1-23-2000

Monitoring Relative Abundance of American Shad in Virginia's Rivers Annual Report 1998

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Annual Report

Funding Agencies: US Fish and Wildlife Service and Virginia Marine Resources Commission Virginia Institute of Marine Science

Contract Number: F-116-R-1

Project Period: 9 March 1998 - 8 March 1999

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Submitted To:

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24 January 2000

Executive Summary

- A staked gill net was set and fished two days per week on the James, York and Rappahannock rivers in the spring of 1998. The primary objective was to establish a time series of catch rates that could be compared to historical catch rates recorded in logbooks that were voluntarily submitted by commercial fishers prior to the imposition of the current moratorium. This new monitoring program provides information on the current status of shad stocks relative to conditions prior to the moratorium.

- Sampling occurred for 11 weeks on the York River (16 March - 1 June 1998), eight weeks on the James River (16 March - 4 May 1998) and seven weeks on the Rappahannock River (23 March - 4 May 1998).

- A total of 1,224 American shad (1,674.9 kg total weight) were captured. Catches were highest on the York River (779 females) and lowest on the Rappahannock River (75 females). Catches on the James River were intermediate (155 females).

- Based on age estimates from whole otoliths, the 1993 and 1994 year classes of American shad were the most abundant on all three rivers. Total instantaneous mortality rates of females and males (respectively) calculated from age-specific catch rates were: York River, 1.43, 1.37; James River, 1.12, 1.43; and Rappahannock River, 1.66, 0.34.

- The proportion of the catch with hatchery marks on the James and York rivers were 8.2% and < 0.2%, respectively.

- The maximal geometric mean catch of juvenile American shad (based on weekly summer pushnet surveys) was above the time-series average on the Mattaponi River in 1998 (average, 33.4; 1998 value, 77.3), and below average on the Pamunkey River in 1998 (average 7.2; 1998 value 3.5). The combined integrated catch index for the York system (both the Pamunkey and Mattaponi rivers) was above the time-series average (average, 1,008.3; 1998 value, 2,417.5).

- Twenty-four species of by-catch were taken in the monitoring gear. Almost 2,000 striped bass were captured. Ratios of the total number (both sexes) of American shad to the total number of striped bass taken on each river were: York, 0.51:0.49; James, 0.17:0.83; Rappahannock, 0.59:0.41. The proportions of dead striped bass on each river were: York, 36%; James, 51%; and Rappahannock, 55%.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day of the year for 1998 and for each year of the historical record of staked net catches on each river. On the York River, the seasonal catch rate was higher than any historical value. On the James River, the catch rate was similar to those obtained by the fishery in the years immediately preceding the moratorium. Catch rate on the Rappahannock River was low but they were low throughout the historical record thus making interpretation problematic.

Introduction and need

A moratorium on the taking of American shad in the Chesapeake Bay and its tributaries was established by the Virginia Marine Resources Commission (VMRC) beginning 1 January 1994. The prohibition applied to both recreational and commercial fishers. The moratorium was imposed at a time when commercial catch rates of American shad in Virginia's rivers were experiencing declines. Data from the commercial fishery were the best available for assessing the status of individual stocks. Catch-per-unit-effort (CPUE) data were compiled from logbooks that recorded landings by commercial fishermen using staked gill nets at various locations throughout the middle reaches of the three rivers. The logbooks were voluntarily provided to the Virginia Institute of Marine Science (VIMS) during the period 1980-1993, and subsequently used in an assessment of the status of American shad stocks along the Atlantic coast by the Atlantic States Marine Fisheries Commission (ASMFC) (ASMFC 1999).

Since the moratorium, there have been no monitoring programs that provided direct assessment of stock recovery. The ban on in-river fishing in Virginia remained in effect, creating a dilemma for managers who needed reliable information in order to make a rational decision on when the in-river ban could safely be lifted. To address this deficiency, we proposed a method of scientific monitoring to estimate catch rates relative to those recorded before the prohibition of in-river fishing in 1994. This monitoring program consisted of sampling techniques and locations that were consistent with, and directly comparable to, those that generated historical logbook data collected by VIMS during the period 1980-1993 in the York, James and Rappahannock rivers. The results of the first year's sampling program are reported in this document.

In addition to the objective of assessment of stock recovery in Virginia's rivers, there are other significant information needs. First, extensive efforts are being made to rehabilitate shad stocks through release of hatchery-raised fish. Evaluating the success of these programs requires determination of the survival of the stocked fish to adulthood. Second, there is an extensive time series of observations on juvenile shad abundance in the York River system. This juvenile index could have utility for predicting future spawning run sizes and confirming the health of the stocks. However, it needs to be critically evaluated since the ASMFC has mandated sampling for juveniles starting in 2000.

These ongoing studies of American shad in Virginia waters is significant for recreational fisheries for at least four reasons.

- American shad fight well when angled using light tackle. The recreational fishery is closed in Virginia but is popular in North Carolina, Maryland and some other states. Anecdotal information suggests that there were historical recreational fisheries for American shad on the Mattaponi and Rappahannock rivers. Thus, development of a recreational shad fishery in Virginia could constitute an important opportunity to expand or restore recreational fishing opportunities if the stocks are rehabilitated and managed carefully.

- American shad are important for trophic and ecological reasons. The abundance of juveniles is closely linked to water quality and the availability of good fish habitat. The shads and river herrings (*Alosa* and *Dorosoma*) form an important prey group for striped bass and other recreationally important species in Chesapeake Bay. In recent years, there have been shifts in community structure in the major tributaries to the Bay with striped bass and gizzard shad numbers increasing greatly. Monitoring changes in abundance of key species is essential for understanding community dynamics.

- Monitoring the shad spawning run using historic gear characterizes the bycatch associated with a commercial fishery for shad in Virginia's rivers. This is important for determining the impact of a reopened commercial fishery for shad on other recreationally important species, especially striped bass.

Background

Herring and shad have supported recreational and commercial fisheries along the east coast of the United States and within the Chesapeake Bay since colonial times. They also play a vital ecological role. Juvenile *Alosa* are an important prey species for striped bass and other recreational species while they remain on their freshwater and upper estuarine nursery grounds. In the autumn they move to coastal waters where they are subjected to predation by many types of marine piscivores until they return to their native streams to spawn for the first time at ages 3 to 5.

Attempts to manage and conserve Virginia's stock of American shad date to colonial times. Before Virginia was settled, native Americans caught American shad in large quantities using a seine made of bushes (Walburg and Nichols 1967). Shad were so plentiful that they could be speared with pointed sticks as they swam on the flats (VCF 1875). The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, shad were less abundant, presumably due to fishing and obstructions that prevented the fish from reaching their spawning grounds. Concerned colonists passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (VCF 1875). In 1771, the Virginia Assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to the last day of May. However, due to the approaching conflict of the Revolutionary War, the law was never enforced (VCF 1875).

The shad fishery of Chesapeake Bay became important about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and staked gill nets (Walburg and Nichols 1967). Catches reached a low in 1878, and the U.S. Fish Commission and Virginia Commission of Fisheries instituted an artificial hatching program in 1875. By 1879 the fishery began to improve, and the increase in catches led biologists to believe that the shad fishery was largely dependent upon artificial propagation. However, by the early 1900's the decline in shad harvests resumed despite improved hatching methods and increased numbers of fry released (Mansueti and Kolb 1953).

Today, many *Alosa* stocks along the eastern seaboard of the United States are depressed and there is evidence of recent and persistent stock declines of American shad in three of 12 systems, based on a recently completed stock assessment (ASMFC 1999). Two of these are Virginia stocks in the Rappahannock and York rivers. Large catches no longer occur as they did at the turn of the century. Commercial American shad landings in Virginia decreased from 11.5 million pounds in 1897 to less than a million pounds in 1982. Over-fishing, dam construction, pollution, and loss of natural spawning grounds are a few of the factors that may be related to this decline. Historically, the majority of American shad were captured within the rivers. Beginning in 1984, the largest proportion of American shad taken in Virginia's fishery was captured offshore. The overall impact of this shift in the fishery on egg production and annual recruitment of Virginia stocks is unknown. Genetic studies of the catch composition of Virginia and Maryland's coastal landings have suggested that the intercept fishery claims a highly variable proportion of Virginia's riverine stocks (Brown and Epifanio 1994). American shad were pursued by recreational fishermen in Virginia in the past, but the extent and success of this activity is not easily assessed.

In spring 1994, the Virginia Department of Game and Inland Fisheries (VDGIF) and the US Fish and Wildlife Service (USFWS) began a hatchery-restocking effort in the James and Pamunkey rivers. Native adult shad are used as brood stock, eggs are stripped and fertilized in the field, and larvae are reared in the VGIF hatchery at Stephensville, Virginia and the USFWS hatchery at Harrison Lake. Prior to release the larvae are immersed in an oxytetracycline (OTC) solution that marks otoliths with a distinctive epifluorescent ring. The success of this ongoing program is not well understood. Annual monitoring of the abundance of juvenile *Alosa* has been conducted annually on the Pamunkey River system since 1979. Since 1995, juveniles bearing the OTC mark have been collected. The data show that hatchery-released shad constituted 4-8 % of the total catch of juveniles during the 3-y period (1995-1997).

Prior to 1991, there were no restrictions on the American shad commercial fishery in Virginia rivers and the Chesapeake Bay. A limited season (4 February - 30 April) was established for 1991 by the Virginia Marine Resources Commission (VMRC), and kept in place in 1992. In 1993, a further limitation to the season was established (15 March - 15 April 1993). However, due to bad weather conditions, the season was extended through 30 April. A complete moratorium was established in 1994. The current regulation states that:

> "On and after 1 January 1994 it shall be unlawful for any person to catch and retain possession of American shad from the Chesapeake Bay or its tidal tributaries." (VMRC Regulation 450-01-0069).

In 1997 and 1998, during a series of public hearings, commercial fishing interests asked that the in-river ban on shad fishing be lifted. This proposal was opposed by the VMRC staff, the Virginia Institute of Marine Science, and various other public and private agencies. The Commission decided to leave the ban in place but also decried the lack of information necessary to assess the recovery of Virginia stocks of American shad. The current monitoring project began in the spring of 1998 in response to the VMRC's request for information.

Current Information

There is mandatory reporting of offshore catches to the VMRC. These data can be accessed through the VMRC website (http://www.state.va.us/mrc/homepage.htm). Annual monitoring of the abundance of juvenile *Alosa* is conducted on the York River system with a pushnet developed in the late 1970s (Kriete and Loesch, 1980). Because of the negative phototropic behavior of juvenile *Alosa* (Loesch et al., 1982; Dixon, 1996), the pushnet is used at night to determine catch-per-unit-of-effort. The data record extends from 1979 through 1987 but sampling was not conducted in 1988 and 1989 because of a lack of funding. These data can be accessed through the VIMS website (http://www.fisheries.vims.edu/research.htm).

Objectives

The 1998 objectives were to: (1) establish time series of relative abundance indices of adult American shad during the spawning runs in the James, York and Rappahannock rivers; (2) relate contemporary indices of abundance of American shad to historical log-book data collected during the period 1980-1992; (3) assess the relative contribution of hatchery-reared and released cohorts of American shad to adult stocks; (4) relate recruitment indices (young-of-the-year index of abundance) of American shad based on pushnet surveys in the York River system to relative year-class strength of spawning adults; and (5) determine the amount of bycatch of other species in the staked gill nets.

Methods

We developed a fishery-independent monitoring protocol that was similar to traditional shad fishing methods in the middle reaches of Virginia's rivers. When the in-river fishing moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGNs) were allowed to retain priority rights for the locations of those stands in the various rivers. VIMS has records of the historic fishing locations, and one of these locations on each river (the James, York and Rappahannock) was used to monitor catch rates by SGN's in 1998. Three commercial fishermen were contracted to prepare and set SGN poles, hang nets, replace or repair poles or nets, and set nets for each sampling event during the monitoring period. Two of these commercial fishermen (Mr. Raymond Kellum and Mr. Mark Brown) were authors of the historical logbooks on the James and York rivers. However, authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders) with previous experience in SGN fishing but who had not participated in the shad fishery on the Rappahannock River in the 1980's. Scientists accompanied commercial fishermen during each sampling trip, and returned the catch to the laboratory.

It is possible that the absence of down-river fishing activity at present might bias the current monitoring program results upwards. To investigate this, we examined historic maps available at VIMS of fishing locations on the York River.

Another issue is whether a single gill net stand can provide a precise indicator of relative strength of a spawning run. To investigate this, we compared the index of abundance obtained

from the chosen fisher from the York and the James River for each year with an index obtained by considering the logbooks of all the cooperating fishers in the 1980s.

One SGN, 900 ft (~ 273 m) in length, was set on each river (Figures 1-3). Locations of the sets were as follows: lower James River near the James River Bridge at river mile 10 (36^0 50.0' N, 76^0 28.8' W); middle York River near Clay Bank at river mile 14 (37^0 20.8' N, 76^0 37.7' W); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock) at river mile 36 (37^0 55.9' N, 76^0 50.4' W). Historical catch-rate data on the York and James rivers were derived from nets constructed of 4 7/8" stretched-mesh monofilament netting, while historic data from the Rappahannock River were based on larger mesh sizes (nets constructed of 5" stretched-mesh). To insure that 1998 catch rates were comparable to logbook records, nets on the York and James rivers were constructed of 4 7/8" (12.4 cm) stretched-mesh monofilament netting, while nets on the Rappahannock River were constructed of 5" (12.7 cm) netting. Panel lengths were consistent with historical records (30 ft each on the James and York rivers; 48 ft each on the Rappahannock River). Each week, nets were fished on two succeeding days (two 24-h sets) and then hung in a non-fishing position until the next sampling episode. Occasionally, high winds prevented the regularly scheduled sampling on Sunday and Monday, and sampling was either postponed or canceled. We monitored catch rates from 16 March 1998 to 4 May 1998 on the James River; from 23 March 1998 to 4 May 1998 on the Rappahannock River; and from 16 March 1998 to 1 June 1998 on the York River. Surface water temperature was recorded at each sampling event.

Individual American shad collected from the monitoring sites were measured and weighed on a Limnoterra FMB IV electronic fish measuring board interfaced with a Mettler PM 30000-K electronic balance. The board recorded measurements (fork length, total length and body depth) to the nearest mm, received weight input from the balance, and allowed manual input of additional data (such as field data and comments) or subsample designations (such as gonadal tissue and otoliths) into a data file for subsequent analysis. All gonads were examined macroscopically; in randomly selected individuals, subsamples of gonad tissue were taken for histological determination of maturity stage. Catches of all other species were recorded on log sheets by observers on each river. By-catch taken in randomly selected panels of the SGN were returned to the laboratory for length and weight determination. The remaining by-catch was released if alive or returned to the laboratory if dead. For striped bass, separate records were kept of the number of live and dead fish in the nets.

Sagittal otoliths were removed from samples of adult American shad, placed in numbered tissue culture trays, and stored for subsequent aging. Whole otoliths were cleaned by immersing in a 10% bleach and hydrogen peroxide bath. After immersion, the cleaning solution was drawn off by pipette, and otoliths were rinsed with distilled water. Otoliths were mounted on slides, ground and polished by hand using wet laboratory-grade sandpaper. All otoliths were scanned for hatchery marks using epifluorescent microscopy and processed for age determination. Otoliths were examined under a dissecting microscope at 40x with reflected light, and independently aged by one individual (J. Goins, VIMS). An otolith annulus was considered as one opaque zone and its successive hyaline zone. Scales were removed from a midlateral area on the left side posterior to the pectoral-fin base of each fish and archived for future examination.

Catch-at-age data were used to determine relative year-class strengths of American shad in the York River. These data can be compared to predictions of year-class strength based on analysis of historical trends in the juvenile index of abundance of American shad in the York River system. Annual surveys of juvenile abundance of alosines are conducted on the York River system with a pushnet developed in the late 1970's (Kriete and Loesch 1980). Because of the negative phototropic behavior of juvenile Alosa, the pushnet is deployed at night (Dixon, Goins and Olney 1997). Because the interpretation of indices of abundance is not always straightforward (Hoenig 1995), several measures of year class strength were computed.

Catch data from each river was summarized in terms of a standardized catch rate. These catch rates were compared to summaries of historical logbook data to provide a measure of the relative size of the current shad populations. The first step was to calculate the area under the curve of catch rate versus time of year. This is done for each year and provides a raw (unadjusted) index of abundance. The catch rates for previous years differ conceptually from the current year in the sense that in previous years there was fishing activity downstream of the index-fishing site which may have affected (lowered) the catch rate at the index site whereas in 1998 there is no downstream fishing. To address this, we attempted to summarize the historic logbook data by river mile to determine if there is a spatial trend in catch rate. We reasoned that if there is no appreciable trend then the raw indices of abundance may be directly comparable across years. (Alternatively, if there is a trend then the rate of decline in catch rate as a function of river mile (i.e., as a function of cumulative fishing effort) would provide a means for constructing a removal estimator of absolute stock abundance.

Results

Catches of American shad by staked gill nets in 1998

Fishing days, numbers of American shad captured, and catch rates (males and females) are reported in Tables 1-6 and Figures 4 and 5. A total of 1,224 American shad (215 males:1,009 females) were captured. The total weight of the sample was 1,674.9 kg (3,684.8 lbs). Catches of males and females were low on the Rappahannock River (16 males and 75 females), higher on the James River (51 males and 155 females) and highest on the York River (148 males and 779 females). On the James River, catches of females peaked on 4-6 April 1998 when catch rates exceeded 0.09 fish/m or 0.12 kg/m. On the York River, catches peaked between 22 March and 7 April 1998 when catch rates of females exceeded 0.2 fish/m or 0.33 kg/m and catch rates of males exceeded 0.1 fish/m or 0.1 kg/m. Catches of males and females on the Rappahannock River and males on the James River remained at relatively low and steady levels throughout the fishing period. The highest recorded daily catch occurred on 22 March 1998 when 220 (307 kg or 675.4 lbs) American shad were taken in the York River (Tables 3-4). For females, catches were usually higher on the first fishing day of each week (day 1, Sunday) than on the second fishing day (day 2, Monday) on all rivers (Figure 4). Mean catch rates of females on day 1 were about equivalent with those on day 2 on the James and Rappahannock rivers but mean catch rate on day 1 was higher than that on day 2 on the York River (0.24 vs. 0.13 kg/m). Differences between these means were not significant on either river (two-sample t-test, $p>0.1$).

The duration of the spawning run (defined as the number of days between the first and last observation of a catch rate that equals or exceeds 0.01 female kg/m) was estimated to be 49 days on the James River (16 March-3 May) and 71 days on the York River (16 March-25 May). Due to delays related to net construction and pole setting, sampling did not begin on the Rappahannock River until 23 March. At that time, catch rate was well above the minimum catch rate. For this reason, the duration of the spawning run on the Rappahannock was not estimated.

Biological characteristics of the American shad in 1998

Age, length (mm TL) and weight (g) of American shad in staked gill nets are summarized in Tables 7-8 and depicted in Figures 6-7. Males and females ranged in size from 390-570 mm TL and 410-620 mm TL, respectively. Overall, the 1993 and 1994 year classes (males and females) of American shad were the most abundant on all three rivers. On the James River, six age classes were represented (1990-1996) and the sample was dominated by age-4 females (47.9% of the total that were aged) and age-5 males (46.7%). On the York River, eight age classes were represented (1989-1996) and the sample was dominated by age-5 males and females (48.9% and 46.9% of the total that were aged, respectively). On the Rappahannock River, five age classes were taken (1991-1994) and catches were dominated by age-4 males and females (42.3% and 48.5% of the aged sample, respectively).

Age-specific catch rates of American shad are reported in Tables 9-10 and depicted in Figure 8. Total instantaneous mortality (Z) was estimated using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve. Estimates of Z for females for each stock were: James, 1.12 (r^2= 0.97); York, 1.43 (r^2= 0.98); and Rappahannock, 1.66 (r^2= 0.99). Estimates of Z of males (with values of r^2 in parentheses) for each stock were: James, 1.43 (r^2= 0.98); York, 1.37 (r^2= 0.98); and Rappahannock, 0.34 (r^2= 0.91).

Evaluation of hatchery origin of American shad in 1998

Otoliths from 934 adult American shad taken in the James and York rivers were scanned for hatchery marks. The proportion of the staked gill net catch in 1998 with hatchery marks was 8.2% (14 out of 170 fish that were 3 to 5 years old) from the James River, and <0.2% (1 out of 764 fish aged 3 to 5) from the York River. The biological attributes of these specimens are presented in Table 11.

Relative cohort strength of adults and juvenile abundance of American shad

Tables 12 and 13 report several indexes of juvenile abundance of American shad and associated estimated standard deviations. Traditionally, the juvenile index in Virginia has been reported as maximum geometric mean catch rate (Figure 9). This index is defined as the maximal geometric mean catch (the maximal mean CPUE) in a sampling period (i.e., during any one week of sampling) that exceeds the mean CPUE in all other periods (i.e., over a series of weekly cruises). The maximal geometric mean catch was well above the time-series average on

the Mattaponi River in 1998 (average, 33.4; 1998 value, 77.3), and below average on the Pamunkey River in 1998 (average 7.2; 1998 value 3.5).

Cruise-specific catch rates of juvenile shad, reported as mean catch rates over all stations sampled each week, were used to estimate the annual geometric mean catch (and the standard deviation) for each river, the area under the catch curve for each river annually, and the combined area under the catch curve of both rivers annually (Table 13). Linear regression analysis was used to examine the relationship between one of these non-traditional indexes (the area under the catch curve for each river) with the maximal mean CPUE (Figure 10). The two indexes were more closely related on the Mattaponi (r^2= 0.90) than the Pamunkey River (r^2= 0.65). This preliminary analysis suggests that the combined area under the catch curve for both rivers approximates the traditional index (maximal mean CPUE).

The time series of the combined area under the catch curve for both rivers (Table 13) depicts average or better-than-average production of juveniles in the York River system in 1994, 1996, 1997 and 1998 relative to the other years in the record (dating back to 1979), while index values were very low in 1991, 1992 and 1995. There are no data on juvenile abundance in 1989 and 1990. Thus, when considering only years 1990-1996, the index predicts that ages 3, 6 and 7 (the 1995, 1992 and 1991 year classes) should not have dominated the age-frequency composition of the 1998 catch in the York River. This comparison is depicted in Figure 11. Since age-2 and age-3 American shad are not fully recruited to the fishing gear, the 1995-1996 recruitment contribution should be ignored. The age structure observed in 1998 matches that predicted by the recruitment index since the relative strengths of the 1993 and 1994 adult year classes and recruitment years are similar.

By-catch of striped bass and other species in 1998

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 14-16. Twenty-four species of by-catch were captured. The most commonly encountered by-catch species were: menhaden (*Brevoortia tyrannus*), gizzard shad (*Dorasoma cepedianum*), striped bass (*Morone saxatilis*), white catfish (*Ictalurus catus*), blue catfish (*Ictalurus furcatus*), channel catfish (*Ictalurus punctatus*), white perch (*Morone americana*), hickory shad (*Alosa mediocris*), Atlantic croaker (*Microponias undulatus*), weakfish (*Cynoscion regalis*) and summer flounder (*Paralichthys dentatus*). Almost 2,000 striped bass were captured by the gear (York River, 874; James, 1,010; Rappahannock, 63). Ratios of the total number (both sexes) of American shad to the total number of striped bass taken on each river were: York, 0.51:0.49; James, 0.17:0.83; Rappahannock, 0.59:0.41. We counted and released live striped bass that were captured. The proportions of dead striped bass on each river were: York, 64%; James, 51%; and Rappahannock, 55%.

High levels of bycatch could interfere with a net's ability to capture shad, thus resulting in a lower index of shad abundance. To evaluate this hypothesis, we examined daily catch rates of shad and striped bass in all rivers (Figure 12), and plotted the daily catch of American shad versus the daily catch of all other species (Figures 13 and 14). Catch rates of striped bass were usually higher than catch rates of shad on the James River but this pattern was not observed frequently on the York

or Rappahannock rivers (Figure 12). We reasoned that if striped bass by-catch had interfered with the catching power of a net for American shad, then this interference might be detected as a trend line with a negative slope. This trend was not evident when all data were combined (Figure 13) or in the plots of data from the York or James rivers (Figure 14). Catch data for the Rappahannock River suggested that shad catches declined when catch rates of other species were high but striped bass were not abundant there (Figure 14).

Seasonal catch indexes, 1980-1992 and 1998

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day of the year for 1998 and for each year in the historical logbook data (Tables 17-19, Figures 15-17). The time series indicated that 1998 catch rates were comparable to historic data on the Rappahannock River, low relative to historic data on the James River, and higher than recorded catch rates on the York River (Figure 18).

A seasonal catch index was constructed from historic logbook data from all fishers on a river. This was compared to the index obtained from Mr. Kellum for the corresponding years (Fig. 19). In most instances (nine of 13 years), the discrepancy between Kellum's catch rate and those of the other fisheries did not exceed 20%. The largest discrepancy for the York River was about 36%.

Examination of the historic logbook and map data show that from 1980 through 1993 the total number of staked gill nets on the York River varied from roughly 80 to140 (Figure 19). The number of staked gill nets below the current monitoring location (Figure 20) varied from about 26 to 45.

Discussion

The staked gill net monitoring program appears to be useful for assessment of the current status of stocks of American shad in Virginia. It is the only method available to determine the size of the spawning runs relative to what was obtained in the decade prior to the moratorium. The program also provides information for validating the juvenile index of abundance and for determining the amount of bycatch in the commercial fishery that can be expected if the in-river fishing ban is lifted. The validity of the staked gill net monitoring program cannot be established unequivocally but the fact that Mr. Kellum's catch rates in the past was in close agreement with the catch rates calculated over all fishers who supplied logbooks in reassuring. Further, the historical records show that the amount of fishing down river from the monitoring sites on all three rivers was low in the past. Thus, the absence of this effort during the current monitoring program is not likely to affect the catch rates being obtained by in the current monitoring program.

The monitoring program catch rate was higher than those observed in the 1980-1992 historical record on the York River. On the James River, the catch rate was as low as at the time the moratorium was imposed. For the Rappahannock River, the catch rate was extremely low but during the entire historical record the catch rate was low. Thus, interpretation of the data for the Rappahannock is problematic. It might be inferred from this first year of monitoring that the prospects for the York River look promising while for the James River the outlook is poor. This

interpretation is strengthened somewhat by noting that the juvenile index of recruitment in recent years on the York River appears higher than in the past. Unfortunately, there is no systematic surveys for juveniles on the James River. Two points argue for a cautious interpretation of the York River results. First, monitoring has been conducted for only a single year; examination of the historical record shows that there was considerable variability in run strength even as there was a strong downward trend in abundance. Thus, high catch rates for more than one year should be observed before concluding abundance is now higher than at the time the moratorium was imposed. Second, the juvenile index of abundance has not yet been validated. Therefore, it hasn't been established that the index has any predictive value for run strength. If the juvenile index of abundance were validated we would have two indicators of stock strength which could provide greater assurance of a stock recovery.

Literature Cited

ASMFC. 1999. Amendment 1 to the Interstate Fishery Management Plan for Shad and River Herring. Fishery Management Rept. No. 35, 76 pp.

Brown, B. L. and J. M. Epifanio. 1994. Mixed-stock analysis of American shad in Virginia's and Maryland's coastal intercept fisheries. Final report to the VMRC, Sport Fish Restorarion Project F-110-R.

Dixon, D. A. 1996. Contributions to the life history of juvenile blueback herring (*Alosa aestivalis*): phototactic behavior and population dynamics. Doctoral Dissertation. School of Marine Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA.

Dixon, D. A., J. D. Goins and J. E. Olney. 1996. A stock assessment program for Chesapeake Bay fisheries - Development of an Alosa juvenile index of Abundance: 1995 and 1996 index sampling results. Completion Report to the VMRC, Project CF 96-8.

Hoenig, J.M. 1995. Striped Bass Young-of-the-Year Indices of Abundance: Comments by John M. Hoenig on a Workshop Held in Grasonville, Maryland, January 21 to 23, 1992. Pages 65-83 *in* Paul J. Rago, C. Dianne Stephan and Herbert M. Austin, Report of the Juvenile Abundance Indices Workshop. Special Report No. 48, Atlantic States Marine Fisheries Commission.

Kriete, W.H. Jr. and J.G. Loesch. 1980. Design and relative efficiency of a bow-mounted pushnet for sampling juvenile pelagic fishes. Transactions of the American Fisheries Society 109(6): 649-652.

Loesch, J. G., W. H. Kriete Jr., and E. J. Foel. 1982. Effects of light intensity on the catchability of juvenile anadromous *Alosa* species. Trans. Amer. Fish. Soc. 111:41-44.

Mansueti, R. J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. MD. Dept. Res. and Educ., Pub. No. 97. 293 pp.

VCF (Virginia Commission of Fisheries). 1875. Annual report for 1875. Richmond, VA. 38 pp.

Walburg, C. H. and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. U. S. Fish. Wildl. Serv. Sci. Rep. Fish. No. 550. 105 pp.

Table 1. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the James River, spring 1998.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/16/98	2	0.007	2,444.70	0.009
3/17/98	7	0.026	11,813.50	0.043
3/22/98	16	0.058	22,099.50	0.081
3/23/98	12	0.044	15,451.00	0.056
3/29/98	11	0.036	14,423.10	0.047
3/30/98	8	0.029	10,697.00	0.039
4/5/98	28	0.092	37,649.50	0.124
4/6/98	37	0.135	54,373.20	0.198
4/12/98	10	0.035	13,832.80	0.048
4/13/98	6	0.021	9,234.40	0.032
4/19/98	9	0.032	12,934.90	0.046
4/20/98	3	0.010	3,612.50	0.012
4/26/98	2	0.006	2,493.10	0.008
4/27/98	0			
5/3/98	3	0.011	3,909.20	0.014
5/4/98	1	0.003	1,193.00	0.004
Total	155		216,161.40	

Table 2. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the James River, spring 1998.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/16/98	1	0.004	980.40	0.004
3/17/98	7	0.026	8,765.90	0.032
3/22/98	11	0.040	11,522.50	0.042
3/23/98	4	0.015	4,342.90	0.016
3/29/98	3	0.010	3,646.80	0.012
3/30/98	5	0.018	6,057.80	0.022
4/5/98	5	0.017	5,436.60	0.018
4/6/98	12	0.044	14,503.30	0.053
4/12/98	3	0.011	3,671.10	0.013
4/13/98	0			
4/19/98	0			
4/20/98	0			
4/26/98	0			
4/27/98	0			
5/3/98	0			
5/4/98	0			
Total	51		58,927.30	

Table 3. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the York River, spring 1998.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/16/98	26	0.076	36,880.30	0.108
3/17/98	22	0.080	30,486.20	0.111
3/22/98	184	0.758	264,772.10	1.090
3/23/98	95	0.346	137,572.60	0.502
3/29/98	116	0.432	169,595.50	0.631
3/30/98	79	0.282	115,951.60	0.414
4/7/98	64	0.233	92,679.30	0.338
4/8/98	30	0.128	42,859.20	0.183
4/12/98	41	0.153	63,242.30	0.235
4/13/98	19	0.069	27,052.60	0.099
4/19/98	24	0.093	35,935.60	0.140
4/20/98	7	0.025	10,050.90	0.036
4/26/98	20	0.070	25,553.70	0.089
4/27/98	17	0.057	21,323.10	0.072
5/3/98	5	0.018	7,663.20	0.027
5/4/98	7	0.026	9,967.90	0.036
5/11/98	13	0.024	16,973.00	0.031
5/17/98	4	0.015	4,728.00	0.018
5/18/98	2	0.008	2,785.80	0.011
5/24/98	0			
5/25/98	3	0.010	3,907.80	0.013
5/31/98	0	0.000	0.00	0.000
6/1/98	1	0.004	1,009.70	0.004
Total	779		1,120,990.40	

Table 4. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the York River, spring 1998.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/16/98	7	0.020	8,025.70	0.023
3/17/98	12	0.044	13,160.60	0.048
3/22/98	36	0.148	42,232.00	0.174
3/23/98	28	0.102	30,964.00	0.113
3/29/98	16	0.060	17,691.80	0.066
3/30/98	15	0.054	18,314.60	0.065
4/7/98	10	0.036	11,107.30	0.040
4/8/98	5	0.021	5,438.20	0.023
4/12/98	1	0.004	1,098.40	0.004
4/13/98	2	0.007	2,480.30	0.009
4/19/98	1	0.004	797.10	0.003
4/20/98	1	0.004	1,424.50	0.005
4/26/98	3	0.011	1,952.60	0.007
4/27/98	2	0.007	1,520.30	0.005
5/3/98	0			
5/4/98	0			
5/11/98	9	0.016	8,933.30	0.016
5/17/98	0			
5/18/98	0			
5/24/98	0			
5/25/98	0			
5/31/98	0			
6/1/98	0			
Total	148		165,140.70	

Table 5. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the Rappahannock River, spring 1998.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/23/98	8	0.033	11,792.40	0.048
3/24/98	8	0.029	11,793.40	0.043
3/29/98	13	0.052	19,205.90	0.077
3/30/98	10	0.036	16,856.90	0.061
4/5/98	9	0.032	13,952.20	0.050
4/6/98	3	0.011	4,680.00	0.017
4/12/98	11	0.040	15,072.80	0.054
4/13/98	5	0.018	8,516.20	0.031
4/19/98	1	0.004	1,413.90	0.006
4/20/98	1	0.004	1,392.90	0.005
4/26/98	2	0.007	2,860.90	0.010
4/27/98	2	0.008	2,958.50	0.011
5/3/98	2	0.008	3,229.90	0.014
5/4/98	0			
Total	75		113,725.90	

Table 6. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 1998.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/23/98	5	0.021	5,961.90	0.025
3/24/98	4	0.015	4,739.50	0.017
3/29/98	3	0.012	3,793.10	0.015
3/30/98	2	0.007	2,461.60	0.009
4/5/98	0	0.000	0.00	0.000
4/6/98	1	0.004	822.20	0.003
4/12/98	1	0.004	1,496.40	0.005
4/13/98	0			
4/19/98	0			
4/20/98	0			
4/26/98	0			
4/27/98	0			
5/3/98	0			
5/4/98	0			
Total	16		19,274.70	

Table 7. Mean total length (mm) and mean weight (g) of male American shad captured in gill nets in the James, York and Rappahannock rivers, spring 1998. Abbreviations are: NA, not aged; Rapp, Rappahannock River; SD, standard deviation. Age estimates are based on presumptive annuli observed in whole otoliths.

River	Year Class	Number	Mean length	SD	Mean Weight	SD
James	1995	2	436.5	10.6	906.8	1,489.0
	1994	18	457.7	20.5	1,075.6	160.1
	1993	21	470.1	29.1	1,177.8	173.7
	1992	3	495.3	31.5	1,452.7	323.1
	1991	1	568.0		1,437.5	
	NA	6	469.0	33.4	1,204.0	219.9
York	1995	3	425.3	7.0	799.5	93.1
	1994	46	448.8	24.1	1,032.0	166.0
	1993	66	460.8	23.4	1,137.2	196.9
	1992	14	472.6	23.1	1,246.1	175.7
	1991	5	495.0	22.1	1,382.6	199.4
	1990	1	506.0		1,034.2	
	NA	13	459.4	23.1	1,140.0	188.2
Rapp	1994	6	467.2	28.0	1,189.5	236.6
	1993	5	462.2	7.2	1,208.8	61.5
	1992	3	466.3	3.2	1,210.8	67.8
	NA	2	468.0	17.0	1,230.8	129.1

Table 8. Mean total length (mm) and mean weight (g) of female American shad captured in gill nets in the James, York and Rappahannock rivers, spring 1998. Abbreviations are: NA, not aged; Rapp, Rappahannock River; SD, standard deviation. Age estimates are based on presumptive annuli observed in whole otoliths.

River	Year Class	Number	Mean length	SD	Mean Weight	SD
James	1996	1	448.0		1,058.8	
	1995	15	477.7	21.9	1,323.2	192.5
	1994	69	476.0	22.9	1,310.6	185.5
	1993	45	494.8	27.4	1,498.3	266.6
	1992	11	515.7	30.3	1,560.7	269.9
	1991	2	542.0	60.8	1,868.8	524.7
	1990	1	500.0		1,494.6	
	NA	10	485.6	19.6	1,349.2	128.6
York	1996	1	491.0		1,483.2	
	1995	22	474.9	19.4	1,366.9	160.8
	1994	218	477.6	23.5	1,330.2	215.4
	1993	331	490.1	28.6	1,446.2	264.0
	1992	101	502.7	33.9	1,584.8	286.3
	1991	28	518.4	31.6	1,674.8	379.2
	1990	3	538.3	23.7	1,762.7	430.1
	1989	1	562.0		2,129.4	
	NA	72	491.2	39.3	1,431.4	336.5
Rapp.	1995	3	491.3	9.9	1,600.8	186.8
	1994	34	491.4	19.6	1,511.7	212.1
	1993	27	489.9	19.7	1,477.9	137.1
	1992	5	498.2	19.6	1,613.7	156.4
	1991	1	525.0		1,441.2	
	NA	5	501.0	29.5	1,622.7	285.0

Table 9. Number, total weight and seasonal catch rates (total number per season per m; total weight per season per m) by year class of female American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 1998.

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James	1996	1.00	1.06	16.7	0.00022	0.00023
	1995	15.00	19.85	16.7	0.00328	0.00434
	1994	69.00	90.43	16.7	0.01509	0.01978
	1993	45.00	67.42	16.7	0.00984	0.01474
	1992	11.00	17.17	16.7	0.00241	0.00375
	1991	2.00	3.74	16.7	0.00044	0.00082
	1990	1.00	1.49	16.7	0.00022	0.00033
		10.00	13.49	16.7	0.00219	0.00295
York	1996	1.00	1.48	23.9	0.00015	0.00023
	1995	22.00	30.07	23.9	0.00335	0.00458
	1994	218.00	289.97	23.9	0.03322	0.04419
	1993	331.00	478.70	23.9	0.05044	0.07295
	1992	101.00	160.07	23.9	0.01539	0.02439
	1991	28.00	46.89	23.9	0.00427	0.00715
	1990	3.00	5.29	23.9	0.00046	0.00081
	1989	1.00	2.13	23.9	0.00015	0.00032
		72.00	103.06	23.9	0.01097	0.01571
Rapp	1995	3.00	4.80	13.4	0.00080	0.00129
	1994	34.00	51.40	13.4	0.00912	0.01378
	1993	27.00	39.90	13.4	0.00724	0.01070
	1992	5.00	8.07	13.4	0.00134	0.00216
	1991	1.00	1.44	13.4	0.00027	0.00039
		5.00	8.11	13.4	0.00134	0.00218
Total		1,006.00	1,446.04			

Table 10. Number, total weight and seasonal catch rates (total number per season per m; total weight per season per m) by year class of male American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 1998.

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James	1995	2.00	1.81	16.7	0.00044	0.00040
	1994	18.00	19.36	16.7	0.00394	0.00423
	1993	21.00	24.73	16.7	0.00459	0.00541
	1992	3.00	4.36	16.7	0.00066	0.00095
	1991	1.00	1.44	16.7	0.00022	0.00031
		6.00	7.22	16.7	0.00131	0.00158
York	1995	3.00	2.40	23.9	0.00046	0.00037
	1994	46.00	47.47	23.9	0.00701	0.00723
	1993	66.00	75.06	23.9	0.01006	0.01144
	1992	14.00	17.45	23.9	0.00213	0.00266
	1991	5.00	6.91	23.9	0.00076	0.00105
	1990	1.00	1.03	23.9	0.00015	0.00016
		13.00	14.82	23.9	0.00198	0.00226
Rapp.	1994	6.00	7.14	13.4	0.00161	0.00191
	1993	5.00	6.04	13.4	0.00134	0.00162
	1992	3.00	3.63	13.4	0.00080	0.00097
		2.00	2.46	13.4	0.00054	0.00066
Total		215.00	243.34			

Table 11. Biological attributes (age, sex, maturity stage, fork length, total length, and total weight) of American shad with hatchery marks taken in staked gill net monitoring on the James and York rivers in 1998. Gonad stages are: 2, maturing; 3, hydrated/running ripe. Age estimates are based on presumptive annuli observed in whole otoliths.

James River						
Specimen number	Age	Sex	Gonad Stage	Fork Length (mm)	Total Length (mm)	Total Weight (g)
93	4	male	2	379	424	939.50
646	5	female	3	414	464	1,256.20
655	5	female	3	424	488	1,385.30
765	5	female	3	422	480	1,344.00
777	4	female	2	408	466	1,095.20
778	4	female	2	399	448	1,179.40
788	4	female	2	418	471	1,408.60
827	4	female	3	432	492	1,425.10
867	4	female	3	442	496	1,470.60
991	5	female	3	454	516	1,676.70
1072	5	female	3	428	482	1,294.10
1083	bad otolith	female	3	434	500	1,466.00
1088	4	female	3	429	488	1,416.50
1186	4	female	3	420	478	1,267.70
York River						
559	5	male	3	390	448	974.8

Table 12. Summary of maximum (June 1 - August 15) geometric mean catch rate (numbers of juveniles per standard tow) for juvenile blueback herring, alewife, and American shad in the Pamunkey and Mattaponi rivers: 1979-1998.

River	Year	Blueback herring	Alewife	American shad
		Maximum CPUE	Maximum CPUE	Maximum CPUE
Pamunkey	1979	49.1	3.5	32.0
	1980	50.2	2.9	3.5
	1981	6.1	2.7	3.3
	1982	177.2	11.6	1.9
	1983	59.4	1.9	3.6
	1984	25.0	0.9	1.0
	1985	61.2	5.9	10.1
	1986	33.3	3.7	4.4
	1987	80.1	2.9	0.4
	1988	*	*	*
	1989	*	*	*
	1990	*	*	*
	1991	7.5	1.2	6.3
	1992	0.1	0.0	0.1
	1993	2.3	0.1	0.7
	1994	59.3	3.9	9.5
	1995	5.9	0.1	2.2
	1996	66.1	4.4	31.5
	1997	39.7	0.5	8.2
	1998	29.7	0.8	3.5
Mattaponi	1979	24.4	2.9	24.3
	1980	3.8	1.3	18.5
	1981	9.0	5.0	13.5

River	Year	Blueback herring	Alewife	American shad
		Maximum CPUE	Maximum CPUE	Maximum CPUE
	1982	92.3	18.3	9.3
	1983	17.1	3.2	7.3
	1984	93.4	19.0	22.6
	1985	127.2	13.6	26.0
	1986	15.5	7.1	26.1
	1987	14.6	0.8	7.3
	1988	*	*	*
	1989	*	*	*
	1990	*	*	*
	1991	4.6	0.3	7.0
	1992	0.2	0.0	1.5
	1993	5.1	0.2	30.3
	1994	38.8	12.8	51.5
	1995	0.4	0.1	6.4
	1996	63.6	22.4	144.2
	1997	27.4	6.6	95.4
	1998	68.1	6.8	77.3

* No sampling was conducted in 1988 and 1989, and only partial sampling was conducted in 1990.

Table 13. Indexes of abundance of juvenile American shad in pushnet surveys on the Mattaponi and Pamunkey rivers, 1979-1998. Geometric means (GM), standard deviations (SD) and areas under the catch curve were estimated from cruise-specific catch rates for each year. Data are not available for 1998-1990.

Year	Mattaponi Mean GM	Pamunkey Mean GM	Mattaponi Area under the Catch Curve	Pamunkey Area Under the catch Curve	Combined Area Under the catch Curve
1979	5.1 (8.8)	3.6 (16.5)	315.0	300.0	615.0
1980	5.3 (8.8)	1.2 (2.9)	119.7	33.6	153.3
1981	2.3 (0.6)	0.7 (1.4)	17.2	24.5	41.7
1982	4.3 (3.3)	0.4 (0.7)	179.9	16.8	196.7
1983	3.0 (2.8)	1.5 (1.2)	226.8	81.9	308.7
1984	9.6 (6.6)	0.8 (0.4)	434.7	25.2	459.9
1985	7.2 (4.6)	3.7 (3.5)	345.5	132.3	477.8
1986	10.6 (7.1)	3.1 (0.7)	525.7	91.7	617.4
1987	1.9 (2.5)	0.3 (0.1)	162.8	4.9	167.7
1991	1.2 (2.3)	1.5 (2.1)	68.6	82.6	151.2
1992	0.4 (0.5)	2.3 (<0.1)	35.8	1.6	37.4
1993	14.7 (9.4)	0.2 (0.2)	903.0	11.2	914.2
1994	15.0 (14.6)	2.7 (19.0)	1,007.3	519.1	1,526.4
1995	4.0 (1.8)	1.3 (0.6)	226.8	83.3	310.1
1996	88.3 (28.2)	14.8 (7.2)	5,823.0	907.9	6,730.9
1997	29.7 (27.1)	2.3 (2.2)	1,854.0	161.7	2,015.7
1998	26.7 (21.6)	1.1 (1.0)	2,331.7	85.8	2,417.5
Mean			**857.5**	**150.8**	**1,008.3**

Table 14. Daily numbers and seasonal totals of striped bass and other species captured by staked gill net in the York River, 1998.

Date	Striped Bass	Other Species	Total
3/16/98	269	627	930
3/17/98	26	500	558
3/22/98	70	495	792
3/23/98	60	310	498
3/29/98	131	154	412
3/29/98	142	137	375
4/7/98	16	588	675
4/8/98	12	491	539
4/12/98	6	548	603
4/13/98	12	414	447
4/19/98	7	382	414
4/20/98	7	214	229
4/26/98	7	496	528
4/27/98	8	520	547
5/3/98	14	302	321
5/4/98	26	466	499
5/10/98	18	137	169
5/11/98	8	79	94
5/17/98	13	53	70
5/18/98	2	52	56
5/24/98	7	78	85
5/25/98	7	67	77
5/31/98	5	25	30
6/1/98	1	42	44
TOTALS	874	7,177	8,992

Table 15. Daily numbers and seasonal totals of striped bass and other species captured by staked gill net in the James River, 1998.

Date	Striped Bass	Other Species	Total
3/16/98	283	206	492
3/17/98	126	221	361
3/22/98	82	209	317
3/23/98	105	464	585
3/29/98	79	140	233
3/30/98	73	146	232
4/5/98	69	209	311
4/6/98	37	286	373
4/12/98	26	282	321
4/13/98	18	191	215
4/19/98	27	334	370
4/20/98	40	278	321
4/26/98	7	347	356
4/27/98	11	231	242
5/3/98	12	203	218
5/4/98	15	296	312
TOTALS	1,010	4,043	5,259

Table 16. Daily numbers and seasonal totals of striped bass and other species captured by staked gill net in the Rappahannock River, 1998.

Date	Striped Bass	Other Species	Total
3/23/98	12	43	68
3/24/98	14	46	72
3/29/98	13	40	69
3/30/98	3	55	70
4/5/98	8	174	192
4/6/98	4	119	127
4/12/98	0	71	83
4/13/98	1	95	103
4/19/98	1	186	189
4/20/98	2	305	308
4/26/98	1	149	152
4/27/98	0	76	78
5/3/98	4	104	110
5/4/98	0	149	149
TOTALS	63	1,612	1,770

Table 17. Summary of historical and recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia. Historical data are taken from the voluntary log books of Mr. M. Delano, Urbanna, Virginia. Catch rates are expressed as female kg/d. Duration of the run was not estimated in 1998 since monitoring began late in the season.

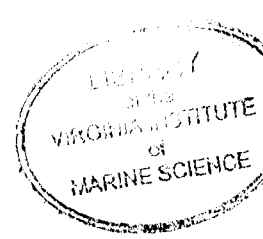
Year	Effort (10^3 m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve
1980	43.4	35	0.121	0.036	1.79
1981	112.1	57	0.032	0.011	1.89
1982	82.3	51	0.046	0.009	1.68
1983	106.7	59	0.093	0.031	0.59
1984	30.5	48	0.139	0.033	0.60
1985	77.2	60	0.136	0.029	1.83
1986	34.9	43	0.155	0.039	2.18
1987	23.3	37	0.090	0.023	0.97
1988	23.2	53	0.073	0.025	1.25
1989	16.2	44	0.856	0.123	6.19
1990	41.3	55	0.092	0.023	1.31
1991	25.9	54	0.129	0.022	1.13
1992	8.6	51	0.299	0.044	1.44
1998	3.82	----	0.053	0.02	1.46

Table 18. Summary of historical and recent catch and effort data of American shad by staked gill nets in the York River, Virginia. Historical data are taken from the voluntary log books of Mr. R. Kellum, Achilles, Virginia. Catch rates are expressed as female kg/d.

Year	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve
1980	79.4	44	0.556	0.268	10.15
1981	114.7	51	0.259	0.121	4.35
1982	86.4	44	0.326	0.101	5.31
1983	121.3	40	0.212	0.066	3.06
1984	171.4	48	0.548	0.139	8.21
1985	205.4	49	0.227	0.091	4.61
1986	185.2	38	0.145	0.055	2.17
1987	152.9	37	0.088	0.039	1.78
1988	126.2	40	0.134	0.028	1.34
1989	146.3	55	0.397	0.131	4.92
1990	106.9	38	0.951	0.037	1.31
1991	77.8	40	0.111	0.062	2.72
1992	60.8	41	0.079	0.041	1.60
1998	5.73	78	1.080	0.190	13.47

Table 19. Summary of historical and recent catch and effort data of American shad by staked gill nets in the James River, Virginia. Historical data are taken from the voluntary log books of the Brown family, Rescue, Virginia. Catch rates are expressed as female kg/d.

Year	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve
1980	20.5	41	2.239	0.699	29.2
1981	67.7	41	0.547	0.130	5.2
1982	49.3	35	0.331	0.115	4.2
1983	94.0	57	1.274	0.297	16.5
1984	89.7	50	0.897	0.036	19.3
1985	91.3	45	0.295	0.103	4.9
1986	31.5	26	1.289	0.152	6.1
1987	30.1	30	0.352	0.085	2.7
1988	19.1	20	0.487	0.193	9.3
1989	31.5	30	0.331	0.176	6.4
1990	29.7	25	0.184	0.079	2.1
1991	28.3	40	0.138	0.062	1.9
1992	59.8	50	0.562	0.232	7.7
1998	3.8	50	0.198	0.051	2.6



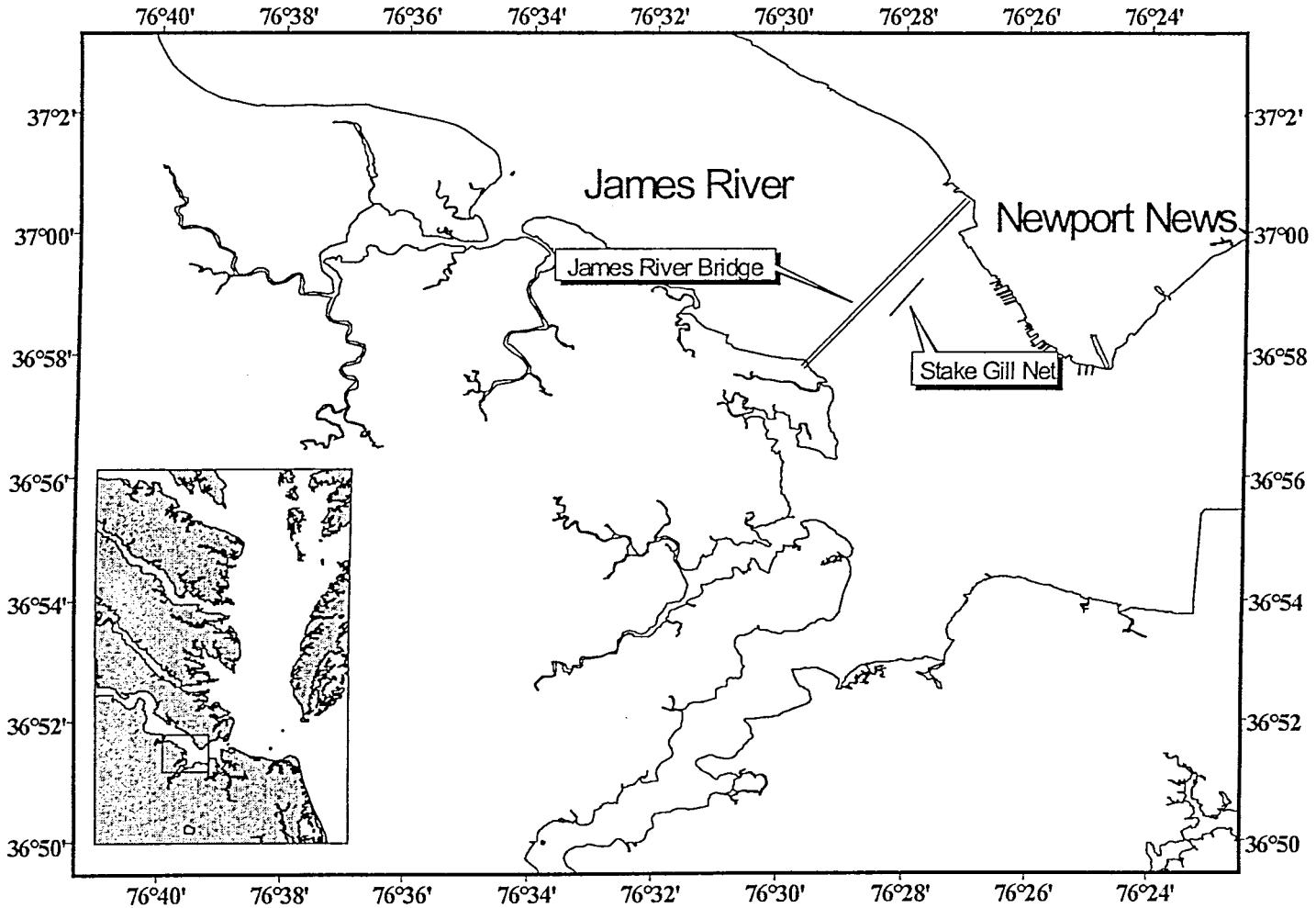


Figure 1. **Location of the staked gill net fished by Mr. Mark Brown on the James River. The length of the net (273 m) is not to scale.**

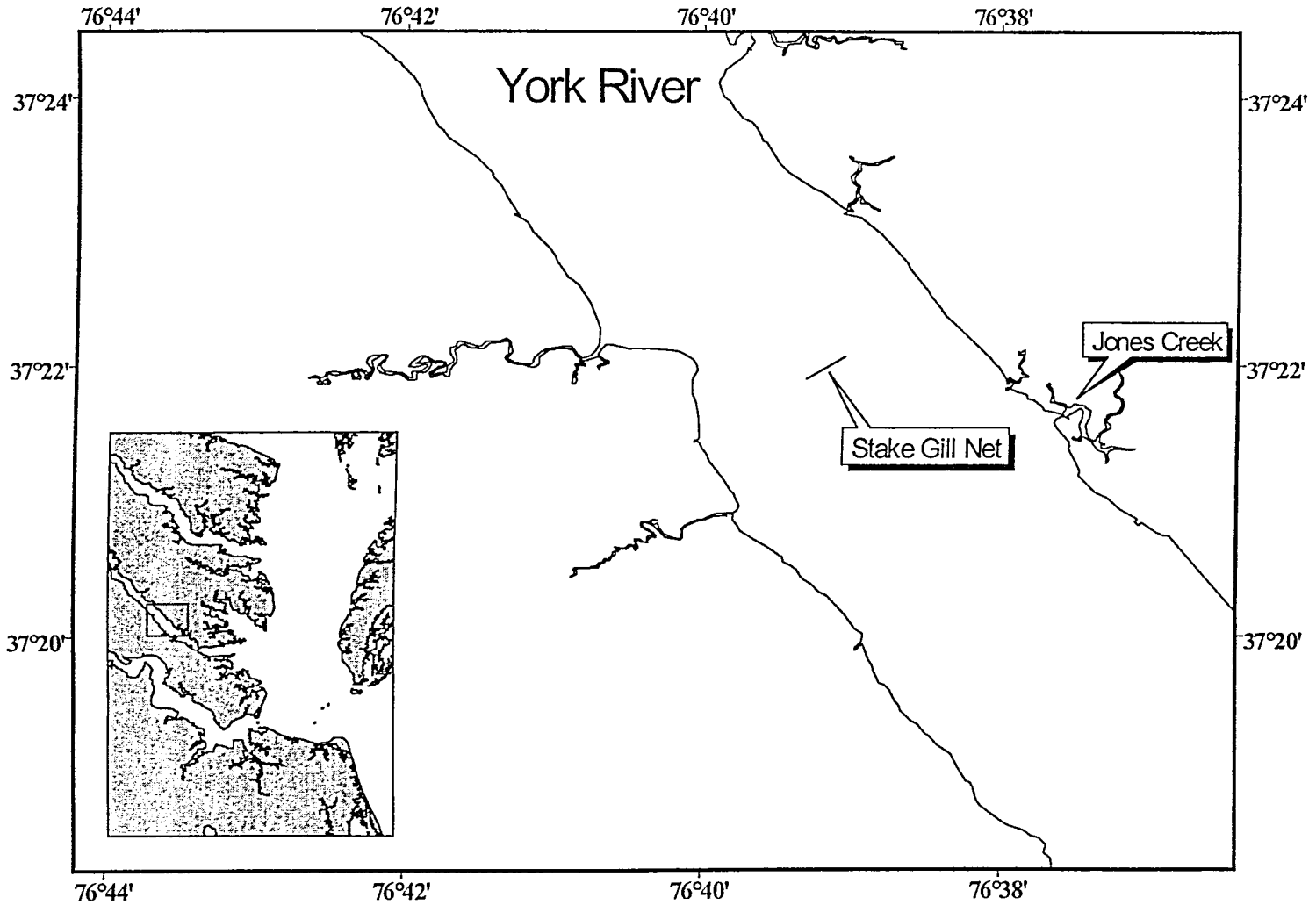


Figure 2. **Location of the staked gill net fished by Mr. Raymond Kellum on the York River. The length of the net (273 m) is not to scale.**

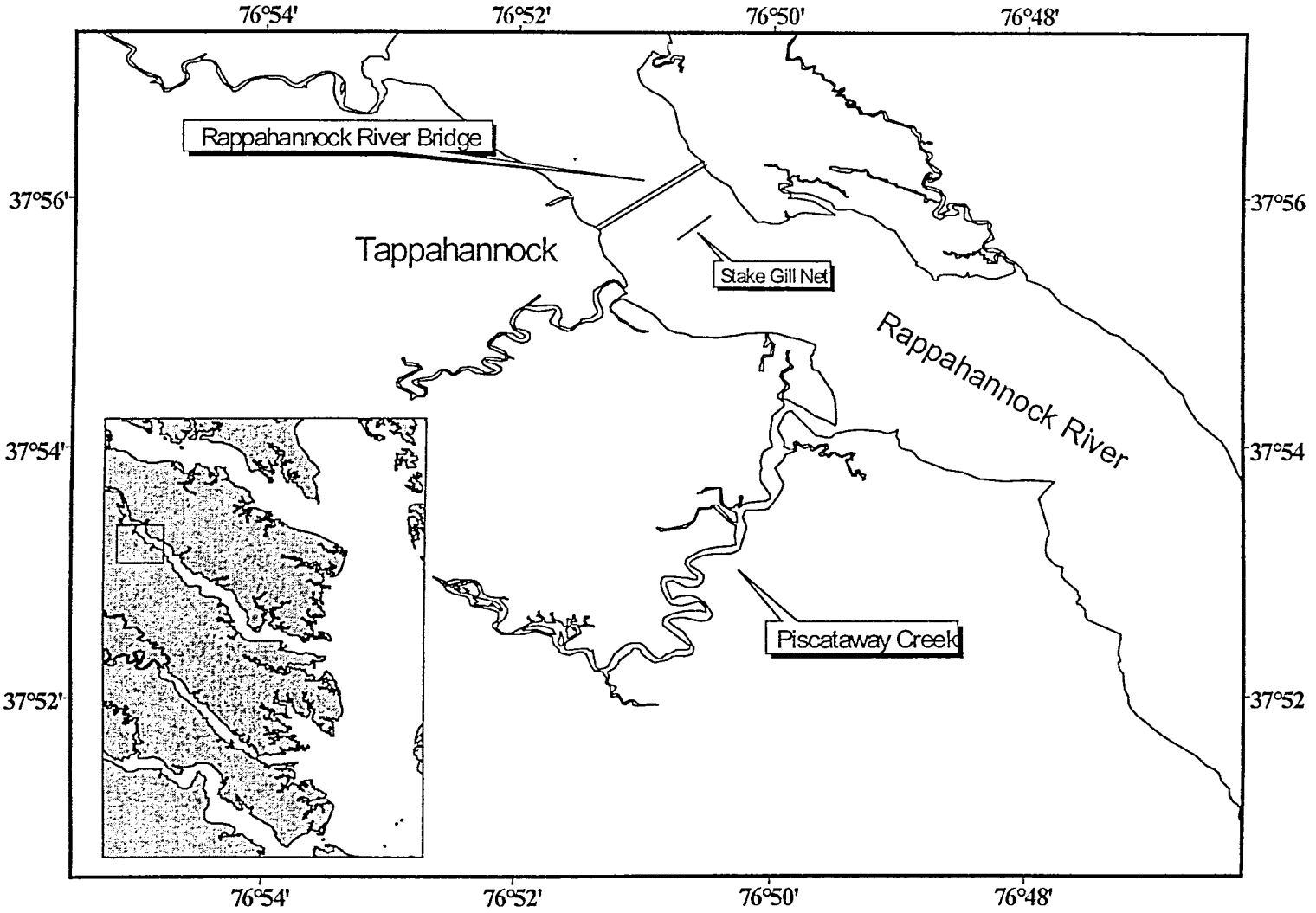


Figure 3. **Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River. The length of the net (273 m) is not to scale.**

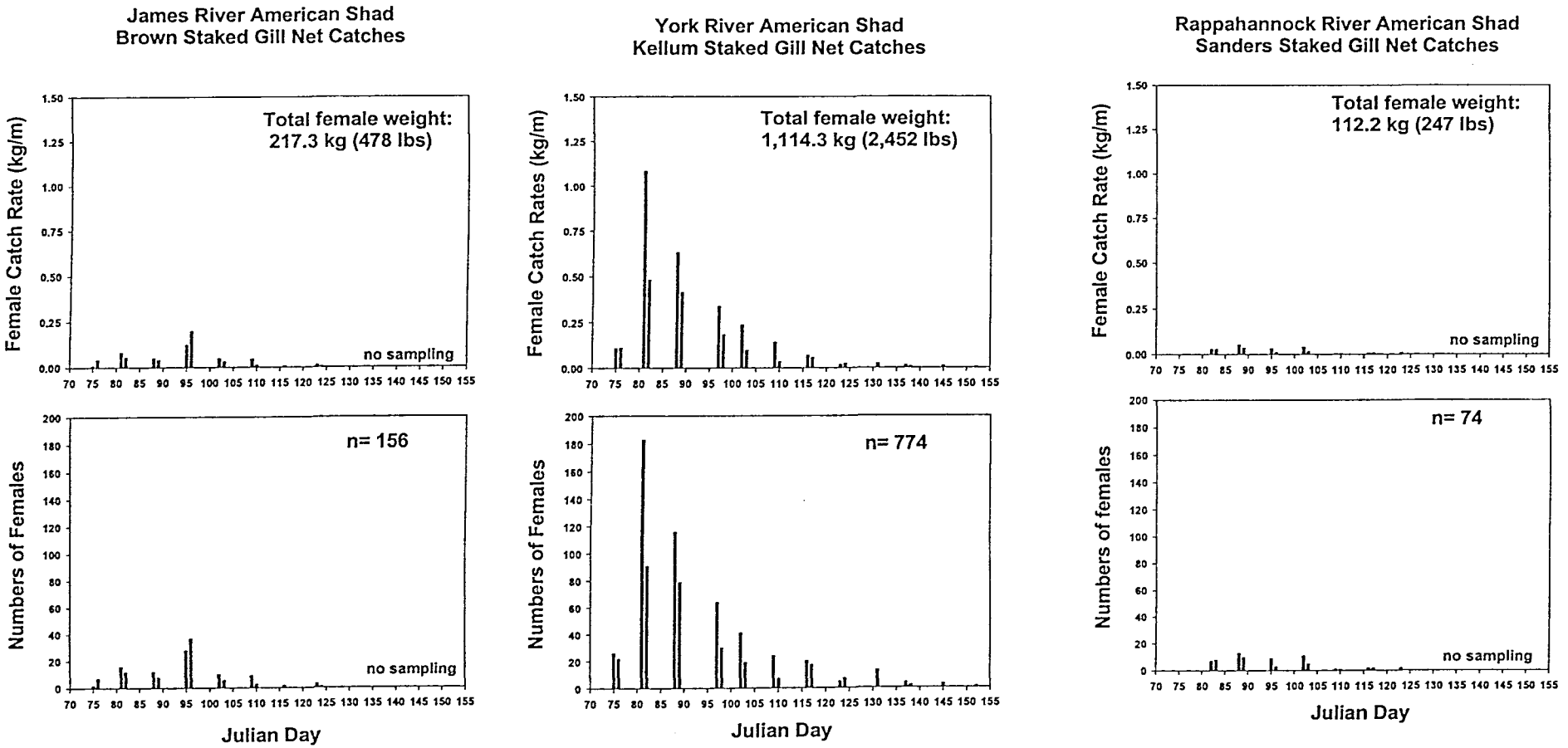


Figure 4. Catch rates and total numbers of female American shad taken by staked gill nets in the James, York and Rappahannock rivers, spring 1998.

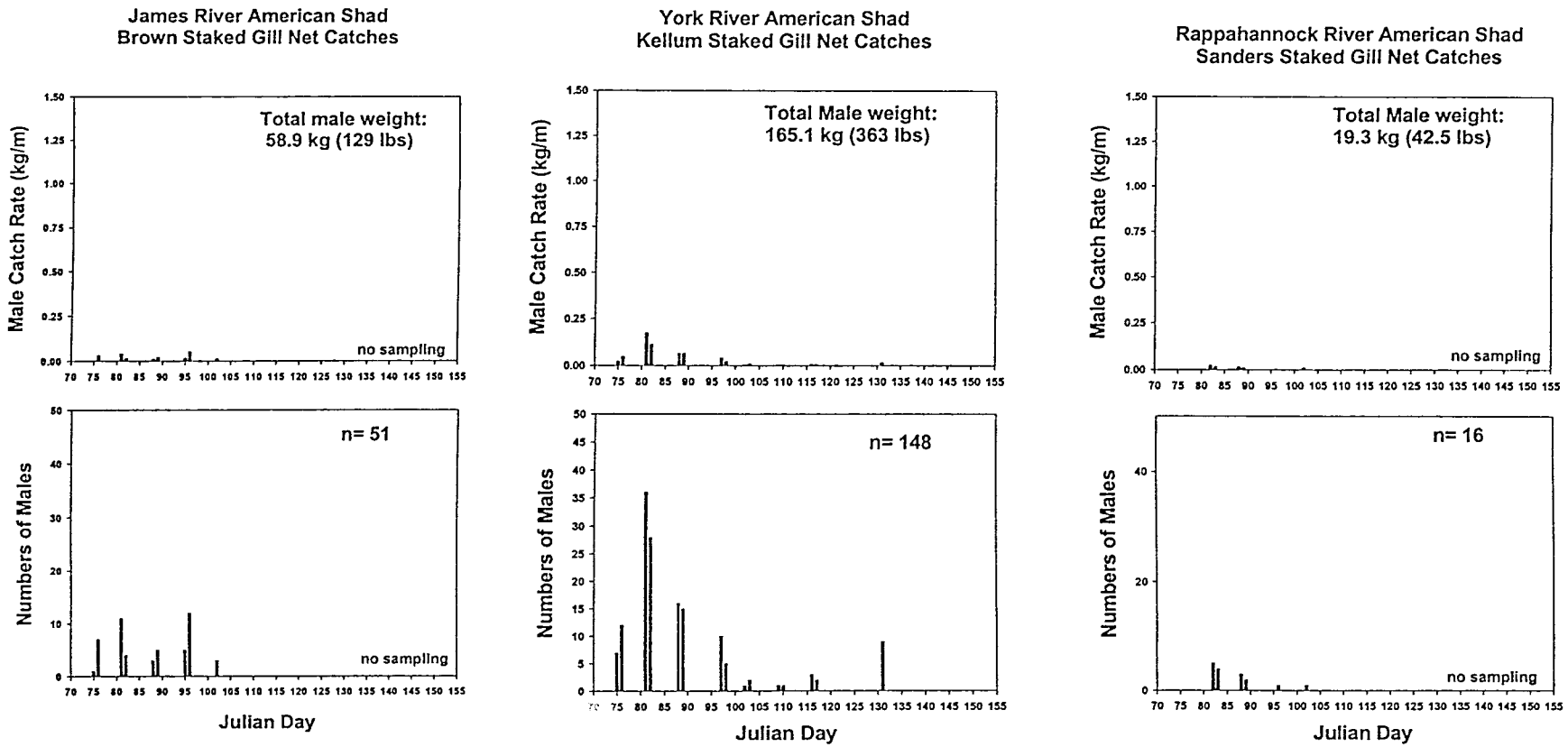


Figure 5. **Catch rates and total numbers of male American shad taken by staked gill nets in the James, York and Rappahannock rivers, spring 1998.**

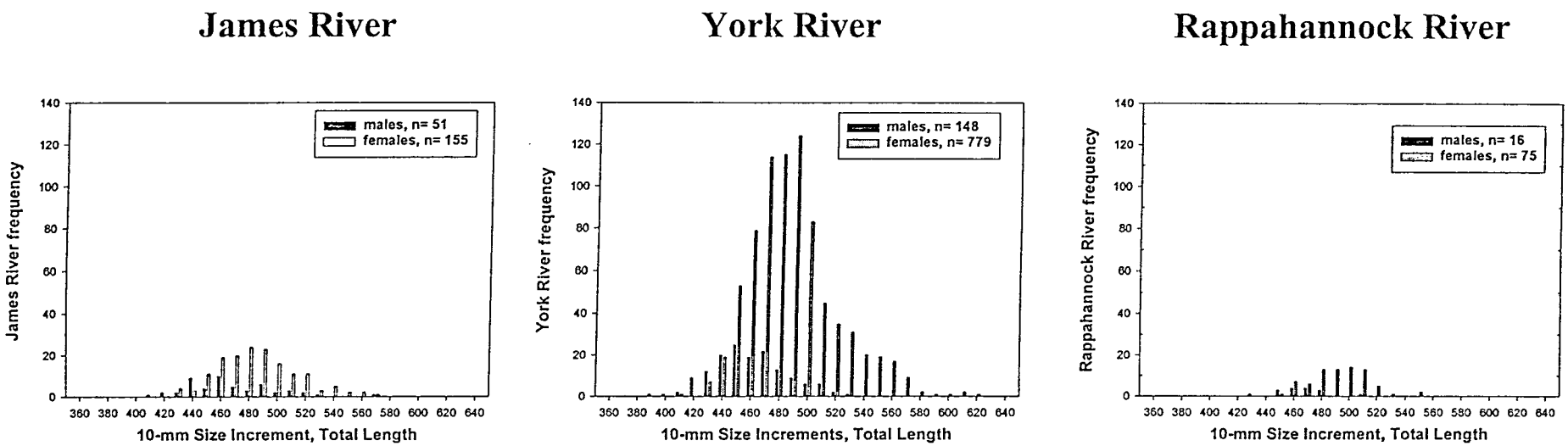


Figure 6. Total length (mm) frequency distributions for American shad captured in staked gill nets on the James, York and Rappahannock rivers, spring 1998.

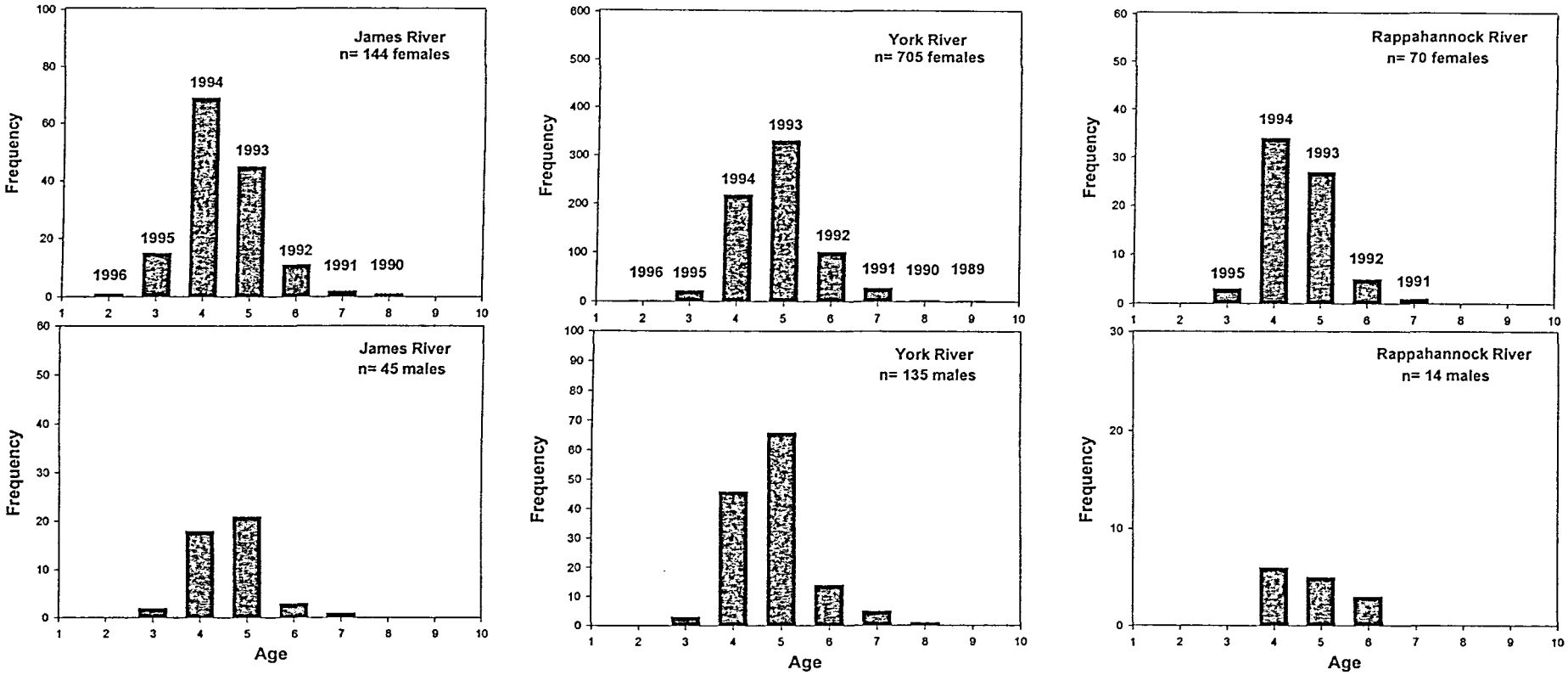


Figure 7. The age composition of American shad captured in staked gill nets in the James, York and Rappahannock rivers, spring 1998. Year classes are designated above each bar in the upper panel. Age estimates are based on presumptive annuli observed in whole otoliths.

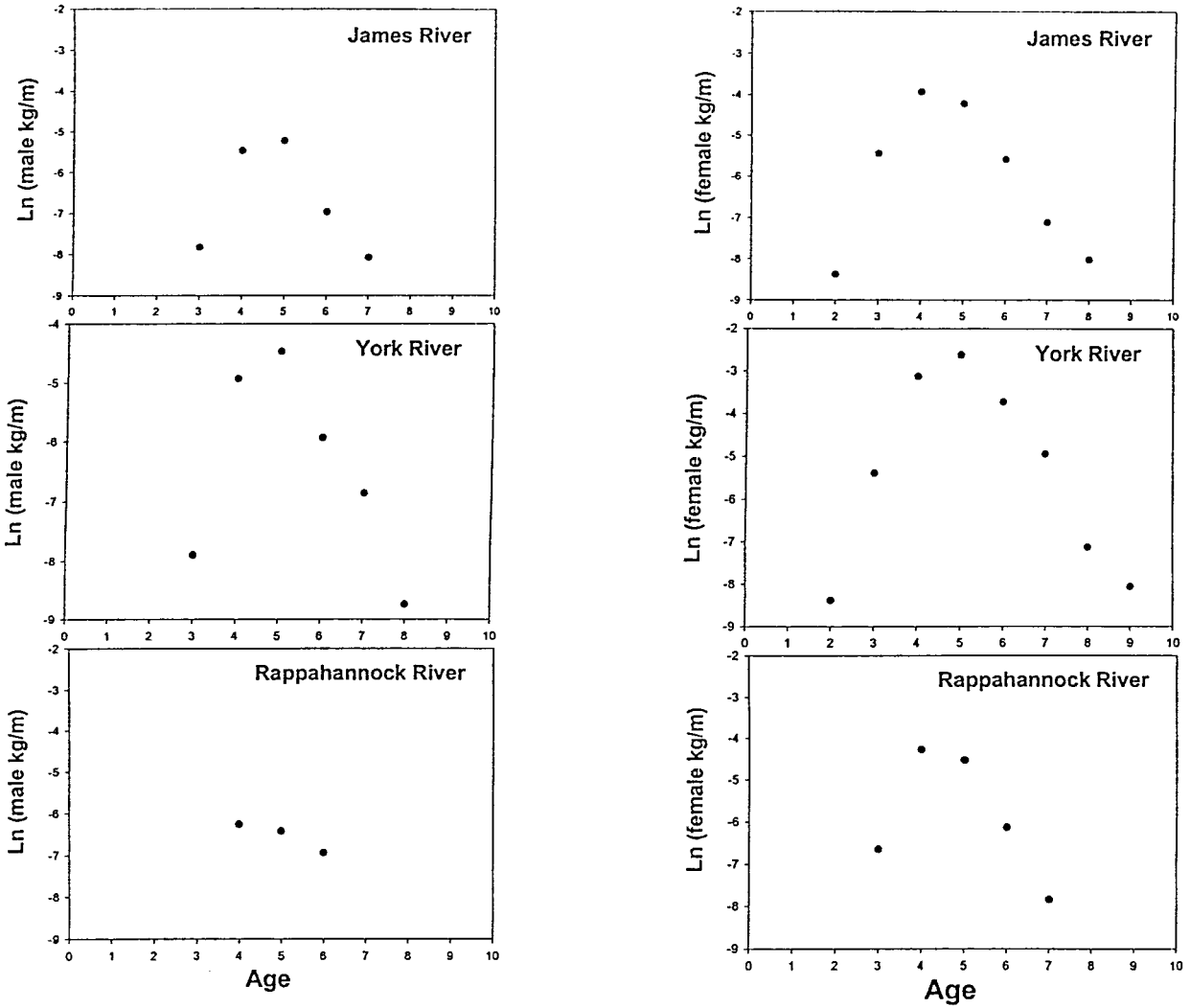


Figure 8. Age-specific catch rates (kg/m) of male (left) and female (right) American shad taken by staked gill net in the James, York and Rappahannock rivers, 1998.

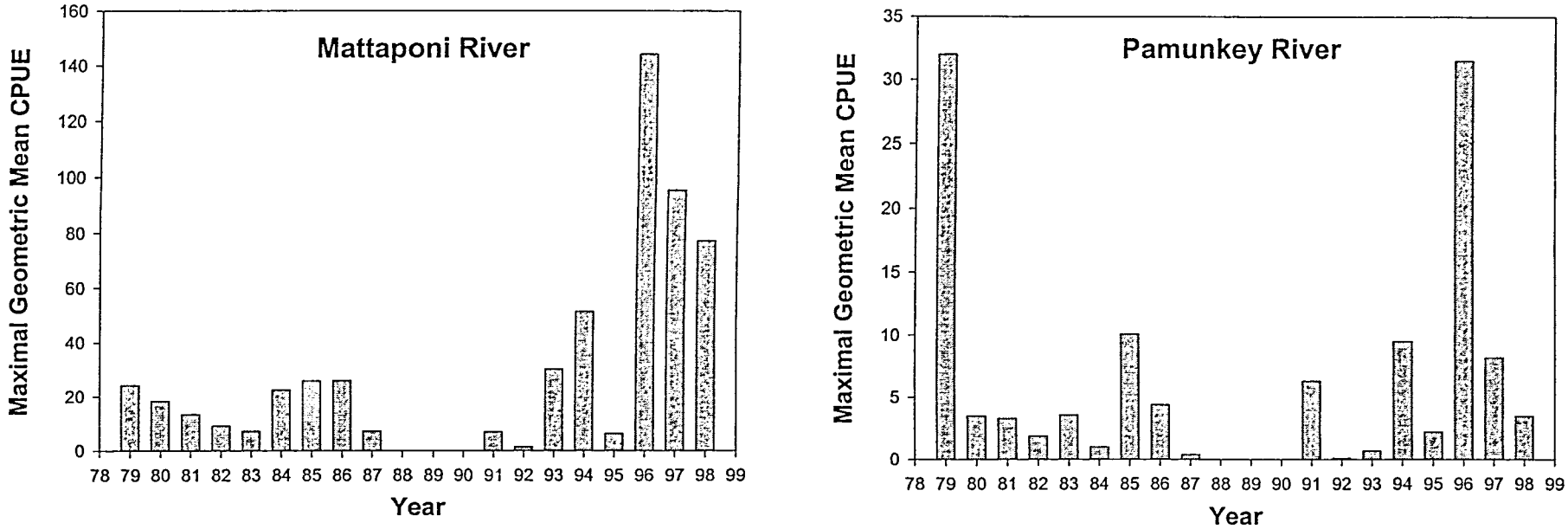
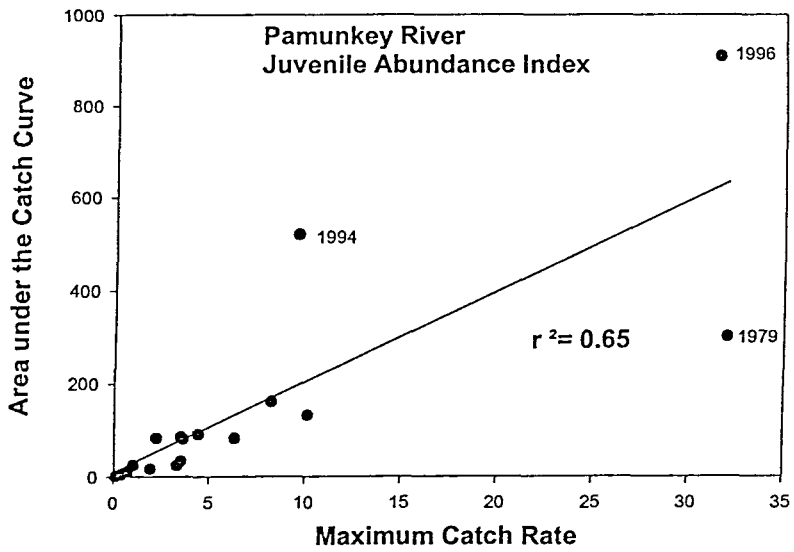


Figure 9. The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by evening pushnet surveys. Each value is the maximum catch rate (expressed as a geometric mean for any weekly cruise) observed in each year.



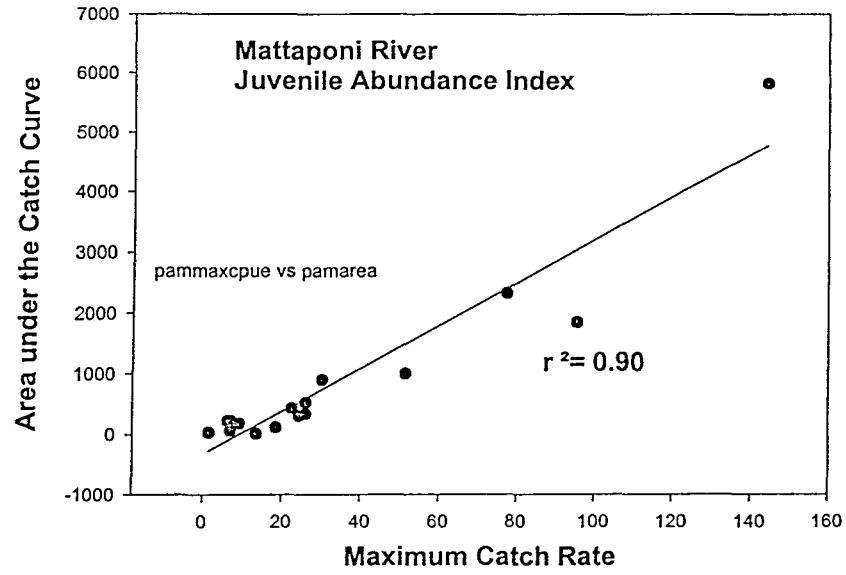


Figure 10. Linear regressions describing the relationships between two indexes of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers: the area under the curve of weekly catches and the maximal catch rate observed during any year.

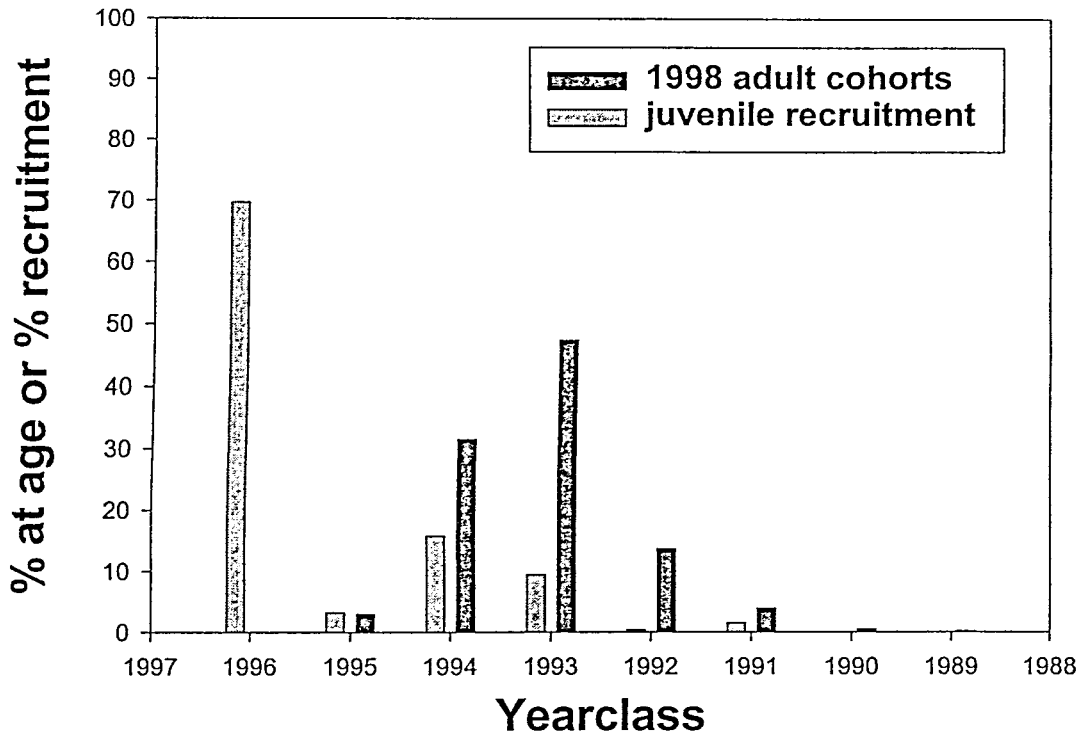


Figure 11. **Comparison of the relative strengths (as percent of total) of the 1998 adult year classes (both sexes combined) and the juvenile recruitment (the combined area under the catch curve of juvenile American shad in 1990-1996) in the York River system.**

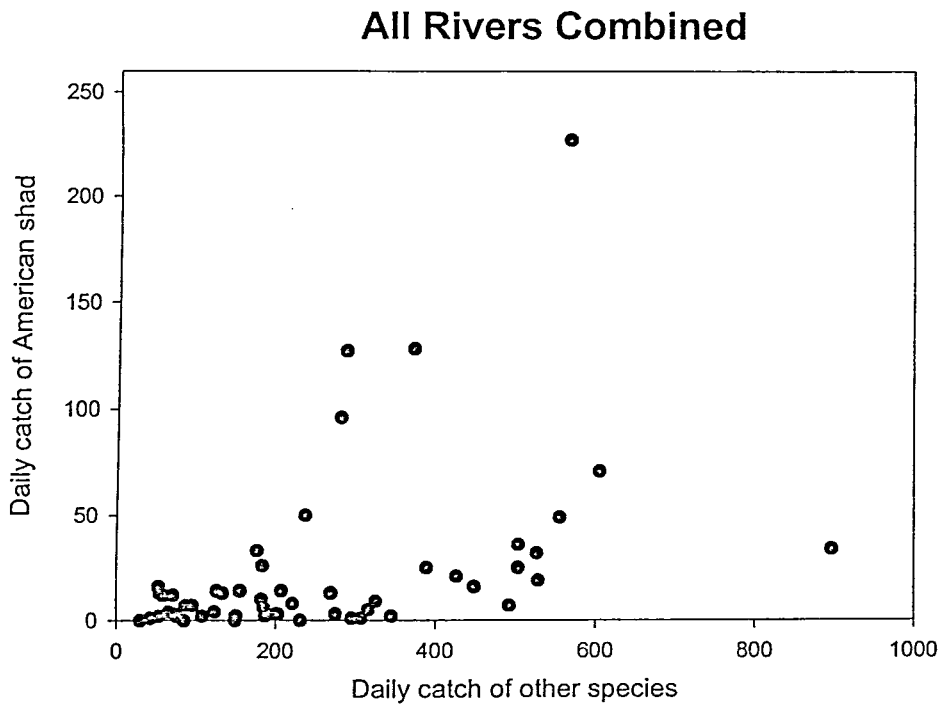


Figure 13. The relationship between numbers of American shad and numbers of all other species captured each day in staked gill nets on the James, York and Rappahannock rivers, spring 1998.

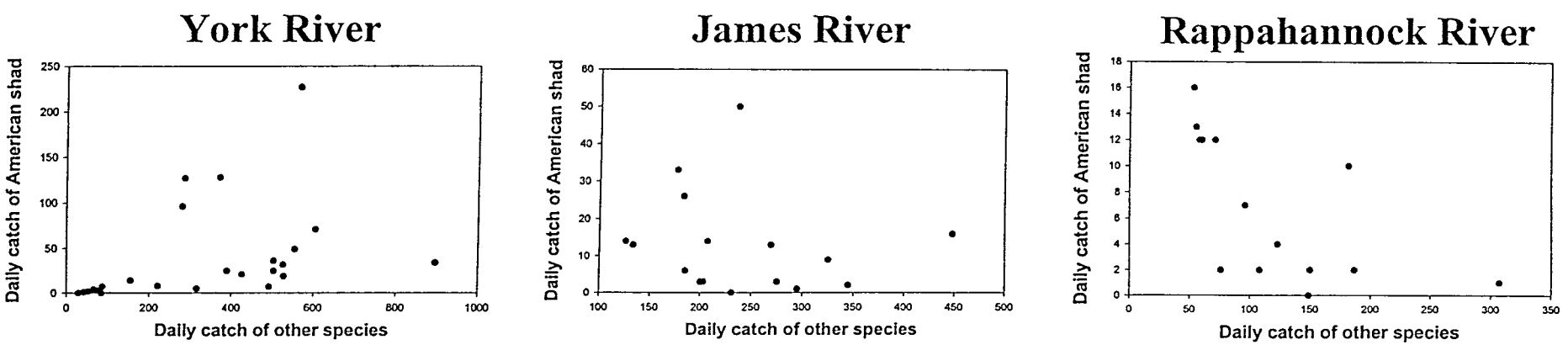


Figure 14. The relationship between numbers of American shad and numbers of all other species captured each day in staked gill nets on each river (James, York and Rappahannock rivers), spring 1998. Note that axis scales differ among rivers.

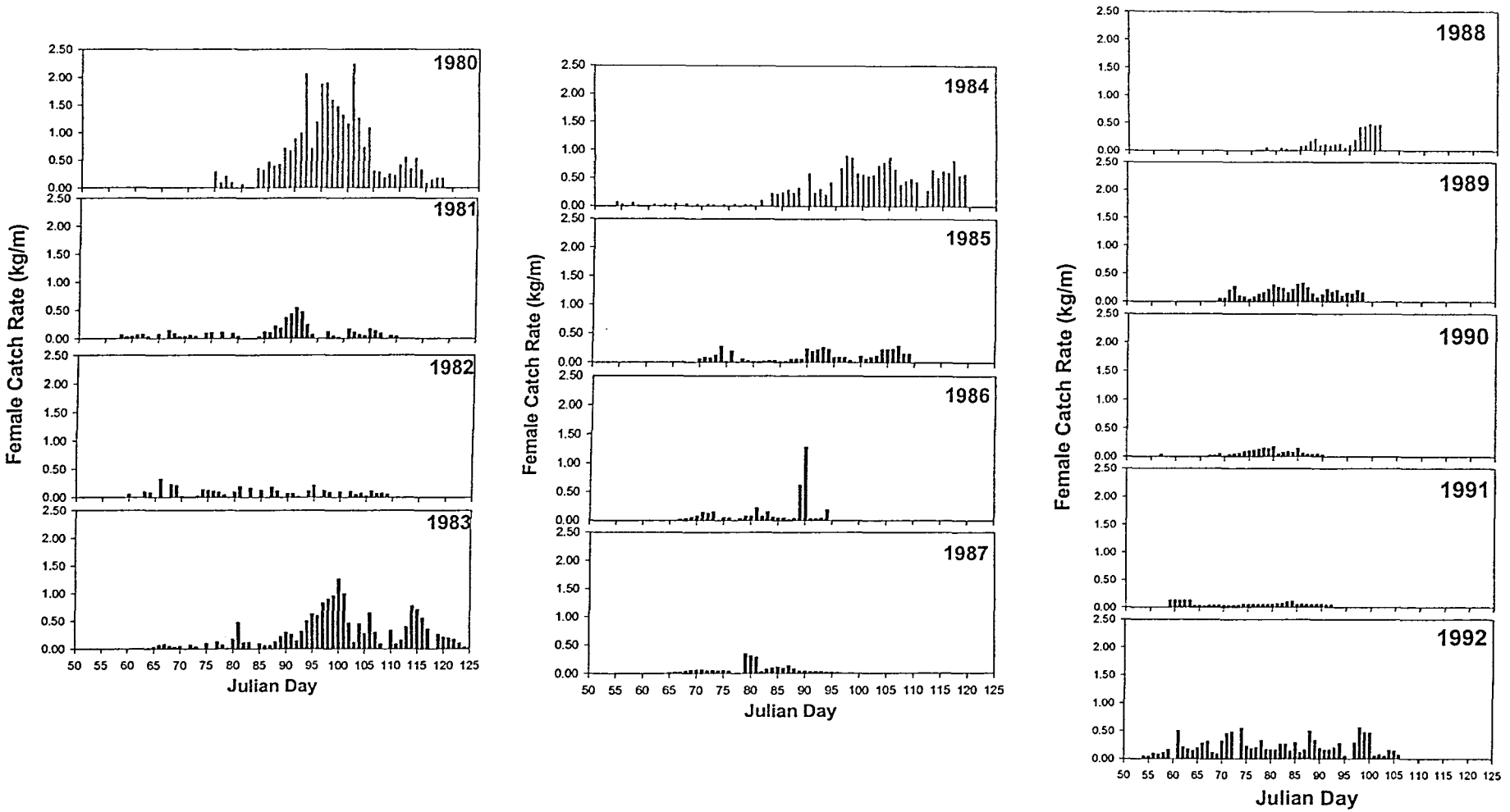


Figure 15. Historical catch rates of female American shad taken by staked gill nets in the James River (1980-1992) based on voluntary logbooks given to the Virginia Institute of Marine Science by the Brown family, Rescue, Virginia.

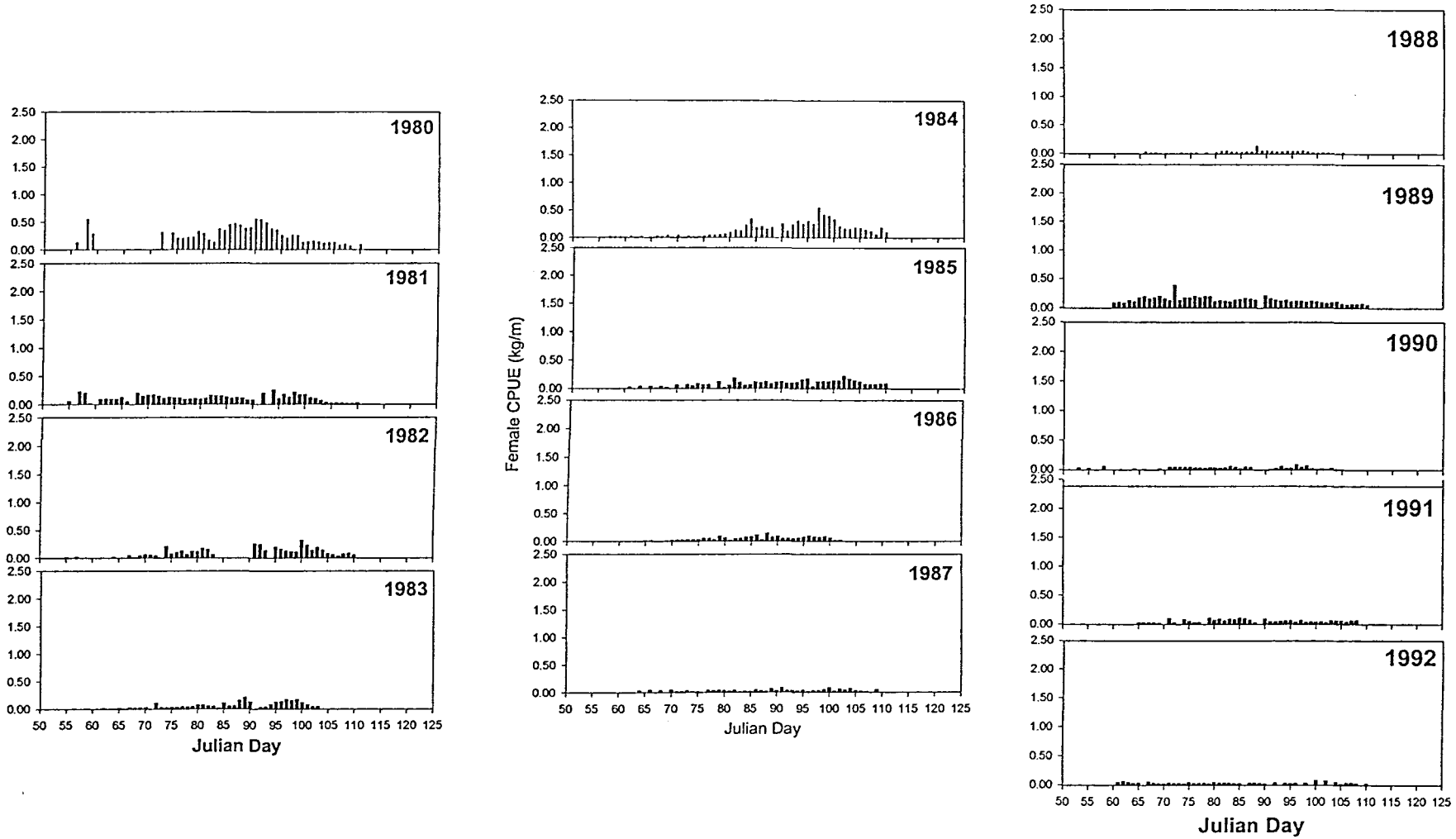


Figure 16. Historical catch rates of female American shad taken by staked gill nets in the York River (1980-1992) based on voluntary logbooks given to the Virginia Institute of Marine Science by Raymond Kellum, Gloucester County, Virginia.

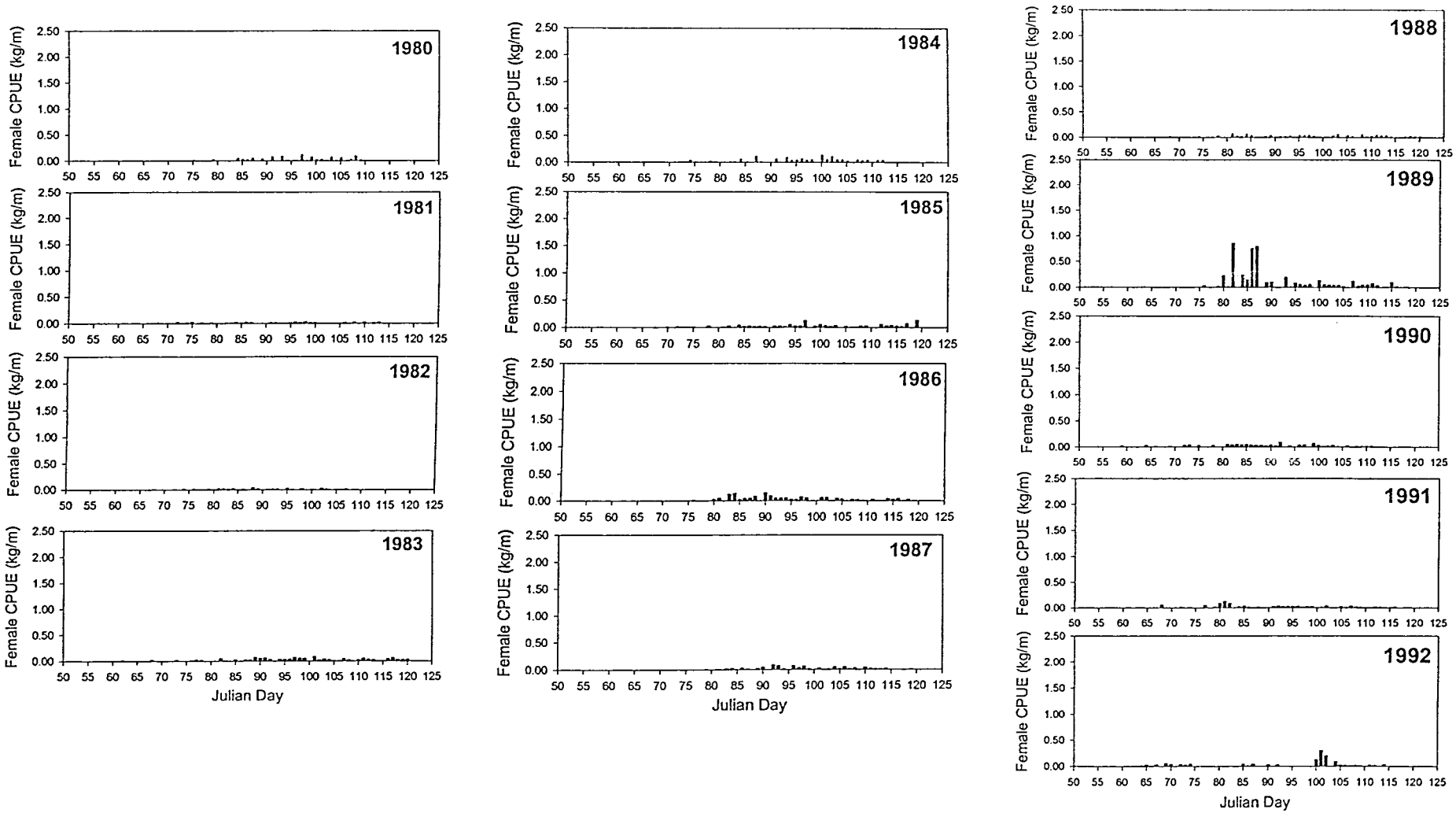


Figure 17. Historical catch rates of female American shad taken by staked gill nets in the Rappahannock River (1980-1992) based on voluntary logbooks given to the Virginia Institute of Marine Science by Marvin Delano, Tappahannock, Virginia.

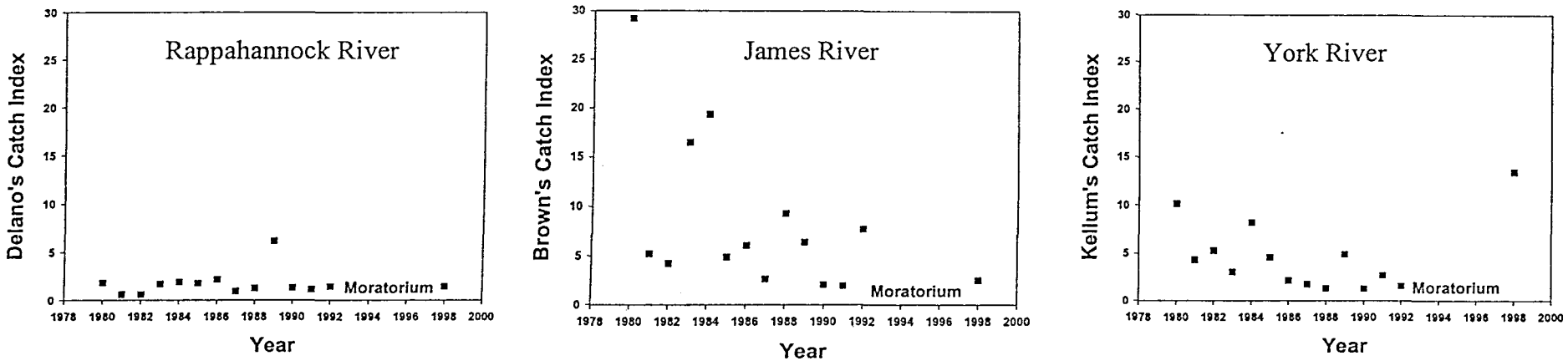


Figure 18. Recent (1998) and historic values of the catch index of female American shad on the Rappahannock (left), James (middle) and York rivers (right).

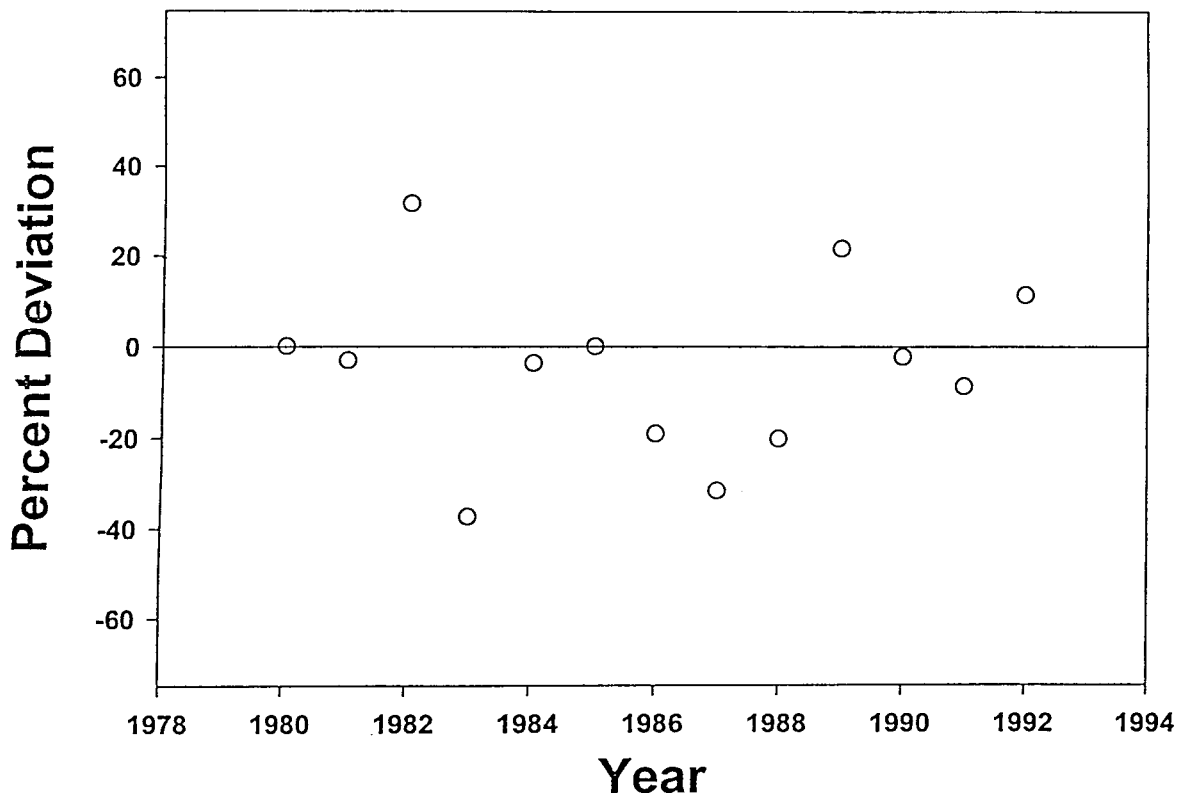


Figure 19. The percent deviation of the mean annual catch rate (female kg/m) by Raymond Kellum from the mean annual catch rate of all other commercial fisherman combined using staked gill nets in the York River, 1980-1992)

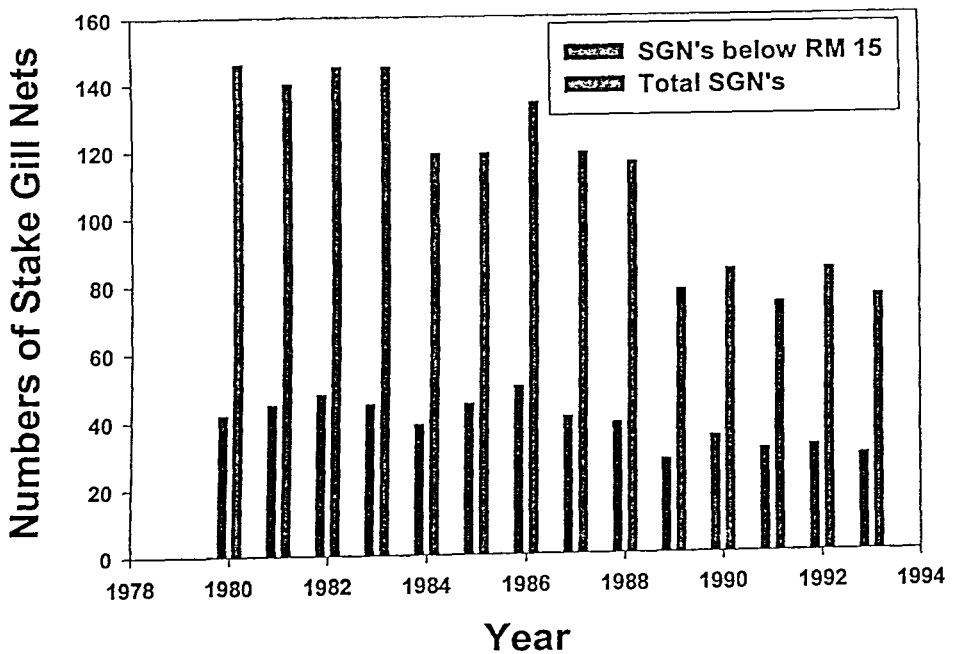


Figure 20. The numbers of staked gill nets situated farther down river of the 1998 monitoring location on the York River. The data are taken from historic aerial and boat surveys on file at the Virginia Institute of Marine Science.