# Final Report, 2001

**Project Title:** A study of the river origin of American shad captured in the Atlantic Ocean intercept fishery in Virginia

**Project Number:** AFC-33
**NOAA Award Number:** NA16FA1212
**Award Period:** 6/1/2001-5/31/2002



Prepared by:

Kristin L. Maki[1], John E. Olney[2] and John M. Hoenig[3]

School of Marine Science
Virginia Institute of Marine Science
The College of William and Mary
Gloucester Point, Virginia 23062

31 August 2002

(1) Office: 804-684-7308, email: makik@vims.edu
(2) Office: 804-684-7334, email: olney@vims.edu
(3) Office: 804-684-7125, email: hoenig@vims.edu

**Table of Contents**

## Preface and Acknowledgements

This document is the final report for P.L. 89-304, AFC 33 project, titled "A study of the river origin of American shad captured in the Atlantic Ocean intercept fishery in Virginia." The project was conducted from 1 June 2001 to 31 May 2002.

The Virginia Department of Game and Inland Fisheries (VDGIF) has been releasing larval American shad into the James and York river systems since 1993 and these fish are given river-specific marks before release. Our in-river monitoring program had established that we could estimate the proportion of fish returning to spawn in the rivers that have hatchery marks. Furthermore, we were able to obtain a sample of 200 fish from the intercept fishery off Chincoteague Island, Virginia, in 2000 and screening of the otoliths by VDGIF personnel revealed the presence of one fish with a James River hatchery mark and one with a York River mark. No marks from any other river were found. Thus, it appeared that hatchery markings would allow the opportunity to estimate the proportion of Virginia stocks that were harvested in the offshore fishery. On the basis of these preliminary findings, we proposed the present study.

We thank commercial fisherman Ernie Bowden, Raymond and Tony Kellum, Jamie Saunders and Marc Brown for participating in this study, and the staff of the Anadromous Fishes Research program for their hard work and dedication. VDGIF scientists Dave Hopler and Tom Gunter continue to be important collaborators in our research and monitoring programs for American shad in Virginia

## Objectives

1) Sample the Virginia offshore (intercept) fishery landings of American shad to determine the proportion of the catch with hatchery marks and tabulate the results by river of origin.

2) Develop a model to estimate the proportion of the fish caught in the Virginia intercept fishery that come from the York and James rivers.

## List of Tables

**List of Figures**

**Executive Summary**

(1) The offshore or intercept fisheries for American shad in the Atlantic Ocean harvest a mixture of stocks and are an important component of the harvest for several coastal states. The planned phase-out of these fisheries is controversial since there was no direct evidence of negative impact of these fisheries in the assessment of the stocks by Crecco (1998). The risk associated with the offshore fishery is dependent on the magnitude and stock composition of the fish harvested. Existing hatchery programs that produce marked specimens of known origin allowed the development of a new methodology for estimating stock composition.

(2) The proportion of the offshore catch that is attributable to a particular river can be estimated by comparing the observed proportion of fish from the offshore fishery with hatchery marks from that river and the estimated fraction of the shad in that river with hatchery marks (determined from in-river sampling). American shad were collected from the Virginia intercept fishery as well as from ongoing monitoring programs in the James and York Rivers to test this methodology.

(3) A total of 625 American shad (males, n = 176); females, n = 449) were examined and dissected from the intercept fishery. Oxytetracycline marks were discovered on 5 of the otoliths taken from the intercept fishery specimens including four with James River marks and one with a Pamunkey River (York River system) mark. The proportion of the staked gill net samples with hatchery marks on the James and York rivers was 40.2% (103 of 256 fish) and 4.8% (9 of 186 fish), respectively.

(4) The estimated proportion of the monitored offshore catch in 2001 that is attributable to the James River was 1.67% and the estimated proportion of the catch attributable to the York River was 3.50%.

(5) Direct comparisons of age and length distributions with ocean samples were not feasible for York and James river samples due to differences in sampling gear. Differences in age and length distributions for Rappahannock River and ocean fish were significant.

(6) Hatchery marks from rivers other than the York and James rivers were not detected in the ocean samples.

(7) We conclude that: (a) unmarked (presumably wild) fish comprise most (99%) of the offshore catch monitored in 2001; (b) Virginia's offshore harvest includes fish from the James and York rivers but the proportions of the catch from these rivers were small in 2001; (c) unless exploitation of fish from the Rappahannock River was unexpectedly high, the offshore catch sampled in 2001 did not contain appreciable numbers of fish from Virginia stocks.

## Introduction

The American shad (*Alosa sapidissima*) is the largest clupeid in North America. The species is native to the western Atlantic Ocean and was introduced to the Pacific coast in 1870. Each spring, adult American shad migrate from mixed population assemblages at sea into the freshwater portions of rivers to spawn. Juveniles exit the natal stream by late fall and remain in the ocean until they reach sexual maturity. Most sexually mature fish return to the streams of their birth to spawn (Talbot and Sykes, 1958; Walburg, 1960; Carscadden and Leggett, 1975; Melvin et al., 1986) and spawning populations constitute genetically distinct assemblages (Bentzen et all, 1989; Nolan et al., 1991). Spawning runs of American shad exist in approximately 193 rivers from the St. Johns River, Florida, north to Atlantic Canada (Rulifson, 1994). Along the latitudinal gradient, populations of American shad may be either semelparous in southern rivers from Florida to North Carolina or predominately iteroparous in more northerly rivers (Leggett and Carscadden, 1978).

American shad are highly prized for their large ripe ovaries and delicate meat that is sold as fresh product. Historically, the species supported large commercial fisheries with landings along the Atlantic coast of approximately 30 million kg at the turn of the 20th century (Walburg and Nichols, 1967). Since that time, there has been a steady decline in coast-wide landings (Fig. 1), and most populations are in serious decline (ASMFC, 1999). Today, there are relatively strong spawning runs (and commercial fisheries) in only a few systems including the Hudson and Connecticut rivers (ASMFC, 1999).

The offshore or intercept fisheries for American shad in the Atlantic Ocean harvest a mixture of stocks and are an important component of the harvest for several coastal states. From 1980-1996, the majority of offshore commercial harvest of American shad was taken by Virginia (24%), Delaware (19%), New Jersey (18%), South Carolina (14%) and Maryland (9%). Because of uncertainty over the impact of the fisheries on stocks currently under restoration, a phase-out of these fisheries over a five-year period was mandated to begin in January 2000 (ASMFC 1999). The Interstate Fishery Management Plan requires a 40% reduction in effort in the first three years, with full closure slated for 2005. However, the issue is controversial since there was no direct evidence of negative impact of these fisheries in the assessment of the stocks by Crecco (1998). The risk associated with the offshore fishery is dependent on the magnitude and stock composition of the fish harvested. The mandatory phase-out was recommended based on the assumption that the intercept harvest threatened small stocks and hindered restoration efforts currently underway in several systems.

Recent studies of stock composition based on analysis of mitochondrial DNA (Brown et al., 1996) have concluded that there is insufficient genetic divergence among shad stocks to assign individual fish with any great confidence to a particular river. If a better method could be developed to estimate the fraction of the offshore catch arising from each of the rivers of concern, it would be possible to evaluate the impacts of the offshore fisheries. In particular, it might be possible to identify times and places where the harvest contains few fish from rivers of concern. One method, using trace chemical constituents in otoliths as natural tags, is currently under development by Dr. Simon Thorrold (Woods Hole Oceanographic Institution). In a separate study, Thorrold is evaluating this new method by investigating the composition of a monitoring sample in the York River (Virginia) where two tributary-specific sub-stocks mix. For the present study, we are investigating another method that takes advantage of existing hatchery programs that produce marked samples of known origin.

## Materials and Methods

*Development of the Model*

Larval or juvenile American shad with river-specific oxytetracycline marks on the otoliths are released into many rivers that are under restoration (Table 1). This provides a method for estimating the composition of the offshore catches. Suppose that a representative sample of 600 fish are obtained from the offshore fishery. Suppose further that samples are also obtained during the subsequent spawning runs in the James and York rivers and it is found that 30% of the fish are of hatchery origin on the James and 10% are of hatchery origin on the York River. Now, if all of the fish caught in the offshore fishery were from the James River, we would expect that about 30% of the offshore sample (180 fish) would have James River hatchery marks because 30% of James River fish have marks. Suppose instead, in the example, we found that 3/600 = 0.5% of the fish had James River marks. This would imply that 0.5/30 = 1.67 % of the fish from the offshore fishery were James River fish. Similarly, if 3 fish with York River marks were found in the offshore catch, we would conclude that 0.5/10 = 5 % were of York River origin.

Formally, the proportion of the offshore catch that is of river origin i, $P_i$, can be estimated by

$$\hat{P}_i = \frac{O_i / n}{\pi_i}$$

where the ^ indicates an estimate, $O_i$ is the observed number of fish in a sample of size n from the offshore fishery with hatchery marks from river i, and $\pi_i$ is the estimated fraction of the shad in river i with hatchery marks (determined from in-river sampling).

It should be noted that, in general, one does not know precisely how many hatchery-reared fish are released in any year, nor do we know the survival rate of the released fish. However, this information is not needed for application of the method. This is because the method is based on comparing only the *relative* abundance of hatchery marks in the offshore catch with that in the rivers.

*Specimen Collection and Processing*

Samples from Virginia's offshore catch in 2001 were obtained from Mr. Ernie Bowden of Chincoteague, Virginia. Mr. Bowden is a commercial waterman and has been a participant in Virginia's offshore intercept fishery for American shad since 1990. We contacted other commercial waterman but were unable to obtain their cooperation. Samples were obtained from Mr. Bowden (anchored gill net, 5-inch stretched mesh) twice weekly from 17 February to 17 April 2001 by randomly selecting 30-40 fish from his daily catch. Samples were returned to the laboratory for processing and otolith extraction. All specimens were measured (total length and fork length to the nearest mm) and weighed (total weight to the nearest g). Scales were collected from each specimen and aged following the methods of Cating (1953). Shad specimens were also obtained during February to May, 2001 from staked gill nets (4.88-inch stretched mesh) in the James and York rivers as part of an ongoing monitoring and stock assessment program for American shad (Olney and Maki, 2002).

Sagittal otoliths were removed from all specimens, cleaned by immersion in warm distilled water, placed in numbered tissue trays and stored for subsequent screening for oxytetracycline marks. One otolith from each offshore specimen (excluding 31 fish whose otoliths were not intact following removal) was examined for oxytetracycline marks by personnel at the Virginia Department of Game and Inland Fish (VDGIF). Otoliths of all American shad captured in staked gill nets in 2001 on the James River (n = 267) and York River (186 specimens) were scanned for hatchery marks. There are currently no hatchery marked fish released in the Rappahannock River, a third major Virginia tributary to the Chesapeake Bay. Thus the methodology developed here does not allow estimation of the proportion of the intercept fishery comprised by the Rappahannock stock.

**Results and Discussion**

Biological characteristics of American shad sampled in the 2001 offshore intercept fishery are summarized in Tables 2-3. A total of 625 American shad (males, n = 176); females, n = 449) were examined and dissected. Total sample weight was 927.8 kg (males, 223.4 kg; females, 704,8 kg). Scale ages were assigned to 520 of the 625 American shad (Table 4). The remaining 105 fish could not be aged due to regeneration or absence of appropriate scales.

Oxytetracycline marks were discovered on 5 of the otoliths taken from the intercept fishery specimens (Table 5). Four of these fish (0.67 %) had James River marks while one (0.17 %) had a Pamunkey River (York River system) mark. The proportion of the staked gill net samples with hatchery marks on the James and York rivers was 40.2% (103 of 256 fish) and 4.8% (9 of 186 fish), respectively. Total numbers of female American shad captured in our monitoring gear were highest on the York River (n= 677) and equal on the James and Rappahannock rivers (n= 267) in 2001. Overall, the temporal trends in the staked gill net monitoring program in Virginia suggest that recent catches American shad in the York and Rappahannock rivers are at or above the average of the historical data while those in the James River are well below the historical average (Figure 2).

Following from the developed model, the estimated proportion of the offshore catch that is of James River origin is equal to (4/594)/0.402), or 1.67%. The estimated proportion of the offshore catch that is of York River origin is equal to (1/594)/.048, or 3.50%. Thus, it appears that James and York River stocks comprised just over 5% of Ernie Bowden's catch in 2001.

We also compared the sizes (fork length) and ages of samples from the James, York, and Rappahannock rivers, and the ocean (Figures 3-6). Our purpose was to determine if the samples captured offshore and in rivers were identical in their size and age distributions. Unfortunately, the gill net mesh size for the James and York rivers is smaller than that of the ocean fishery, thus preventing a direct comparison of the catch. The mesh size of the gill net on the Rappahannock River is the same as that of Bowden's gill nets, however. Kolomogorov-Smirnov tests rejected the null hypothesis of equivalent distributions for male and female fork length ($p < 0.0001$ for each) and male and female age ($p = 0.035$, and $p < 0.0001$ respectively) for Rappahannock River and ocean samples. These findings suggest that fish from the Rappahannock River did not make up a large proportion of the offshore sample in 2001.

Hatchery marks were not detected from any other river including the Susquehanna River in the Chesapeake Bay system where a large hatchery release program has existed since 1985. Unmarked (presumably wild) fish comprised 99% of the offshore catch monitored in 2001. We conclude that Virginia's offshore harvest includes fish from the James and York rivers but the proportions of the catch from these rivers were small in 2001. Furthermore, unless exploitation of fish from the Rappahannock River was unexpectedly high in 2001, the offshore catch sampled did not contain appreciable numbers of fish from Virginia stocks. Our new OTC method is a useful alternative to genetic analysis and otolith microchemistry and can yield valuable information on the composition of the offshore catch. However, the large number of wild fish in our sample for which no stock identification was possible, the low frequency of marked fish in the sample, and the large number of US stocks that do not have hatchery programs constrain the applicability of the method to full mixed stock analysis. One potential important use of our new method is in validation of other approaches. For example, OTC marks could be used to verify stock classifications in future studies using otolith microchemistry.

## Literature Cited


Atlantic States Marine Fisheries Commission (ASMFC). 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring. ASMFC Fishery Management Report 35:1-76.

Bentzen, P., G. G. Brown, and W. C. Leggett. 1989. Mitochondrial DNA polymorphism, population structure, and life history variation in American shad (*Alosa sapidissima*). Canadian Journal of Fisheries and Aquatic Sciences 46:1446-1454.

Brown, B. L., J. M. Epifanio, P.E. Smouse and C. J. Kobak. 1996. Temporal stability of mtDNA haplotype frequencies in American shad stocks: to pool or not to pool across years? Can. J. Fish. Aquat. Sci. 53: 2274-2283.

Carscadden, J. E., and W. C. Leggett. Meristic differences in spawning populations of American shad, *Alosa sapidissima*: evidence for homing to tributaries in the St. John River, New Brunswick. Journal of the Fisheries Research Board of Canada 32:653-660.

Cating, J. P. 1953. Determining age of Atlantic shad from their scales. Fishery Bulletin 54:187-199.

Leggett, , W. C., and J. E. Carscadden. 1978. Latitudinal variation in reproductive characteristics of American shad (Alosa sapidissima): evidence of population specific life history strategies in fish. Journal of the Fisheries Research Board of Canada 35:1469-1478.

Melvin, G. D., M. J. Dadswell, M. J., and J. D. Martin. 1986. Fidelity of American shad, *Alosa sapidissima* (Clupeidae), to its river of previous spawning. Canadian Journal of Fisheries and Aquatic Sciences 43:640-646.

Nolan, K., J. Grossfield, and I. Wirgin. 1991. Discrimination among Atlantic coast populations of American shad (*Alosa sapidissima*) using mitochondrial DNA. Canadian Journal of Fisheries and Aquatic Sciences 48:1724-1734.

Olney, J. E. and K. L. Maki. Monitoring relative abundance of American shad in Virginia's rivers. 2002 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-4, April 2002.

Rulifson, R. A. 1994. Status of anadromous *Alosa* along the east coast of North America. Pages 134-158 in Cooper, J. A., Eades, R. T., Klauda, R. J., Loesch, J. G. (Editors). Anadromous *Alosa* Symposium, Tidewater Chapter, American Fisheries Society, Bethesda, Maryland, USA.

Talbot, G. B., and J. E. Sykes. 1958. Atlantic coast migrations of American shad. Fishery Bulletin 58:473-490.

Walburg, C. H. 1960. Abundance and life history of shad, St. Johns River, Florida. Fishery Bulletin 60:487-501.

Walburg, C. H., and P. R. Nichols. 1967. Biology and management of the American shad and the status of the fisheries, Atlantic coast of the United States. U.S. Fish and Wildlife Service Special Scientific Report Fisheries 550:1-105.

Table 1. A partial list of US east coast rivers into which larval American shad are released with river-specific hatchery marks.

| River | Releases since | Program authority |
|---|---|---|
| Roanoke | 1998 | NC Department of Marine Fisheries |
| York | 1994 | VA Game and Inland Fisheries Commission |
| York | 2000 | Pamunkey Indian Tribal Government |
| James | 1993 | US Fish and Wildlife Service |
| Potomac | 1995 | US Fish and Wildlife Service |
| Delaware | 1985 | PA Fish and Boat Commission (Lehigh and Schuylkill Rivers) |
| Susquehanna | 1985 | PA Fish and Boat Commission |

Table 2. Total numbers, date of capture, mean size (total length, fork length and weight) and total weight of samples of male American shad taken from the weekly catch of Mr. Ernie Bowden, Chincoteague, Virginia in spring 2001.

| Date of Capture | Number | Mean Total Length (mm) | Mean Fork length (mm) | Mean Weight (g) | Total Weight (g) |
|---|---|---|---|---|---|
| 2/17/01 | 8 | 505.6 | 444.6 | 1,327.2 | 10,617.4 |
| 2/18/01 | 9 | 492.9 | 435.2 | 1,316.3 | 11,846.3 |
| 2/27/01 | 3 | 514.7 | 457.0 | 1,382.8 | 4,148.3 |
| 2/28/01 | 9 | 508.9 | 446.2 | 1,419.8 | 12,778.2 |
| 3/8/01 | 7 | 502.1 | 440.6 | 1,307.6 | 9,152.9 |
| 3/9/01 | 15 | 493.3 | 433.9 | 1,216.3 | 18,244.3 |
| 3/14/01 | 3 | 524.7 | 460.3 | 1,388.3 | 4,165.0 |
| 3/15/01 | 16 | 495.1 | 435.6 | 1,220.9 | 19,533.7 |
| 3/19/01 | 16 | 497.4 | 438.1 | 1,258.1 | 20,129.7 |
| 3/20/01 | 11 | 490.5 | 431.8 | 1,220.5 | 13,425.5 |
| 3/26/01 | 6 | 497.0 | 436.2 | 1,287.1 | 7,722.5 |
| 3/27/01 | 14 | 492.1 | 433.1 | 1,261.5 | 17,660.6 |
| 4/2/01 | 18 | 506.1 | 443.0 | 1,300.5 | 23,408.7 |
| 4/3/01 | 18 | 490.7 | 428.9 | 1,249.7 | 22,494.5 |
| 4/9/01 | 2 | 487.5 | 427.0 | 1,270.5 | 2,540.9 |
| 4/10/01 | 4 | 493.5 | 431.3 | 1,236.3 | 4,945.1 |
| 4/16/01 | 17 | 492.2 | 433.0 | 1,211.2 | 20,590.6 |

Table 3. Total numbers, date of capture, mean size (total length, fork length and weight) and total weight of samples of female American shad taken from the weekly catch of Mr. Ernie Bowden, Chincoteague, Virginia in spring 2001.

| Date of Capture | Number | Mean Total Length (mm) | Mean Fork length (mm) | Mean Weight (g) | Total Weight (g) |
|---|---|---|---|---|---|
| 2/17/01 | 27 | 532.1 | 469.0 | 1,609.6 | 43,460.5 |
| 2/18/01 | 26 | 541.4 | 478.2 | 1,718.9 | 44,692.0 |
| 2/27/01 | 31 | 546.6 | 483.5 | 1,729.9 | 53,628.3 |
| 2/28/01 | 26 | 535.5 | 469.9 | 1,628.2 | 42,332.1 |
| 3/8/01 | 28 | 534.0 | 471.6 | 1,665.3 | 46,627.0 |
| 3/9/01 | 20 | 540.4 | 475.6 | 1,684.8 | 33,695.9 |
| 3/14/01 | 5 | 512.2 | 453.6 | 1,415.7 | 7,078.7 |
| 3/15/01 | 45 | 523.6 | 460.2 | 1,521.5 | 68,466.9 |
| 3/19/01 | 19 | 505.1 | 445.7 | 1,416.1 | 26,906.6 |
| 3/20/01 | 24 | 517.0 | 455.8 | 1,440.1 | 34,562.7 |
| 3/26/01 | 29 | 542.8 | 478.5 | 1,661.3 | 48,176.6 |
| 3/27/01 | 19 | 519.7 | 457.3 | 1,522.7 | 28,931.5 |
| 4/2/01 | 17 | 517.5 | 453.2 | 1,596.7 | 27,143.4 |
| 4/3/01 | 17 | 518.5 | 452.9 | 1,540.4 | 26,186.3 |
| 4/9/01 | 33 | 508.4 | 446.7 | 1,464.3 | 48,323.1 |
| 4/10/01 | 31 | 514.8 | 450.3 | 1,511.0 | 46,841.2 |
| 4/16/01 | 17 | 516.5 | 455.6 | 1,485.1 | 25,247.5 |
| 4/17/01 | 35 | 513.6 | 452.0 | 1,489.8 | 52,142.4 |

Table 4. Ages of American shad (based on examination of scales) taken from the weekly catch of Mr. Ernie Bowden, Chincoteague, Virginia in spring 2001. NA indicates the number of fish for which the age could not be determined from collected scales.

| Sex | Year Class | Number |
|---|---|---|
| Male | 1997 | 18 |
| | 1996 | 52 |
| | 1995 | 45 |
| | 1994 | 22 |
| | 1993 | 6 |
| | NA | 33 |
| Female | 1997 | 58 |
| | 1996 | 165 |
| | 1995 | 98 |
| | 1994 | 44 |
| | 1993 | 10 |
| | 1992 | 2 |
| | NA | 72 |

Table 5. Date of capture, sex, size (total length, fork length and weight), and probable river of origin for American shad with river-specific oxytetracycline marks taken from the weekly catch of Mr. Ernie Bowden, Chincoteague, Virginia in spring 2001.

| Date of Capture | River of Origin | Sex | Total Length | Fork Length | Weight |
|---|---|---|---|---|---|
| 2/28/01 | James | Male | 486 | 426 | 1381.7 |
| 3/8/01 | James | Female | 505 | 446 | 1326.1 |
| 3/27/01 | James | Female | 540 | 472 | 1674.9 |
| 4/2/01 | James | Female | 538 | 470 | 2073.2 |
| 4/3/01 | Pamunkey | Female | 516 | 446 | 1413.5 |

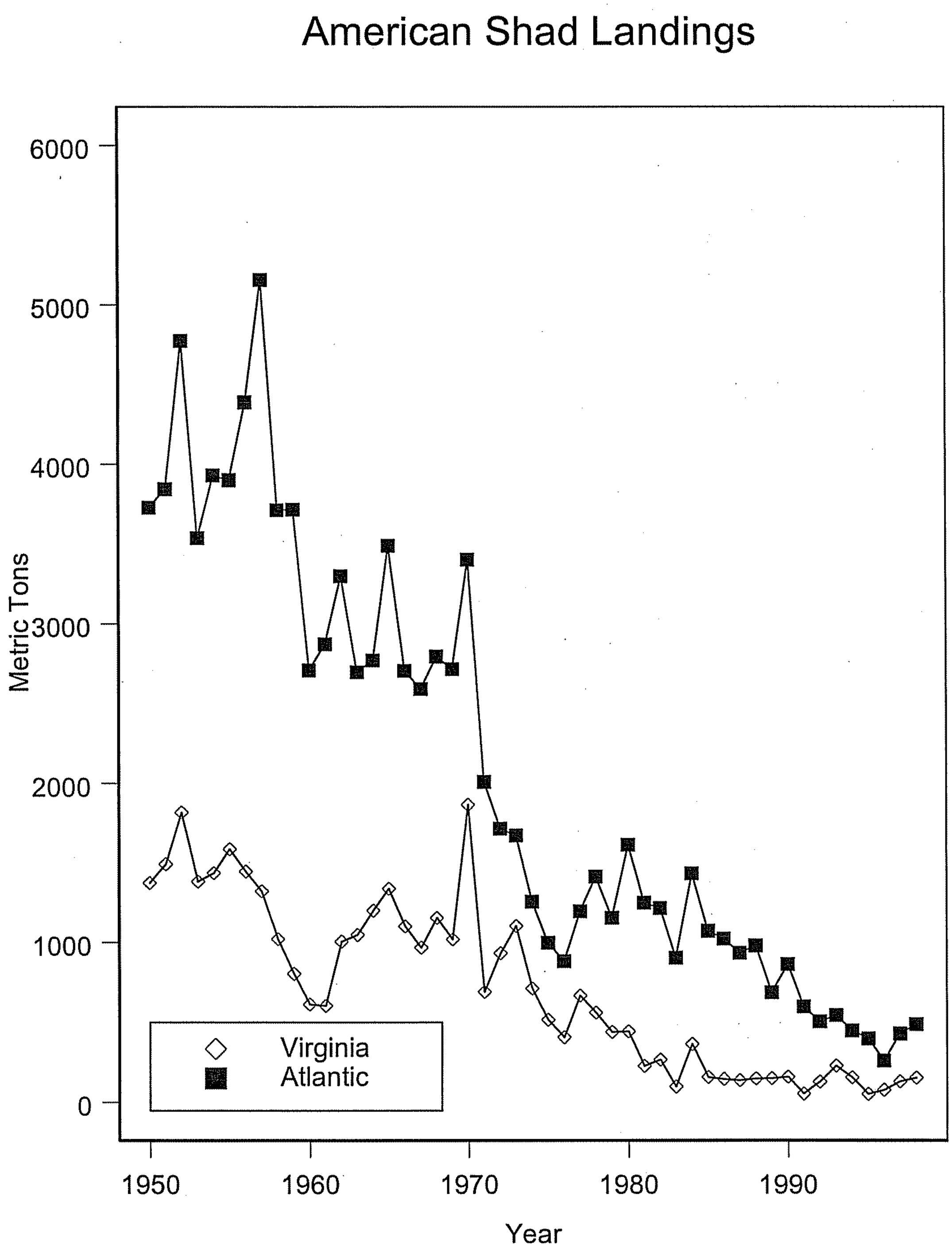


Figure 1. Commercial landings of American shad along the Atlantic coast and in Virginia since 1950. Data source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

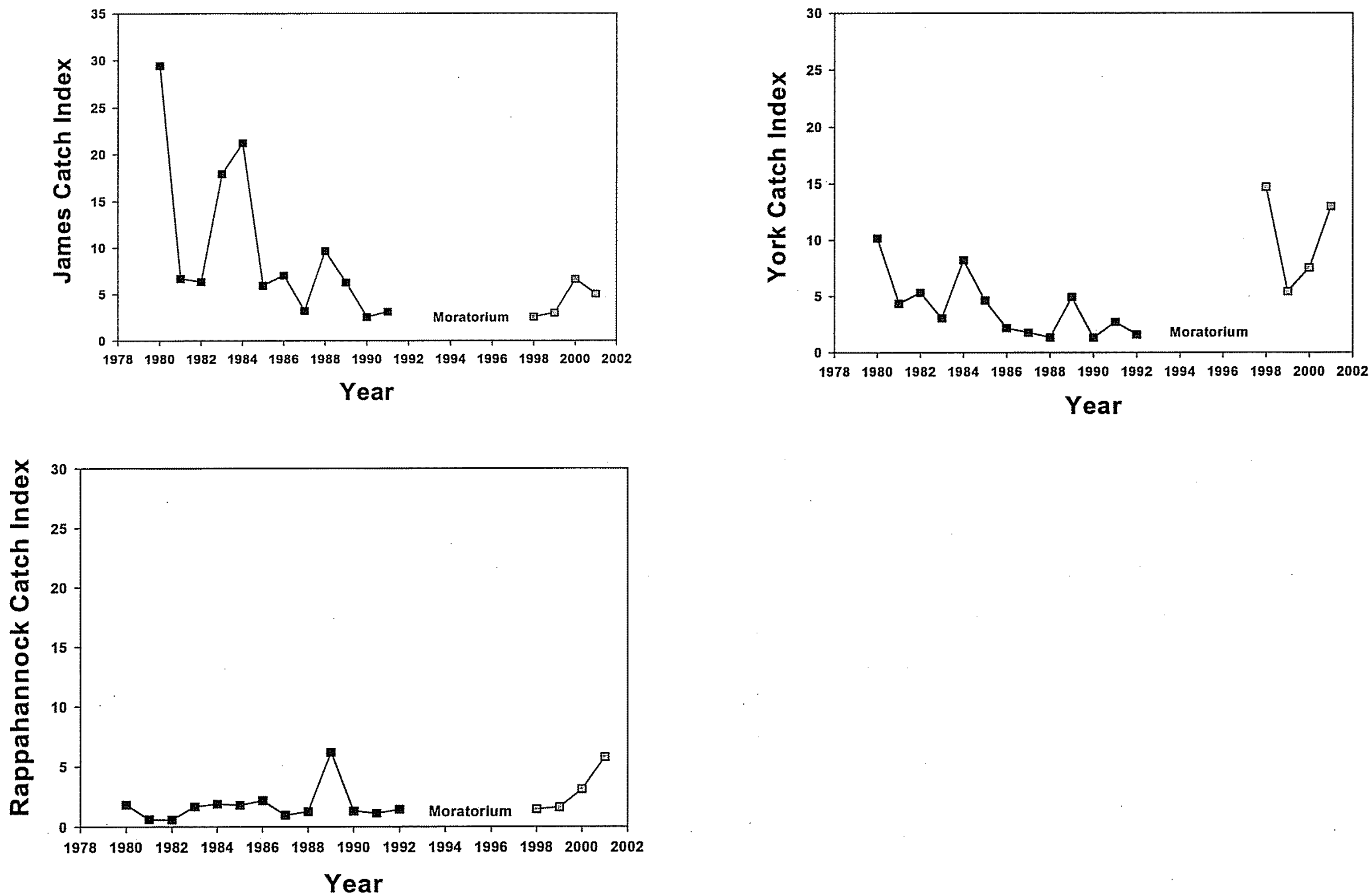


Figure 2. Recent (1998-2001) and historic values of the catch index of female American shad on the James, York and Rappahannock rivers.

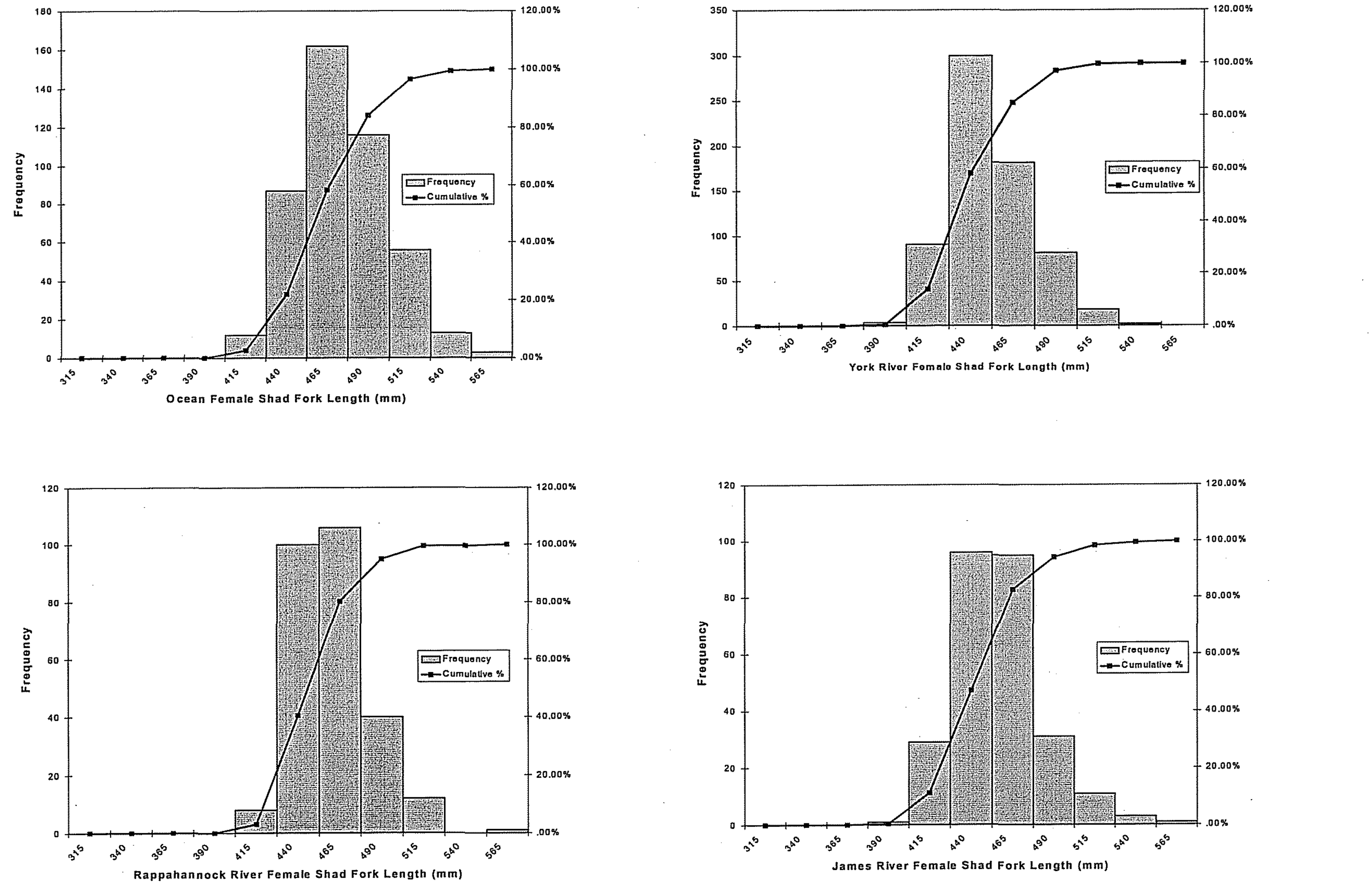


Figure 3. Fork length frequencies for female American shad collected from the ocean fishery (n=449) and the Rappahannock (n=267), York (n= 677), and James (n=267) Rivers.

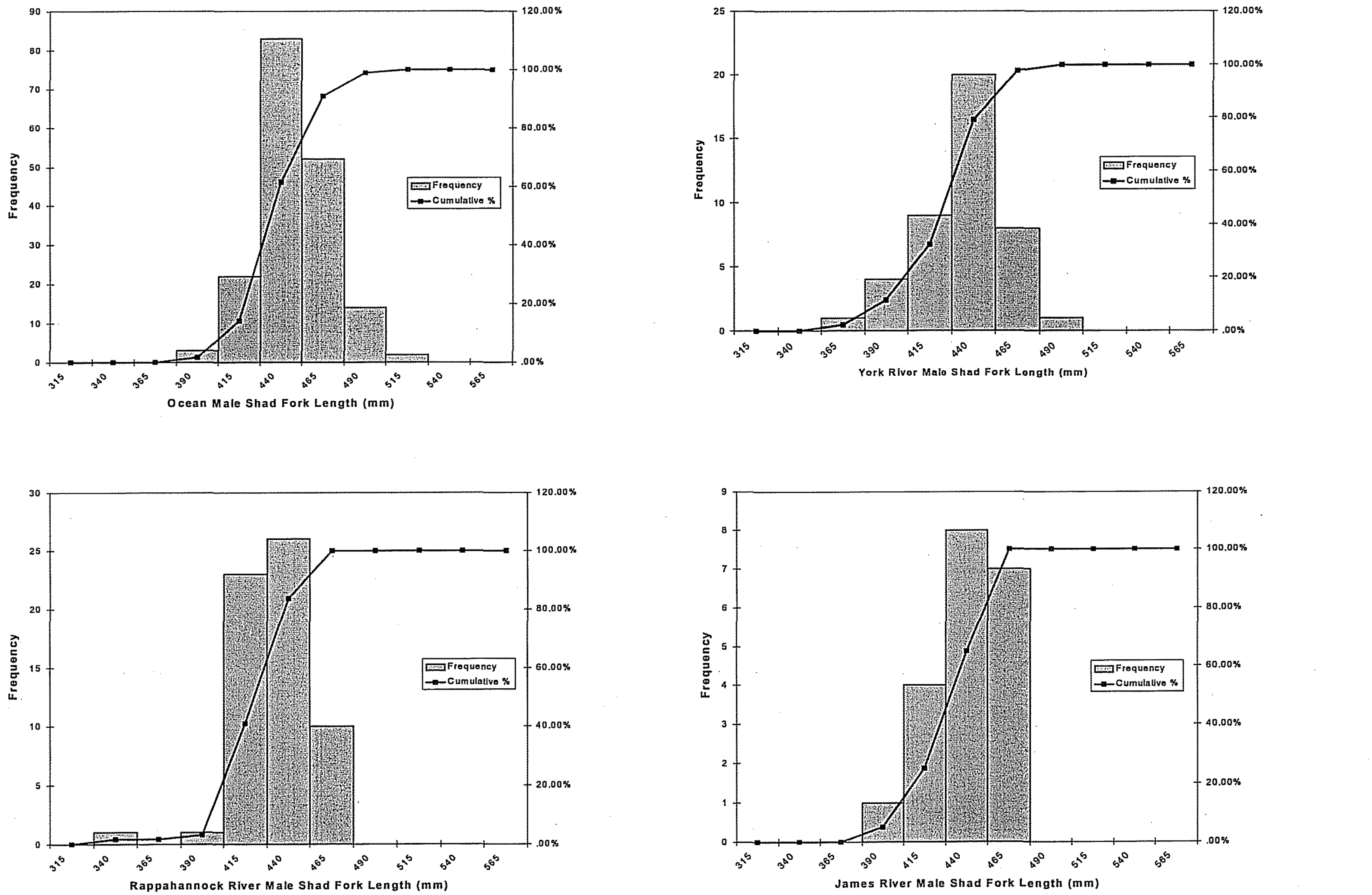


Figure 4. Fork length frequencies for male American shad collected from the ocean fishery (n=176) and the Rappahannock (n=61), York (n=43), and James (n=20) Rivers.

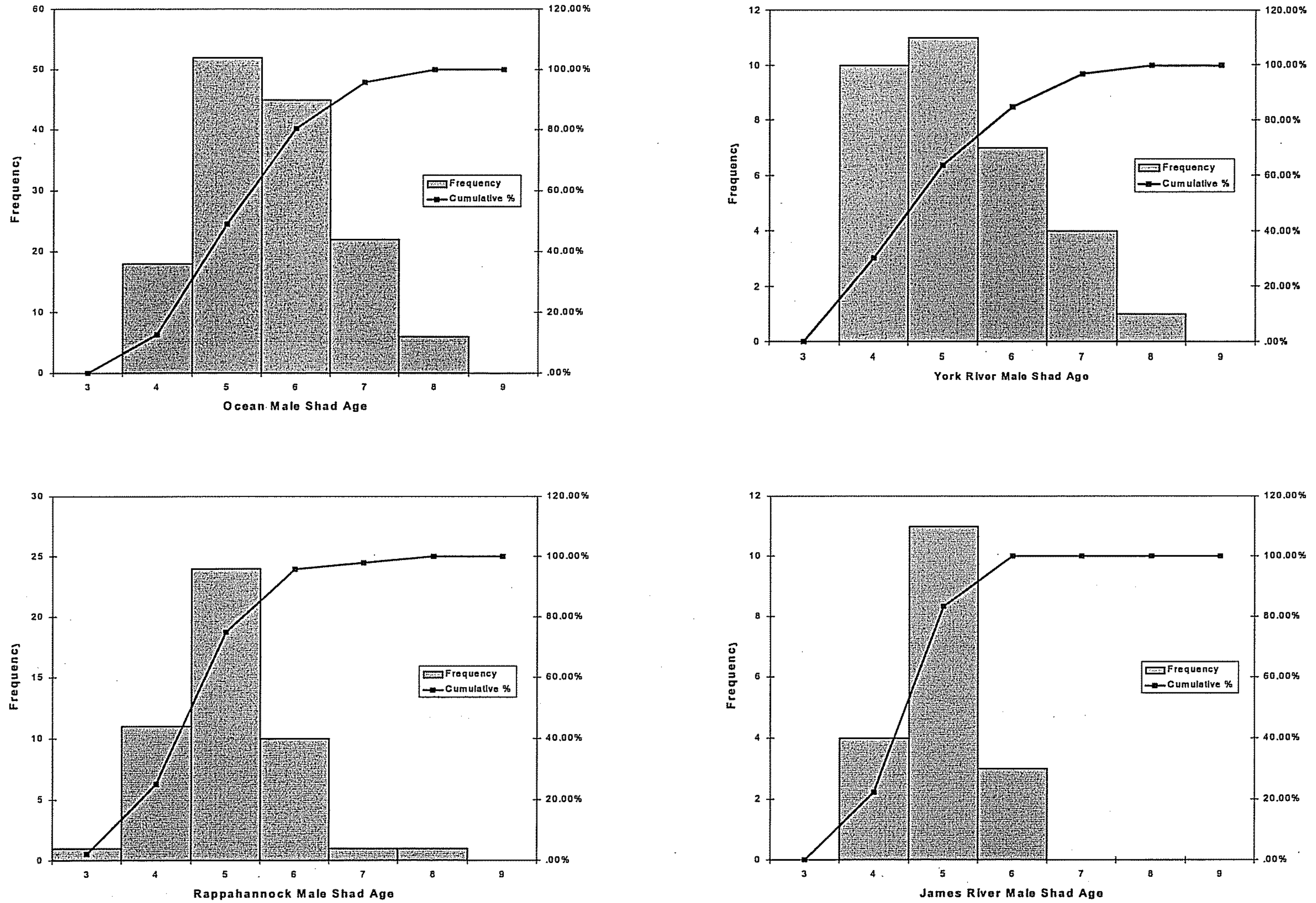


Figure 5. Age frequencies for female American shad collected from the ocean fishery (n=377) and the Rappahannock (n=233), York (n=590), and James (n=242) Rivers. Sample sizes for ages do not equal that for lengths due to the inability to age some of the collected specimens.

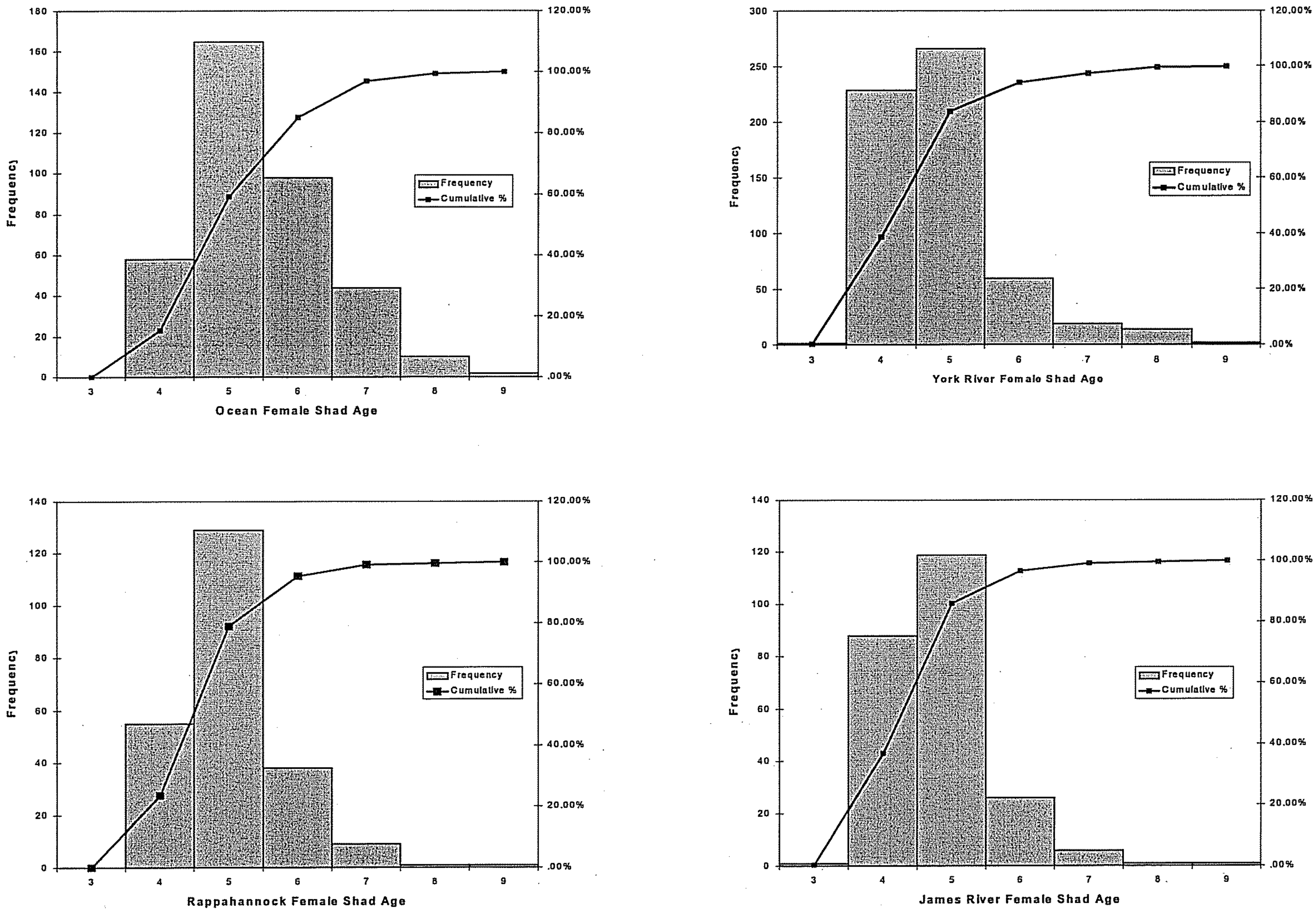


Figure 6. Age frequencies for male American shad collected from the ocean fishery (n=143) and the Rappahannock (n=48), York (n=33), and James (n=18) Rivers. Sample sizes for ages do not equal that for lengths due to the inability to age some of the collected specimens.