Completion Report, 1980-83

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TABLE OF CONTENTS

Table of Contents (continued)

PREFACE

This presentation is the completion report for P. L. 89-304, AFC 10 project "Anadromous Fisheries Research, Virginia," for the period 1 October 1979 to 31 December 1983. The fishes of concern were the alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), and the blueback herring (*A. aestivalis*).

The *Alosa* species were once an important component of the landings of Virginia fisheries. In the last decade, however, there has been a dramatic decrease in American shad and river herring landings. The 1981 landings of *Alosa* species in Virginia were the lowest ever recorded. American shad and river herring are also sought by recreational fishermen in Virginia; however, data are few and the extent of this activity is unknown. Additionally, these species have a vital ecological role. Young-of-the-year *Alosa* are the dominant pelagic prey species in their extensive freshwater and upper estuarine nursery grounds. After spawning, adults return to the sea and are prey of many marine piscivores. It is important that studies of the *Alosa* stocks in Virginia be continued. Current data, as well as historical data, are needed in order that analyses are constructive contributions to rational management strategies.

The research presented herein directly addresses research concerns stated in the Shad and River Herring Action Plan and augments on-going research monitoring and extant data classes. These data will be a pertinent contribution to the total data base that is being constructed to assist in the formulation of management strategies for the east coast *Alosa* stocks.

The following jobs were contracted by the Virginia Institute of Marine Science.

Job 1. Catch and Effort Statistics of the Virginia Alosa Fisheries

Objectives

1. Estimate fishing effort, landings, and catch-per-unit-of-effort (CPUE) of adult river herring (alewife and blueback herring) and American shad in Virginia during the 1983 fisheries.

2. Determine the present status of the stocks relative to former years by comparison of landings and CPUE.

Job 2. Population Dynamics of the Virginia Alosa Fisheries

Objectives

1. Estimate current vital statistics (age and size frequencies, species composition, mortality rates, etc.) of river herring and American shad.

2. Contrast current vital statistics to the existing Virginia data base for the *Alosa* fisheries.

Job 3. Annual Index of Juvenile Alosa Abundance

Objectives

1. Determine an index of abundance of juvenile river herring and American shad.

2. Study the growth and relative abundance of juveniles over time.

ACKNOWLEDGMENTS

We are indebted to the following Virginia Institute of Marine Science personnel for their assistance in this project: Steve Atran, Loisirene Blumberg, Joice Davis, Deane Estes, Carol Furman, Lillian Hudgins, Curtis Leigh, James Owens, and Gloria Rowe.

The project was funded, in part, by the United States National Marine Fisheries Service, Northeast Region, through Public Law 89-304.

LIST OF TABLES

List of Tables (continued)

List of Tables (continued)

LIST OF FIGURES

Executive Summary

1. Stake gill nets in the James River yielded an estimated 193.5 metric tons (MT) of American shad in 1983, a three-fold increase relative to 1982.

2. A decline in pound net effort and catch-per-unit-of-effort contributed to a dramatic decline in the 1983 river herring landings in the York River relative to 1982.

3. Stake gill nets in the York River landed an estimated 213.3 MT of American shad in 1983, a 35% increase relative to 1982.

4. Pound nets landed an estimated 1.0 MT of American shad and 41.7 MT of river herring in the Rappahannock River in 1983; gill nets landed 7.1 MT of American shad.

5. Landings of river herring in the York River in 1983 were the lowest in the period 1977 to 1983.

6. The 1983 landings of river herring in Virginia were 833 MT, a 40% increase relative to the 1982 landings; the 1982 landings were, in turn, a 151% increase relative to the 1981 landings. However, these catches are far below the average annual landings of 8,760 MT for the decade 1966-1975.

7. American shad landings in Virginia also increased in 1982 and 1983 relative to 1981. The increases from 226 MT in 1981 to 265 MT in 1982 and to 289 MT in 1983 were modest, and the landings are well below those prior to 1981.

8. Year-class contributions to the river herring fishery were estimated from species composition, sex ratio, age structure, and mean length and weight-at-age data. Annual declines in cohort CPUE were used to estimate mortality, survival, and exploitation rates.

9. With but one exception, the juvenile indexes of abundance for alewives and American shad were higher in the Mattaponi River than in the Pamunkey River in the years 1980-1983. Conversely, the indexes for blueback herring in this period were always higher in the Pamunkey River.

10. The instantaneous daily mortality rates for juvenile American shad and river herring were estimated as 0.048 and 0.044, respectively.

Job 1. Catch and Effort Statistics of the Virginia Alosa Fisheries

INTRODUCTION

Stock assessment consists essentially of the collection and analysis of basic data such as catch, effort and development of an index (relative or absolute) of abundance of the fish stock under consideration (Gulland 1978). Estimates of total landings by gear type may be obtained from the product of catch-per-unit-of-effort (CPUE) and the total units of gear fished. Specific values of effort by gear type and CPUE in any particular year are not themselves of exceptional significance but rather it is the trend in the data from year to year that is important (Gulland 1978).

The CPUE and the estimated landings may be used as a relative indicator (index) of stock abundance by a simple comparison with such estimates in prior years, provided there are not large annual fluctuations in availability of the fish and the total units of gear fished remains relatively constant (Rounsefell 1975).

MATERIALS AND METHODS

Pound net catch estimates were determined by multiplying the CPUE (kg/net per half-month) of the index nets by the number of nets actively fishing (weighted by net size) in each strata of the river. Index nets are those for which daily records were kept by cooperating fishermen. Effort was determined by semi-monthly aerial counts of active pound nets (Table 1.1 and Fig. 1.1). Seasonal pound net CPUE was determined by dividing total landings by the average number of nets fished adjusted for the length of the fishing season for each species.

Stake gill net catch estimates were determined by multiplying the CPUE (kg/m of net/half-month) of index nets by meters of stake gill netting in 5-nautical mile strata of the river. Effort was determined by a count of stake gill nets during the peak of the American shad fishing season (Table 1.2). Yearly stake gill net CPUE was determined by dividing total landings by total netting fished for shad.

Because of the close proximity of all the nets to adjoining strata, nets in the mile 10-15 stratum in the James River (four gill net stands in the lower and two in the upper portion of the stratum) were assigned to respective adjoining strata.

Records from pound net fishermen were unavailable for the lower strata in the Rappahannock River; thus landings were estimated from an average proportion for the years 1978-1982.

RESULTS AND DISCUSSION

Low stock abundance of American shad and lack of a market for river herring as food fish are reflected in the decline of a directed pound net fishery for these species. Except for the Rappahannock River few pound nets were deployed until April 1983 (Table 1.1). Those nets installed earlier were set primarily to supply bait for crabbers. The peak number of nets did not occur until the first of June, too late to be considered part of the directed fishery for *Alosa* species.

Total estimated landings of all Alosa species by pound nets decreased relative to 1982 (Loesch and Kriete, 1982) with the alewife in the York River exhibiting the greatest decrease (Table 1.3). Conversely, estimated landings of American shad by stake gill nets increased relative to 1982 in all rivers except the Rappahannock River.

Pound net effort in the Rappahannock River and gill net effort in all rivers increased compared to 1982 (Table 1.4). The decrease in York River pound net effort is due, in part, to a reduction of effort towards Alosa species.

Pound net CPUE for river herring (alewife and blueback herring) decreased in the Rappahannock and York rivers relative to 1982 (Table 1.4). Data for individual species of river herring were not presented in Table 1.4 for three reasons which were presented in the 1982 report (Loesch and Kriete 1982). Pound net CPUE data for American shad are not presented because re-evaluation of effort data, although attempted, is inconclusive. Landings of American shad are sporadic in pound nets during periods of low abundance, thus the data are of limited value in analyses. Stake gill net CPUE of American shad declined in all rivers except in the Rappahannock River.

James River

No pound nets were set in the James River during 1983. The capture of finfish is severely restricted as a result of kepone contamination, making pound net operations in the river unprofitable.

Stake gill nets landed an estimated 193,500 kg of American shad in 1983 (Table 1.5), a three-fold increase relative to 1982 (Table 1.3). Almost half of the increase is attributable to the lower stratum of the river (miles 05-10) which landed 42% of the catch during April. As in 1982, it is possible that landings for the remainder of the river are underestimated. An unknown proportion of the catch in the upper strata (miles 20-60) was sold to local markets.

Peak landings in 1983 occurred during the first half of April as opposed to the second half of March in 1982 (Loesch and Kriete 1982).

York River

Estimated landings in 1983 of alewife and blueback herring declined dramatically relative to 1982 (Table 1.3). The decline is not only attributed to a reduction in effort but also to a decline in the CPUE (Table 1.4). Peak landings of river herring, primarily blueback herring, occurred during the second half of May (Table 1.6) and consisted mainly of spent fish. Peak landings of male American shad occurred in the same period. However, since no female American shad were reported by index fishermen for this period, it is probable that the spent females were included in the reported landings of male American shad.

Increases in effort and CPUE in 1983 contributed to increased estimated landings of American shad by gill nets in the York River relative to 1982 (Table 1.3, Table 1.4). Peak landings of 75,822 kg occurred during the second half of March followed very closely by landings of 70,831 kg in the first half of April (Table 1.7).

Rappahannock River

Pound nets in the Rappahannock River landed an estimated 1,000 kg of American shad and 417,000 kg of river herring in 1982 (Table 1.8), virtually no change in landings relative to 1982 (Table 1.3). River herring were either sold as bait for crab and eel pots or to a pet food processing plant, and few, if any, were sold for human consumption.

Stake gill nets in the Rappahannock River landed 7,100 kg of American shad in 1983 (Table 1.9), a slight decline of 11% relative to 1982. The continued decline may be attributed to a lack of effort directed toward shad (Table 1.2). Those nets set between miles 35 and 70, although considered an optimum mesh size for shad, were set to target other species. Index fishermen reported only incidental catches of American shad and thus were not included in the estimated landings for the Rappahannock River.

Catch-effort evaluation

Landings of American shad and river herring (alewife and blueback herring) have been declining since around 1970 (Loesch and Kriete 1976). River herring landings in the late 1960's averaged around 13,500 metric tons (MT) (Job 2, this report); however, landings in recent years have been less than 1,000 MT.

River herring landings declined 79% in 1983 (43,700 kg) in the York River relative to 1982 (213,120 kg) following an increase from 1981 (195,200 kg) (Table 1.3). The estimated increase in landings in the Rappahannock River was negligible; however, the decline (79%) in the York River was dramatic, resulting in the lowest estimated landings during 1977-1983 (Table 1.3). The reasons for the decline in the York River are two-fold: 1) effort declined 44% relative to 1982 and 2) CPUE declined 63%, the lowest CPUE since 1977 (Table 1.4). Pound net effort in the York River peaked in late May in 1983 whereas maximum effort was regularly attained by mid-March during the late 1960's, a period of high *Alosa* abundance. Present-day effort in the York River is driven by two factors, the run of "summer fish" (spot, croaker, weakfish, etc.) and the demand for crabpot bait, neither of which occurs during the peak of the *Alosa* spawning runs.

Total estimated landings of American shad from pound nets decreased in 1983 in the York and Rappahannock rivers relative to 1982 (Table 1.3); this follows an increase from an all time low in 1981. As mentioned earlier, the apparent decrease of female shad in the York River is probably not real. Over 40% of the shad landings in this river occurred during May (Table 1.6). Spent females were sold with the males because the roe was no longer of any value.

Landings of American shad by gill nets increased in the James and York rivers and remained relatively stable in the Rappahannock River in 1983 (Table 1.3). The increases are the result of increased effort as well as increases in CPUE (Table 1.4). Gill net effort in the James and Rappahannock rivers remains at levels well below peak levels of previous years. Effort in the York River has continued to increase. Regardless of increases in effort, as well as CPUE in the

James and York rivers in 1983, landings of American shad remain well below the levels in 1980 (Table 1.4).

Factors other than abundance and effort can greatly affect landings as well as CPUE. Gill nets can be fouled with bryozoans which affects catch and effort. A different problem, but with the same results, can occur when jellyfish (Cyanea capillata) are very abundant in the lower portions of the rivers. Some fishermen reported gill-netting torn from the supporting lines, and poles were broken from the weight of the jellyfish.

Job 2. Population Dynamics of the Virginia *Alosa* Fishery

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) continued its annual assessment of the structure of adult *Alosa* populations in Virginia inshore waters. These data are essential for any eventual consideration of an *Alosa* management plan in Virginia, and the State-Federal coastwide management plan presently being developed.

MATERIALS AND METHODS

Samples of river herring were collected biweekly in the months of April and May from the York and weekly from the Rappahannock River in March, April and May. American shad samples were collected in April from the James, York, and Rappahannock fisheries (Table 2.1).

When available, 90.7 kg and 45.4 kg of river herring were randomly sampled from commercial pound net catches in the York and Rappahannock rivers, respectively. These nets employ a 50.8 mm stretched mesh in their entrapment section, and are assumed to be nonselective for river herring age 3 or older.

Random samples of up to 100 American shad were taken from commercial catches. The fishery primarily employs gill nets with 12.4 to 14.0 cm stretched mesh which favor the capture of females, the larger of the sexes.

River herring samples were returned to VIMS where they were sorted by species and sex, body length and weight recorded, and scales and otoliths removed from random subsamples. American shad data were collected at the sampling site, except for age data which were derived from laboratory analysis of scales. Ages of river herring were determined from otoliths and American shad age from scales by the method of Cating (1953), i.e., counting the number of annuli and spawning check marks, and adding a year for the scale edge.

A sonic digitizer microcomputer complex was used to "read" American shad scales. The use of the sonic digitizer interfaced with a microcomputer has dramatically decreased the time needed to read scales, and has also eliminated transcription errors. A scale image is projected onto a microfiche reader screen; the plastic needlepoint stylus of the sonic digitizer is touched to the screen, first at the nucleus of the scale and then at each successive annulus. Measurements and calculations are stored on a "floppy disk" and after the last measurement they may be viewed on the computer monitor screen or printed. The microcomputer program DISBCAL for these analyses was written by Richard V. Frie (1982) at the University of Minnesota. Mr. Frie interfaced a microcomputer with a digitizing pad. With minor modifications, the program has been used by us and others with a sonic digitizer.

Domestic Alosa landings data for the years 1965-1972 were obtained from the respective U.S. Fishery Statistical Digests. The 1973-1976 data were from the annual summaries of Current Fisheries Statistics, NMFS, Division of Statistics and Market News. Subsequent landings data have been obtained from the Virginia Marine Resources Commission. These data all differ from those in job 1 in that they include landings from the Potomac River, Chesapeake Bay proper, and the haul seine fishery in the James River.

The PRIME 750 computer system at VIMS was used in conjunction with a "package program," SPSS (Nie et al. 1975) to analyze data, and to construct tables and figures.

RESULTS AND DISCUSSION

Sampling Effort

A total of 981 alewives, 1,346 blueback herring and 316 American shad were sampled in 1983 (Table 2.1). The number of river herring collected since 1979 has been considerably less than in previous years. The reduction in sampling was, in part, due to monetary considerations, and, in part, due to a savings in time, effort and experimental units by the use of otoliths. Very few otoliths have been found to be unreadable. In contrast, very large samples were needed to obtain a relatively small proportion of usable scales due to their loss or damage during spawning and handling in the fishery.

Landings

The 1983 landings of river herring in Virginia were 833 metric tons (MT), a 40% increase relative to the 1982 landings of 593 MT. The increases in river herring landings in Virginia in 1982 and 1983 appear to reverse the general decline that started in 1970 (Fig. 2.1). However, to put the increases in proper perspective, it must be realized that the 593 MT in 1982 and the 833 MT in 1983 are, respectively, only 6.8% and 9.5% of the average annual landing of 8,760 MT for the decade 1966-1975.

American shad landings in Virginia, like those of the river herring, increased in 1983 relative to 1982 (Fig. 2.1). The increase from 265 MT in 1982 to 289 MT in 1983 is, however, modest (9%), and only 45% of the mean landings for the decade preceding 1981 (Fig. 2.1).

It is not known, at this time, if the increased landings of American shad and river herring are due to increased effort, improved stock sizes or both. Landings of river herring and the associated CPUE in the Rappahannock River increased in 1982 and 1983 relative to 1980 and 1981 (Table 1.4). In contrast, pound net effort in 1981 was the highest since 1975 but CPUE was the lowest since 1977. Catch-effort data in the York River, however, do not parallel that for the Rappahannock River. In 1982 landings of river herring in the York River increased (Table 1.3) apparently as a result of increased pound net effort (Table 1.4). In 1983 all river herring catch-effort statistics for the York River declined, relative to 1980, 1981 and 1982. As explained in job 1, this was probably due to the sparse fishing effort in March 1983. A renewed haul seine fishery in the Chickahominy River also contributed to the 1982 and 1983 increases in river herring landings relative to 1981. Data supplied by the Virginia Marine Resources Commission (VMRC) showed that the haul seine catches rose from 44 MT in 1981, to 76 MT in 1982, and to 84 MT in 1983. Data from VMRC also show strong increases in river herring landings in the Potomac River in 1982 and 1983, about 241 and 646 MT, respectively, relative to the 33 MT landed in 1981.

Age Composition

The 1983 age frequencies of river herring (sexes pooled) and American shad by river, determined from samples of the catches in the commercial fisheries are presented in Tables 2.2-2.6. The age structure data in 1982 (Loesch and Kriete 1982) when compared with the age structure data in 1981 (Loesch and Kriete 1981), indicate that the rise in river herring catches in 1982 was due, at least in part, to an increase in the age 4 alewife contribution to the total landings. Sample data in 1983 (Tables 2.2-2.5) indicates that the 1978 year class at age 5 was still a strong component of the alewife and blueback herring stocks. These data (adjusted frequencies) do not translate to stock numbers, but the relatively high juvenile index of river herring abundance for the 1982 year class (job 3) complements recent reports of high catches of 1982 striped bass in the Potomac River.

The American shad age structure (Loesch and Kriete 1980, 1981, 1982 and Table 2.6 herein) consistently indicated a high relative abundance of ages 5 and 6. Observed age structures of American shad, however, are strongly influenced by gill-net selectivity. The selection for females by the gill nets used in the American shad fishery, and the practice of discarding males at the net when their market price is low is indicated by the disparity between the numbers of males and females in our samples (Loesch and Kriete 1980, 1981, 1982 and Table 2.6 herein).

The river herring age composition data were used in conjunction with sex ratio and mean weight-at-age data to estimate year-class contributions to the total landings in 1982. Analysis of American shad year-class data has never been a stated objective of our anadromous programs, but it will be pursued as time permits.

Length and Weight Analysis

Mean values for fork length and total body weight for river herring, derived from samples of the pound net catches in the York and Rappahannock rivers, are presented in Table 2.7. Similar data for American shad, derived from samples of gill net catches in the James, York, and Rappahannock rivers, are presented in Table 2.8.

As previously stated, river herring mean weight-at-age data were used in conjunction with age composition and sex ratio data to estimate year-class contributions to the annual landings. The feasibility of utilizing these year-class data in production models is being investigated.

Species Composition

Alewives constituted 42.1% of the river herring sampled in 1983 (Table 2.1), despite sparse catches in the York River. In contrast, alewives represented 19.1%, 8%, and 13.4% of our river herring samples in 1980, 1981, and 1982. The increase in 1983 was due to the higher catches of alewives in the Rappahannock River in March and April in 1983. Since effort in 1983 (Table 1.4) and 1982 (Loesch and Kriete 1982) in March and April were nearly identical the increased catch reflects greater availability and/or increased abundance.

The percentage of alewives in the fishery is not indicative of their proportion in the river herring stock. Alewife spawning migrations are controlled by water temperatures and in Virginia rivers spawning can commence any time from early to late March. However, early-season fishing effort is also variable and in some years there may be few or no catches of the earliest runs of alewives.

Species composition data were used to partition commercial landings of river herring into the species-specific components.

Sex Ratios

The sex ratio data (Table 2.1) were used in conjunction with species age structure and mean weight-at-age data to estimate year-class contributions to the total landings.

Mortality Estimates

Estimates of instantaneous total mortality rates (Z) for river herring in the Rappahannock River were made for the year classes 1969-1975 (Table 2.9). These Z values and an assumed instantaneous natural mortality rate were used to calculate the annual rates of mortality (A), survival (S), and exploitation (E). A value of M = 1.1 was assumed reasonable because of the relatively short life span of river herring and the rigors of anadromous spawning. The estimates are considered tenuous because some Z values were derived from catch curves and, thus, are "historical," while others, through necessity, were derived from $\log_e$ ratios of successive CPUE's and are therefore age specific. Additionally, the Z value for the alewife 1973 year class was omitted as an outlier based on a statistical consideration ($P<0.05$); however, no bio-physical justification for omission is offered. Catch curves were plotted and Z values were determined from the portion of the descending right limb that was, by inspection, linear. Log_e ratios were used when CPUE values for age 4 and ages ≥ 7 were not used because the values produced sharp inflections which, respectively, indicated recruitment and an increased mortality rate due to advanced age.

Annual mortality rates of about 80% and exploitation rates of 40% were estimated for river herring in the Rappahannock River. In the Herring River in Massachusetts, DiCarlo (1981) reported annual mortalities of 73% and 80% for spawning alewives in 1980 and 1981. Walton (1981) reported that alewife fishing mortalities ranged from 80% to 95%.

Attempts to assess the relationship between total mortality (Z) and mean effort (f) in order to estimate fishing mortality (F) and natural mortality (M) from pound net catch-effort data have not had an acceptable degree of precision (Loesch and Kriete 1980). One source of variability is the measure of effort, pound net days. Pound nets fish continuously, except for brief periods when emptied or cleaned, but the river herring enter the river in spawning waves (pulses). The period between spawning waves is greater and more variable, and the individual fish weigh less during the early and late segments of the spawning season. The use of catch and effort data occurring in the peak periods of landings for estuarine mortality rates will be investigated in the near future.

Job 3. Annual Index of Juvenile *Alosa* Abundance

INTRODUCTION

Juvenile, migratory *Alosa* were sampled in order to estimate relative abundance, growth, and mortality. Long-term objectives are to determine if there is a relationship between the annual index of abundance and future recruitment, and to determine if there is a periodicity of strong year classes.

MATERIALS AND METHODS

Indices of juveniles *Alosa* abundance were estimated by sampling in their nursery zones (tidal freshwater) in the Mattaponi and Pamunkey rivers. The nursery zone in the Mattaponi River was sampled nine times between 6 June and 15 August 1983, and the Pamunkey River was sampled six times between 14 June and 4 August 1983.

A stratified random sampling plan was employed. Each nursery zone was divided into a series of strata, each 9.3 km. Each stratum was further divided into five 1.9 km substrata. Perpendicular to this stratification, the 9.3 km sections were divided into three nearly equal parts, a center section and two shoreward sections bounded by the 1.8 m depth contour lines at mean low water (MLW) indicated on the respective navigation charts. Thus, each 9.3 km stratum was partitioned into 15 "cells." Three sites were randomly chosen from the 15 cells in each stratum. The nursery zones in each sampling period were demarcated by the last upstream and the last downstream stratum in which juvenile *Alosa* were captured.

Samples were collected with a bow-mounted 1.5 m x 1.5 m pushnet developed at VIMS (Kriete and Loesch 1980); the net has a high catch efficiency for juvenile *Alosa* relative to surface trawls. A calibrated flowmeter mounted at mid-height and one-third width indicated the pushnet strained an average of 654 m^3 of water both with and against the current in 5-min samples, and 663 m^3 at slack water. These values were not significantly different ($P > 0.75$) and 655 m^3 was taken as the overall mean (Loesch et al. 1982). The practice of taking 5-min samples has been used throughout the annual segments of this project, and all catches have been adjusted, as flowmeter values indicated, to the standard of 655 m^3 of water filtered. Sampling was conducted at night to minimize the effects of variation in incident light, because juvenile *Alosa* or the prey they follow exhibit negative phototrophic responses (Loesch et al. 1982). Additionally, juvenile catch data in 1982 were adjusted for a minimum fish size. Small juvenile *Alosa* capable of passing through the 12.7-mm stretched mesh of the pushnet codend are retained to varying degrees by larger fish and debris in the net. To ascertain escapement, a sleeve of 6.35-mm stretched mesh was loosely fitted over the codend in a series of 25 samples in 1979. The median fork length of *Alosa* passed through the codend and retained in the sleeve was 25 mm. Fish $\geq$ 26 mm represented 30% of the fish in the sleeve, and for lengths $\geq$ 27 mm, 18% passed through the codend. Only 5.4% of the fish $\leq$ 26 mm were retained in the codend. An *Alosa* fork length of 27 mm was chosen as a lower limit for catch-effort considerations. We believe this limit increases the reliability of our estimates, but we also recognize that the effect of masking (see Pope et al. 1975) could be confounded in our data. The presence of a masking effect could be ascertained in a series of sleeve-and-sleeveless trials.

A weighted overall mean CPUE, where stations were replicates per stratum, was calculated for each sampling period. The largest of these CPUE values was defined as the index of abundance, and is referred to as the maximal CPUE. A maximal CPUE was chosen as an index, in preference to a seasonal mean CPUE, for several major reasons. First, a general downstream drift of the larger juveniles in the fall, ahead of the mass migration associated with decreasing river temperatures, has been reported for blueback herring and American shad (Loesch 1969, Marcy 1976). Thus, annual variations in the time of spawning and/or variations in the growth rate would definitely affect downstream drift and late-season availability in the nursery zone. Second, if gear avoidance increases with size, the effect is minimized with maximal CPUE since it occurs relatively early in the total period of juvenile availability in the nursery zones. Another major factor was the need to reduce the sampling season because of economic considerations. A seasonal CPUE for the juvenile Alosa decreases the more protracted the sampling season due to mortality and emigration. Finally, because of the cost limitations of sampling and data analysis, a "full season" program would increase the time between surveys without increasing the number of surveys. Turner and Chadwick (1972) reported serious deficiencies in their annual index of juvenile striped bass when the index was developed from catch data collected at two-week intervals.

Estimates of mean CPUE that followed the maximal CPUE, but clearly preceded the onset of the seaward migration, were used in conjunction with the maximal value to estimate the instantaneous natural mortality rate (M). The $\log_e$ of the ratio of maximal CPUE to a subsequent CPUE was used to calculate M when there was only one usable CPUE subsequent to the maximal value. Division by the number of days elapsed from the maximal CPUE (day 1) to the subsequent CPUE gave the daily instantaneous rate of natural mortality (M_d). With two or more usable CPUE values following the maximal CPUE, catch curves (Ricker 1975) were used to derive M_d.

Increases in mean fork length were used to calculate juvenile *Alosa* growth. All juveniles in samples of size N $\leq$ 50 were measured; for N > 50, a random subsample of 50 fish was taken.

RESULTS AND DISCUSSION

Relative Abundance

The maximal CPUE values and their dates of occurrence for alewife, blueback herring, and American shad were determined (Tables 3.1 and 3.2). Similar data were presented in the previous segments of this study (Loesch and Kriete 1980, 1981 and 1982). Certain general patterns are repeated in the series of maximal CPUE values from 1978 through 1983. The maximal CPUE values for alewives and American shad occurred earlier than those for the blueback herring; however, the blueback herring index was, with one exception (1981), of greater magnitude (Table 3.3). The superiority of the blueback herring CPUE is probably, in part, due to differences in *Alosa* phototropic behavior (Loesch et al. 1982); however, commercial landings indicate that the blueback herring is the most abundant *Alosa* species in Virginia. There is also a pattern between the two rivers with respect to the magnitude of maximal CPUE values. The maximal CPUE values for alewives and American shad were most often greater in the Mattaponi River than in the Pamunkey River (Table 3.3). The only exception to the pattern for alewives occurred in 1980. Midway into the sampling program on 7 July in the Pamunkey River a vessel problem delayed for one week the completion of the program in that river and the entire sampling program in the Mattaponi River. The only exception to the pattern for American shad was on 20 June 1979, when the highest mean CPUE to date for shad (or alewife) was obtained in stratum 55-60 in the Pamunkey River. In contrast to the alewife and

American shad, the maximal CPUE values for blueback herring in the Pamunkey River have exceeded those for the Mattaponi River since push net sampling began in 1978 (Table 3.3).

A frequent problem, primarily with alewife and American shad in the years 1980, 1981 and 1982, was the occurrence of the maximal CPUE in the first sampling period; obviously the index could have been underestimated. A possible adjustment to such questionable index values is discussed below. The catch results since multiple periods of sampling were introduced in 1979 indicate that the quest for unambiguous juvenile Alosa indexes must begin, at the latest, in the first week of June. Differences in the time of the maximal CPUE occurrences stem from the differences in time when the bulk of each species spawns. Also, different species-specific growth rates, effects of density, and environmental variation affecting diet will affect size at age, ergo, availability at age.

If CPUE is a valid and reasonably precise indicator of year-class strength, the mean CPUE values determined in 1978 (Loesch et al. 1979) indicate that it was a stronger year class than any subsequent year class to date. The upswing in the Virginia landings of Alosa which occurred in 1982 (Figure 2.1) was dominated by an apparently strong 1978 year class (Loesch and Kriete 1982). At age 5, the 1978 year class was a strong contributor to the 1983 age composition of alewives and was the modal year class for blueback herring in the York River (Tables 2.2 and 2.3). Additionally, the 1982 indexes for river herring were the highest since 1978, implying a parent-progeny relationship. Thus, the 1978 river herring indexes appear to have been harbingers for the 1982 events. The study of the validity or temerity of the apparent causal relationship will continue. The mean CPUE values in 1978 were derived from a single sampling period that was late in the year relative to the observed occurrence of maximal CPUE in subsequent years. It is reasonable to assume that mean CPUE values in 1978 would have been higher earlier in the season. Maximal CPUE values for alewives and American shad have generally been observed about the third week in June and the maximal CPUE for blueback herring has generally occurred in the first 10 days of July. Assuming a relation exists between CPUE and the year-class size, then an adjustment to the mean CPUE can be made from the relation

$$CPUE_5 = CPUE_o e^{(-M_d)(d)}$$

where $CPUE_t$ is the observed index value, $CPUE_o$ is the index at an earlier date, e^{-M_d} is a survival rate, and d is the number of days elapsed between sampling periods. For example, in the Pamunkey River on 5-7 September 1978, the mean CPUE for blueback herring was 505.6. Using the instantaneous daily mortality rate (M_d) of 0.04 derived in 1979 for river herring, and a 7 July date, the adjusted index ($CPUE_o$) is

$$CPUE_o = (505.6)e^{(.04)(61)} = 5,801$$

The 1978 data have not been so adjusted, nor have maximal CPUE values that occurred in first sampling periods. The data are too few at this time to formulate logical inferences about annual variations in estimates of M_d solely due to chance, variations in M_d, if any, due to year-class abundance, and species-specific time intervals in which maximal CPUE values are expected to occur.

Growth

Growth curves were constructed from the juvenile fork length data (Loesch and Kriete 1980, 1981, 1982; and Figs. 3.1, 3.2 and 3.3 herein). Two aspects of these curves must be interpreted from the life history of the *Alosa*. During the season, there is a tendency for the larger juveniles to migrate downstream (Loesch 1969, Marcy 1976). Thus, growth will be underestimated if these individuals leave the nursery zone. The other aspect of Alosa behavior that affects estimates of juvenile growth (and mortality) is their protracted spawning period. Juveniles collected in June in the Virginia nursery zones are primarily products of the early spawners. From about mid-July to mid-August, depending on the time of spawning and the growth rate, the juveniles produced by the bulk of the spawners become susceptible to capture by the pushnet. The result of this recruitment is an apparent decrease in the growth rate (Figs. 3.1, 3.2 and 3.3) or an observed decrease in mean length (Figs. 3.2 and 3.3). This apparent "negative growth" was reported in the previous annual reports of this contract period and also for juvenile blueback herring in the Susquehanna River (Whitney 1961) and in the Connecticut River (Loesch 1969); it is also apparent in the juvenile American shad growth curve presented by Marcy (1976; his Fig. 46). Thus, observed growth determined from body length is only apparent growth because of the effects of recruitment and emigration. Loesch and Kriete (1980) reported that the slower growth and high natural mortality of blueback herring in the Chickahominy River may be more apparent than real. The Chickahominy River has a small nursery zone, about 27 km, and emigrants would soon enter the James River. The downstream drift of the larger juveniles would result in an underestimate of growth and are overestimate of mortality. The Chickahominy River, upstream of Walker's Dam, is used as a water source by the City of Newport News. There are no data that would indicate environmental problems in the river that could account for the lowest observed growth rates, or a daily instantaneous mortality rate for blueback herring that is double (or more) that estimated in the other river systems (Loesch and Kriete 1980). Conversely, the relatively slow decline in CPUE in the James River between July and August in 1979 and 1980 (Loesch and Kriete 1980), and again in 1981 (Loesch and Kriete 1981) could be the result of blueback herring emigration from the Appomattox and Chickahominy rivers and the large Jones Neck and Turkey Island oxbows.

The mean length estimates in the four segments of this project in early July when the problems of recruitment and emigration should have had the least effect, indicate that: 1) juvenile blueback herring, on the average, were largest in the James River and smallest in the Mattaponi River; intermediate mean sizes in descending order, occurred in the Rappahannock and Pamunkey rivers, 2) alewife mean length was greatest in the Rappahannock River, intermediate in the Pamunkey River, and smallest in the Mattaponi River; and 3) American shad were generally larger in the Pamunkey River than in the Mattaponi River; the 1983 findings were an exception. These findings are in agreement with data previously presented by Loesch and Kriete (1980). The Mattaponi River is the clearest of the rivers sampled; this condition could reflect a limiting food supply which is responsible for the smaller observed mean juvenile fork lengths. A VIMS daytime, bottom trawl survey in the James, York and Rappahannock rivers from December 1981 through February 1982 captured 80 juvenile alewives and 159 blueback herring. For the pooled data, the mean fork lengths (and standard errors) were 89.7 mm (0.8262) and 78.5 mm (0.5043) for alewives and blueback herring, respectively. It is not known if these values are valid statistics for the bulk of the juvenile river herring which migrated to sea.

Estimates of instantaneous growth rates have not been made at this time because of the unknown confounding effects of juvenile recruitment and emigration. Loesch and Kriete (1982) suggested that the use of daily increments to otoliths for the study of growth and mortality would be superior to the use of body length data. (The technology for determining daily increments to otoliths is not new, e.g., see Panella 1971). In fact, juvenile otoliths from American shad and blueback herring are being used for such studies (Creco et al. 1982).

Natural Mortality

Catch curves were constructed for the three *Alosa* species where catch data were sufficient. Catch curves are characterized by an ascending left limb, a dome, and a descending right limb. The ascending left limb and the dome represent ages incompletely recruited; linearity of the descending right limb is considered as evidence that recruitment and natural mortality are adequately constant for application of the model (Ricker 1948, Royce 1972). When catch curves do not have a straight descending right limb, there is reason to suspect that recruitment or catchability varies, or that the population is not in equilibrium (Royce 1972). Catch curves for the three *Alosa* species most often had an upward inflection in the descending right limb that corresponded to the period of depressed mean growth due to recruitment. For this condition the instantaneous mortality rate (M) was calculated from the $\log_e$ of the ratio of $CPUE_t/CPUE_{t+1}$, and the daily rate (M_d) from the division of M by the number of days elapsed between time t and t + 1.

Estimates of daily instantaneous mortality rates (M_d) of alewives, American shad, and blueback herring have been made since 1979 (Table 3.4). Most estimates of M_d were made from catch curves in 1979 and 1982 (Loesch and Kriete 1980, 1982) because of the greater frequency of sampling periods, relatively short time lapse between the periods and the absence of secondary modes. Effort was reduced and the time between sampling periods was increased to about three weeks in 1980 and 1981. Juvenile recruitment in mid-August 1980 and 1981 further restricted the amount of usable data;

consequently, log ratios, as described above, were used to estimate M_d. With the exception of the M_d for American shad in Mattaponi River, all estimates of M_d in 1983 were made from log ratios. Very obvious secondary modes occurred within any three consecutive sampling periods. Bimodal distributions of mean CPUE in 1983 occurred in the Mattaponi River for alewife and blueback herring (Table 3.1), and in the Pamunkey River for alewife and American shad (Table 3.2). The mean CPUE for blueback herring in the Pamunkey River was maximum on 23 June 1983, but subsequently on 13 July and 4 August the mean CPUE increased after previous declines (Table 3.2). Thus, with secondary modes M_d can be estimated from one or another period of decline or determined as a mean value. We most often chose the earliest period of decline because it generally allowed the maximal CPUE and minimized the errors of recruitment, emigration, and gear avoidance.

In the annual quest for maximal CPUE since 1979 lessons have been learned. Sampling must begin early and be repeated at reasonably short time intervals to obtain reliable estimates of growth and mortality. The present data base indicates that sampling in the Mattaponi and Pamunkey rivers should begin about 1 June and continue weekly in order to isolate the maximal CPUE for American shad and alewives. Weekly intervals appear to be sufficiently short so that growth and mortality curves reflect incidences of recruitment and emigration. It was for these reasons that sampling effort was concentrated in the Mattaponi and Pamunkey rivers in 1982. It is concluded that the 1979 and 1982 estimates of M_d primarily from catch curves are the most reliable. The M_d values for alewives and blueback herring in 1979 and 1982 are all very similar with one exception. The 1982 estimate of the blueback herring mortality rate in the Mattaponi River (M_d = 0.077) was much higher than the mortality estimate in the Pamunkey River (M_d = 0.046).

Both mortality estimates were derived from $\log_e$ ratios, but the slower growth of blueback herring and their greater relative recruitment between mid-July and early August (Loesch and Kriete 1982) in the Mattaponi River suggested that the higher M_d was a segment of the right limb that is closer to the dome-shaped upper portion of the catch curve. The preliminary estimates of daily mortality (M_d) based on the 1979 and 1982 data are 0.044 and 0.048 for river herring and American shad, respectively. Creco et al. (1982) reported that American shad larval mortality was inversely related to age. They estimated daily Z values (M_d herein) of 0.202 among prolarvae 3-5 days old, 0.113 among 9-16 day old larvae, and 0.090 among advanced larvae 17-25 days old. The latter age group ranged from about 18.5 to 23.5 mm in length. Thus, our estimates of lower mortality rates for juveniles appear reasonable.

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Table 1.1. Number of active pound net stands in Chesapeake Bay and its Virginia tributaries during January-June, 1983.

Area	Jan	Feb	Mar		Apr		May		Jun	
	18	18	14	23	15	27	10	24	14	23
A. James River										
B. Back River	0	0	1	1	1	1	1	0	1	1
C. Poquoson River	0	0	0	0	1	1	1	0	1	1
D. York River	0	0	0	4	9	12	15	16	15	17
E. Mobjack Bay	0	0	3	3	3	3	3	3	2	2
F. Piankatank River	0	0	1	2	4	5	5	5	5	5
G. Rappahannock River	0	0	16	29	45	46	46	48	45	39
H. Great Wicomico River	0	0	0	1	4	6	6	6	6	7
I. Potomac River	0	0	6	8	34	45	61	63	66	64
a. Virginia tributaries to Potomac R.	0	0	0	0	3	2	4	4	4	3
J. Cape Henry to Fort Wool	0	0	0	0	4	4	6	7	8	8
K. Old Point-Tue Marsh Point	0	0	4	6	9	10	9	9	10	5
L. York Spit	0	0	0	0	6	8	11	11	11	10
M. New Point-Stingray Point	0	0	4	8	15	18	20	21	23	20
N. Windmill Point-Smith Point	0	0	10	14	19	20	23	25	27	30
Eastern Shore										
O. Above Hungar Creek	0	0	0	0	0	0	0	0	0	0
P. Below Hungar Creek	0	0	0	2	11	15	19	19	21	24
TOTAL	0	0	45	78	168	196	230	237	245	236

Table 1.2. Number of stake gill net stands fished in Virginia rivers 1981-1983 (A) and linear meters of gill netting fished primarily for American shad per five-mile block (B) in 1983. Figures in parentheses represent the total meters of gill netting in the James, York and Rappahannock rivers.

A. River	Number of Gill Net Stands 1981	1982	1983
James	142	124	151
York	147	174	149
Rappahannock	98	55	46

B. River	Mile	Number of Stands	Number of Sections	Average Length/Section	Meters of Net	
James	05-10	35	896	9.4	(8,422)	8,375
	10-15					
	15-20	55	978	10.2	(9,976)	3,990
	20-25	26	451	15	(6,765)	2,706
	25-60	33	569	15	(8,535)	3,414
	Total	151	2,894		(33,698)	18,485
York	05-10	1	14	15.1	(211)	211
	10-15	40	720	15.1	(10,872)	10,872
	15-20	39(a)	700	15.1	(10,570)	10,570
	20-25	26	445	7.2	(3,204)	3,113
	25-29	43(a)	806	7.2	(5,803)	5,638
	Total	149	2,685		(30,660)	30,404
Rappahannock	25-30	11	205	17.2	(3,526)	2,419
	30-35	12	221	17.2	(3,801)	2,607
	35-40	13(a)	242	9.1	(2,202)	1,171
	40-60	11(a)	132	9.1	(1,201)	639
	Total	47	775		(10,730)	6,836

(a) Includes anchor gill net converted to stands.

Table 1.3. Yearly landings in kg of American shad by pound nets and stake gill nets, and river herring by pound nets. Landings for the James, York and Rappahannock rivers are estimations.

	Stake Gill Net		Pound Net			
	American Shad		American Shad		River Herring	
	♂	♀	♂	♀	Alewife	Blueback
James						
1977	11,612	186,495	(a)			
1978	116,348	574,935				
1979	17,328	263,203				
1980	59,003	343,026				
1981	12,056	105,550				
1982	21,811	37,731				
1983	46,822	146,715				
York						
1977	3,376	137,748	8,894	3,217	10,298	87,966
1978	31,666	174,780	16,676	13,141	16,021	135,954
1979	23,460	186,074	5,492	10,224	22,256	195,150
1980	25,012	246,719	2,267	6,453	43,391	176,955
1981	23,453	158,905	2,361	630	5,454	189,769
1982	23,811	134,676	5,236	179	15,499	197,621
1983	45,717	167,590	2,780	2,157	2,714	40,979
Rappahannock						
1977	2,298	22,053	2,949	1,268	84,688	209,163
1978	10,909	45,870	2,096	1,871	130,804	381,734
1979	2,199	21,619	2,046	1,562	56,016	423,633
1980	1,366	8,831	614	1,038	23,283	195,354
1981	2,621	10,015	824	832	33,767	287,963
1982	2,616	5,256	2,395	1,487	87,689	327,893
1983	2,113	4,969	1,629	747	103,066(b)	313,873(b)

(a) Data not available.
(b) See text for explanation.

Table 1.4. Yearly catch-per-unit-of-effort for American shad in stake gill nets and river herring in pound nets for the years 1975-1983. Stake gill net effort is in meters of netting. Pound net effort is in number of nets per season.

	Stake Gill Net			Pound Net	
		American Shad			
	Effort	♂	♀	Effort	River Herring
James River					
1975	25,832	2.7	8.8	(a)	(a)
1976	20,464	1.9	25.1	(a)	(a)
1977	26,884	0.4	6.9	(a)	(a)
1978	28,134	4.1	20.4	(a)	(a)
1979	37,207	0.5	7.1	(a)	(a)
1980	41,739	1.4	8.2	(a)	(a)
1981	38,250	0.3	2.8	(a)	(a)
1982	15,088	1.4	2.5	(a)	(a)
1983	18,485	2.5	7.9	(a)	(a)
York River					
1975	22,106	0.5	4.5	(a)	(a)
1976	21,424	0.3	3.0	(a)	(a)
1977	19,326	0.2	7.1	9.88	9,946
1978	15,954	2.0	10.9	12.74	11,929
1979	13,968	1.7	13.3	12.00	18,117
1980	19,940	1.3	12.4	15.95	13,815
1981	21,298	1.1	7.5	17.50	11,156
1982	28,262	0.8	4.8	21.05	10,124
1983	30,404	1.5	5.5	11.82	3,696
Rappahannock River					
1975	28,973	0.1	0.8	50.67	4,819
1976	32,517	0.1	0.5	35.09	3,185
1977	13,595	0.2	1.6	32.01	6,534
1978	13,681	0.8	3.4	27.28	18,788
1979	13,497	0.2	1.6	34.93	13,732
1980	8,758	0.2	1.0	28.00	7,808
1981	11,591	0.2	0.9	45.53	7,066
1982	6,736	0.4	0.8	32.44	12,811
1983	6,836	0.3	0.7	34.80(b)	11,981(b)

(a) Data not available.
(b) See text for explanation.

Table 1.5. Estimated catch in kg of American shad by stake gill nets for 5-mile sections in the James River 1983 by half-month intervals and by sex. Effort from Table 1.2. Index in kg/m of net.

Half-Month Period	River Mile	American Shad: Male Index	Male Estimated Catch	American Shad: Female Index	Female Estimated Catch	Total Estimated Catch
February 2nd	05-10					
	10-15(a)	(b)		(b)		
	15-20	0.0505	202	0.0025	10	212
	20-60		309		15	324
	Total		511		25	536
March 1st	05-10	0.8457	7,083	0.5372	4,499	11,582
	10-15(a)					
	15-20	0.3610	1,440	0.2190	874	2,314
	20-60		2,209		1,320	3,529
	Total		10,732		6,693	17,425
March 2nd	05-10	0.9243	7,741	1.7398	14,571	22,312
	10-15(a)					
	15-20	0.9508	3,794	1.4269	5,693	9,487
	20-60		5,819		8,733	14,552
	Total		17,354		28,997	46,351
April 1st	05-10	1.0450	8,752	5.1902	43,468	52,220
	10-15(a)					
	15-20	0.5094	2,033	1.7160	6,847	8,880
	20-60		3,118		10,502	13,620
	Total		13,903		60,817	74,720
April 2nd	05-10	0.2692	2,255	3.1856	26,679	28,934
	10-15(a)					
	15-20	0.0900	359	0.9523	7,976	8,335
	20-60		551		5,828	6,379
	Total		3,165		40,483	43,648
May 1st	05-10	0.1269	1,063	0.8602	7,204	8,267
	10-15(a)					
	15-20	0.0094	37	0.2469	985	1,022
	20-60		57		1,511	1,568
			1,157		9,700	10,857
	Total		46,822		146,715	
	Grand Total					193,537

(a) See text for explanation.
(b) None reported by index fishermen.

Table 1.6. Estimated catch in kg of American shad and river herring by pound nets in the York River 1983 by half-month intervals. Figures in parentheses are estimated species composition.

		American Shad				River Herring						
		Male		Female				Alewife		Blueback		
Half-Month Period	Number Nets	Index	Estimated Total	Index	Estimated Total	Index	Estimated Total	Percent	Estimated Total	Percent	Estimated Total	Number of Index Nets
March 2nd	4	42.5	170	153.5	614	(a)						4
April 1st	9	45.6	407	121.0	1,089	745.3	6,708	13.3	892	86.7	5,816	6
April 2nd	12	11.3	136	37.8	454	266.2	3,194	8.0	255	92.0	2,939	6
May 1st	15	35.7	535	(a)		905.2	13,578	(5.4)	738	(94.6)	12,840	9
May 2nd	16	95.7	1,531	(a)		1263.3	20,213	4.1	829	95.9	19,384	9
Total			2,779		2,157				2,714		40,979	
Grand Total				4,936			43,693					

(a) None reported by index fishermen.

Table 1.7. Estimated catch in kg of American shad by stake gill nets for 5-mile sections in the York River 1983 by half-month intervals. Effort from Table 1.2. Index in kg/m of net.

Half-Month Period	River Mile	American Shad: Male Index	American Shad: Male Estimated Catch	American Shad: Female Index	American Shad: Female Estimated Catch	Total Estimated Catch
February 2nd	05-10		8		3	11
	10-15	0.0379	412	0.0151	164	576
	15-20		405		160	565
	20-25	0.0557	174	0.0318	99	273
	25-29		314		179	493
	Total		1,313		605	1,918
March 1st	05-10		57		73	130
	10-15	0.2682	2,916	0.3427	3,726	6,642
	15-20		2,835		3,622	6,457
	20-25	1.2218	3,803	1.1770	3,664	7,467
	25-29		6,889		6,636	13,525
	Total		16,500		17,721	34,221
March 2nd	05-10		77		317	394
	10-15	0.3667	3,987	1.5027	16,337	20,324
	15-20		3,876		15,884	19,760
	20-25	1.1064	3,444	2.9325	9,129	12,573
	25-29		6,238		16,533	22,771
	Total		17,622		58,200	75,822
April 1st	05-10		22		348	370
	10-15	0.1033	1,123	1.6472	17,908	19,031
	15-20		1,092		17,411	18,503
	20-25	0.6924	2,155	3.0702	9,558	11,713
	25-29		3,904		17,310	21,214
	Total		8,296		62,535	70,831
April 2nd	05-10		7		149	156
	10-15	0.0333	362	0.7046	7,660	8,022
	15-20		352		7,448	7,800
	20-25	0.1445	450	1.5166	4,721	5,171
	25-29		815		8,551	9,366
			1,986		28,529	30,515
	Total		45,717		167,590	
	Grant Total					213,308

Table 1.8. Estimated catch in kg of American shad and river herring by pound nets in the Rappahannock River 1983 by half-month intervals.

Half Month		Number	American Shad				River Herring						Number of
			Male		Female				Alewife		Blueback		
Period	Mile	Nets	Index	Estimated Total	Index	Estimated Total	Index	Estimated Total	%	Estimated Total	%	Estimated Total	Index Nets
March 1st	31-70	16	2.6	42	1.1	17	126.4	2,022	100.0	2,022		(a)	14
March 2nd	31-70	20	8.9	179	4.5	90	154.0	3,080	98.0	3,018	2.0	62	18
April 1st	31-70	25	9.7	243	6.6	165	437.8	10,945	83.9	9,183	16.1	1,762	18
April 2nd	31-70	25	1.2	29	2.3	58	192.7	4,817	49.3	2,375	50.7	2,442	18
May 1st	31-70	25	3.0	75	1.2	30	817.0	20,425	42.8	8,742	57.1	11,683	18
May 2nd	31-70	25	3.4	85	0.1	3	429.8	10,745	10.2	1,096	89.8	9,649	18
Total				653		363				26,436		25,598	
Grand Total					1,016			52,034					
Estimated landings mile 0-30				976		384				76,630(b)		288,275(b)	
					1,360			364,905(c)					
Grand Total for Rappahannock River					2,376			416,939					

(a) None reported by index fishermen.
(b) Species ratio estimated from 1977-1979 commercial landings data.
(c) Landings for miles 0-30 estimated from 1978-1982 commercial landings data.

Table 1.9. Estimated catch in kg of American shad by stake gill nets in the Rappahannock River 1983 by half-month intervals. Effort from Table 1.2. Index in kg/m of net.

		American Shad				
		Male		Female		Total
Half-Month Period	River Mile	Index	Estimated Catch	Index	Estimated Catch	Estimated Catch
February 2nd	25-30	0.0056	14	(a)		14
	30-35		15			15
	35-65(b)					
	Total		29			29
March 1st	25-30	0.0800	194	0.0417	101	295
	30-35		209		109	318
	35-65(b)					
	Total		403		210	613
March 2nd	25-30	0.1506	364	0.2109	510	874
	30-35		393		550	943
	35-65(b)					
	Total		757		1,060	1,817
April 1st	25-30	0.1254	303	0.3862	934	1,237
	30-35		327		1,007	1,334
	35-65(b)					
	Total		630		1,941	2,571
April 2nd	25-30	0.0518	125	0.2890	699	824
	30-35		135		753	888
	35-65(b)					
	Total		260		1,452	1,712
May 1st	25-30	0.0068	16	0.0609	147	163
	30-35		18		159	177
	35-65(b)					
	Total		34		306	340
Total			2,113		4,969	7,082

(a) None reported by index fishermen.
(b) See text for explanation.

Table 2.1. Summary of sample data from the *Alosa* commercial fisheries during the 1983 spawning run in the major Virginia tributaries to Chesapeake Bay.

River and Month	Alewife		Blueback		American Shad	
	Male	Female	Male	Female	Male	Female
James						
April					35	65
York						
April	15	27	152	121	100	15
May	19	23	246	307		
Rappahannock						
March	212	267	4			
April	126	140	63	75	32	69
May	77	75	210	168		
Totals (M&F)	981		1,346		316	

Table 2.2. Year-class frequency of alewives (sexes pooled) in the York River commercial fishery samples, 1983.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
AGE 7+	0.*	2	2.4	2.6	2.6
	76.	2	2.4	2.6	5.2
	77.	7	8.3	9.1	14.3
	78.	28	33.3	36.4	50.6
	79.	35	41.7	45.5	96.1
	80.	3	3.6	3.9	100.0
	9.*	7	8.3	MISSING	100.0
		------	------	------	
	TOTAL	84	100.0	100.0	

MEAN	76.364	STD ERR	1.433	MEDIAN	78.482
MODE	79.000	STD DEV	12.578	VARIANCE	158.208
KURTOSIS	35.569	SKEWNESS	-6.040	RANGE	80.000
MINIMUM	0.000	MAXIMUM	80.000		

VALID CASES 77 MISSING CASES 7

*Age codes

0 - includes some age ≥ 7 or 1975 or older
9 - missing age data

Table 2.3. Year-class frequency of blueback herring (sexes pooled) in the York River commercial fishery samples, 1983.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
AGE 7+	0.*	34	4.1	7.8	7.8
	74.	3	0.4	0.7	8.5
	75.	13	1.6	3.0	11.5
	76.	28	3.4	6.4	17.9
	77.	72	8.7	16.5	34.4
	78.	188	22.8	43.1	77.5
	79.	87	10.5	20.0	97.5
	80.	9	1.1	2.1	99.5
	81.	2	0.2	0.5	100.0
	9.*	390	47.2	MISSING	100.0
	TOTAL	826	100.0	100.0	

MEAN	71.761	STD ERR	1.002	MEDIAN	77.862
MODE	78.000	STD DEV	20.920	VARIANCE	437.648
KURTOSIS	7.959	SKEWNESS	-3.145	RANGE	81.000
MINIMUM	0.000	MAXIMUM	81.000		

VALID CASES 436 MISSING CASES 390

*Age codes

0 - includes some fish ≥ 7 or 1973 or older
9 - missing age data

Table 2.4. Year-class frequency of alewives (sexes pooled) in the Rappahannock River commercial fishery samples, 1983.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
AGE 7+	0.*	2	0.2	0.4	0.4
	77.	23	2.3	4.8	5.3
	78.	199	20.0	41.8	47.1
	79.	225	22.6	47.3	94.3
	80.	27	2.7	5.7	100.0
	9.*	521	52.3	MISSING	100.0
		------	------	------	
	TOTAL	997	100.0	100.0	

MEAN	78.210	STD ERR	0.235	MEDIAN	78.562
MODE	79.000	STD DEV	5.131	VARIANCE	26.322
KURTOSIS	227.250	SKEWNESS	-14.975	RANGE	80.000
MINIMUM	0.000	MAXIMUM	80.000		

VALID CASES 476 MISSING CASES 521

*Age codes

0 - includes some fish age $\geq$ 7 or 1975 or older
9 - missing age data

Table 2.5. Year-class frequency of blueback herring (sexes pooled) in the Rappahannock River commercial fishery samples, 1983.

CATEGORY LABEL	AGE CODE	ABSOLUTE FREQ	RELATIVE FREQ (PCT)	ADJUSTED FREQ (PCT)	CUM FREQ (PCT)
AGE 7+	0.*	4	0.8	1.7	1.7
	76.	3	0.6	1.3	3.0
	77.	24	4.6	10.2	13.2
	78.	87	16.7	37.0	50.2
	79.	111	21.3	47.2	97.4
	80.	6	1.2	2.6	100.0
	9.*	285	54.8	MISSING	100.0
		------	------	------	
	TOTAL	520	100.0	100.0	

MEAN	77.068	STD ERR	0.665	MEDIAN	78.494
MODE	79.000	STD DEV	10.191	VARIANCE	103.859
KURTOSIS	54.320	SKEWNESS	-7.452	RANGE	80.000
MINIMUM	0.000	MAXIMUM	80.000		

VALID CASES 235 MISSING CASES 285

*Age codes

0 - includes some fish age $\geq$7 or 1975 or older
9 - missing age data

Table 2.6. Year-class frequency of American shad in the Virginia commercial gill net fishery, 1983.

Sex	Year Class	James	York	Rappahannock	Total	Frequency (%)
Male	1977	6		1	7	8.86
	1978	19	11	12	42	53.2
	1979	7	2	19	28	35.4
	1980		2		2	2.53
		—	—	—	—	
Total		32	15	32	79	
Female	1976			1	1	0.40
	1977	5	27	24	56	24.9
	1978	52	55	33	140	62.2
	1979	4	15	9	28	12.4
		—	—	—	—	
Total		61	97	67	225	

Table 2.7. Length (mm) and weight (g) statistics for river herring in the York and Rappahannock rivers, 1983.

			York			Rappahannock		
Species	Sex		N	Mean	Std. Error	N	Mean	Std. Error
Alewife	Male	Length	34	244.8	2.089	433	242.7	0.571
		Weight	34	185.4	4.821	432	213.9	1.967
	Female	Length	50	256.7	1.624	564	256.9	0.477
		Weight	50	209.1	4.591	564	275.8	2.293
Blueback	Male	Length	398	243.2	0.712	277	234.5	0.697
		Weight	398	72.9	1.293	277	156.8	1.761
	Female	Length	428	256.1	0.782	243	246.4	0.854
		Weight	428	208.1	2.331	243	192.7	3.037

Table 2.8. Length (mm) and weight (g) statistics for American shad in the James, York and Rappahannock gill net fisheries, 1983.

		James			York			Rappahannock		
Sex		N	Mean	Std. Error	N	Mean	Std. Error	N	Mean	Std. Error
Male	Length	35	420.2	2.602	15	405.2	3.960	32	411.4	2.925
	Weight	35	1276.5	22.521	15	1195.8	34.639	32	1249.5	30.094
Female	Length	65	452.6	2.125	100	445.9	2.118	69	455.2	2.523
	Weight	65	1785.9	27.151	100	1737.8	26.841	69	1802.5	31.894

Table 2.9. Estimates of the instantaneous total mortality rate (Z) for the 1969-1975 year classes of river herring in the Rappahannock River.

Year Class	Z Values	
	Alewife	Blueback Herring
1969	1.92	2.22
1970	1.38	1.72*
1971	1.21	2.30
1972	1.65*	1.74
1973	3.01*	1.30
1974	1.53	1.04
1975	1.78*	1.25*
Mean	1.58+	1.65

* Z estimated from the $\log_e$ of the ratio of CPUE values at ages 5 and 6. All other Z values were estimated from catch curves.

+ The Z value for the 1973 year class of alewives was a statistical outlier, and was omitted from the calculation of the mean.

Table 2.10. Estimates of the mean annual rates of mortality (A), survival (S), and exploitation (E) for alewives and blueback herring in the Rappahannock River.

Rate	Alewife	Blueback Herring
A	0.794	0.807
S	0.205	0.192
E	0.381	0.423

Estimates were derived from $\bar{Z}$ values in Table 2.9 and an assumed instantaneous natural mortality rate of 1.1.

Table 3.1. A summary of the sampling statistics for juvenile *Alosa* in the nursery zone of the Mattaponi River, 1983.

Species	Date	Zone Limits (naut. miles)	No. of Samples	Mean CPUE
Alewife	6 Jun[a]			0
	13 Jun[a]			0
	22 Jun	40-55	9	17.2
	27 Jun	35-55	11	14.2
	6 Jul	30-60	18	36.2
	11 Jul	40-60	12	5.4
	18 Jul	35-55	15	3.8
	3 Aug	40-50	9	4.9
	15 Aug	45-55	6	2.7
Blueback Herring	6 Jun[a]			0
	13 Jun[a]			0
	22 Jun	50-55	6	0.2
	27 Jun	40-55	12	0.3
	6 Jul	40-60	12	10.8
	11 Jul	40-60	12	14.4
	18 Jul	40-60	12	13.7
	3 Aug	40-60	12	36.1
	15 Aug	45-60	9	26.9
American Shad	6 Jun	30-60	18	3.4
	13 Jun	40-60	12	11.2
	22 Jun	40-60	12	10.2
	27 Jun	35-60	14	16.5
	6 Jul	30-60	18	11.2
	11 Jul	35-60	14	9.3
	18 Jul	35-60	15	3.0
	3 Aug	35-60	15	2.5
	15 Aug	45-55	9	1.7

(a) no fish $\geq$ 27 mm (see text).

Table 3.2. A summary of the sampling statistics for juvenile *Alosa* in the nursery zone in the Pamunkey River, 1983.

Species	Date	Zone Limits (naut. miles)	No. of Samples	Mean CPUE
Alewife	14 Jun	40-55	9	3.2
	23 Jun	40-70	12	4.2
	7 Jul	35-60	15	1.6
	13 Jul	40-70	18	2.2
	21 Jul	40-55	6	1.0
	4 Aug	45-70	15	1.0
Blueback Herring	14 Jun	40-60	15	38.1
	23 Jun	40-70	19	120.7
	7 Jul	35-70	21	58.0
	13 Jul	40-70	18	86.3
	21 Jul	35-70	15	38.7
	4 Aug	45-70	15	105.0
American Shad	14 Jun	40-70	18	5.2
	23 Jun	45-70	15	7.5
	7 Jul	45-70	15	2.5
	13 Jul	45-70	15	4.2
	21 Jul	55-70	7	1.3
	4 Aug	50-70	12	1.0

Table 3.3. Maximal catch-per-unit-of-effort (CPUE) values for juvenile *Alosa* in the Mattaponi and Pamunkey rivers, 1980-1983.

		Maximal CPUE			
Species	River	1980	1981	1982	1983
Alewife	Mattaponi	2.9*	10.0*	38.0	36.2
	Pamunkey	3.6	6.5*	28.3*	4.2
Blueback herring	Mattaponi	4.6*	11.6	289.0	36.1
	Pamunkey	87.9	16.7	408.2	120.7
American shad	Mattaponi	38.8*	18.0*	21.1	16.5
	Pamunkey	7.1	5.3*	3.0	7.5

*Maximal CPUE occurred in the first sampling period.

Table 3.4. Estimates of instantaneous daily mortality (M_d) for juvenile *Alosa*, 1979-1982.

Species	River	1979	1980	1981	1982	1983
Alewife	Mattaponi	0.036	0.33	0.105	0.036	0.038
	Pamunkey	0.040	0.041	0.058	0.043	0.068
American shad	Mattaponi	0.040	0.056	0.080	0.042	0.030
	Pamunkey	0.060	0.080	0.043	0.050	0.078
Blueback herring	Mattaponi	0.034	0.022	(a)	0.077	0.041
	Pamunkey	0.040	0.031	0.016	0.046	0.052

(a) Data are too few to reasonably estimate M_d.

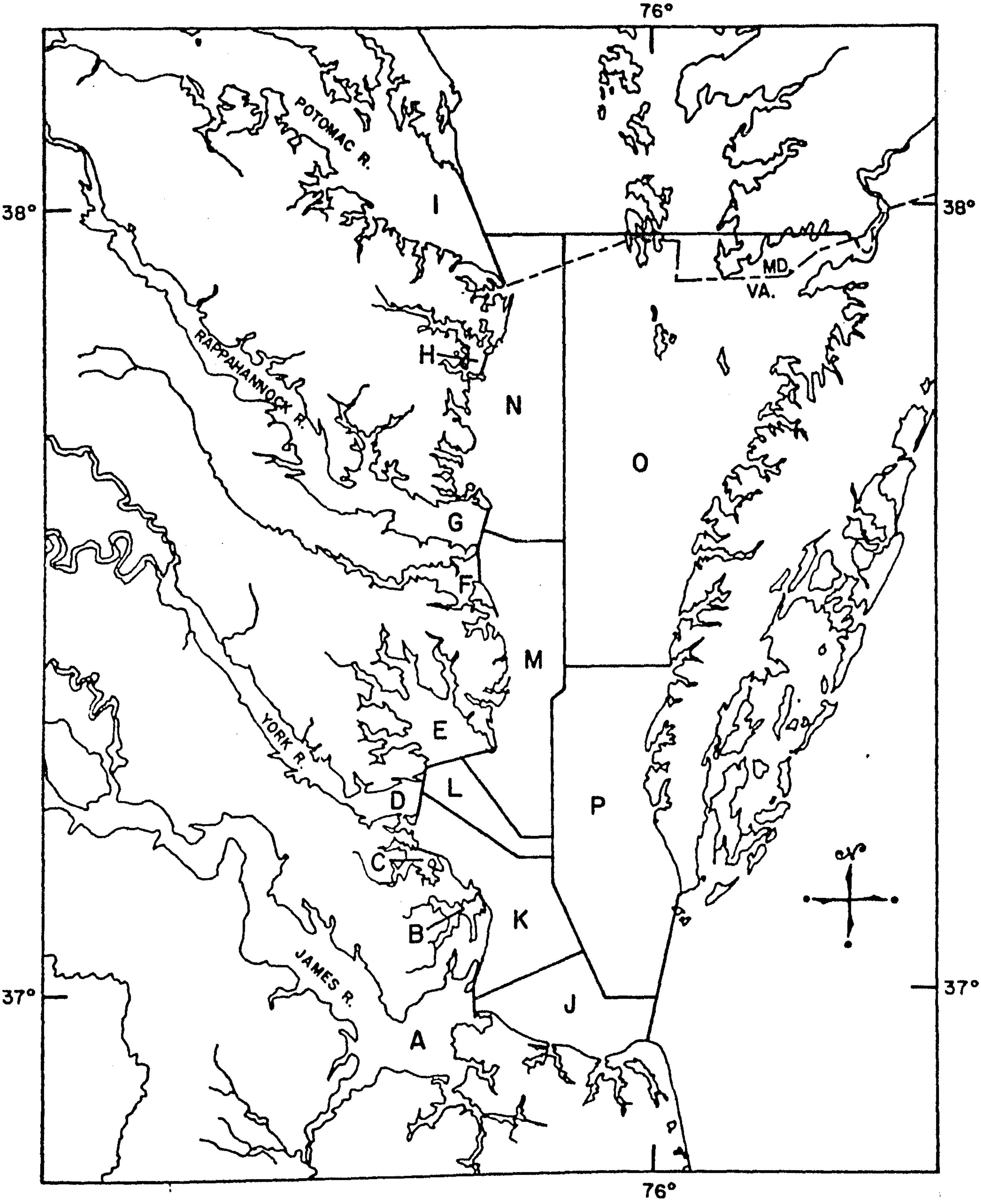
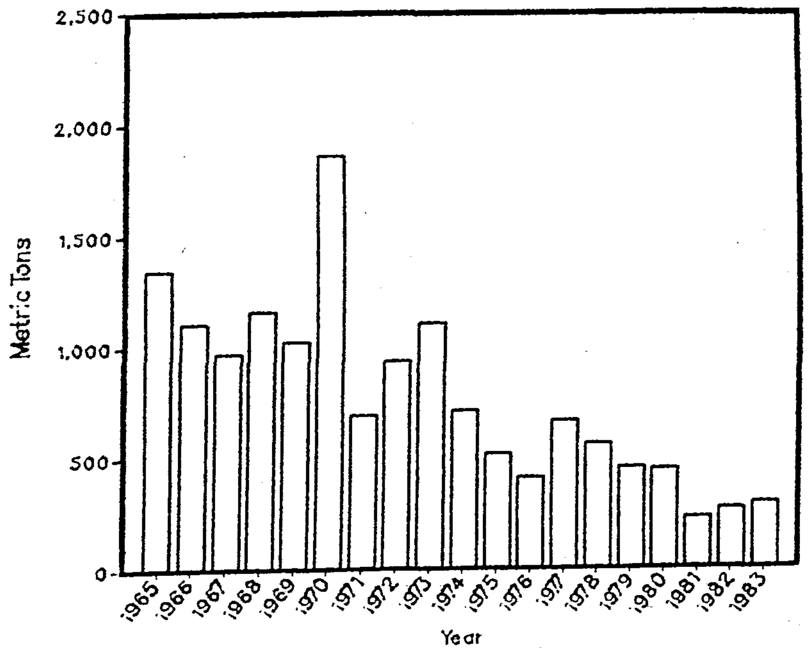


Figure 1.1. Area designations utilized during aerial pound net counts.

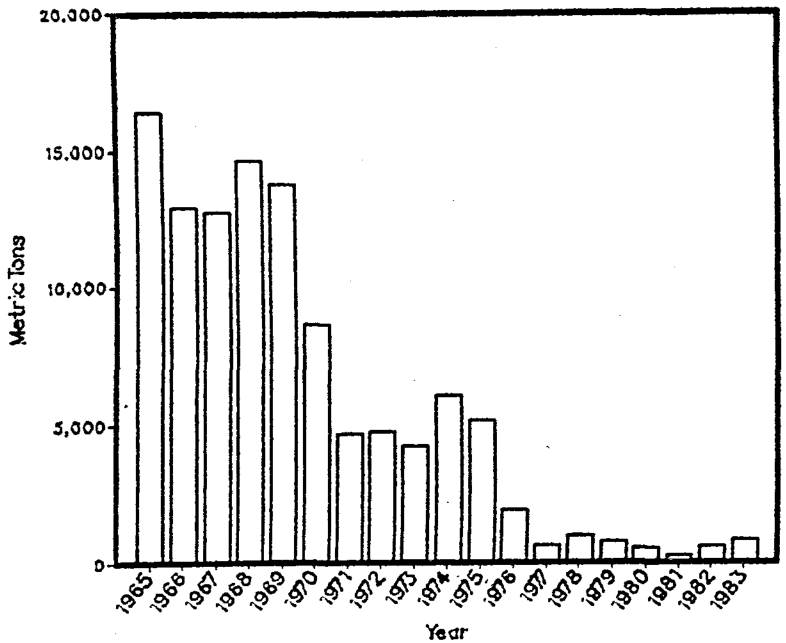
Figure 2.1. Virginia Landings 1965–1983.

American Shad
1965–1983



1 metric ton = 2205 lb.

River Herring
1965–1983



1 metric ton = 2205 lb.

Figure 3.1. Growth Curves for Juvenile Alewives, 1983

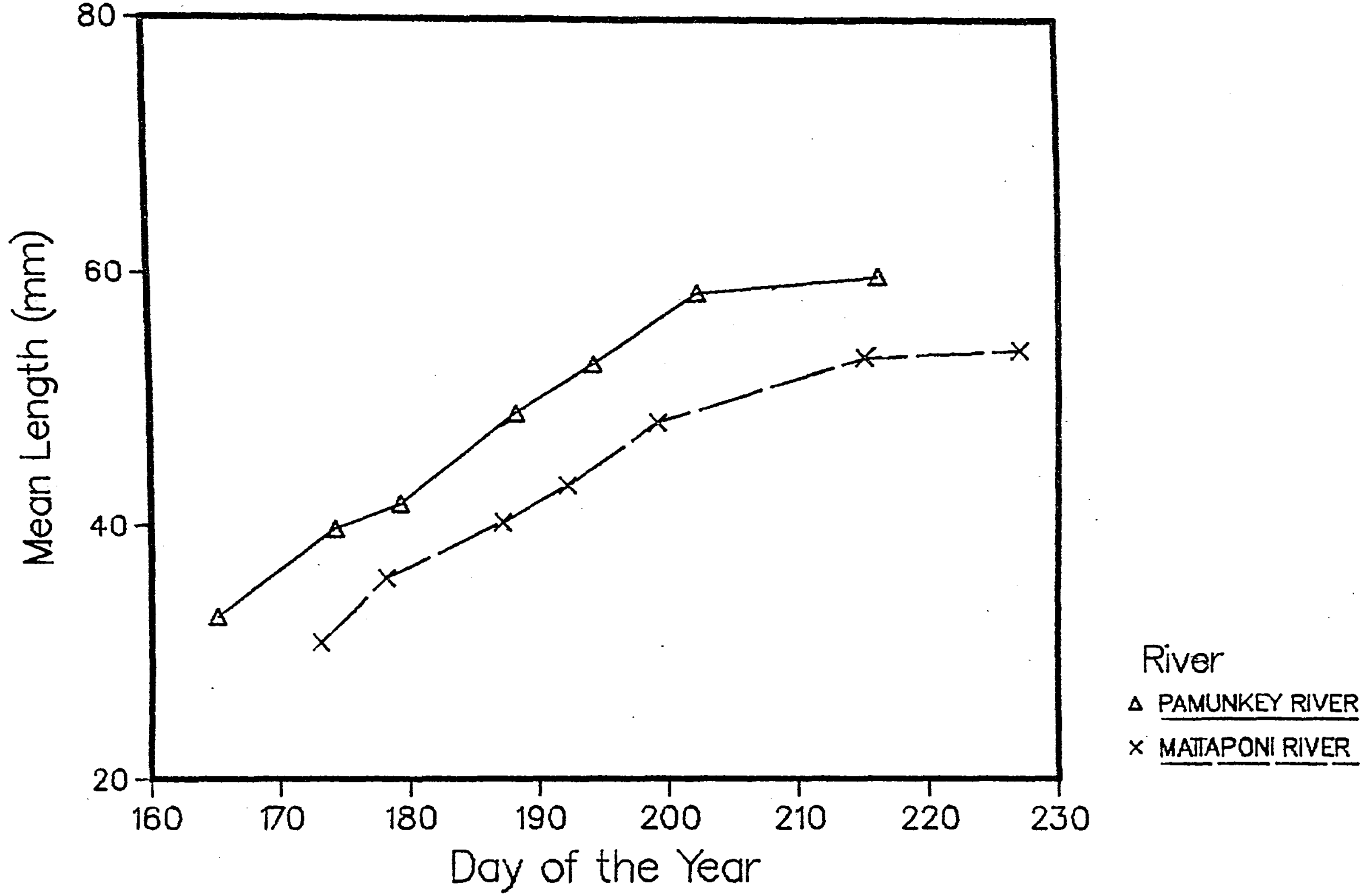


Figure 3.2. Growth Curves for Juvenile Blueback Herring, 1983

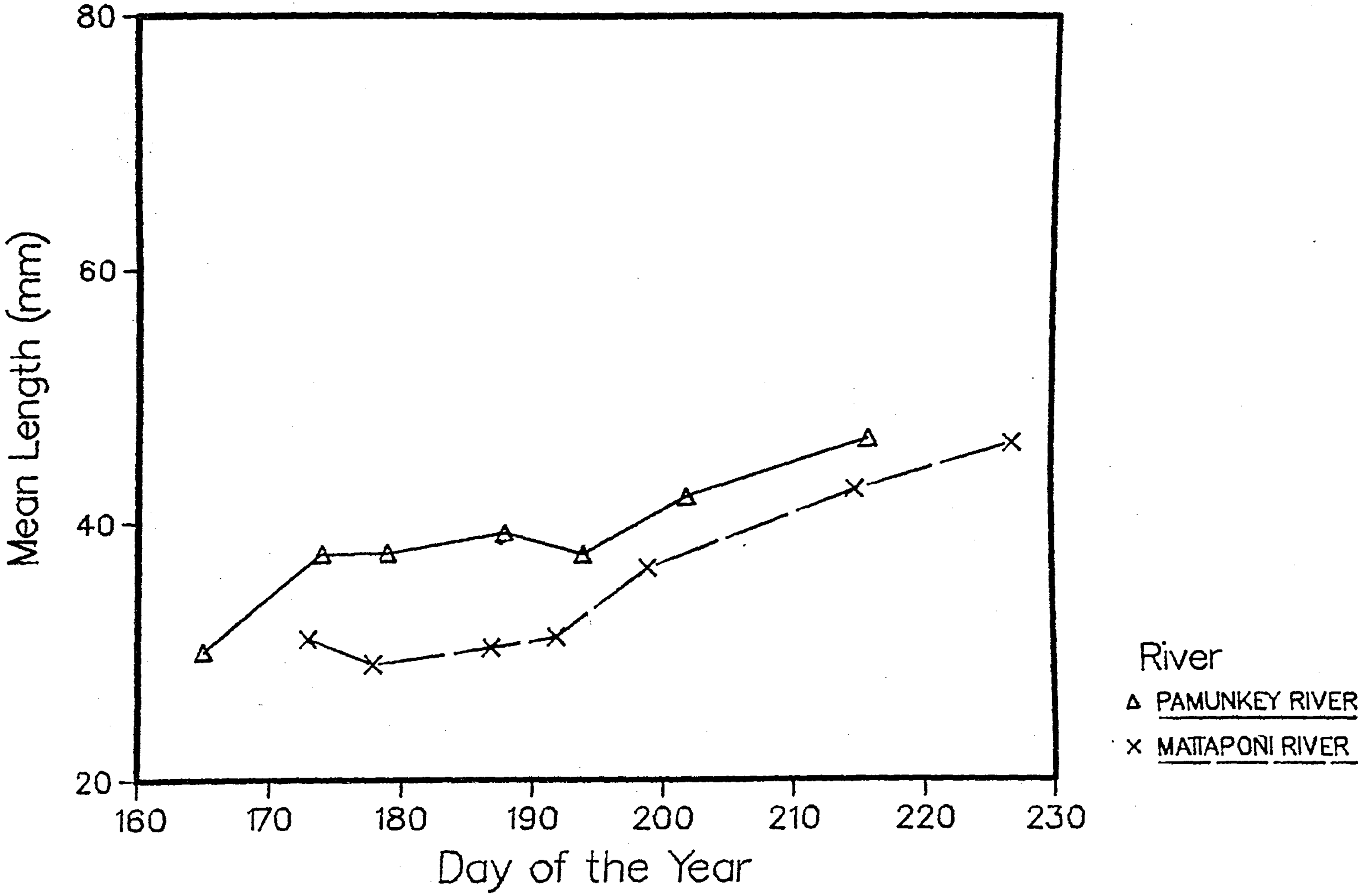


Figure 3.3. Growth Curves for Juvenile American Shad, 1983