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# Study of Alosa stock composition and year-class strength in Virginia - Completion Report 1984-1986

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Completion Report, 1984-1986

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# PREFACE

This presentation is the completion report for P. L. 89-304, AFC 13-1-3 project "Study of Alosa stock composition and year-class strength in Virginia," for the period 1 January 1984 to 31 July 1986. The fishes of concern were the alewife (*Alosa pseudoharengus*), American shad (*A. sapidissima*), and the blueback herring (*A. aestivalis*).

The abundance of the *Alosa* stocks, once an important component of the landings of Virginia fisheries, dramatically decreased in the last decade. The 1981 landings of *Alosa* species in Virginia were the lowest ever recorded. American shad and river herring are also pursued by recreational fishermen in Virginia, but the extent and success of this activity is largly 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 data analyses may make 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 monitoring research and extant data bases. 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: Evaluation of the Alosa Stocks and Fisheries in Virginia

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 1985 fisheries.
2. Determine the present status of the stocks relative to former years by comparison of landings and CPUE.
3. Estimate current biological statistics (age and size frequencies, species composition, etc.) of river herring and American shad.
4. Estimate the total contributions of year classes to the river herring fishery.

Job 2: A Study of Juvenile Alosa Abundance, Growth and Mortality

Objectives

1. Determine an index of abundance for juvenile river herring and American shad.
2. Estimate growth and mortality rates of juveniles in tidal freshwater.

Job 3: Analysis of American Shad Growth: Circa 1970 versus Circa 1980

Objectives

1. Back calculate length-at-age from scales collected in a period of high American shad abundance (Circa 1970), and from scales collected in a period of low abundance (1980).
2. Statistically compare the length-at-age relationships of the two groups.

## ACKNOWLEDGMENTS

We are indebted to the following Virginia Institute of Marine Science personnel for their assistance in this project: Loisirene Blumberg, Joice Davis, Deane Estes, Carol Furman, Lillian Hudgins, Curtis Leigh, James Owens, and Gloria Rowe. We also express our thanks to the many commercial fishermen who have so kindly helped us when we asked for their assistance. The Virginia Landings data were supplied by the Virginia Marine Resources Commission.

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

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## EXECUTIVE SUMMARY


1. Landings in Virginia of all *Alosa* species decreased in 1986 relative to 1985. Overall gill net effort declined, accompanied by an increase in catch-per-unit-of-effort (CPUE).
2. Gill net fishermen landed an estimated 138 MT of American shad in the James, York and Rappahannock rivers.
3. Age 5 blueback herring remained a strong component of the pound net catches in 1986 whereas the modal age for alewife in the York River was age 5 and age 4 was the modal age in the Rappahannock River.
4. Mean estimates of total mortality (Z) were 1.47 and 1.61 for alewife and blueback herring, respectively.
5. Juvenile indices of abundance for American shad were again higher in the Mattaponi River than in the Pamunkey River. Indices for alewife and blueback herring were higher in the Pamunkey River.
6. Data indicate higher mortality rates of juvenile *Alosa* in the Pamunkey River than in the Mattaponi River.

## Job 1. Evaluation of the Alosa Stocks and Fisheries in Virginia

### INTRODUCTION

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

### MATERIALS AND METHODS

Samples of river herring were collected weekly from 31 March to the first week of May from the York River and weekly from mid-March to the first week in May from the Rappahannock River. American shad samples were collected in April from the York and Rappahannock fisheries (Table 1.1). Due to the paucity of American shad no commercial samples were collected from the James River in 1986.

When available, 22.7 kg of river herring were randomly sampled from commercial pound net catches in the York and Rappahannock rivers. 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 favors the capture of females, the larger of the sexes.

River herring samples were returned to VIMS where species, sex, fork length, and weight were recorded. These data were used to partition the log-book estimates of landings in each sampling period into biomass and numbers-at-age. American shad data, except for age, were collected at the sampling site. Ages of river herring were determined from otoliths, while scales that were collected are held in reserve. American shad were aged 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 (Loesch and Kriete, 1983).

Pound net catch estimates for fisheries in the Rappahannock River were determined by multiplying the catch-per-unit-of-effort (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 1.2 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.

Pound net fishermen in the lower strata of the Rappahannock River have not supplied catch and effort data since 1982. An estimate of the missing data for the lower portion of the river was made from its average proportion of the total catch in the upper and lower portions in the years 1978-1982.

The catch-and-effort data for alewife and blueback herring were pooled because the fishery does not target one species or the other and both federal and state agencies report all river herring landings as alewife.

Stake gill net catch estimates for the fisheries in the James, York, and Rappahannock rivers were determined by multiplying the CPUE (kg/m of net per 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 1.3). Effort for miles 15-45 on the James River was adjusted through interviews with fishermen since some of the effort was directed toward white perch and catfish. Stake gill net effort on the York River was also adjusted as it was determined that many of the stands that were set were never fished (no nets put in place). Yearly stake gill net CPUE was determined by dividing total landings by total netting fished for shad.

Annual Alosa landings data from all Virginia waters and the Potomac River 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, National Marine Fisheries Service (NMFS), Division of Statistics and Market News. Since 1976, total landings data for Virginia have been obtained from the Virginia Marine Resources Commission (VMRC). As was reported in 1985, estimates of the 1986 catches of river herring in the Rappahannock and York rivers were made from VIMS logbook data. The total catch in Virginia was determined by adding our estimates to the landings reported by VMRC for river herring fisheries other than in the Rappahannock and York rivers.

The PRIME 850 computer at VIMS was used in conjunction with the statistical package SPSS (Nie et al. 1975) to analyze data, and to construct tables and figures.

## RESULTS AND DISCUSSION

### Total Virginia Landings

We estimate that approximately 427 metric tons (MT) of river herring were landed in Virginia in 1986. The landings were a 55% decrease relative to our estimated 1985 catch (951 MT). VMRC data indicate that American shad landings in Virginia increased 8% in 1986 (311 MT) relative to 1985 (287 MT).

Decline in *Alosa* landings in the last two years probably do not reflect decreases in stock sizes. In 1985, the onset of cold weather shortly after the commencement of spawning reduced *Alosa* availability. Also, reported landings have been reduced by the method of handling catches of *Alosa*, particularly river herring. Increasing numbers of river herring, and to some degree American shad, are simply being sold as scrap.

Some specific contributions to the total 1986 landings of alosids are considered below.

## James River Landings

Our aerial observations of pound net effort showed that no pound nets were set in the James River during 1986. The capture of finfishes is severely restricted as a result of kepone contamination, making pound net operations in the river unprofitable.

It was estimated from the logbooks of cooperating fishermen that stake gill nets caught about 30 MT of American shad in 1986 (Table 1.5), a 66% decrease relative to 1985 (Table 1.6). As a result of depressed landings, an unknown proportion of the catch in the upper strata (miles 20-60) was sold to local markets, and it is possible that landings for that portion of the river are underestimated.

Peak landings in 1986 occurred during the second half of March with the greatest contribution occurring in the lower strata (miles 05-15).

Chickahominy River Landings

Landings data collected by VMRC showed that approximately 147 MT of river herring were caught in the haul seine fishery in the Chickahominy River in 1986. The landings were about 92 MT more than the 1985 catch, and represented a substantial increase relative to 1985 river herring landings in the river. No other alosid fisheries are conducted in the Chickahominy River.

York River Landings

Estimated landings from logbook data showed a continued decrease in both stake gill net landings of American shad and the associated CPUE in 1986 relative to 1985 (Tables 1.4 and 1.6). Much of the decrease can be attributed to a decrease in effort. This does not explain the dramatic decline that began in 1984 and it must be presumed that at least a portion of the decrease is due to a decline in spawning population. Peak landings of 40 MT of shad occurred during the second half of March (Table 1.7).

Rappahannock River Landings

Analysis of logbook data from cooperating pound net fishermen indicated that about 0.6 MT of American shad and 82 MT of river herring were landed in the Rappahannock River in 1986 (Table 1.9). Much of the dramatic decrease in river herring landings can be attributed to the lack of market for river herring. Except for a few local markets most of the river herring were sold for scrap and thus were never reported as river herring. Much of the scrap is then sold in southern states when the supply of crab pot bait there is depleted.

Stake gill netters in the Rappahannock River landed 3 MT of American shad in 1986 (Table 1.10). The decrease in landings may be in part due to a decrease in effort as a result of the closure of the river to striped bass fishing from mile 38 to mile 68 as well as the cost associated with setting a stake gill net.

## 1984-1986 Landings

Landings of American shad and river herring have declined in all rivers in Virginia since 1984. As previously noted, much of the decline may be attributed to a decrease in fishing effort or a lack of market. River herring from most of the pound nets set in the lower strata (miles 0-30) are sold for pet food or to a reduction plant and are never recorded as river herring. On the other hand, American shad are sold to small local markets and these too never enter the reporting system.

It is expected that this trend will continue for the next several years or until the regulations on striped bass are eased somewhat. Presently, and particularly during the spring and fall, many fishermen are unable to fish because of the large numbers of striped bass. Too much time and money is spent on discarding non-legal striped bass from their nets to warrant a continued fishing effort for other species.

## Age Composition

The age frequencies of river herring (sexes pooled) and American shad determined from the 1986 samples of commercial catches in pound nets in the James, York, and Rappahannock River fisheries are presented in Tables 1.10-1.14. The 1981 year class (age 5) of alewife was the modal age group in the York River in both 1985 (Loesch et al. 1985) and 1986 (Table 1.10). In

1985, the 29.5% and 31.2% representations of the 1982 year class in the York and Rappahannock catches (Loesch et al. 1985) exceeded the highest occurrence of age 3 alewives previously reported (Hoagman and Kriete 1975). Although the 1982 year class was the modal group in the Rappahannock River in 1986 (Table 1.12), the anticipated strong representation in the York River did not occur (Table 1.10).

The blueback herring had older modal groups than the alewife in 1984, 1985, and 1986. The modal age of alewives was age 4 with but one exception (age 5 in 1986 in the Rapahannock River) while the modal age for blueback herring was either 5 or 6. The older modal age for blueback herring relative to the alewife reflects the somewhat later maturation of blueback herring (PSEG 1982, 1984). Modality is also readily affected by the presence of a strong year class or by recruitment failure.

As in past years, American shad data reflect gill-net selectivity for large females (Table 1.14). Since females are larger at age than males, the female age structure is older.

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.

## 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 1.15. Similar data for American shad, derived from samples of gill net catches in the James, York, and Rappahannock rivers, are presented in Table 1.16.

As stated above, 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.

Species Composition

Alewife constituted 26.5% of the river herring sampled in the York and Rappahannock rivers in 1986 (Table 1.1), but were only 24.2% of the total landings in these two rivers (Table 1.6). The difference occurs each year because the samples are a constant weight (22.7 kg) rather than a constant proportion of the catch. Alewife are the major proportion of the river herring samples only in periods when landings are low (March and early April). The proportion of blueback herring in the samples is superior when landings are much greater. Thus, the proportion of alewife in our total sample is enhanced relative to the actual contribution to the biomass of river herring landed. Each estimate of species percentages was therefore weighted by landings in the sampling period in 1984, 1985, and 1986. The weighted estimates were then summed throughout the season to obtain the contribution of each species to the total biomass landed.

Sex Ratios

The sex ratio data (Table 1.1) 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) were not made in 1986. In 1984, estimates of Z were made for the 1969-1977 year classes in the Rappahannock River (Loesch and Kriete, 1984). Using an assumed instantaneous natural rate (M=1.1), annual rates of mortality (A), survival (S), and exploitation (E) were also made. With the additional 1985 data, Z, A, S and E values were calculated for the 1978 alewife year class (Loesch et al. 1985). The Z for the 1978 blueback herring year class, however, was anomalously low, and, therefore, omitted from the long-term average.

The mean estimate of total mortality (Z) was 1.47 for alewife and 1.61 for blueback herring (Table 1.17), thus, the estimates of the mean annual mortality rates ($\bar{A}$) were 77% and 80% and the mean exploitation rates ($\bar{E}$) were 31% and 40%, respectively (Table 1.17).

The range in annual mortality rates for alewife (70% to 87%) and blueback herring (67% to 89%) in Virginia are similar to alewife mortality rates in New England; which range from 73% to 95% (DiCarlo 1981; Walton 1981). Although the New England river herring stocks did not exhibit a decline with heavy fishing pressure for some years, the stocks in Maine recently had a sharp decline in abundance.

Job 2. Annual Index of Juvenile *Alosa* Abundance

## INTRODUCTION

The VIMS annual study of juvenile migratory *Alosa* was continued in 1986. The intent of the study was to estimate relative abundance, growth, and mortality. Long-term objectives are to assess any 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 juvenile *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 seven times between 2 June and 14 July 1986 and the Pamunkey River was sampled five times between 3 June and 2 July 1986.

Loesch and Kriete (1983) established a standardized sampling unit and a minimum size limit for catch-effort considerations, and detailed the stratifed sampling plan employed. A bow-mounted 1.5 m x 1.5 m pushnet (Kriete and Loesch 1980) was used to capture the juveniles (young-of-the-year). Because juvenile *Alosa*, or their prey, exhibit negative phototropic responses (Loesch et al. 1982), samples were collected at night to minimize the effects of varying intensities of incident light.

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. The advantages of a maximal CPUE vis-à-vis a seasonal mean CPUE were also discussed by Loesch and Kriete (1983). Sampling was conducted weekly to enhance the accuracy of the estimate of maximal relative abundance. 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

### Index of Abundance

Maximal CPUE values for alewife, blueback herring, and American shad in the Mattaponi and Pamunkey rivers are given in Table 2.1. The maximal CPUE for alewives, American shad and blueback herring in the Mattaponi and Pamunkey rivers in 1986 occurred on June 2 and 3, June 9 and 11, and June 23 and 17, respectively, for species and rivers. The later dates of maximal

CPUE for blueback herring are an annual occurrence and reflect their later spawning relative to alewives and American shad.

In the years 1979 to 1986, the relative index values of blueback herring exceeded the values for American shad and alewife in the Pamunkey River (Table 2.1). The blueback herring index values also exceeded the values for the alewife in the Mattaponi River (with one exception), and exceeded the values for the American shad in five of the eight years.

Although commercial landings indicate that blueback herring are more numerous than alewife and American shad, the maximal CPUE values for juveniles cannot be contrasted among species because of differences in availability. Loesch et al. (1982) found that although both species exhibited a diel periodicity, blueback herring remain higher in the water column than do alewives. Thus, the juvenile blueback herring are more susceptible to capture by surface gear than are alewives. The vertical density distribution of juvenile Aamerican shad, relative to the other alosids is unknown.

Most often the maximal CPUE for alewives and American shad was greater in the Mattaponi River than in the Pamunkey River (Table 2.1). In contrast, the relative abundance of blueback herring was most often larger in the Pamunkey River. It is not known why these differences occur.

The data base of juvenile indices of abundance and the subsequent contributions of year classes to the fisheries are not large enough for a thorough analysis of spawner-recruit relationships.

## Growth

Loesch and Kriete (1983) discussed in detail the problems of estimating juvenile alosid growth from observed mean lengths. Briefly, two major sources of error that result in an underestimation of growth are the tendency for the precocious juveniles to migrate downstream (Loesch 1969, Marcy 1976), and protracted recruitment due to a lengthy spawning period. These two aspects of alosid behavior result in apparent periods of little or no growth or even "negative growth."

The principal use of juvenile length data herein and in previous segments of the study is to note salient changes in the growth rate. In conjunction with apparent changes in the slope of the catch curves, the observed changes in the growth rate aid in the selection of CPUE values for the estimation of juvenile mortality.

<u>Natural Mortality</u>

Estimates of daily instantaneous natural mortality rates ($M_d$) have been made since 1979 (Table 2.2). Because of three-week intervals between sampling, the 1980 and 1981 values are not considered reliable (Loesch and Kriete 1983).

The data (Table 2.2) indicate that the rates of mortality tended to be higher in the Pamunkey River. Of the 18 estimates of $M_d$ (1980 and 1981 data excluded), the $M_d$ values in the Mattaponi River exceed those in the Pamunkey River only four times. The reason(s) for the general occurrence of higher juvenile mortality rates in the Pamunkey River relative to the rates in the Mattaponi River is not known. It does not appear to be density related since the larger catches and larger maximal CPUE values for alewives and American shad most often occur in the Mattaponi River.

## Job 3. Analysis of American Shad Growth: Circa 1970 versus Circa 1980

### INTRODUCTION

Growth of American shad, Alosa sapidissima, has been described by Leim (1924), La Pointe (1958), Cating (1953) and Judy (1961). Leim (1924) established that growth in American shad scale radii was proportional to the growth in fish length. Fish growth can be affected by many factors, one of which is population density (Everhart and Youngs 1981). Density of American shad in the James and York rivers of Virginia was high during the era 1968 through 1972, relative to the last decade. Conversely, low population densities were reported during the era 1979 through 1983 (Loesch and Kriete 1983). Although decreases in effort may have resulted in reduced landings, it appears that these changes in effort were not large enough to explain the drastic decline in landings over the past decade (Richkus and DiNardo 1984).

The objective herein was to access the possible existence of density dependent growth of American Shad.

### MATERIALS AND METHODS

Samples of American shad were collected in March, April and May from the fisheries of the James and York rivers during the periods of 1968-1972 and 1979-1983. A total of 753 shad were aged from the high population density period of 1968-1972, and 497 from the low density period of 1979-1983. Only those scales judged to be of good quality were used. Samples were obtained from stake gill nets, the dominant gear used in the American shad fishery: landings from other gear types are negligible, particularly when population densities are low. The American shad fishery primarily employs stake gill nets with 12.4 to 14.0 cm stretched mesh. These mesh sizes select for the larger, economically more important females. Consequently, this study used data obtained from females only.

Scales were removed from each fish and fork length (mm) and weight (g) were recorded. The scales were mounted and pressed onto acetate sheets using a method similar to Merriman's (1941). Age was determined by Cating's (1953) method, i.e., counting the number of annuli and adding a year for the scale edge. Each specimen's collection number, fork length and age were entered into a microcomputer. The distance from the focus to each successive annulus was then established through the use of a sonic digitizer, and entered into the computer (Loesch and Kriete 1983). All of these data were subsequently transferred into a Prime 850 computer system.

For the purpose of enhancing replications at age, analysis of covariance was used to determine the validity of pooling the James and York River scale-radius-body length data within each era. Also, because of the "art-science" element of scale reading, a conservative level of significance ( $\alpha = 0.01$) was chosen. Estimated lengths-at-age were calculated using version 6.1 of DisBcal (Frie, 1982). These estimated lengths-at-age were then run in a non-linear least squares program using the Von Bertalanffy growth function fitted to the calculated lengths-at-age. A t-test (SPSS) was then employed to determine if there were significant differences in eras for mean length-at-age for ages 1-9.

## RESULTS AND DISCUSSION

An analysis of covariance resulted in non-significant differences ($P > 0.02$ for the 1968-72 era and $P > 0.90$ for the 1979-1983 era) with $\alpha = 0.01$. Following this test, the data were pooled within each era.

Back calculated lengths-at-age proved to be less than the mean observed lengths-at-age for both eras with the exception of age 9 in the 1979-1983 era. (Tables 3.1, 3.2, 3.3 and 3.4). Both the observed mean lengths-at-age and the estimated mean lengths-at-age were larger in the 1968-1972 high population density era relative to the low density era.

Estimates of the Von Bertalanffy growth function fitted to the calculated lengths-at-age yielded $L(t) = 533.9 [1 - \exp(-0.2579 (t + 1.6653))]$ for 1968-1972 and $L(t) = 524.0 [1 - \exp(-0.2126 (t + 2.7274))]$ for 1979-1983 where $L(t)$ is in mm and t is in years.

Results of t-tests of between-era length-at-age gave strong evidence for significant differences in mean length ($P < 0.001$) at all ages except age 9 ($P = 0.16$). This could be explained by the small sample size of 13 at this age.

It is generally accepted that, during times of high population density, growth of fish is slowed; and, during times of low population density, growth rate increases (Wilson et al. 1975; McFadden 1977). The results of the present data analyses suggest the contrary. Fish from the 1968-1972 high population density era demonstrated a faster growth rate than those from the low population density era.

Everhart and Youngs (1981) stated that factors influencing growth of fish are: the amount and size of food available; the number of fish using the same food resource; temperature, oxygen, and other water quality factors; and the size, age, and sexual maturity of the fish. There are many factors which can be attributed to the decline of population density of shad. Construction of dams reduced the amount of available spawning grounds in the 1800's. Prior to the building of the dams, American shad migrated 291 nautical miles up the James River. They are now limited to 91 nautical miles due to the existence of Boshers Dam (Atran et al. 1982). Recent declines may have resulted from man's encroachment on what is left of the spawning grounds. Contamination of these areas may be detrimental to growth and survival of American shad. Loesch et al. (1982) reported kepone in juvenile American shad and blueback herring in the Mattaponi River. A factor such as contamination could explain both a reduction in population density and in individual growth of the fish. In the Connecticut River, high river flows in June are strongly correlated with poor year-class recruitment (V.A. Crecco, Connecticut Department of Environmental Protection: personal communication). Thus, the present American shad growth data should be analyzed in conjunction with chemical and physical parameters of the river systems.

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Table 1.1. Summary of sample data from the *Alosa* commercial fisheries during the 1986 spawning run in the major Virginia tributaries to Chesapeake Bay.

| River and Month | Alewife | | Blueback | | American Shad | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| York | | | | | | |
| March | 12 | 9 | 121 | 86 | 2 | |
| April | 21 | 31 | 160 | 269 | 13 | 187 |
| May | 3 | 0 | 105 | 140 | | |
| Rappahannock | | | | | | |
| March | 95 | 92 | 2 | 1 | | |
| April | 95 | 109 | 147 | 127 | 9 | 59 |
| May | 24 | 16 | 144 | 102 | | |
| Totals (M&F) | 507 | | 1,404 | | 270 | |

Table 1.2. Number of active pound net stands in Chesapeake Bay and its Virginia tributaries during January-June, 1986.

| Area | Jan 9 | Feb 24 | Mar 12 | Mar 20 | April 3 | April 23 | May 7 | May 27 | June 11 | June 24,* 25 |
|---|---|---|---|---|---|---|---|---|---|---|
| A. James River | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B. Back River | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 |
| C. Poquoson River | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D. York River | 0 | 0 | 1 | 1 | 5 | 8 | 10 | 11 | 10 | 11 |
| E. Mobjack Bay | 0 | 0 | 0 | 0 | 2 | 5 | 5 | 5 | 5 | 2 |
| F. Piankatank River | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G. Rappahannock River | 0 | 0 | 4 | 10 | 24 | 29 | 31 | 31 | 26 | 22 |
| H. Great Wicomico River | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| I. Potomac River | 0 | 0 | 4 | 12 | 32 | 47 | 61 | 62 | 61 | 62 |
| a. Virginia tributaries to Potomac River | 0 | 0 | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 2 |
| J. Cape Henry-Fort Wool | 0 | 0 | 0 | 1 | 3 | 4 | 5 | 5 | 5 | 5 |
| K. Old Point-Tue Marsh Point | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 4 | 4 | 4 |
| L. York Spit | 0 | 0 | 0 | 0 | 1 | 7 | 5 | 6 | 6 | 7 |
| M. New Point-Stingray Point | 0 | 2 | 5 | 6 | 8 | 10 | 15 | 17 | 16 | 16 |
| N. Windmill Point-Smith Point | 1 | 1 | 1 | 2 | 6 | 12 | 13 | 13 | 14 | 13 |
| Eastern Shore | | | | | | | | | | |
| O. Above Hungar Creek | 0 | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 4 | 4 |
| P. Below Hungar Creek | 5 | 0 | 0 | 7 | 9 | 9 | 15 | 16 | 19 | 22 |
| TOTAL | 6 | 3 | 17 | 42 | 98 | 141 | 171 | 179 | 176 | 173 |

*Dense haze and threatening thunderstorms caused the cancellation of flight. Count was completed on 25 June.

Table 1.3. Number of stake gill net stands fished in Virginia rivers 1984-1986 (A) and linear meters of gill netting fished primarily for American shad per 5-mile block (B) in 1986. Figures in parentheses represent the total meters of gill netting in the James, York and Rappahannock rivers.

| A. River | Number of Gill Net Stands 1984 | 1985 | 1986 |
|---|---|---|---|
| James | 107 | 109 | 88 |
| York | 121 | 124 | 132 |
| Rappahannock | 37 | 27 | 8 |

| B. River | Mile | | Number of Stands | Number of Sections | Average Length/Section | Meters of Net | |
|---|---|---|---|---|---|---|---|
| James | 05-10 | | 28 | 826 | 9.1 | (7,517) | 7,465 |
| | 10-15 | | - | - | - | ( - ) | - |
| | 15-20 | | 31 | 495 | 9.1 | (4,505) | 2,253 |
| | 20-25 | | 22 | 339 | 12 | (4,068) | 2,034 |
| | 25-45 | | 13 | 178 | 12 | (2,136) | 216 |
| | | Total | 94 | 1,838 | | (18,226) | 11,968 |
| York | 05-10 | | 2(a) | 22 | 14.2 | ( 312) | 197 |
| | 10-15 | | 42(a) | 762 | 14.2 | (10,820) | 6,817 |
| | 15-20 | | 29(a) | 427 | 14.2 | (6,063) | 3,820 |
| | 20-25 | | 15(a) | 285 | 7.6 | (2,166) | 2,049 |
| | 25-30 | | 44 | 754 | 7.6 | (5,730) | 5,420 |
| | | Total | 132 | 2,250 | | (25,091) | 18,303 |
| Rappahannock | 25-30 | | 3 | 29 | 15.7 | ( 455) | 235 |
| | 30-35 | | 5 | 107 | 15.7 | (1,680) | 867 |
| | | Total | 8 | 136 | | (2,135) | 1,102 |

(a) Adjusted for stands set but not fished.

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 1975-1986. 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 | M | F | 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) |
| 1984 | 16,911 | 2.1 | 10.0 | (a) | (a) |
| 1985 | 23,143 | 0.7 | 3.1 | (a) | (a) |
| 1986 | 11,968 | 1.0 | 1.4 | (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 |
| 1984 | 23,515 | 2.5 | 8.4 | 8.33 | 5,306 |
| 1985 | 25,595 | 1.2 | 4.7 | 7.34 | 2,189 |
| 1986 | 18,303 | 1.8 | 4.0 | (a) | (a) |
| **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 | 11,981 |
| 1984 | 5,742 | 0.9 | 2.3 | 34.26 | 15,401 |
| 1985 | 4,453 | 0.7 | 1.4 | 15.24 | 13,241 |
| 1986 | 1,102 | 0.8 | 1.8 | 24.11 | 3,406 |

(a) Data not available.

Table 1.5. Estimated catch in kg of American shad by stake gill nets for 5-mile sections in the James River 1986 by half-month intervals and by sex. Effort from Table 1.3. Index in kg/m of net.

| Half-Month Period | River Mile | American Shad: Male Index | Male Estimated Catch | Female Index | Female Estimated Catch | Total Estimated Catch |
|---|---|---|---|---|---|---|
| February 2nd | 05-10 | 0.1481 | 1,106 | 0 | | 1,106 |
| | 10-15 | | | | | |
| | 15-20 | | | | | |
| | 20-25 | 0 | | 0 | | |
| | 25-60 | | | | | |
| | | | 1,106 | | 0 | 1,106 |
| March 1st | 05-10 | 0.5113 | 3,817 | 0.5398 | 4,030 | 7,847 |
| | 10-15 | | | | | |
| | 15-20 | | 104 | | 110 | 214 |
| | 20-25 | 0.0461 | 94 | 0.0490 | 100 | 194 |
| | 25-60 | | 10 | | 11 | 21 |
| | Total | | 4,025 | | 4,251 | 8,276 |
| March 2nd | 05-10 | 0.6843 | 5,108 | 0.9825 | 7,334 | 12,442 |
| | 10-15 | | | | | |
| | 15-20 | | 255 | | 417 | 672 |
| | 20-25 | 0.1132 | 230 | 0.1852 | 377 | 607 |
| | 25-60 | | 24 | | 40 | 64 |
| | Total | | 5,617 | | 8,168 | 13,785 |
| April 1st | 05-10 | 0.1171 | 874 | 0.6465 | 4,826 | 5,700 |
| | 10-15 | | | | | |
| | 15-20 | | 75 | | 366 | 441 |
| | 20-25 | 0.0332 | 68 | 0.1625 | 331 | 399 |
| | 25-60 | | 7 | | 35 | 42 |
| | Total | | 1,024 | | 5,558 | 6,582 |
| | Total | | 11,772 | | 17,977 | |
| | Grand Total | | | | | 29,749 |

Table 1.6. 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 | |
| | M | F | M | F | Alewife | Blueback |
| James | | | | | | |
| 1977 | 11,612 | 186,495 | (a) | (a) | (a) | (a) |
| 1978 | 116,348 | 574,935 | (a) | (a) | (a) | (a) |
| 1979 | 17,328 | 263,203 | (a) | (a) | (a) | (a) |
| 1980 | 59,003 | 343,026 | (a) | (a) | (a) | (a) |
| 1981 | 12,056 | 105,550 | (a) | (a) | (a) | (a) |
| 1982 | 21,811 | 37,731 | (a) | (a) | (a) | (a) |
| 1983 | 46,822 | 146,715 | (a) | (a) | (a) | (a) |
| 1984 | 35,531 | 169,990 | (a) | (a) | (a) | (a) |
| 1985 | 16,922 | 71,232 | (a) | (a) | (a) | (a) |
| 1986 | 11,772 | 17,977 | (a) | (a) | (a) | (a) |
| 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 |
| 1984 | 58,104 | 196,550 | 2,469 | 1,056 | 4,131 | 40,066 |
| 1985 | 36,786 | 120,951 | 1,336 | 645 | 5,175 | 14,850 |
| 1986 | 32,886 | 72,542 | (a) | (a) | (a) | (a) |
| 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 | 313,873 |
| 1984 | 5,043 | 12,949 | 2,225 | 936 | 113,787 | 413,839 |
| 1985 | 3,284 | 6,152 | 602 | 248 | 49,104 | 152,696 |
| 1986 | 888 | 1,958 | 382 | 191 | 21,860 | 60,284 |

(a) Data not available.

Table 1.7. Estimated catch in kg of American shad by stake gill nets for 5-mile sections in the York River 1986 by half-month intervals. Effort from Table 1.3. Index in kg/m of net.

| | | American Shad | | | | |
|---|---|---|---|---|---|---|
| | | Male | | Female | | |
| Half-Month Period | River Mile | Index | Estimated Catch | Index | Estimated Total | Total Estimated Catch |
| February 2 | 05-10 | | 16 | | 10 | 26 |
| | 10-15 | 0.0799 | 545 | 0.0503 | 343 | 888 |
| | 15-20 | | 305 | | 192 | 497 |
| | 20-25 | (a) | | (a) | | |
| | 25-30 | | | | | |
| | Total | | 866 | | 545 | 1,411 |
| March 1st | 05-10 | | 96 | | 47 | 143 |
| | 10-15 | 0.4892 | 3,335 | 0.2401 | 1,637 | 4,972 |
| | 15-20 | | 1,869 | | 917 | 2,786 |
| | 20-25 | 0.5562 | 1,140 | 0.3496 | 716 | 1,856 |
| | 25-30 | | 3,015 | | 1,895 | 4,910 |
| | Total | | 9,455 | | 5,212 | 14,667 |
| March 2nd | 05-10 | | 142 | | 259 | 401 |
| | 10-15 | 0.7224 | 4,925 | 1.3139 | 8,957 | 13,882 |
| | 15-20 | | 2,760 | | 5,019 | 7,779 |
| | 20-25 | 0.7881 | 1,615 | 1.6932 | 3,469 | 5,084 |
| | 25-30 | | 4,272 | | 9,177 | 13,449 |
| | Total | | 13,714 | | 26,881 | 40,595 |
| April 1st | 05-10 | | 17 | | 217 | 234 |
| | 10-15 | 0.0866 | 590 | 1.1015 | 7,509 | 8,099 |
| | 15-20 | | 331 | | 4,208 | 4,539 |
| | 20-25 | 0.4178 | 856 | 1.0581 | 2,168 | 3,024 |
| | 25-30 | | 2,264 | | 5,735 | 7,999 |
| | Total | | 4,058 | | 19,837 | 23,895 |
| April 2nd | 05-10 | | 13 | | 117 | 130 |
| | 10-15 | 0.0645 | 440 | 0.5922 | 4,037 | 4,477 |
| | 15-20 | | 246 | | 2,262 | 2,508 |
| | 20-25 | 0.5482 | 1,123 | 1.8277 | 3,745 | 4,868 |
| | 25-30 | | 2,971 | | 9,906 | 12,877 |
| | Total | | 4,793 | | 20,067 | 24,860 |
| Total | | | 32,886 | | 72,542 | |
| Grand Total | | | | | | 105,428 |

(a) none reported by index fishermen.

Table 1.8. Estimated catch in kg of American shad and river herring by pound nets in the Rappahannock River 1986 by half-month intervals. Number of index nets has been rounded to the nearest whole value.

| 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 2nd | 31-70 | 7 | 3.7 | 26 | 2.1 | 15 | 670 | 4,690 | 98.4 | 4,615 | 1.6 | 75 | 4 |
| April 1st | 31-70 | 17 | 2.2 | 37 | 5.7 | 97 | 145 | 2,465 | 63.8 | 1,573 | 36.2 | 892 | 8 |
| April 2nd | 31-70 | 20 | 0.11 | 2 | 2.1 | 42 | 79 | 1,580 | 23 | 363 | 77 | 1,217 | 9 |
| May 1st | 31-70 | 21 | 8.5 | 179 | (a) | | 73 | 1,533 | 14 | 215 | 86 | 1,318 | 9 |
| May 2nd | 31-70 | 20 | 1.3 | 26 | (a) | ___ | (a) | | | ___ | | ___ | 9 |
| Total | | | | 270 | | 154 | | | | 6,766 | | 3,502 | |
| Grand Total | | | | | 424 | | | | | | 10,268 | | |
| Estimated landings mile 0-30 | | | | 112 | | 37 | | | | 15,094 | | 56,782 | |
| | | | | | 149 | | | | | | 71,876 | | |
| Grand Total for Rappahannock River | | | | | 573 | | | | | | 82,144 | | |

(a) None reported by index fishermen.

Table 1.9. Estimated catch in kg of American shad by stake gill nets in the Rappahannock River 1986 by half-month intervals. Effort from Table 1.3. Index in kg/m of net.

| | | American Shad | | | | |
|---|---|---|---|---|---|---|
| | | Male | | Female | | |
| Half-Month Period | River Mile | Index | Estimated Catch | Index | Estimated Catch | Total Estimated Catch |
| March 1st | 25-30 | | 27 | | | 27 |
| | 30-35 | 0.1155 | 100 | (a) | | 100 |
| | Total | | 127 | | | 127 |
| March 2nd | 25-30 | | 102 | | 201 | 303 |
| | 30-35 | 0.4327 | 375 | 0.8574 | 743 | 1,118 |
| | Total | | 477 | | 944 | 1,421 |
| April 1st | 25-30 | | 28 | | 156 | 184 |
| | 30-35 | 0.1196 | 104 | 0.6646 | 576 | 680 |
| | Total | | 132 | | 732 | 864 |
| April 2nd | 25-30 | | 8 | | 52 | 60 |
| | 30-35 | 0.0350 | 30 | 0.2223 | 193 | 223 |
| | Total | | 38 | | 245 | 283 |
| May 1st | 25-30 | | 24 | | 8 | 32 |
| | 30-35 | 0.1042 | 90 | 0.0335 | 29 | 119 |
| | Total | | 114 | | 37 | 151 |
| | Total | | 888 | | 1,958 | |
| | Grand Total | | | | | 2,846 |

(a) None reported by index fishermen.

Table 1.10. Year-class frequency of alewife (sexes pooled) in the York River commercial fishery samples, 1986.

| Category Level | Code | Absolute Freq | Relative Freq (Pct) | Adjusted Freq (Pct) | Cum Freq (Pct) |
|---|---|---|---|---|---|
| | 73. | 2 | 2.6 | 2.8 | 2.8 |
| | 76. | 1 | 1.3 | 1.4 | 4.2 |
| | 77. | 4 | 5.2 | 5.6 | 9.9 |
| | 78. | 3 | 3.9 | 4.2 | 14.1 |
| | 79. | 5 | 6.5 | 7.0 | 21.1 |
| | 80. | 12 | 15.6 | 16.9 | 38.0 |
| | 81. | 31 | 40.3 | 43.7 | 81.7 |
| | 82. | 12 | 15.6 | 16.9 | 98.6 |
| | 83. | 1 | 1.3 | 1.4 | 100.0 |
| | 9.* | 6 | 7.8 | Missing | 100.0 |
| | Total | 77 | 100.0 | 100.0 | |

| | | | | | |
|---|---|---|---|---|---|
| Mean | 80.239 | Std Err | 0.225 | Median | 80.774 |
| Mode | 81.000 | Std Dev | 1.893 | Variance | 3.585 |
| Kurtosis | 4.774 | Skewness | -1.980 | Range | 10.000 |
| Minimum | 73.000 | Maximum | 83.000 | | |

Valid Cases 71 Missing Cases 6

*Age Code

9 - missing age data

Table 1.11. Year-class frequency of blueback herring (sexes pooled) in the York River commercial fishery samples, 1986.

| Category Level | Code | Absolute Freq | Relative Freq (Pct) | Adjusted Freq (Pct) | Cum Freq (Pct) |
|---|---|---|---|---|---|
| | 74. | 1 | 0.1 | 0.3 | 0.3 |
| | 75. | 5 | 0.6 | 1.6 | 2.0 |
| | 76. | 6 | 0.7 | 2.0 | 3.9 |
| | 77. | 15 | 1.7 | 4.9 | 8.9 |
| | 78. | 28 | 3.2 | 9.2 | 18.0 |
| | 79. | 48 | 5.4 | 15.7 | 33.8 |
| | 80. | 65 | 7.4 | 21.3 | 55.1 |
| | 81. | 82 | 9.3 | 26.9 | 82.0 |
| | 82. | 53 | 6.0 | 17.4 | 99.3 |
| | 83. | 2 | 0.2 | 0.7 | 100.0 |
| | 9.* | 579 | 65.5 | Missing | 100.0 |
| | Total | 884 | 100.0 | 100.0 | |

| | | | | | |
|---|---|---|---|---|---|
| Mean | 79.967 | Std Err | 0.097 | Median | 80.262 |
| Mode | 81.000 | Std Dev | 1.686 | Variance | 2.841 |
| Kurtosis | 0.541 | Skewness | -0.869 | Rahge | 9.000 |
| Minimum | 74.000 | Maximum | 83.000 | | |

Valid Cases 305 Missing Cases 579

*Age code

9 - Missing age data

Table 1.12. Year-class frequency of alewife (sexes pooled) in the Rappahannock River commercial fishery samples, 1986.

| Category Level | Code | Absolute Freq | Relative Freq (Pct) | Adjusted Freq (Pct) | Cum Freq (Pct) |
|---|---|---|---|---|---|
| | 77. | 3 | 0.7 | 1.3 | 1.3 |
| | 78. | 6 | 1.4 | 2.5 | 3.8 |
| | 79. | 16 | 3.7 | 6.8 | 10.5 |
| | 80. | 34 | 7.8 | 14.3 | 24.9 |
| | 81. | 79 | 18.2 | 33.3 | 58.2 |
| | 82. | 95 | 21.9 | 40.1 | 98.3 |
| | 83. | 4 | 0.9 | 1.7 | 100.0 |
| | 9.* | 197 | 45.4 | Missing | 100.0 |
| | Total | 434 | 100.0 | 100.0 | |

| | | | | | |
|---|---|---|---|---|---|
| Mean | 81.030 | Std Err | 0.075 | Median | 81.253 |
| Mode | 82.000 | Std Dev | 1.148 | Variance | 1.317 |
| Kurtosis | 1.349 | Skewness | -1.178 | Range | 6.000 |
| Minimum | 77.000 | Maximum | 83.000 | | |
| Valid Cases | 237 | Missing Cases | 179 | | |

*Age Code

9 - Missing age data

Table 1.13. Year-class frequency of blueback herring (sexes pooled) in the Rappahannock River commercial fishery samples, 1986.

| Category Level | Code | Absolute Freq | Relative Freq (Pct) | Adjusted Freq (Pct) | Cum Freq (Pct) |
|---|---|---|---|---|---|
| | 74. | 1 | 0.2 | 0.5 | 0.5 |
| | 75. | 2 | 0.4 | 0.9 | 1.4 |
| | 76. | 3 | 0.6 | 1.4 | 2.8 |
| | 77. | 8 | 1.5 | 3.7 | 6.5 |
| | 78. | 11 | 2.1 | 5.1 | 11.5 |
| | 79. | 42 | 8.0 | 19.4 | 30.9 |
| | 80. | 51 | 9.7 | 23.5 | 54.4 |
| | 81. | 60 | 11.4 | 27.6 | 82.0 |
| | 82. | 38 | 7.2 | 17.5 | 99.5 |
| | 83. | 1 | 0.2 | 0.5 | 100.0 |
| | 9.* | 308 | 58.7 | Missing | 100.0 |
| | Total | 525 | 100.0 | 100.0 | |

| | | | | | |
|---|---|---|---|---|---|
| Mean | 80.106 | Std Err | 0.104 | Median | 80.314 |
| Mode | 81.000 | Std Dev | 1.537 | Variance | 2.364 |
| Kurtosis | 1.408 | Skewness | -0.997 | Range | 9.000 |
| Minimum | 74.000 | Maximum | 83.000 | | |

Valid Cases 217 Missing Cases 308

*Age code

9 - Missing age data

Table 1.14. Year-class frequency of American shad in the Virginia commercial gill net fishery, 1986.

| Sex | Year Class | York | Rappahannock | Total | Frequency (%) |
|---|---|---|---|---|---|
| Male | 1977 | 1 | 1 | 2 | 10.53 |
| | 1978 | 3 | 1 | 4 | 21.05 |
| | 1979 | 4 | 5 | 9 | 47.37 |
| | 1980 | 2 | | 2 | 10.53 |
| | 1981 | 1 | 1 | 2 | 10.53 |
| Total | | 11 | 8 | 19 | |
| Female | 1976 | 2 | 1 | 3 | 2.42 |
| | 1977 | 14 | 7 | 21 | 16.94 |
| | 1978 | 25 | 16 | 41 | 33.06 |
| | 1979 | 19 | 18 | 37 | 29.84 |
| | 1980 | 13 | 3 | 16 | 12.90 |
| | 1981 | 1 | 5 | 6 | 4.84 |
| Total | | 74 | 50 | 124 | |

Table 1.15. Length (mm) and weight (g) statistics for river herring in the York and Rappahannock rivers, 1986.

| | | | York | | | Rappahannock | | |
|---|---|---|---|---|---|---|---|---|
| Species | Sex | | N | Mean | Std. Error | N | Mean | Std. Error |
| Alewife | Male | Length | 36 | 241.2 | 1.869 | 212 | 238.7 | 0.776 |
| | | Weight | 36 | 188.4 | 5.610 | 212 | 195.2 | 2.356 |
| | Female | Length | 40 | 256.5 | 2.063 | 217 | 251.6 | 0.834 |
| | | Weight | 40 | 221.0 | 6.761 | 217 | 233.7 | 3.464 |
| Blueback | Male | Length | 387 | 236.6 | 0.689 | 293 | 232.6 | 0.622 |
| | | Weight | 387 | 171.9 | 1.674 | 293 | 158.5 | 1.799 |
| | Female | Length | 492 | 246.9 | 0.694 | 230 | 243.0 | 0.866 |
| | | Weight | 494 | 196.3 | 1.950 | 230 | 187.8 | 2.821 |

Table 1.16. Length (mm) and weight (g) statistics for American shad in the York and Rappahannock gill net fisheries, 1986.

| Sex | | York N | York Mean | York Std. Error | Rappahannock N | Rappahannock Mean | Rappahannock Std. Error |
|---|---|---|---|---|---|---|---|
| Male | Length | 15 | 409.8 | 18.794 | 9 | 426.7 | 10.901 |
| | Weight | 15 | 1215.2 | 115.970 | 9 | 1328.9 | 94.135 |
| Female | Length | 187 | 461.2 | 1.629 | 59 | 464.7 | 4.063 |
| | Weight | 87 | 1772.2 | 33.675 | 59 | 1857.6 | 47.460 |

Table 1.17. Estimated rates of instantaneous total mortality (Z), annual mortality (A), survival (S), and exploitation (E) for alewife and blueback herring in the Rappahannock River. A natural mortality rate of 1.1 was assumed.

| Year Class | Alewife Z | Alewife A | Alewife S | Alewife E | Blueback Z | Blueback A | Blueback S | Blueback E |
|---|---|---|---|---|---|---|---|---|
| 1969 | 2.06 | 0.87 | 0.13 | 0.62 | 2.22 | 0.89 | 0.11 | 0.67 |
| 1970 | 1.38 | 0.75 | 0.25 | 0.24 | 1.72* | 0.82 | 0.18 | 0.46 |
| 1971 | 1.21 | 0.70 | 0.30 | 0.10 | 1.90 | 0.85 | 0.15 | 0.55 |
| 1972 | 1.65* | 0.81 | 0.19 | 0.42 | 1.74 | 0.82 | 0.18 | 0.47 |
| 1973 | 3.01*+ | - | - | - | 1.47 | 0.77 | 0.23 | 0.31 |
| 1974 | 1.32 | 0.73 | 0.27 | 0.20 | 1.11 | 0.67 | 0.33 | 0.01 |
| 1975 | 1.20* | 0.70 | 0.30 | 0.10 | 1.65 | 0.81 | 0.19 | 0.42 |
| 1976 | 1.58 | 0.79 | 0.21 | 0.38 | 1.31 | 0.73 | 0.27 | 0.19 |
| 1977 | 1.42* | 0.76 | 0.24 | 0.27 | 1.72 | 0.82 | 0.18 | 0.46 |
| 1978 | 1.40 | 0.75 | 0.25 | 0.26 | 0.59+ | - | - | - |
| Mean | 1.47 | 0.77 | 0.23 | 0.31 | 1.61 | 0.80 | 0.20 | 0.40 |

*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 (regression of ln CPUE on age).

+The Z value was a statistical outlier, and omitted from the calculations.

Table 2.1. Maximal catch-per-unit-of-effort (CPUE) values for juvenile *Alosa* in the Mattaponi and Pamunkey rivers, 1979-1986.

| | Maximal CPUE | | | | | |
|---|---|---|---|---|---|---|
| | Mattaponi | | | Pamunkey | | |
| Year | Alewife | Blueback | Amer. Shad | Alewife | Blueback | Amer. Shad |
| 1979 | 6.0 | 73.0 | 38.1 | 6.7 | 224.8 | 57.4 |
| 1980 | 2.9* | 4.6* | 38.8* | 3.6 | 87.9 | 7.1 |
| 1981 | 10.0* | 11.6 | 18.0* | 6.5* | 16.7 | 5.3* |
| 1982 | 38.0 | 289.0 | 21.1 | 28.3* | 408.2 | 3.0* |
| 1983 | 36.2 | 36.1 | 16.5 | 4.2 | 120.7 | 7.5 |
| 1984 | 28.1 | 220.8 | 34.4 | 7.1* | 88.9 | 2.5 |
| 1985 | 31.3 | 206.2 | 35.9 | 12.6 | 154.6 | 15.5 |
| 1986 | 11.5* | 20.7 | 36.6 | 13.2* | 99.3 | 8.9 |

*Maximal CPUE occurred in the first sampling period.

Table 2.2. Estimates of instantaneous daily mortality for juvenile *Alosa* in the Mattaponi (M) and Pamunkey (P) rivers, 1979-1986.

| Species | River | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | Mean* |
|---|---|---|---|---|---|---|---|---|---|---|
| Alewife | M | 0.036 | 0.330 | 0.105 | 0.036 | 0.038 | 0.042 | 0.038 | 0.036 | 0.038 |
| | P | 0.040 | 0.041 | 0.058 | 0.043 | 0.068 | 0.036 | 0.067 | 0.050 | 0.051 |
| American shad | M | 0.040 | 0.056 | 0.080 | 0.042 | 0.030 | 0.056 | 0.053 | 0.080 | 0.050 |
| | P | 0.060 | 0.080 | 0.043 | 0.050 | 0.078 | 0.057 | 0.098 | 0.050 | 0.066 |
| Blueback | M | 0.034 | 0.022 | (+) | 0.077 | 0.041 | 0.030 | 0.035 | 0.047 | 0.044 |
| | P | 0.040 | 0.031 | 0.016 | 0.046 | 0.052 | 0.078 | 0.055 | 0.043 | 0.052 |

*The 1980 and 1981 data were omitted (see text).
(+)Data were too few for a reasonably objective estimate of mortality.

Table 3.1. Observed mean fork lengths of American shad for 1968-1972 era.

| | | | Length at Capture in 1968 | | | |
|---|---|---|---|---|---|---|
| Year Class | Age | N | Average | Maximum | Minimum | Standard Error |
| 1964 | 4 | 29 | 414.38 | 445.00 | 384.00 | 2.654 |
| 1963 | 5 | 284 | 438.23 | 493.00 | 385.00 | 1.103 |
| 1962 | 6 | 323 | 452.41 | 510.00 | 408.00 | 1.014 |
| 1961 | 7 | 97 | 473.21 | 525.00 | 420.00 | 2.122 |
| 1960 | 8 | 18 | 494.28 | 532.00 | 455.00 | 4.758 |
| 1959 | 9 | 2 | 505.00 | 530.00 | 480.00 | 25.000 |

Table 3.2. Back-calculated mean lengths-at-age of American shad for 1968-1972 era.

| Year Class | Age | N | Back-calculated size-at-age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1967 | 1 | 0 | 0.00 | | | | | | | | |
| 1966 | 2 | 0 | 0.00 | 0.00 | | | | | | | |
| 1965 | 3 | 0 | 0.00 | 0.00 | 0.00 | | | | | | |
| 1964 | 4 | 29 | 253.23 | 332.21 | 377.66 | 414.38 | | | | | |
| 1963 | 5 | 284 | 258.20 | 338.15 | 378.48 | 410.55 | 438.23 | | | | |
| 1962 | 6 | 323 | 256.65 | 337.62 | 374.29 | 406.78 | 428.27 | 452.41 | | | |
| 1961 | 7 | 97 | 260.43 | 341.41 | 379.65 | 411.40 | 434.14 | 449.96 | 473.21 | | |
| 1960 | 8 | 18 | 263.54 | 346.59 | 383.84 | 417.12 | 441.51 | 457.52 | 469.84 | 494.28 | |
| 1959 | 9 | 2 | 263.53 | 363.86 | 401.93 | 432.39 | 451.38 | 464.08 | 478.29 | 491.19 | 505.00 |
| All Classes | | | 257.77 | 338.38 | 376.99 | 409.41 | 433.36 | 452.14 | 472.77 | 493.97 | 505.00 |
| N | | 753 | 753 | 753 | 753 | 753 | 724 | 440 | 117 | 20 | 2 |

Table 3.3. Observed mean fork lengths of American shad for 1979-1983 era.

| | | | Length at Capture in 1979 | | | |
|---|---|---|---|---|---|---|
| Year Class | Age | N | Average | Maximum | Minimum | Standard Error |
| 1975 | 4 | 19 | 414.89 | 428.00 | 395.00 | 2.344 |
| 1974 | 5 | 104 | 435.53 | 493.00 | 394.00 | 1.999 |
| 1973 | 6 | 163 | 450.51 | 500.00 | 375.00 | 1.480 |
| 1972 | 7 | 154 | 455.45 | 500.00 | 408.00 | 1.509 |
| 1971 | 8 | 45 | 462.51 | 514.00 | 425.00 | 3.250 |
| 1970 | 9 | 11 | 469.82 | 520.00 | 443.00 | 7.019 |
| 1969 | 10 | 1 | 510.00 | 510.00 | 510.00 | 0.000 |

Table 3.4. Estimated mean lengths-at-age of American shad for 1979-1983 era.

| Year Class | Age | N | Back-calculated size-at-age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1978 | 1 | 0 | 0.00 | | | | | | | | | |
| 1977 | 2 | 0 | 0.00 | 0.00 | | | | | | | | |
| 1976 | 3 | 0 | 0.00 | 0.00 | 0.00 | | | | | | | |
| 1975 | 4 | 19 | 274.03 | 338.34 | 381.53 | 419.83 | | | | | | |
| 1974 | 5 | 104 | 276.12 | 338.23 | 378.88 | 410.15 | 437.19 | | | | | |
| 1973 | 6 | 163 | 278.15 | 340.48 | 377.31 | 405.50 | 424.73 | 445.37 | | | | |
| 1972 | 7 | 154 | 279.23 | 341.15 | 373.06 | 397.98 | 416.63 | 433.19 | 451.40 | | | |
| 1971 | 8 | 45 | 277.16 | 339.89 | 367.79 | 393.51 | 411.38 | 426.96 | 440.92 | 458.48 | | |
| 1970 | 9 | 11 | 282.90 | 344.70 | 374.72 | 396.66 | 411.25 | 427.73 | 440.29 | 454.82 | 471.64 | |
| 1969 | 10 | 1 | 293.48 | 363.59 | 397.25 | 414.08 | 442.13 | 450.54 | 467.37 | 475.78 | 498.22 | 510.00 |
| All Classes | | | 277.95 | 340.22 | 375.61 | 403.42 | 423.30 | 437.63 | 448.66 | 458.07 | 473.86 | 510.00 |
| N | | 497 | 497 | 497 | 497 | 497 | 478 | 374 | 211 | 57 | 12 | 1 |

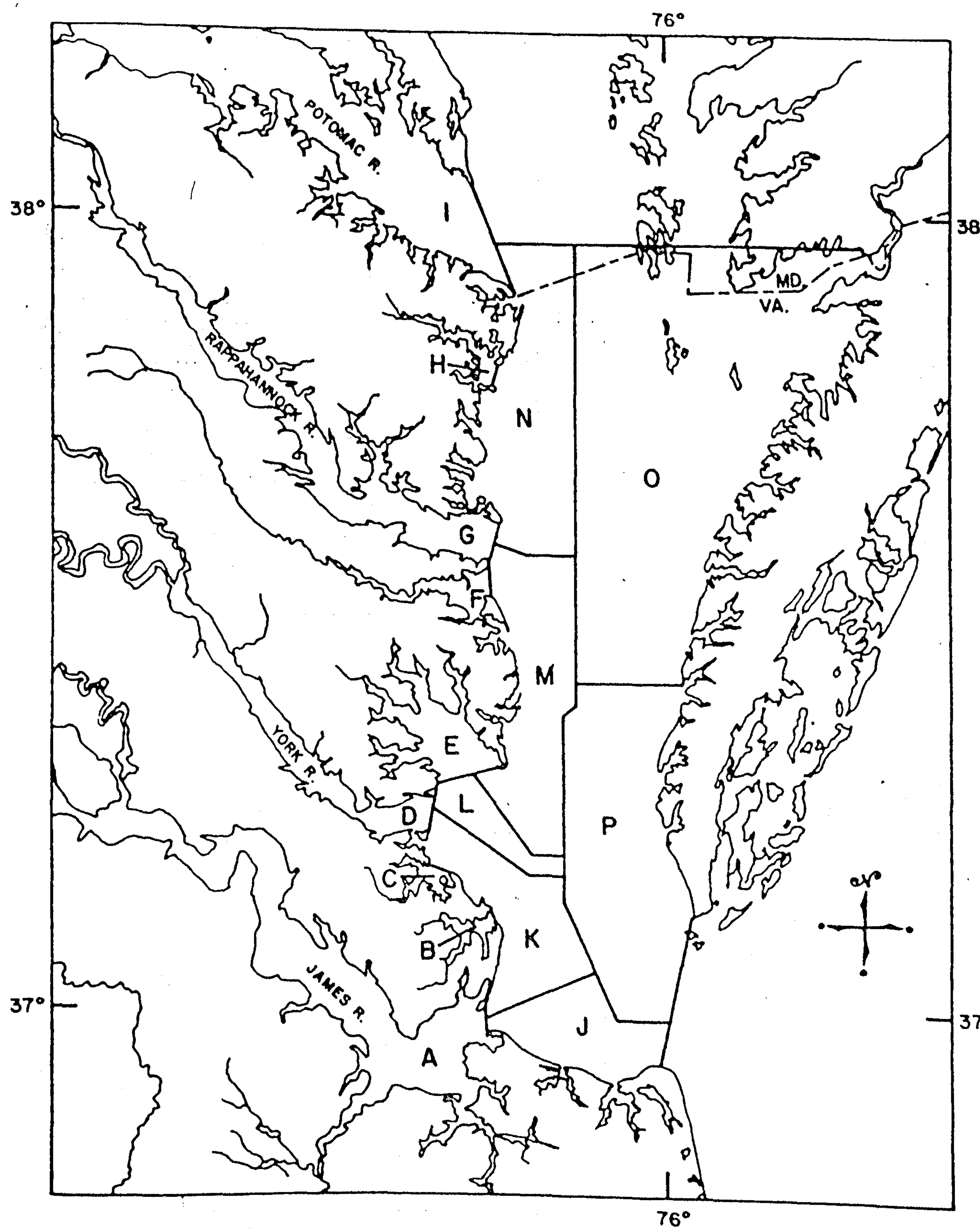
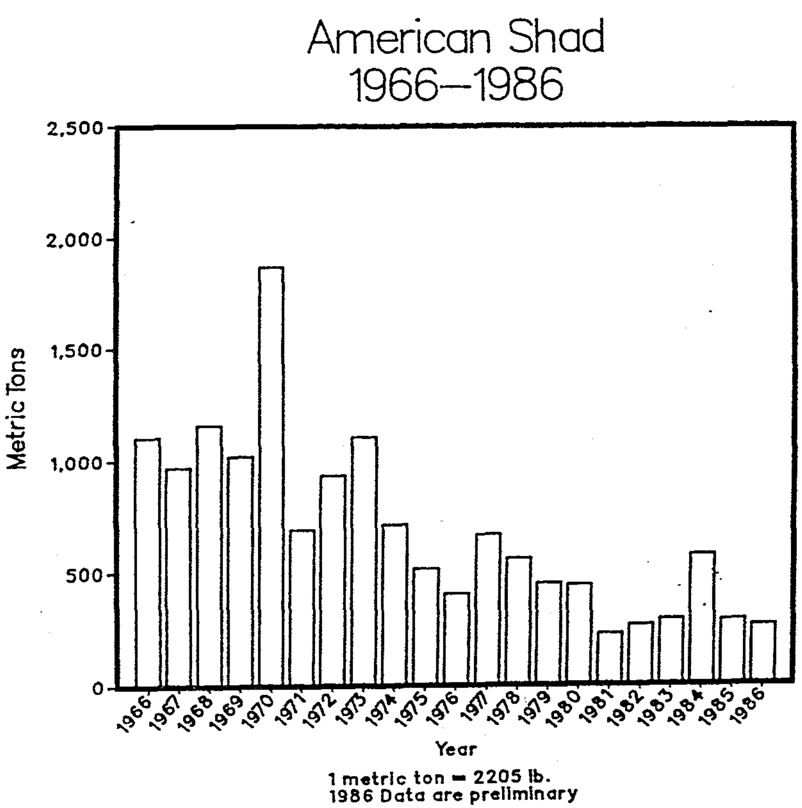



Figure 1.1. Area designations utilized during aerial pound net counts.

# Figure 1.2. Virginia Landings 1966–1986.



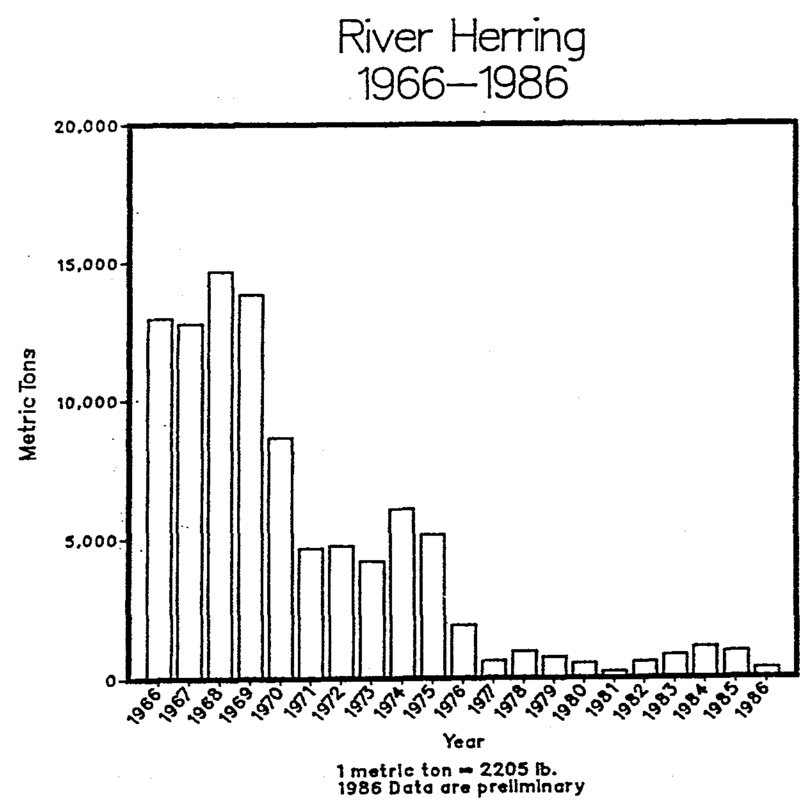



Figure 2.1. Growth Curves for Juvenile Alewives, 1986

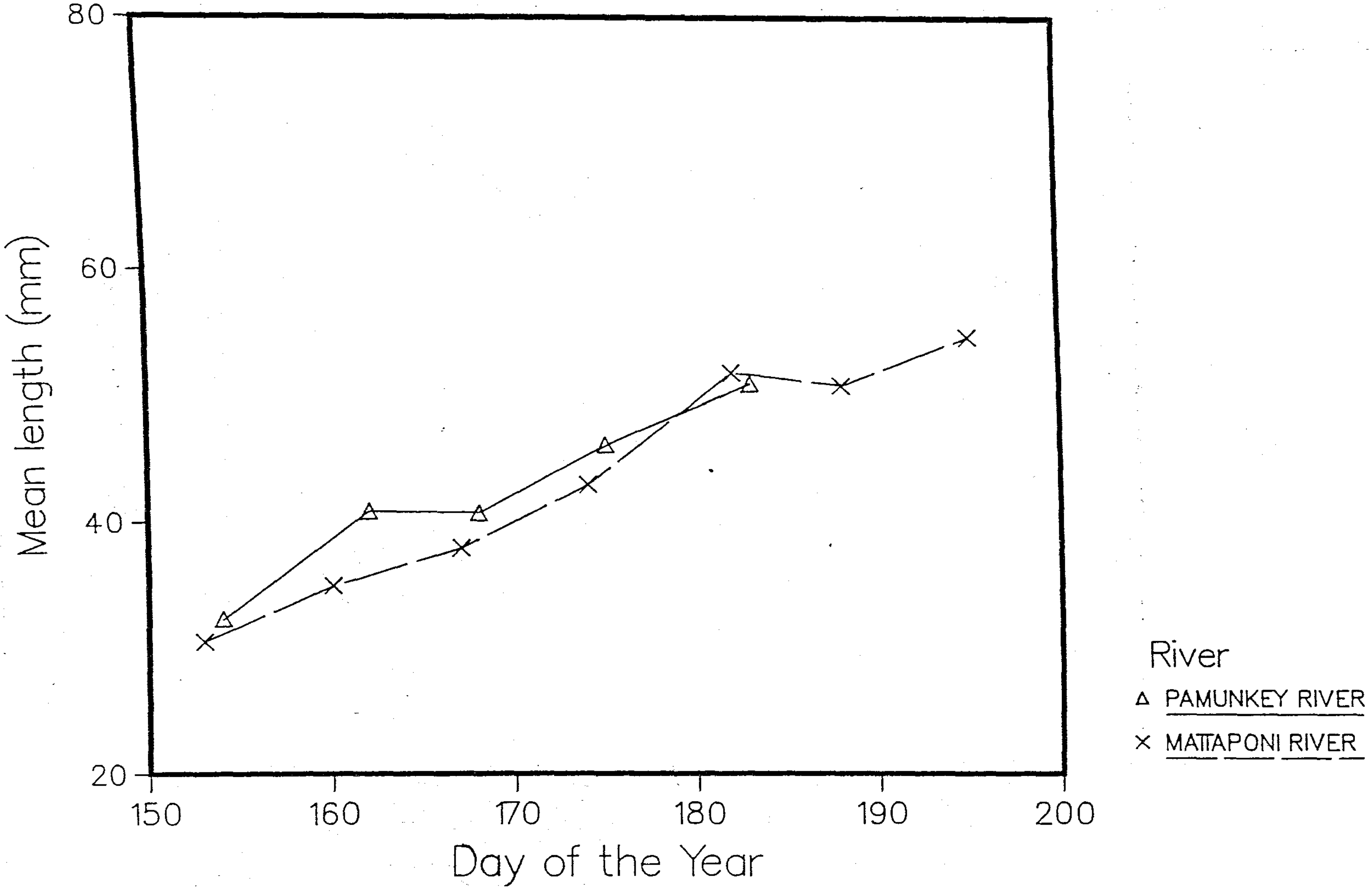
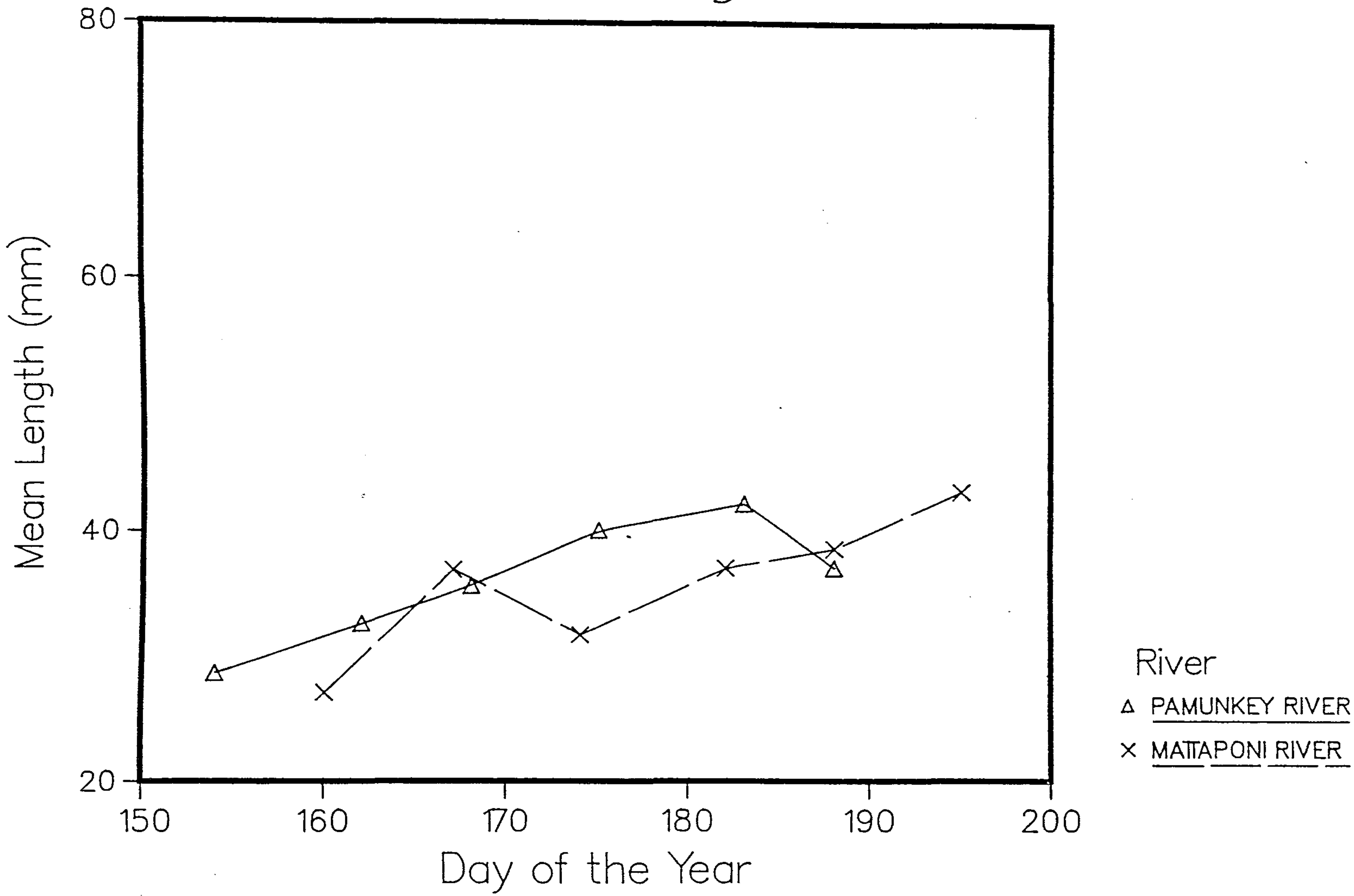


Figure 2.2. Growth Curves for Juvenile Blueback Herring, 1986



# Figure 2.3. Growth Curves for Juvenile American Shad, 1986