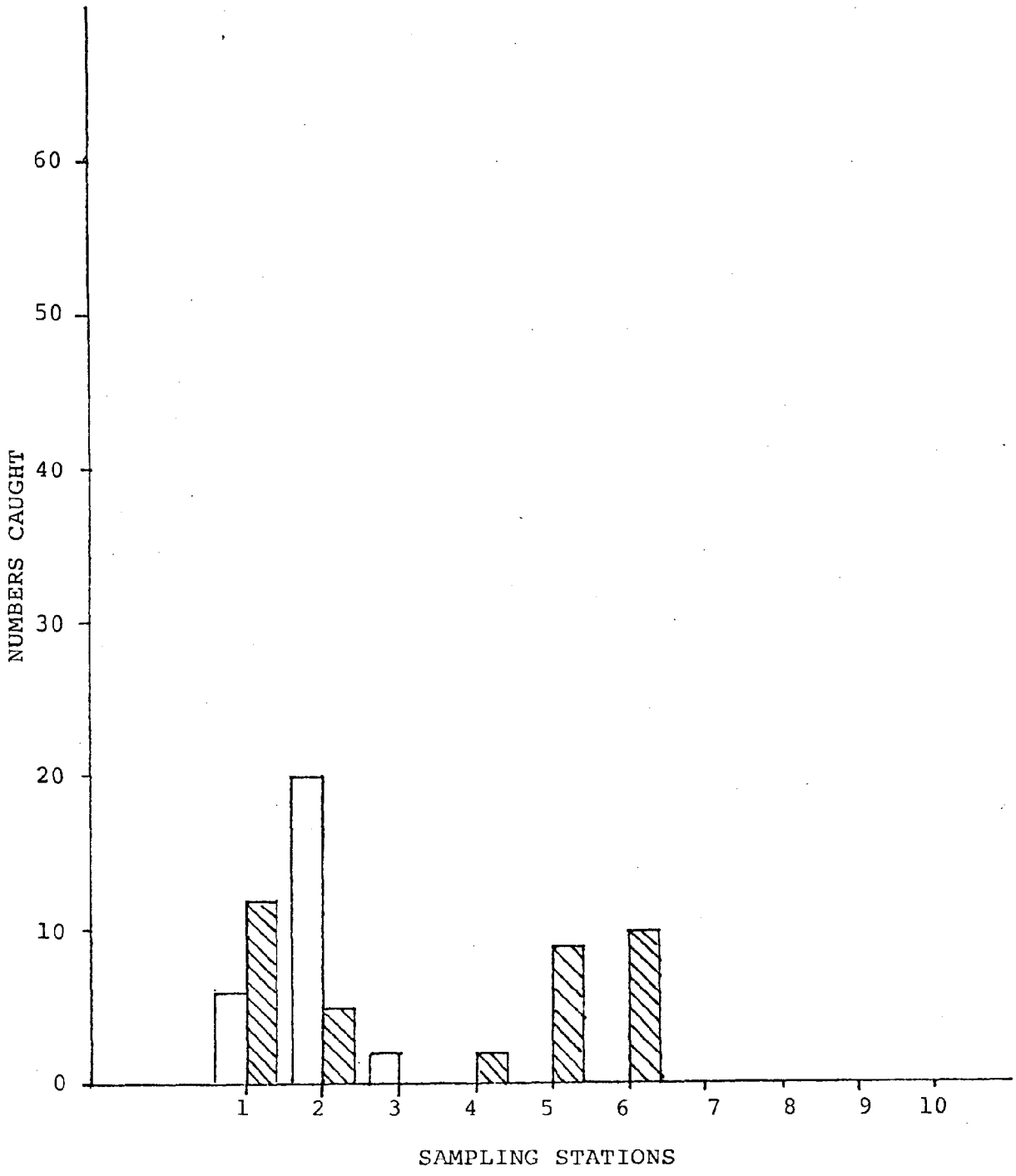


FIGURE XI. Numbers of young-of-the-year Alosa aestivalis (□) and Alosa pseudoharengus (▨) caught by otter trawl per sampling stations during the 1980 Juvenile Recruitment Survey.



JOB V. LITERATURE REVIEW AND SURVEY

A. Extensive literature concerning the biology and management of American shad exists primarily due to the species' sport and commercial value and its widespread range along the entire Atlantic coast. Mansueti and Kolb (1954) cited 1,314 literature sources in their publication "A Historical Review of the Shad Fishery of North America" while Dr. Timothy Robbins (pers. comm.) estimates that approximately 800 literature sources have been produced on the American shad since 1954.

In order to upgrade Project staff familiarity with both published and unpublished material, a literature search was undertaken by the Maryland Tidewater Administration. Accumulation and analysis of pertinent literature and subsequent comparison with Maryland's situation is a prime requisite for improvement of the state's ability to rationally manage its shad stocks.

B. Queried information sources during the past 12 months include:

1. Journals/Periodicals -

Transactions of the American Fisheries Society
Canadian Journal of Fisheries and Aquatic Sciences
Ecology
Estuaries
Progressive Fish Culturist
Scientific American
Biological Conservation
Fisheries
Limnology and Oceanography
Natural History
American Midland Naturalist
Marine Fisheries Review
Fishery Bulletin, National Marine Fisheries Service
Fishery Bulletin, Fish and Wildlife Service

Research Reports, Fish and Wildlife Service

National Marine Fisheries Service Commercial Landings

Fish and Wildlife Service Computer Reference System

2. State Governmental Agencies-

Florida Department of Natural Resources, Division of Marine Resources

Georgia Department of Natural Resources, Coastal Resources Division

South Carolina Wildlife and Marine Resources Department, Marine Resources Division

North Carolina Department of Natural Resources and Community Development, Division of Marine Resources

Virginia Marine Resources Commission

Maryland Department of Natural Resources, Tidewater Administration

Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife

New Jersey Department of Environmental Protection, Division of Fish, Game and Shellfish

New York Department of Environmental Conservation, Division of Fish and Wildlife

Connecticut Department of Environmental Protection, Marine Region

3. Federal Government Agencies-

Department of Interior, Fish and Wildlife Service

Department of Commerce, National Marine Fisheries Service

4. Private Consultants -

Radiation Management Corporation

Environmental Resources Management, Inc.

Martin Marietta Corporation

National Environmental Services, Inc.

Lawler, Matusky, and Skelly

5. Academic Institutions

University of Maryland, Sea Grant

Johns Hopkins University, Applied Physics Laboratory

University of Maryland, Center for Environmental and Estuarine Studies

College of William and Mary, Virginia Institute of Marine Science (VIMS)

6. Personal Communication

A great deal of information was obtained through personal contact with various individuals and groups. Discussions with the Maryland Watermens Association and their various county chapters, individual commercial fishermen, and seafood processors provided insight into the Maryland shad fishery and market system. Further direct contact with specific watermen was invaluable to the Project's field operations as well as providing useful supplemental data such as catch-per-unit of effort.

Personal communication with various state conservation agencies was helpful to all aspects of Maryland's program. The Connecticut DEP assisted in the difficult job of ageing American shad scales. New Jersey DEP personnel provided information concerning the resurgence of Delaware River shad runs. This information may well be applicable to Maryland's problem. Agreement was reached with the VIMS to tag adult American shad in the Virginia portion of the Chesapeake Bay during 1981 so that their movements into Virginia tributaries and the Maryland Bay would become better understood.

C. To better understand the value of this literature survey to Maryland's American shad investigation, a brief discussion concerning one aspect of the survey is presented below.

Table 46 presents the reported commercial catch of American shad by state or major tributary along the east coast from 1962 to 1980. Analysis and comparison of any commercial catch data can be tenuous at times due to differences in effort, gear types employed, gear selectivity, and the accuracy of the reported totals. Because these conditions

which influence this data were unknown, specific conclusions could not be drawn from simple comparisons. However, certain trends appeared obvious with respect to Maryland and warranted mention.

All east coast states have experienced both increases and decreases in reported American shad landings from 1962 to 1980. The most dramatic declines appear to be from the Chesapeake Bay south. With the exception of South Carolina, these southern states have experienced declines from their average catch ranging from 434,000 pounds in Georgia to 1,557,100 pounds in Maryland during this 19 year period. Catches from the three northern rivers and South Carolina, however, appear to be stable and increasing. The declining shad catch from the Delaware River during the late 1960's through the mid-1970's can be attributed to the pollution block created by the cities of Philadelphia and Trenton (Chittenden 1975, Lupine pers. comm.) Poor water quality greatly restricted upstream migration of spawning adults in the spring and downrunning juveniles in the fall. Extensive pollution control measures in these problem areas have shortened the duration of this block, thus permitting more nearly unaltered movements of both adults and young-of-the-year. Consequently, Delaware River American shad catches by both commercial watermen and sport anglers have experienced a sharp increase during the past five years. The 1980 Hudson River totals were expected to substantially exceed the record 1979 totals (Blossum pers. comm.)

In each of these three northern rivers and South Carolina a continuous research program has resulted in effective regulations and management policies for their shad fishery (Fredin 1954, Talbot 1954, Walburg 1963, White and Vurtis 1969, Curtis 1974, Leggett 1976, Marcy 1976, Chittenden 1974, Crochet et al. 1976, Crecco 1979, Lupine 1980, Minta et al. 1980). This has

been one of the major factors contributing to stabilized runs and commercial catches in these locations. Specifically, American shad in the Connecticut River have been extensively studied and managed for over 20 years, and the corresponding commercial harvest has been the most stable of any major east coast river.

The ability to return Maryland's American shad population to stable harvestable levels is directly related to the state's continued study and monitoring of both the fish and its various limiting factors (pollution, stream blockage, habitat alteration, overfishing). Synthesis of this information along with that obtained from outside sources into an effective management policy, strengthened by enforceable regulations should logically follow.

TABLE 46. Reported commercial catch of American shad from all waters in Florida, Georgia, South Carolina, North Carolina, Virginia, Maryland, and the Delaware, Hudson, and Connecticut Rivers from 1962 through 1980.

	CATCH (lbs.)						
YEAR	FLORIDA	GEORGIA	SOUTH CAROLINA	NORTH CAROLINA	DELAWARE RIVER	HUDSON RIVER	CONNECTICUT RIVER
1962	760,000	527,000	115,000	764,000	183,000	218,149	499,369
1963	590,000	331,000	120,000	693,000	196,000	132,564	329,077
1964	613,000	314,000	120,000	640,000	332,000	78,084	311,460
1965	758,000	376,000	176,000	1,069,000	333,000	119,958	347,835
1966	530,000	386,000	119,000	701,000	221,000	67,908	277,779
1967	319,000	334,000	132,000	777,000	136,000	76,491	278,903
1968	531,000	569,000	110,000	842,000	60,300	113,100	251,699
1969	390,000	618,000	176,000	718,645	23,400	122,676	205,061
1970	218,000	532,000	148,000	953,000	29,400	95,900	199,754
1971	253,000	420,000	99,000	680,212	16,000	70,038	200,941
1972	120,000	344,000	159,000	468,484	35,400	93,660	201,748
1973	99,000	239,000	26,000	321,000	29,300	153,357	249,940
1974	100,000	162,000	24,000	369,000	27,544	163,690	230,349
1975	33,000	182,000	62,000	241,000	54,498	196,000	271,957
1976	28,000	93,000	32,000	167,000	75,808	183,200	374,125
1977	97,000	118,000	80,000	120,201	116,363	120,300	308,217
1978	130,000	172,000	287,000	402,017	141,726	306,500	283,662
1979	95,000	250,000	197,000	277,818	119,291	430,300	204,879
1980	141,000	172,000	270,000	194,333	93,700*	1,296,970	323,662

* reported commercial landings of Delaware state fishermen only

TABLE 46. continued

YEAR	CATCH (LBS.) MARYLAND	VIRGINIA
1962	1,574,681	2,201,200
1963	826,227	2,309,100
1964	888,923	2,940,875
1965	1,309,577	2,940,875
1966	1,126,996	2,413,356
1967	886,647	2,101,953
1968	911,346	2,579,249
1969	1,095,332	2,117,002
1970	1,037,731	4,095,923
1971	946,426	1,507,163
1972	821,260	2,049,358
1973	597,793	2,419,810
1974	220,482	1,521,318
1975	183,757	1,095,103
1976	109,173	693,935
1977	73,015	1,409,800
1978*	79,439	1,221,880
1979*	33,668	919,560
1980*	22,704	874,807

* Atlantic Ocean landings not included

CONCLUSIONS AND RECOMMENDATIONS

The major conclusion derived from the 1980 data is that American shad stocks in the upper Chesapeake Bay are in a precarious condition. Prior to 1972, it was common for commercial fishermen to catch as many shad in a week as the estimated upper Bay population for 1980. Sport angling success during the 1960's and early 1970's was among the best along the east coast. Though never as plentiful as other species, young-of-the-year American shad were regularly collected in various head-of-the-Bay juvenile surveys through 1972.

Closing Maryland's waters to all American shad fishing in 1980 was a serious but necessary step to protect the remaining brood stocks. Mansueti and Kolb (1953) noted that the evidence from the majority of previous investigations clearly indicated that overfishing was the primary cause of reduced and declining shad runs in Maryland. Overfishing was also identified as a major factor in declining shad runs on the Hudson River (Talbot 1954), the Connecticut River (Fredin 1954, Marcy 1976, Leggett 1976, Crecco 1979), and in South Carolina (Crochet et al. 1976).

Other factors have been cited as major reasons for Maryland's shad decline. Sidell (1979) stated that barriers preventing anadromous species from reaching their spawning grounds has been the primary cause of fishery declines in the Susquehanna River. Beginning in 1830, construction of dams precluded American shad from ascending the river to their uppermost spawning area, Binghamton, New York, river mile 318. With completion of Conowingo Dam in 1928 all migratory fish were restricted to only the lower 10 miles of the Susquehanna River.

The effects of pollution and habitat alteration pose serious threats to spawning adults, eggs, and larvae. These conditions probably operate to make reproduction less successful for already depleted brood stocks. However, insufficient data indicating changes in pollution levels and habitat alterations for specific

spawning and nursery areas over time makes quantitative relationships difficult, if not impossible, to ascertain.

On the basis of the information presented in this report, the following management recommendations are presented.

I. Continuation of Closed Fishing Season

The scarcity of both spawning adults and juvenile American shad precludes any recreational or economic incentive to reopen the fishery. Continuation of the fishing ban through 1984 would maximize protection of the remaining brood stocks and allow their quickest rebuilding. As mentioned in Job IV, several authors have noted a relationship between the numbers of juvenile American shad and the numbers of spawning adults three to five years later (Chittenden 1975, Marcy 1976, Minta et. al. 1980). Because recruits would not return to Maryland waters for three to five years after being spawned a minimum closure of five years is required to permit the return of at least one unfished generation. A five year closure would also eliminate the problem of immediate "fishing up" whereby individuals who would not normally enter the fishery do so because of nominal increased catches by regular fishermen, thereby overfishing the stocks before they have a chance to rebuild to safe harvestable levels. If the number of spawners in one generation is overfished, thus reducing juvenile recruitment, numbers of fish returning three to five years later as adults will be decreased. This condition is further compounded if this returning cohort is itself overfished. One successful year class will not restore Maryland shad runs to harvestable levels.

II. Chemical Monitoring

Overfishing is probably not the only adverse condition limiting Susquehanna brood stocks and successful recruitment. The effect of pollution on both adults and juveniles (see Job IV) needs to be investigated. Analysis of water samples collected at various locations throughout the Susquehanna drainage would be beneficial in determining the types of pollutants present,

concentrations, and in certain instances their origin. In addition, chemical analysis of both tissues and gonads from Susquehanna shad is needed to determine if contaminants accumulated in the adults are limiting successful reproduction. Adult contamination may result in production of non-fertile eggs and larvae and in hatching deformed, diseased, or weakened larvae incapable of survival. A simple and inexpensive method to test the viability of upper Bay American shad eggs and milt would be to place fertilized eggs in shad hatching boxes stationed throughout the area and monitor their hatching and development.

III. Project Continuation and Expansion

Few specific trends and conclusions can be drawn from one year's data. Successful management practices such as those for the Connecticut River involve the accumulation and analysis of data gathered over many years. Since this data is non-existent for any Maryland shad stocks, continuation of the present investigation is of paramount importance. Effective management policies are only possible with a comprehensive data base.

Data expansion during 1981 centers on a proposed tagging experiment of American shad in the Virginia portion of Chesapeake Bay. The effects of Virginia's fishery on Maryland shad stocks is unknown. This exercise will provide preliminary information concerning effort, the relative importance of the Potomac River as a spawning area, and the possible exploitation rates attributable to the by-catch provisions of the 1981 Maryland closure. As Walburg and Nichols (1967) state, "Successful management probably requires consideration of Chesapeake Bay stocks as units without regard to political boundaries."

IV. Supplemental Stocking

Supplemental stocking of both adults captured from other areas and hatchery reared eggs and larvae is not recommended at this time for the lower (=Maryland) Susquehanna drainage. From 1875 to 1950 over 199,000,000 shad fry were reared

and placed into nine different Maryland rivers; Potomac, Patuxent, Bush, Susquehanna, Northeast, Sassafras, Chester, Choptank, and Wicomico. These releases, however, were not successful in stopping the Maryland shad catches declining from over seven million pounds in 1890 to 1.4 million pounds in 1950. Talbot (1954) concluded that no correlation existed between hatchery operations and the estimated population of American shad entering the Hudson River from 1915 to 1950. The recent resurgence of Delaware River shad runs has been erroneously concluded by the public to be the result of stocking adults collected from various east coast rivers, particularly the Susquehanna. Chittenden (1975) stated that the dominant factor affecting the abundance of American shad runs on the Delaware River for the past 60 years was the pollution block centered around the Philadelphia area. Delaware River fishery research personnel (Lupine pers. comm.) state that the increase in both sport and commercial landings during the late 1970's is a result of a decline in both the severity and duration of this pollution block. They concluded that artificial stocking of adults into the Delaware, terminated in the late 1960's, had little if any beneficial effect on the river's native brood stock.

Until the conditions causing reproductive failure at the head of Chesapeake Bay can be defined, and corrective measures implemented, the stocking of hatchery produced eggs and larvae and transplanted adults will not solve the problem. It is unrealistic to assume that the deleterious factors presently affecting natural populations and reproduction will not produce similar results on artificially propagated and transplanted organisms.

LITERATURE CITED

Bailey, N. J. J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38:293-306.

Boone, J. and J. Uphoff. 1980. Estuarine fish recruitment survey July 1, 1979 - June 30, 1980. Federal Aid Project F-27-R-6 Performance Report. unpubl. 107 p.

Carter, W. R., III. 1973. Ecological study of the Susquehanna River and its tributaries below Conowingo Dam. Federal Aid Project AFSC-1 Completion Report U. S. Dept. Commerce, NOAA, NMFS. 122 p.

Cating, J. P. 1953. Determing age of Atlantic shad from their scales. U. S. Fish Wild. Serv., Fish Bull. 54(85):187-199.

Chapman, D. G. 1951. Some properties of the hyergeometric distribution with application to zoological sample census. Univ. Calif. Publ. Stat. 1:131-160.

Chittenden, M. E., Jr. 1969. Life history and ecology of the American shad, Alosa sapidissima, in the Delaware River. Ph. D. Thesis, Rutgers Univ., New Brunswick, N.J., 458 p.

_____. 1975. Dynamics of American shad, Alosa sapidissima, runs in the Delaware River. Fish. Bull. 73(3):487-494.

Colston, N. V. 1974. Characterization and treatment of urban land runoff. EPA: Environmental Protection Series: EPA 670/2-74-096.

Crecco, V. A. 1979. Population dynamics of the American shad, Alosa sapidissima, in the Connecticut River, 1940-1977. State Geological and Natural History Survey of Connecticut Department of Environemntal Protection. 216 p.

Crochet, D. W., D. E. Allen, and M. L. Hornberger. 1976. Commercial anadromous fishery Waccamaw and Pee Dee Rivers. Federal Aid Project AFC-5 Completion Report. South Carolina Wild. Mar. Res. Dept. 114 p.

Curtis, T. A. 1974. Anadromous fish survey of the Santee and Cooper River system. South Carolina Wild. Mar. Res. Dept. Annual Progress Report, Proj. AFS-3-3, July 1, 1973-June 30, 1973. 44 p.

Fredin, R. A. 1954. Causes of fluctations in abundance of Connecticut River Shad. U. S. Fish Wildl. Serv., Fish. Bull. 54:247-259.

Friedersdorff, J. W. and C. F. Barren. 1978. Delaware River Basin Anadromous Fishery Project Special Report No. 4, The 1977 Delaware River Adult American shad Population estimate. 16 p.

Foerster, J. W. and S. P. Reagan. 1977. Management of the Chesapeake Bay American shad fishery. Biol. Conserv. 12:179-201.

Johnson, H. B., D. W. Crocker, B. F. Holland, J. W. Gilliken, D. L. Taylor, M. W. Street, J. G. Loesch, W. H. Kriete, and J. G. Travelstead. 1978. Biology and management of mid-Atlantic anadromous fishes under extended jurisdiction. Ann. Rep., AFCS 9-2. 175 p.

Jones, R. A., P. Minta, and V. A. Crecco. 1976 A review of American shad studies in the Connecticut River. Proceedings Am. Shad Workshop, NMFS, Amhurst, Mass. 350 p.

Judy, M. H. 1961. Validity of age determination from scales of marked American shad. U. S. Fish Wildl. Serv., Fish. Bull. 61:161-170.

Kriete, W. H., Jr and J. G. Loesch. 1980. Design and relative efficiency of a bow-mounted pushnet for sampling pelagic fishes. Trans. Am. Fish. Soc. 109:649-652.

La Pointe, D. F. 1958. Age and growth of the American shad from three east coast Rivers. Trans. Am. Fish. Soc. 87:139-150.

Leggett, W. C. 1969. Studies on the reproductive biology of the American shad, Alosa sapidissima, A comparison of populations from four rivers in the Atlantic seaboard. Ph. D. Thesis. McGill Univ. 125 p.

_____. 1976. The American shad, Alosa sapidissima, with special reference to its migrations and population dynamics in the Connecticut River. In D. Merriman and L. M. Thorpe (eds.). The Connecticut River ecological study: The impact of a nuclear power plant. Am. Fish. Soc. Monogr. I. 252 p.

_____, and J. E. Carscadden. 1978. Latitudinal variations in reproductive characteristics of American shad (Alosa sapidissima): evidence for population specific life strategies in fish. J. Fish. Res. Board Can. 35:1469-1478.

Lofton, A. J. 1979. Delaware River Basin Anadromous Fishery Project Completion Report. 1978 American Shad Population Report. 18 p.

Lupine, A. J. 1980. Delaware River American shad population estimate. Del. River Fish. Proj. F-38-R Spec. Rep. #1 13 p.

Mansuetti, R. 1958. A brief review of fish and fishes of the lower Susquehanna region in Maryland and Pennsylvania. Md. Dept. Res. Ed. Ref. 14 p.

_____ and H. Kolb. 1953. A historical review of the shad fisheries of North America. Md. Dept. Res. Ed., Ches. Biol. Lab. Publ. 97. 293 p.

Marcy. B. C., Jr. 1976. Early life history studies of American shad in the lower Connecticut River and the effects of the Connecticut Yankee plant. In D. Merriman and L. M. Thorpe (eds.). The Connecticut River ecological study: The impact of a nuclear power plant. Am. Fish. Soc. Monogr. I. 252 p.

Middaugh, D. P., J. A. Couch, and A. M. Grove. 1977. Responses of early life history stages of striped bass, Morone saxatilis, to chlorination. Ches. Sci. 18:141-153.

Minta. P. 1980. Connecticut River shad study. Sixth annual report submitted to Northeast Utilities Company. Conn. Dept. Envir. Prot. 19 p.

_____, V. A Crecco, and R. P. Jacobs. 1980. Connecticut River shad studies, 1977-1979. Fed. Aid Proj. AFC-11 Final Report. unpubl. 23 p.

Morgan, R. P., III, V. J. Rasin, and L. A. Noe. 1973. Effects of suspended sediments on the development of eggs and larvae of striped bass and white perch. Nat. Res. Inst. Univ. Md. Appendix XI NRI Ref. No. 73-110. 21 p.

Pfeiffer, P. W. 1966. The results of a non-uniform probability creel census on a small state-owned lake. Proc. 20th Ann. Conf. Southeastern Assoc. Game Fish Comm. p 409-412.

Radiation Management Corporation. 1979. Report on the sport fishing survey of the lower Susquehanna River below Conowingo Dam. RMC Ecological Division, Drumore, Pa. unpubl. 13 p.

Radiation Management Corporation. 1979. Summary of the operation of the Conowingo Dam fish collection facility during the spring of 1979. Fish Facility Operation Rep. 8. 28 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. 191 Fish. Res. Brd. Canada. 382 p.

Sidell, B. D. 1979. A review of the current status of the American shad (Alosa sapidissima) in the Susquehanna River. Ches. Bay Inst. Johns Hopkins Univ. Spec. Rept. (CB-70). 42 p.

St. Pierre, R. 1978. Historical review of the American shad and river herring fishery of the Susquehanna River. U. S. Dept. Int. Fish Wild. Serv. unpub. 40 p.

Sykes, J. E. and B. A. Lehman. 1957. Past and present Delaware River shad fishery and considerations for its future. U. S. Fish Wildl. Serv., Res. Rep. 46. 25 p.

Talbot, G. E. 1954. Factors associated with fluctuations in abundance of Hudson River shad. Fish. Bull. U. S. 56:373-413.

Ulrich, G., N. Chipley, J. W. McCord, and D. Cupka. 1979. Development of fishery management plans for selected anadromous fishes in South Carolina and Georgia. South Carolina Wildl. Mar. Res. Spec. Sci. Rep. #14. 135 p.

Walburg, C. H. 1963. Parent-progeny relation and estimates of optimum yield for American shad in the Connecticut River. Trans. Am. Fish. Soc. 92:436-439.

_____, and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic Coast of the United States, 1960. U. S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 550. 105 p.

White, M. G., III, and T. A. Curtis. 1969. Anadromous fish survey of the Black River and Pee Dee River watersheds. South Carolina Wildl. Mar. Res. Dept. Job Progress Rep. Proj. AFS 2-4, July 1, 1968 - June 30, 1969. 73 p.

Whitney, R. R. 1961. The Susquehanna fishery study, 1957-1960. A report of a study on the desirability and feasability of passing fish at Conowingo Dam. Md. Dept. Res. Educ. Contract No. 169. 81 p.

NOAA COASTAL SERVICES CENTER LIBRARY
3 6668 00000 9201