## Appendix 1 - Indices

## Northeast Fisheries Science Center Trawl

# River herring (alewife and blueback herring) and American shad indices from the NEFSC spring and fall bottom trawl surveys for fall 1975 - spring 2021

Northeast Fisheries Science Center

September 26 2021

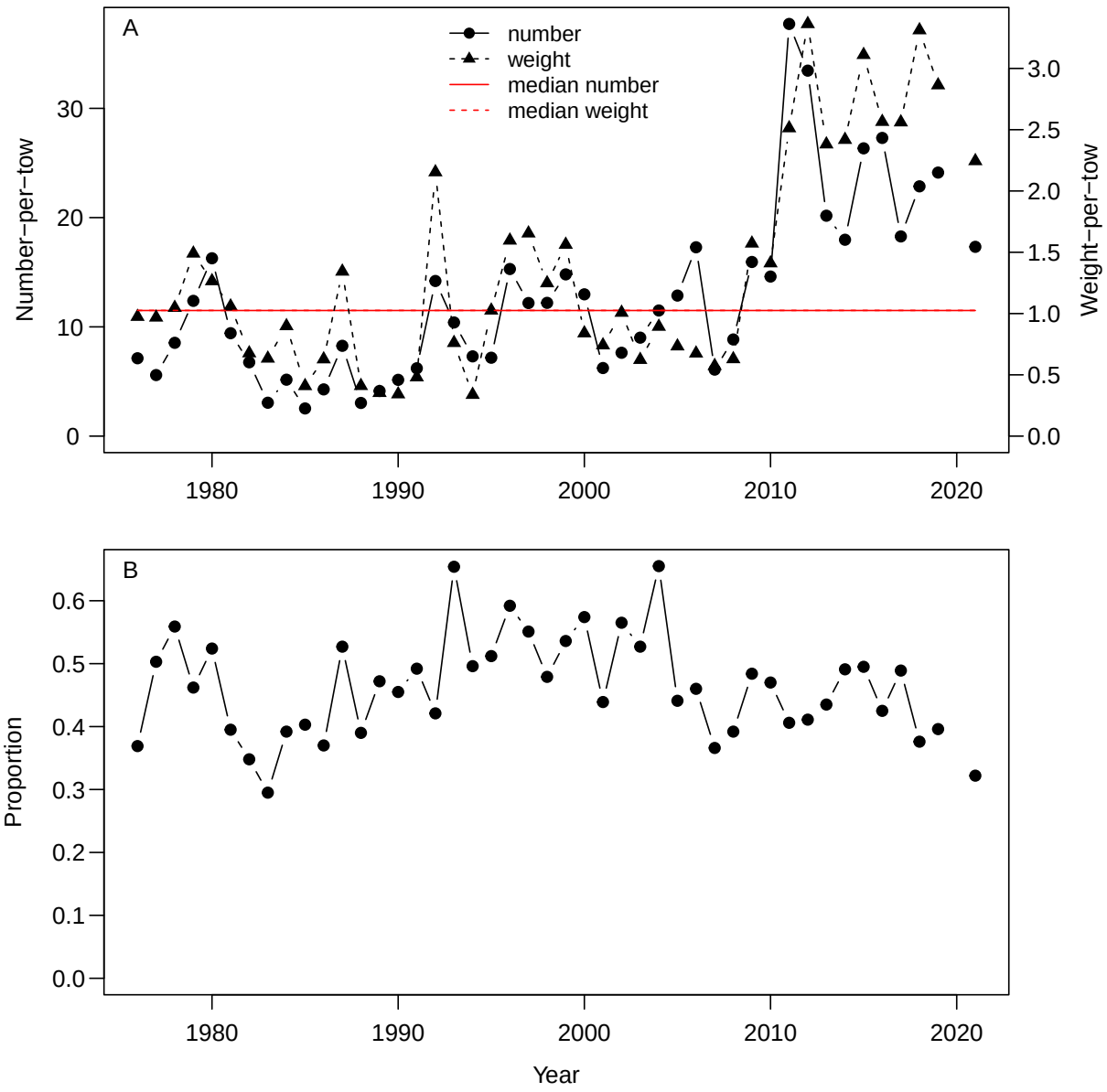



Figure 1: Alewife relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC spring bottom trawl survey for 1976-2021. Indices from 2009 onward were converted to Albatross units. The median number- and weight-per-tow values represent the median indices over 1976-2021. The full strata set was not sampled in 2014 due to delays in the survey (offshore strata 61-68 south of Maryland were not sampled) and the 2020 survey was not completed due to the covid pandemic.

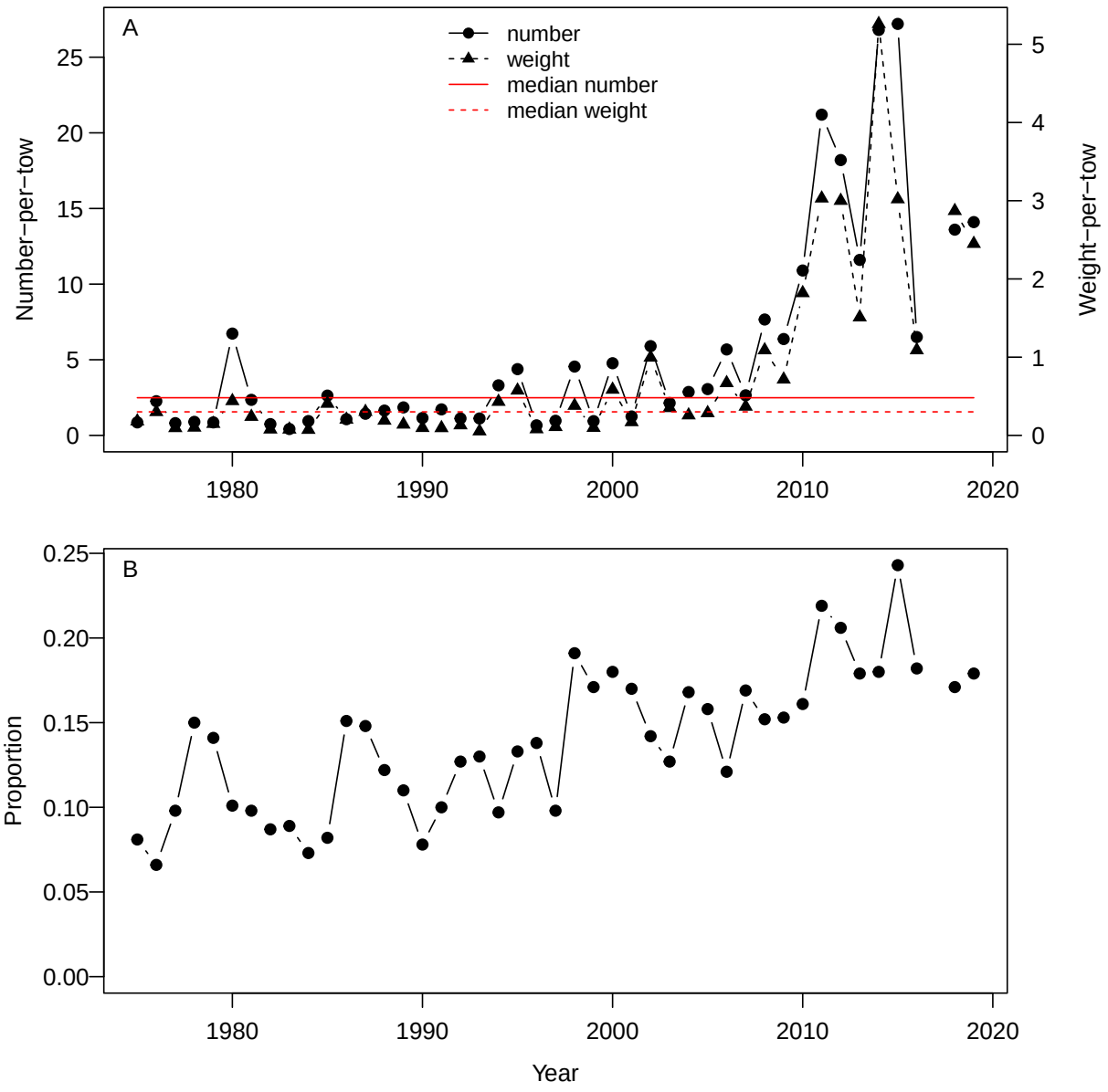



Figure 2: Alewife relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC fall bottom trawl survey for 1975-2019. Indices from 2009 onward were converted to Albatross units. The median number- and weight-per-tow values represent the median indices over 1975-2019. Indices from the 2017 fall bottom trawl survey are treated as missing because the full survey was not completed due to vessel mechanical issues. Additionally, the 2020 survey was not completed due to the covid pandemic.

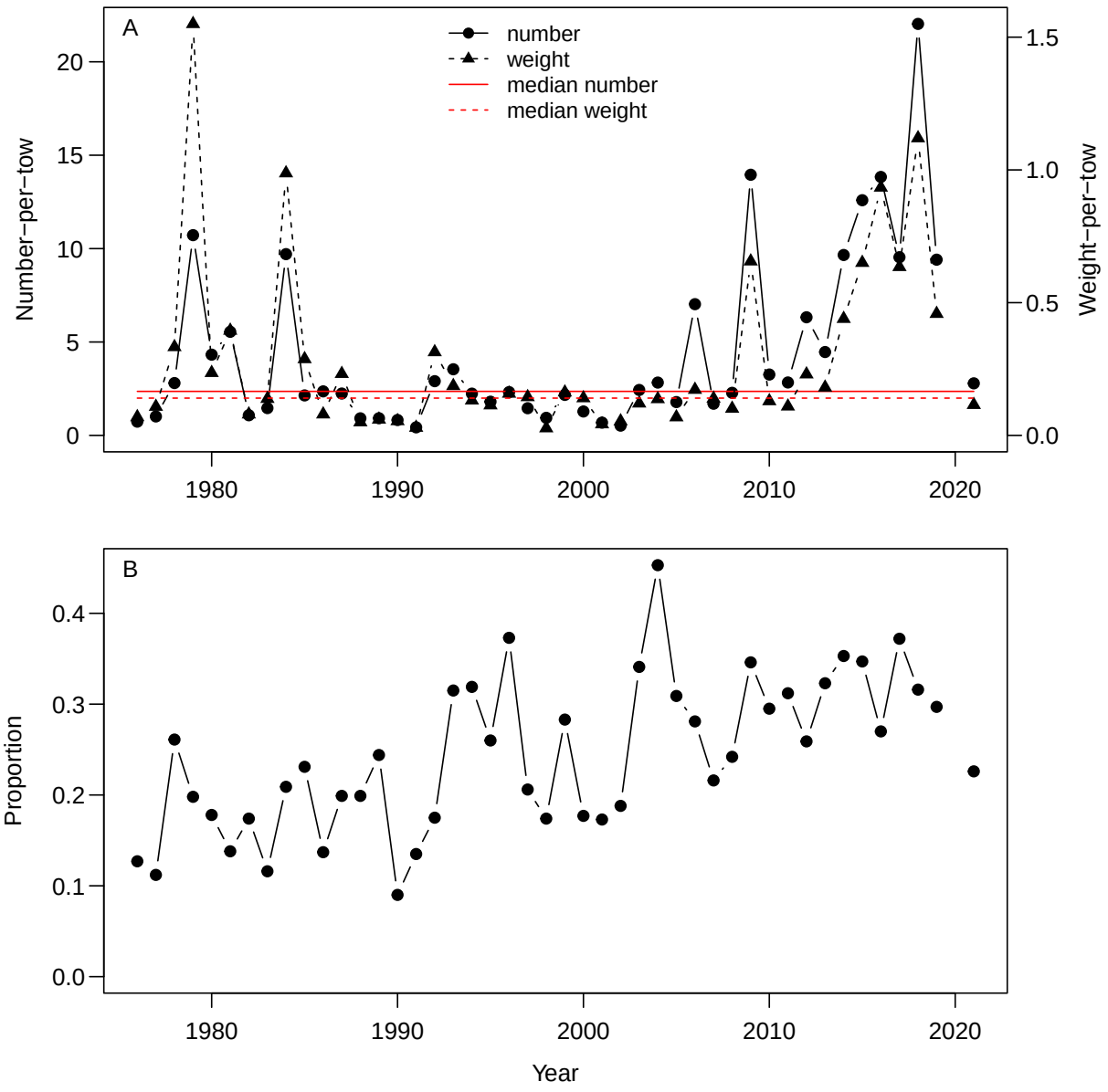



Figure 3: Blueback herring relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC spring bottom trawl survey for 1976-2021. Indices from 2009 onward were converted to Albatross units. The median number- and weight-per-tow values represent the median indices over 1976-2021. The full strata set was not sampled in 2014 due to delays in the survey (offshore strata 61-68 south of Maryland were not sampled) and the 2020 survey was not completed due to the covid pandemic.

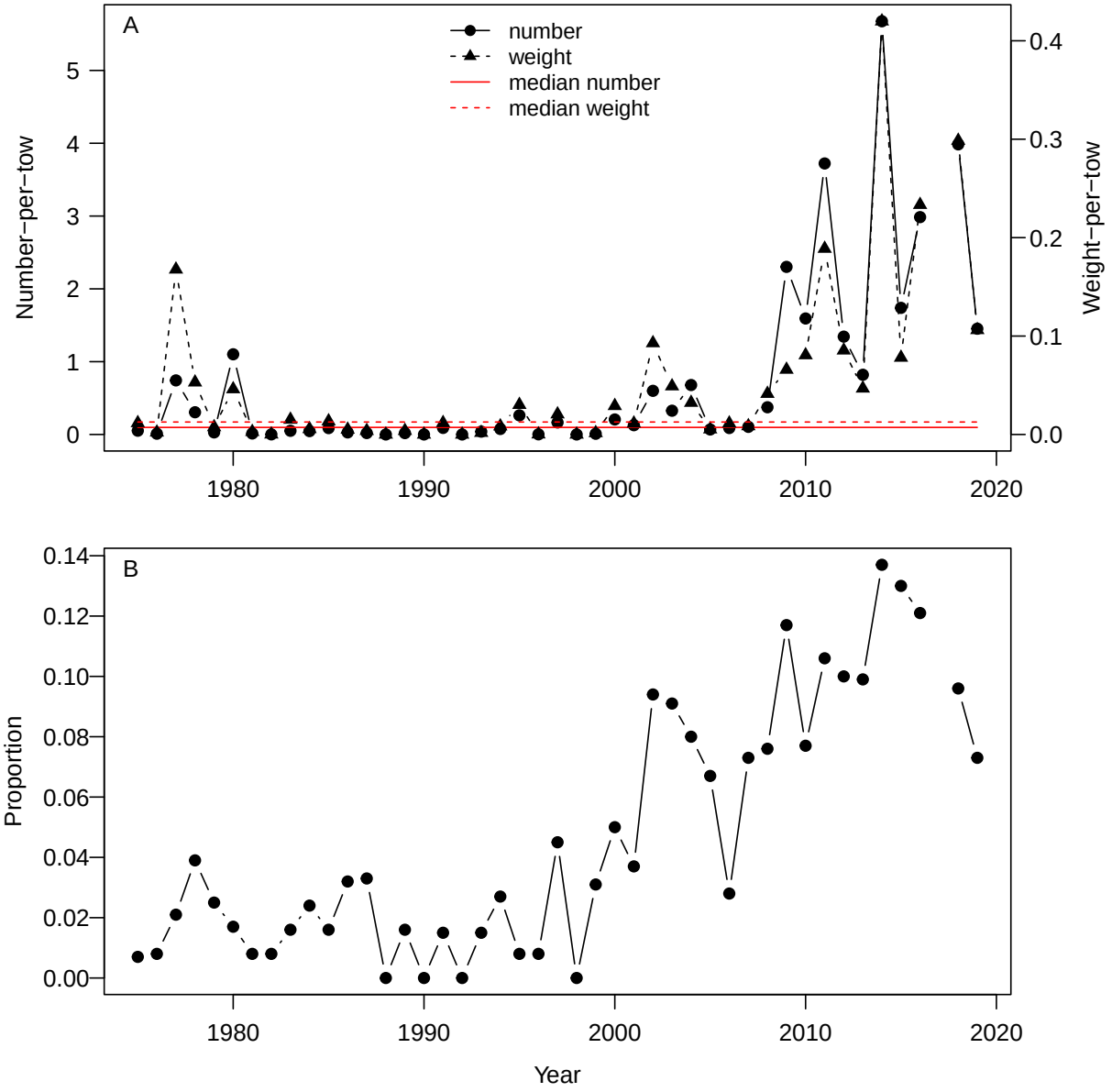



Figure 4: Blueback herring relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC fall bottom trawl survey for 1975-2019. Indices from 2009 onward were converted to Albatross units. The median number- and weight-per-tow values represent the median indices over 1975-2019. Indices from the 2017 fall bottom trawl survey are treated as missing because the full survey was not completed due to vessel mechanical issues. Additionally, the 2020 survey was not completed due to the covid pandemic.

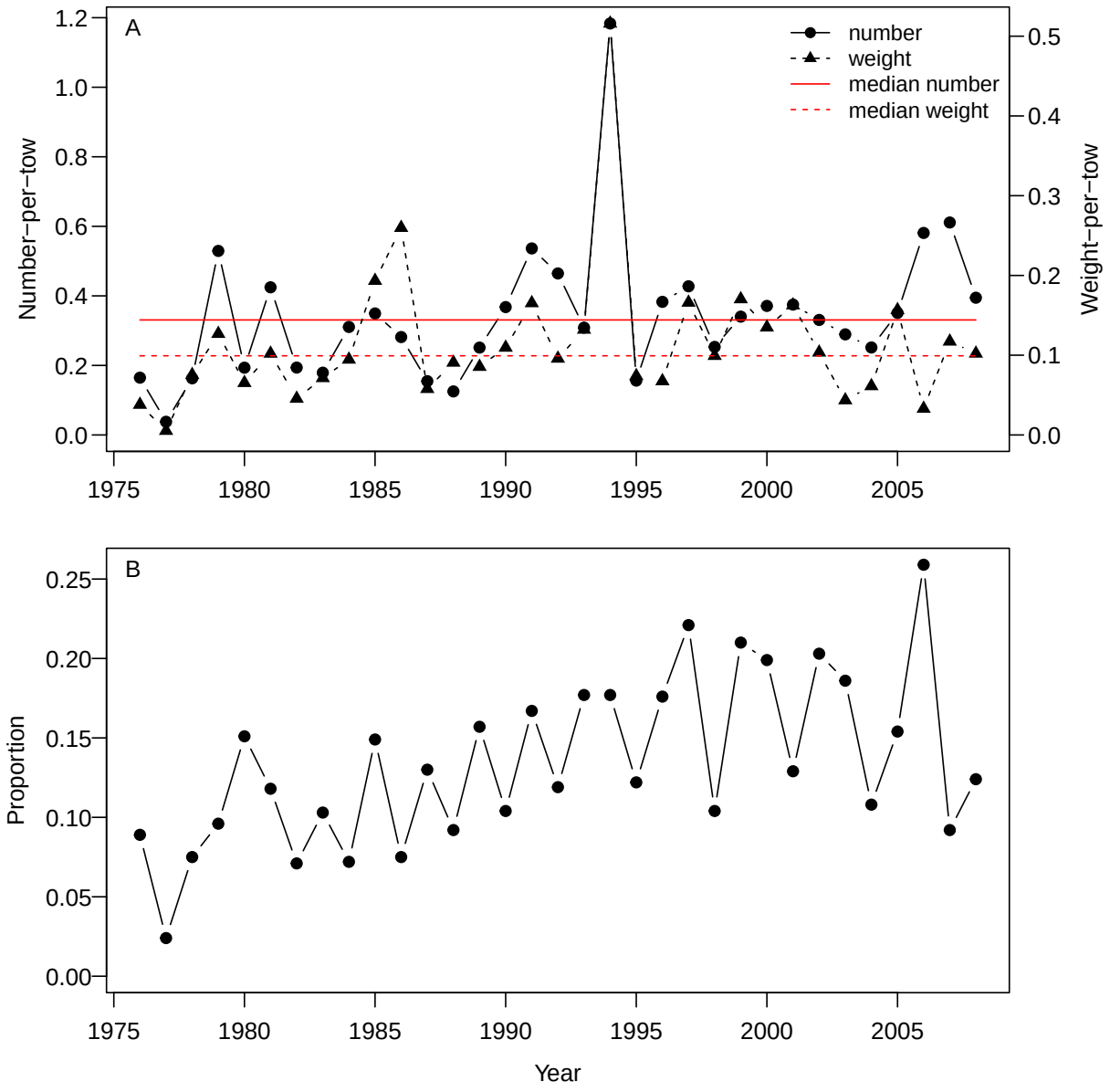



Figure 5: American shad relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC spring bottom trawl survey for 1976-2008. Vessel (Bigelow to Albatross) conversion coefficients are not available for American shad; therefore, the time series was split in 2008. The median number- and weight-per-tow values represent the median indices over 1976-2008.

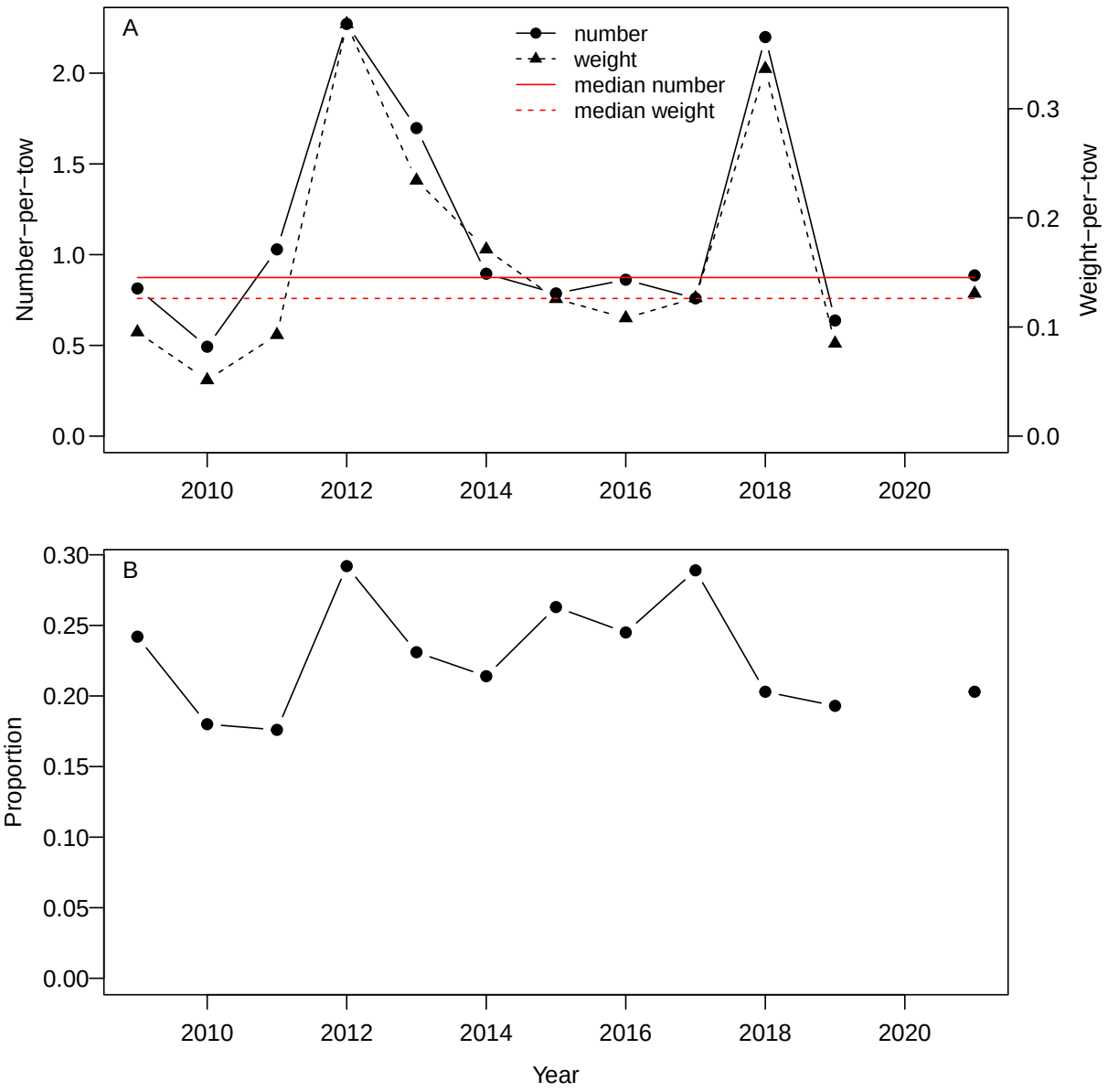



Figure 6: American shad relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC spring bottom trawl survey for 2009-2021 (Bigelow units). The median number- and weight-per-tow values represent the median indices over 2009-2021. The full strata set was not sampled in 2014 due to delays in the survey (offshore strata 61-68 south of Maryland were not sampled) and the 2020 survey was not completed due to the covid pandemic.

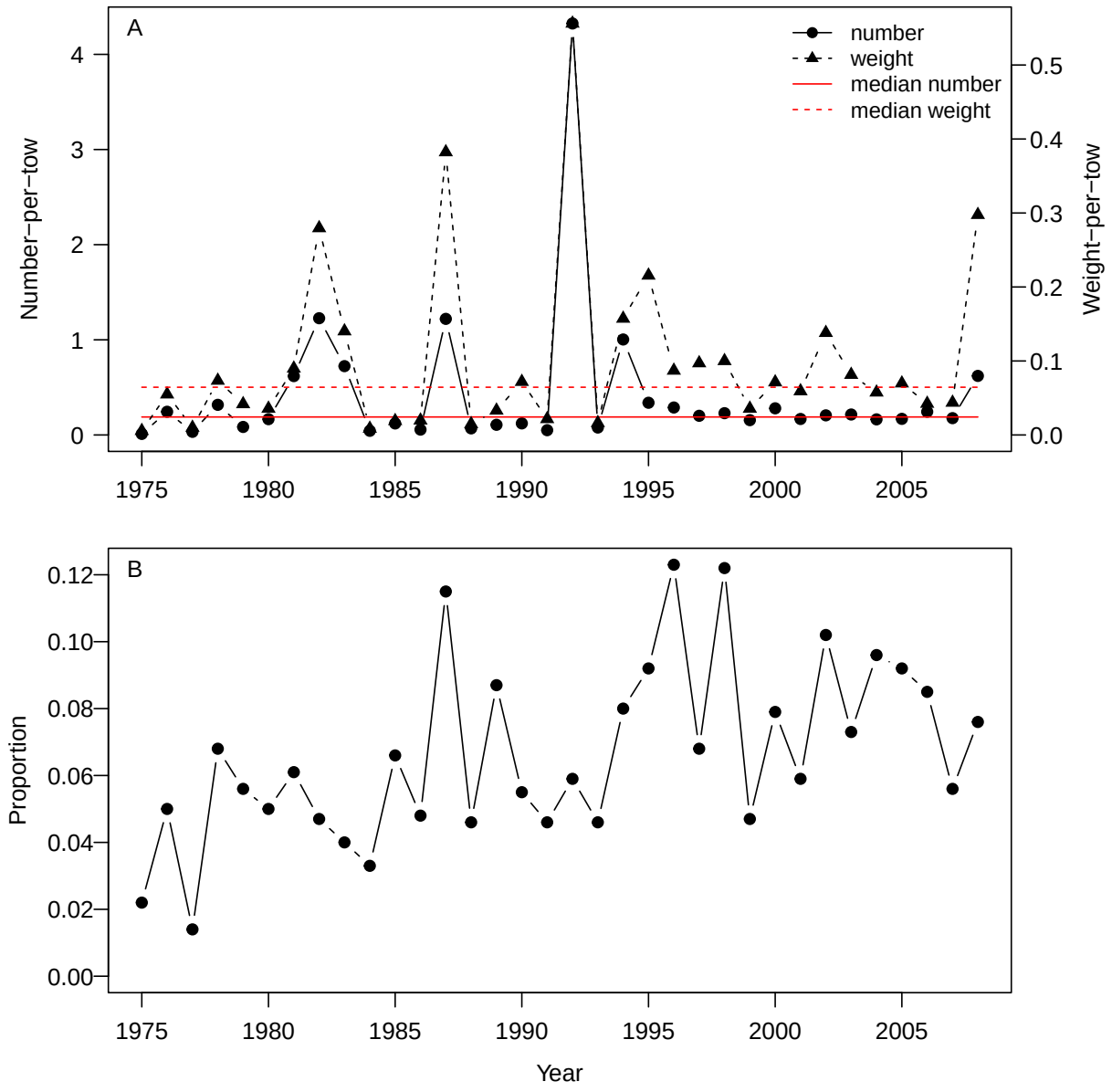



Figure 7: American shad relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC fall bottom trawl survey for 1975-2008. Vessel (Bigelow to Albatross) conversion coefficients are not available for American shad; therefore, the time series was split in 2008. The median number- and weight-per-tow values represent the median indices over 1975-2008.

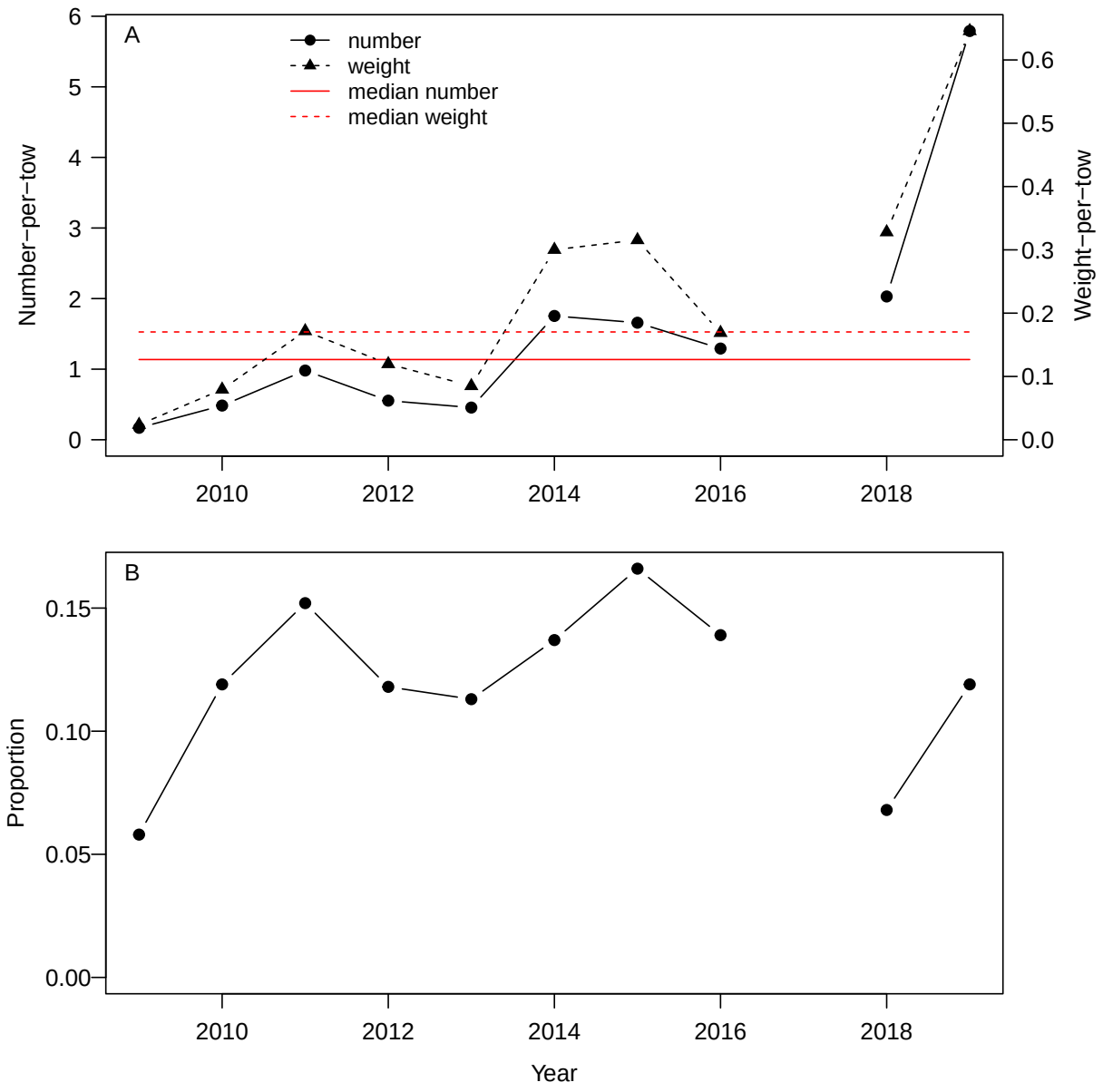
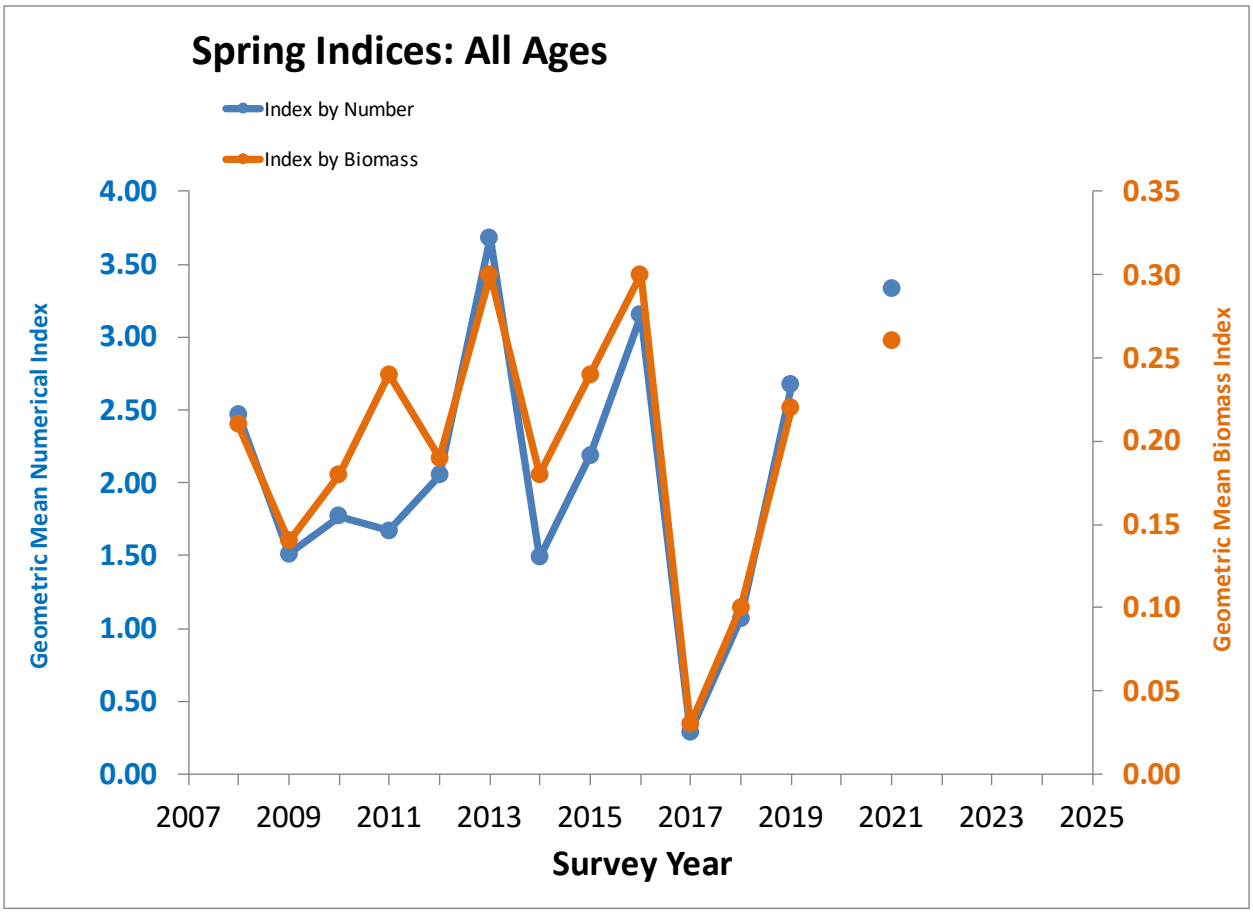


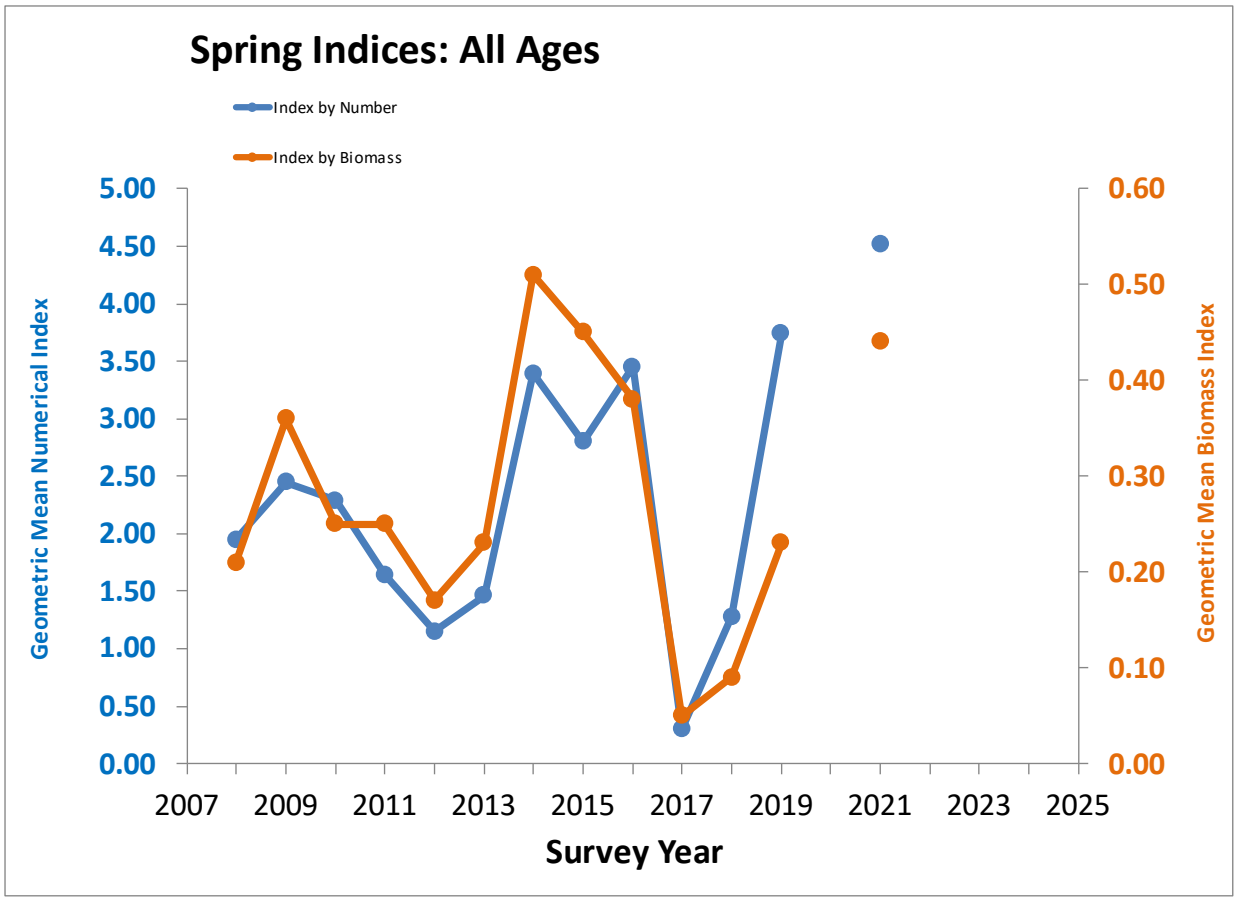

Figure 8: American shad relative abundance (stratified mean number-per-tow) and biomass (stratified mean kg-per-tow) indices (A) and the proportion of positive tows (B) derived from the NEFSC fall bottom trawl survey for 2009-2019 (Bigelow units). The median number- and weight-per-tow values represent the median indices over 2009-2019. Indices from the 2017 fall bottom trawl survey are treated as missing because the full survey was not completed due to vessel mechanical issues. Additionally, the 2020 survey was not completed due to the covid pandemic.

NEAMAP

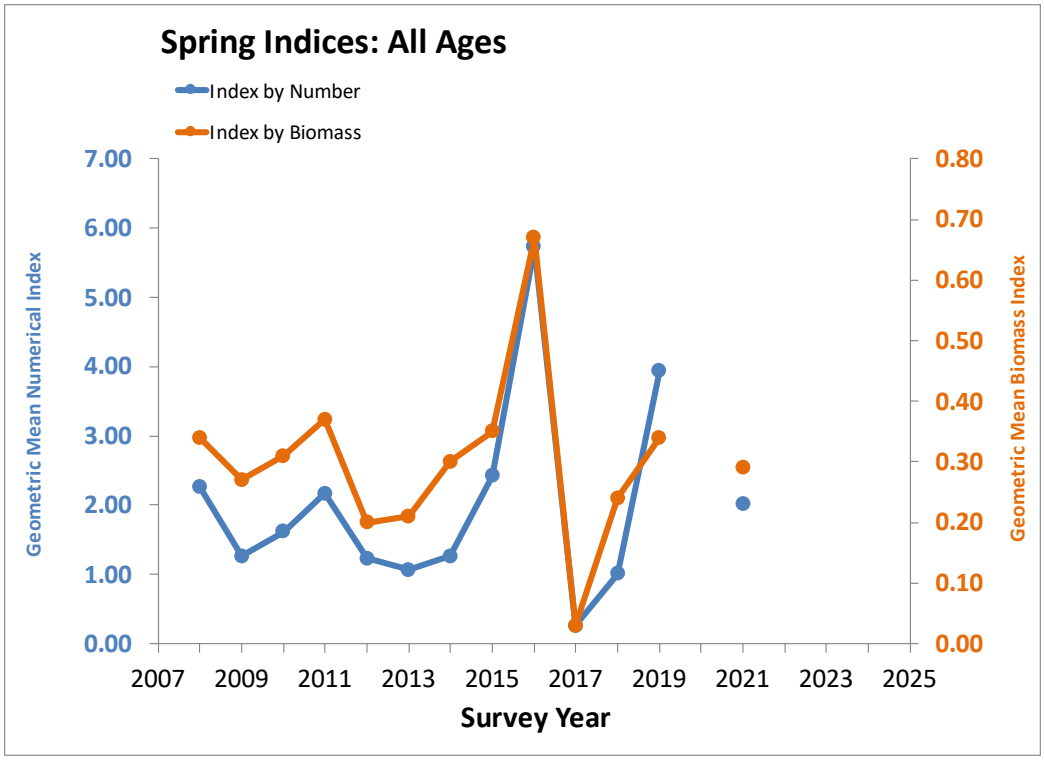
NEAMAP, American Shad all ages, Spring



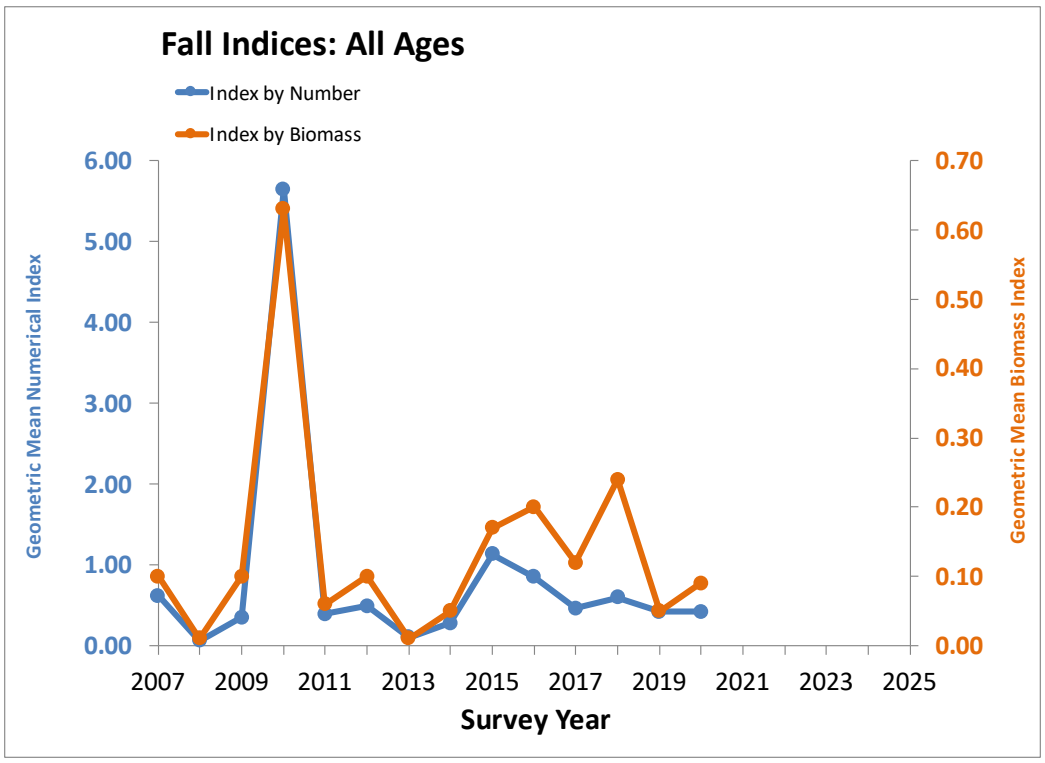
NEAMAP, Bluebacks all ages, Spring



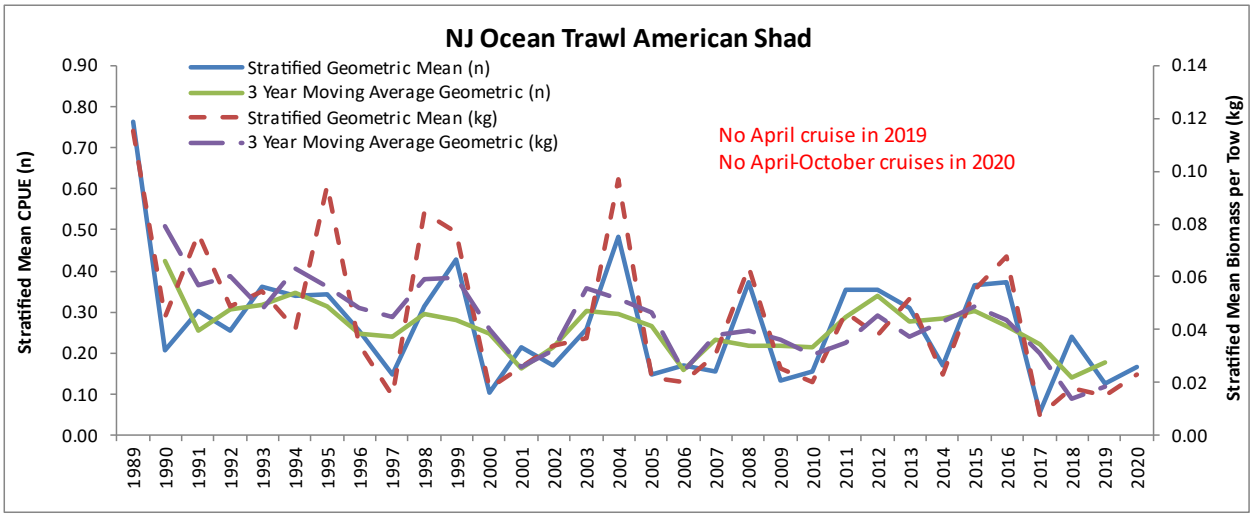
NEAMAP, Alewife all ages, Spring

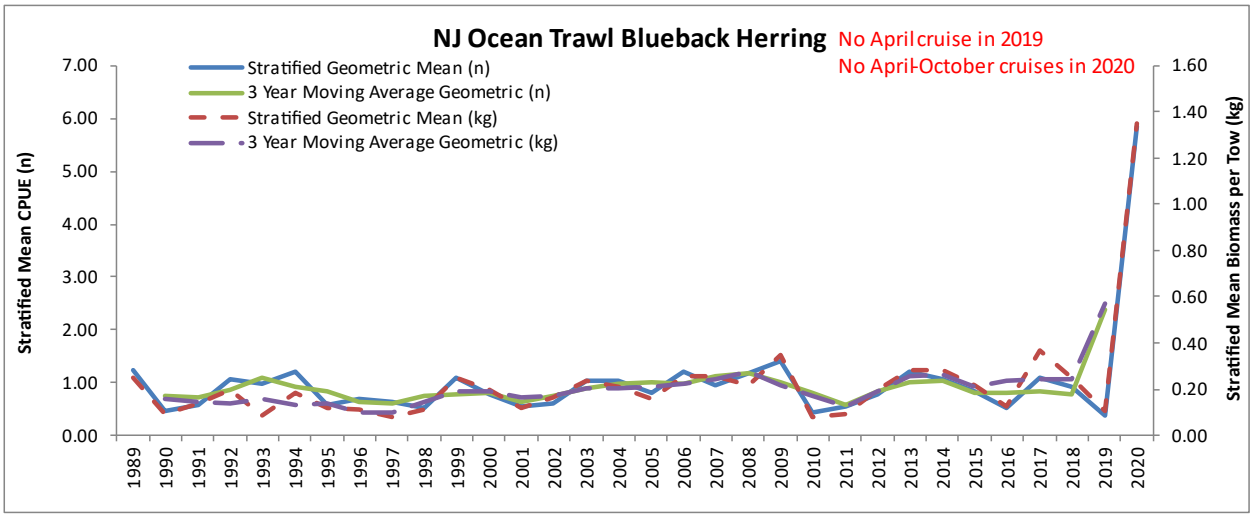


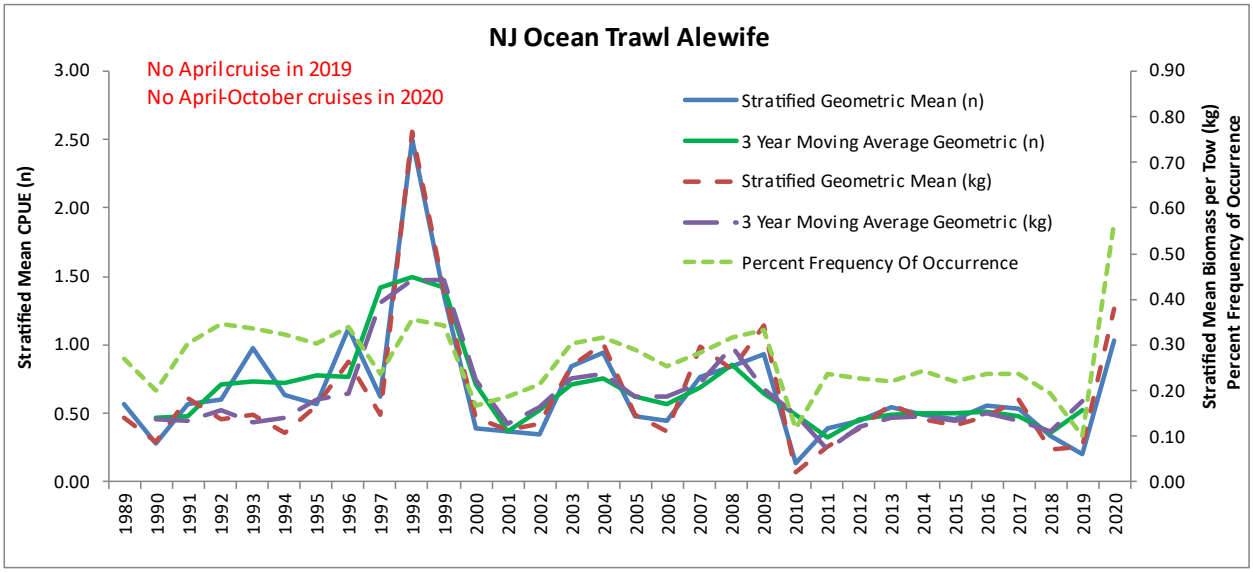

NEAMAP, Alewife all ages, Fall



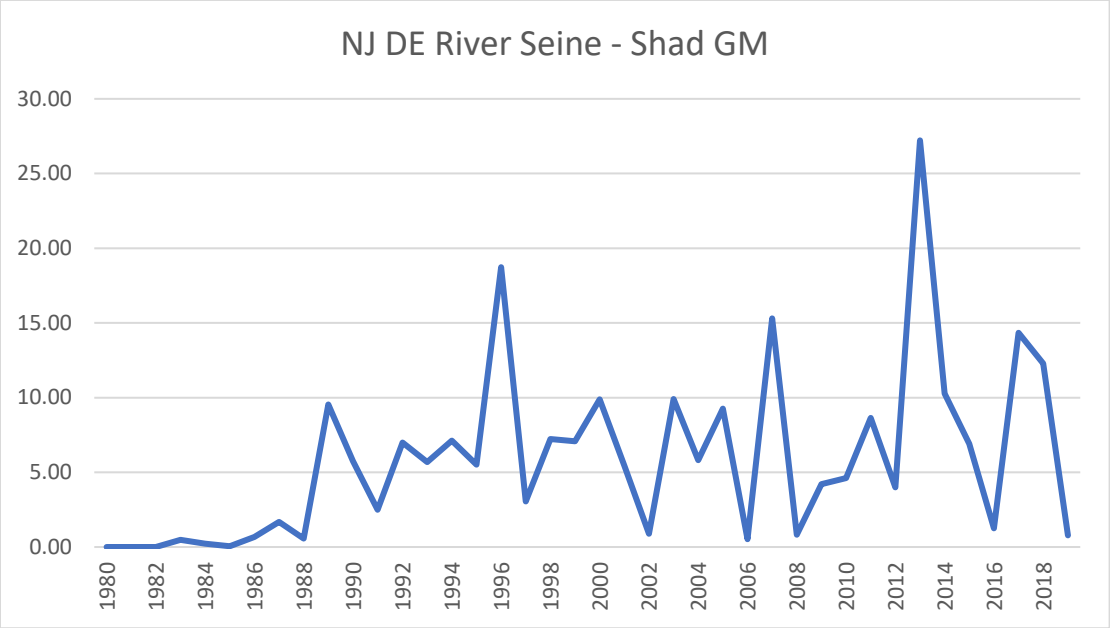
NJ Ocean Trawl (note missed cruises in 2020)

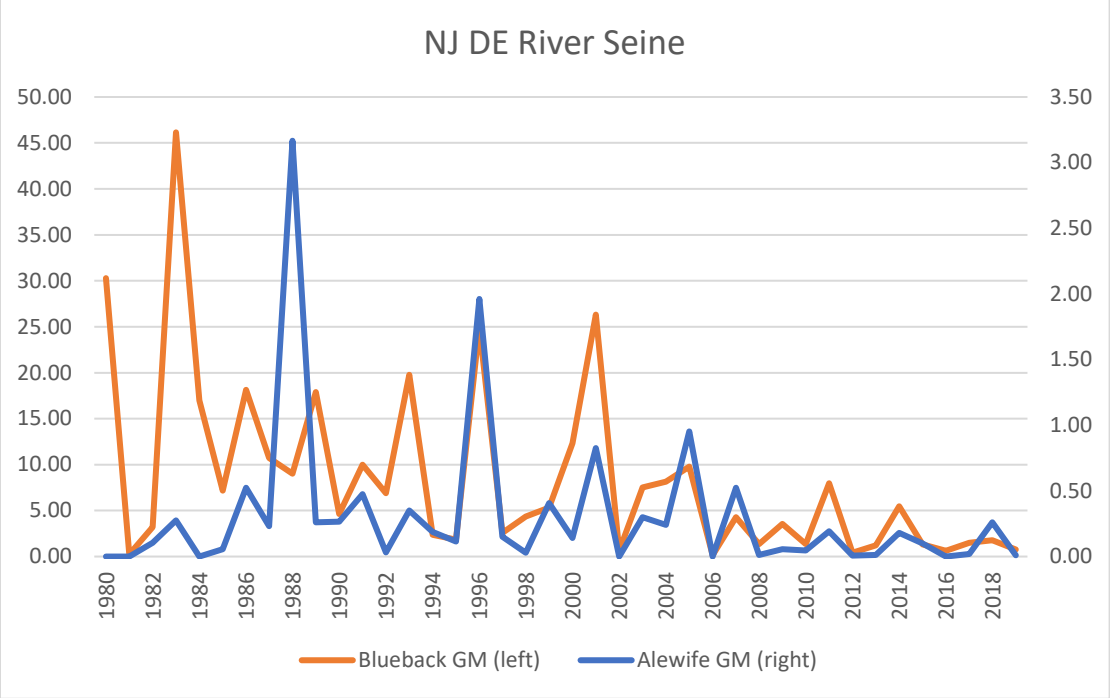


NJ Upper Tidal Delaware River Seine (striped bass recruitment)

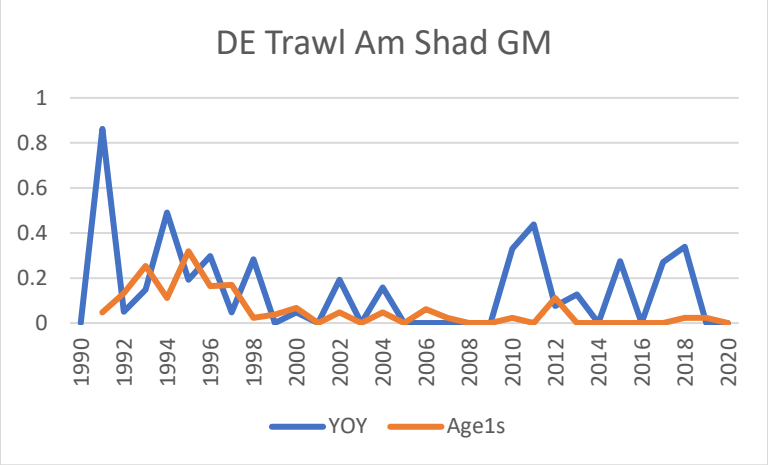


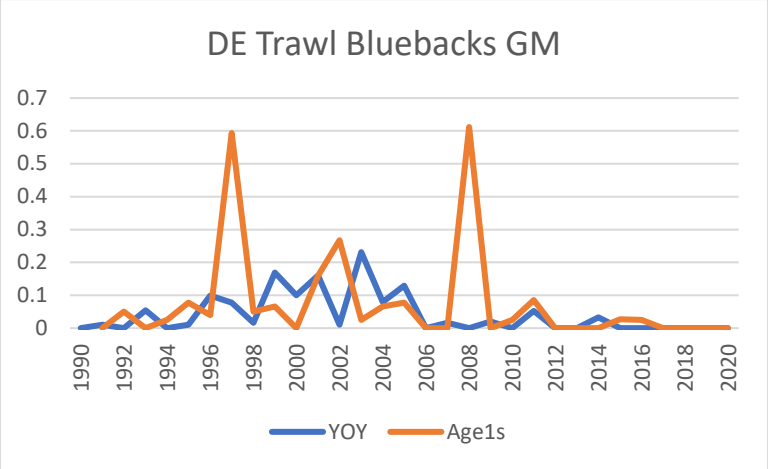



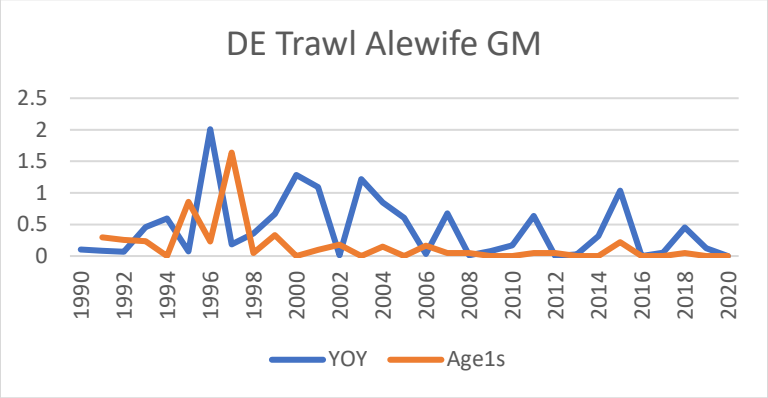
Massachusetts Inshore Survey – Pending

Delaware Trawl Survey

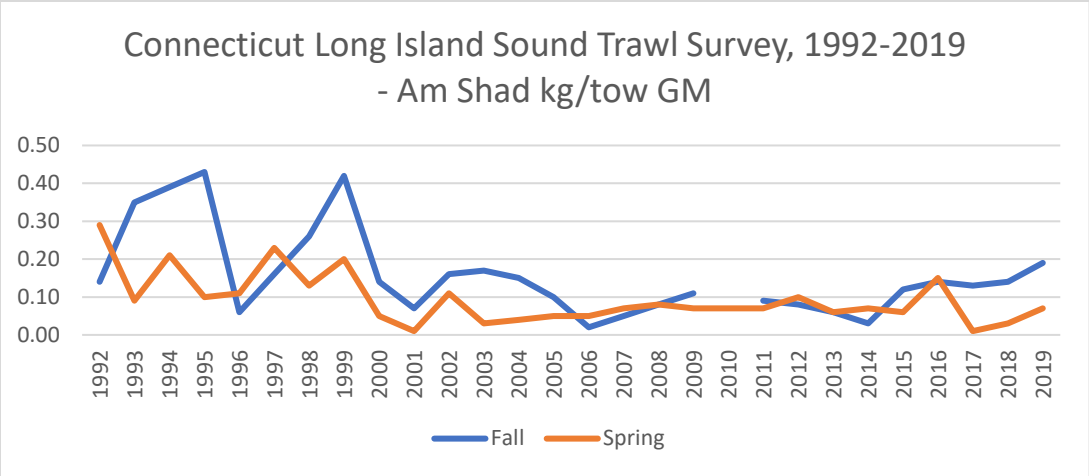
Note: due to restrictions as a result of the Covid-19 pandemic DE was unable to sample some of the stations in April and all the stations in May. This mainly affected the Age-1 indices for the 3 species.

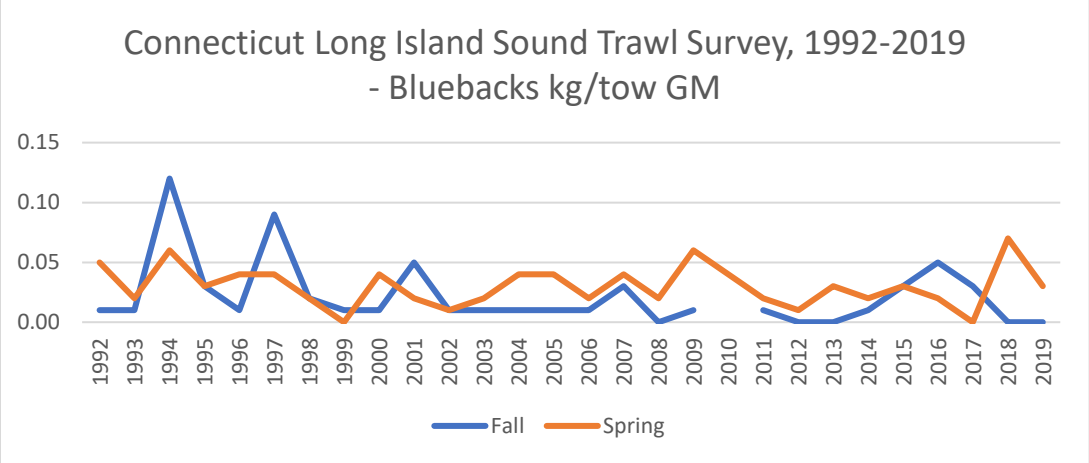


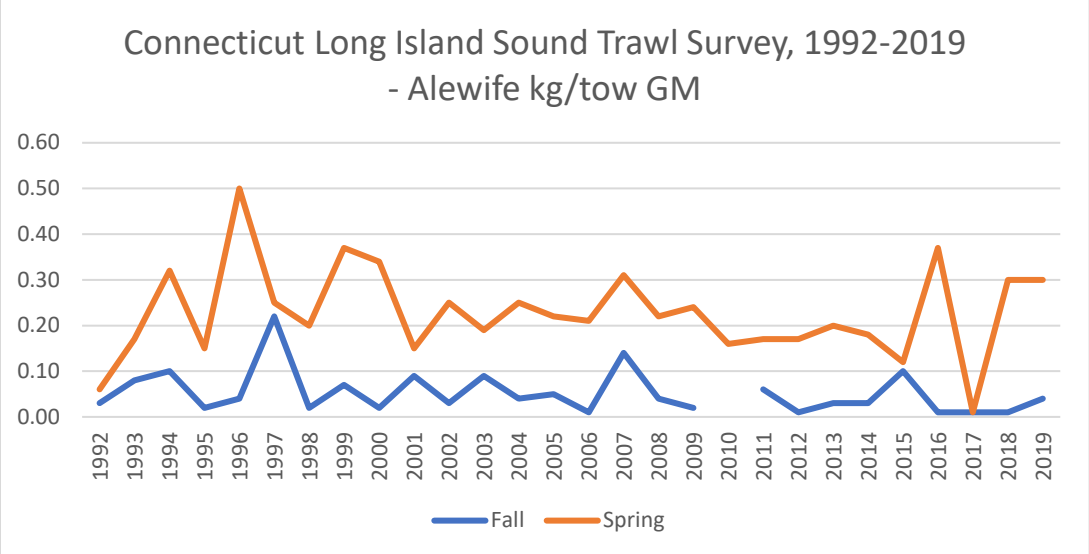



Long Island Sound Indices



ROY COOPER
Governor

ELIZABETH S. BISER
Secretary

KATHY B. RAWLS
Director

To: Jason Didden, MAFMC

From: Holly White, NCDMF

CC: Chris Batsavage, NCDMF

Subject: 2019 and 2020 River Herring and American Shad Indices Update

Hey Jason,

Please find attached the updates to the annual indices that you requested on 5/28/2021. If you need anything else. Please let me know.

Best,

Holly White

Holly.White@ncdenr.gov

Description of work: Juvenile Abundance Index

Eleven seine stations were sampled by DMF bi-monthly with an 18.5 m (60 ft.) bag seine in the western Albemarle Sound area during June-October 2020 (Figure 7). Juvenile Abundance Indices (JAI) for Blueback Herring and Alewife were calculated for the eleven core stations sampled from 1972 through 2020. Only the first sample of each month are use in the calculation.

During the ASMFC 2020 benchmark stock assessment for American Shad a combination of seine stations from the river herring survey (five stations) and the striped bass survey (nine stations), all samples, were selected to determine a juvenile abundance starting in 1996 (zero catches in 1995). A Zero-inflated Negative Binomial (ZINB) generalized linear model (GLM) model was determined as the best recommended predictor of relative annual abundance. Water temperature, salinity, month and cloud cover were all shown to significantly impact catch rates and presence. The best performing model was Counts ~ Year + water temperature + salinity | salinity + cloud cover + month.

Updates to annual trends in abundance are included here as arithmetic mean, in lieu of updating the ZINB model annually. Juvenile Abundance Indices (JAI) for American Shad were calculated for 14 stations sampled from 1996 through 2020.

One unit of effort is equal to one haul of the seine. Samples were sorted by species and 30 randomly selected individuals of each alosine species present were measured. Other species present were also noted. Water temperature, salinity, and other environmental characteristics were measured and recorded.

- Source: Previously, ASMFC North Carolina Shad and River Herring Compliance Report. In 2021, compliance report data reporting moved to a workbook format. Tables are updated below, but are no longer provided to the ASMFC in the body of the report.

Table 12. American Shad juvenile abundance index, from the 14 core stations, Albemarle Sound area, NC, 1972-2020.

| Year | # caught | # samples | JAI | SE | PSE |
|---|---|---|---|---|---|
| 1996 | 62 | 85 | 0.73 | 0.007 | 45 |
| 1997 | 43 | 85 | 0.51 | 0.005 | 42 |
| 1998 | 10 | 89 | 0.11 | 0.008 | 100 |
| 1999 | 19 | 86 | 0.22 | 0.006 | 71 |
| 2000 | 195 | 100 | 1.95 | 0.004 | 65 |
| 2001 | 35 | 99 | 0.35 | 0.006 | 55 |
| 2002 | 84 | 100 | 0.84 | 0.006 | 27 |
| 2003 | 752 | 100 | 7.52 | 0.008 | 26 |
| 2004 | 188 | 103 | 1.83 | 0.010 | 30 |
| 2005 | 203 | 99 | 2.05 | 0.007 | 33 |
| 2006 | 35 | 106 | 0.33 | 0.012 | 38 |
| 2007 | 2 | 105 | 0.02 | 0.004 | 70 |
| 2008 | 70 | 294 | 0.24 | 0.005 | 19 |
| 2009 | 129 | 167 | 0.77 | 0.006 | 29 |
| 2010 | 80 | 167 | 0.48 | 0.007 | 50 |
| 2011 | 134 | 157 | 0.85 | 0.008 | 28 |
| 2012 | 52 | 158 | 0.33 | 0.004 | 40 |
| 2013 | 97 | 157 | 0.62 | 0.005 | 35 |
| 2014 | 393 | 167 | 2.35 | 0.007 | 24 |
| 2015 | 391 | 158 | 2.47 | 0.006 | 26 |
| 2016 | 1,991 | 163 | 12.21 | 0.013 | 43 |
| 2017 | 203 | 167 | 1.22 | 0.007 | 31 |
| 2018 | 910 | 167 | 5.45 | 0.005 | 25 |
| 2019 | 1,163 | 158 | 7.36 | 0.008 | 59 |
| 2020 | 155 | 167 | 0.93 | 0.006 | 24 |

Table 1. Blueback Herring juvenile abundance index, from the 11 core stations, Albemarle Sound area, NC, 1972-2020.

| Year | # caught | # samples | JAI | PSE | Geo. Mean |
|---|---|---|---|---|---|
| 1972 | 4,166 | 13 | 320.46 | 95 | 8.63 |
| 1973 | 16,209 | 38 | 426.55 | 34 | 36.45 |
| 1974 | 3,008 | 48 | 62.67 | 33 | 7.90 |
| 1975 | 6,641 | 50 | 132.82 | 33 | 11.73 |
| 1976 | 7,755 | 47 | 165.00 | 73 | 5.27 |
| 1977 | 5,784 | 50 | 115.68 | 39 | 11.32 |
| 1978 | 4,626 | 49 | 94.41 | 29 | 8.16 |
| 1979 | 4,605 | 36 | 127.92 | 34 | 10.98 |
| 1980 | 11,111 | 46 | 241.54 | 54 | 16.38 |
| 1981 | 55 | 50 | 1.10 | 54 | 0.25 |
| 1982 | 3,541 | 49 | 72.27 | 39 | 7.58 |
| 1983 | 12,561 | 50 | 251.22 | 61 | 3.80 |
| 1984 | 1,038 | 52 | 19.96 | 42 | 1.81 |
| 1985 | 7,124 | 51 | 139.69 | 53 | 2.47 |
| 1986 | 758 | 55 | 13.78 | 64 | 1.16 |
| 1987 | 1,378 | 55 | 25.06 | 49 | 1.25 |
| 1988 | 602 | 52 | 11.58 | 54 | 0.95 |
| 1989 | 1 | 55 | 0.02 | 100 | 0.01 |
| 1990 | 505 | 55 | 9.18 | 47 | 0.99 |
| 1991 | 1,196 | 55 | 21.75 | 96 | 0.40 |
| 1992 | 51 | 55 | 0.93 | 92 | 0.10 |
| 1993 | 3,571 | 39 | 91.56 | 98 | 0.83 |
| 1994 | 0 | 32 | 0.00 | . | 0.00 |
| 1995 | 78 | 55 | 1.42 | 60 | 0.30 |
| 1996 | 827 | 55 | 15.04 | 72 | 1.09 |
| 1997 | 404 | 55 | 7.35 | 47 | 0.97 |
| 1998 | 24 | 55 | 0.44 | 69 | 0.13 |
| 1999 | 97 | 54 | 1.80 | 78 | 0.20 |
| 2000 | 85 | 55 | 1.55 | 47 | 0.39 |
| 2001 | 228 | 55 | 4.15 | 48 | 0.55 |
| 2002 | 43 | 55 | 0.78 | 51 | 0.22 |
| 2003 | 71 | 55 | 1.29 | 56 | 0.31 |
| 2004 | 815 | 55 | 14.82 | 51 | 1.17 |
| 2005 | 354 | 55 | 6.44 | 77 | 0.49 |
| 2006 | 28 | 55 | 0.51 | 86 | 0.10 |
| 2007 | 1 | 55 | 0.02 | 100 | 0.01 |
| 2008 | 143 | 55 | 2.60 | 100 | 0.09 |
| 2009 | 56 | 55 | 1.02 | 68 | 0.17 |
| 2010 | 30 | 55 | 0.55 | 93 | 0.09 |
| 2011 | 3 | 55 | 0.06 | 100 | 0.03 |
| 2012 | 30 | 55 | 0.55 | 74 | 0.10 |
| 2013 | 733 | 55 | 13.33 | 63 | 0.72 |
| 2014 | 100 | 55 | 1.82 | 92 | 0.15 |
| 2015 | 298 | 55 | 5.42 | 59 | 0.56 |
| 2016 | 0 | 55 | 0.00 |  | 0.00 |
| 2017 | 206 | 56 | 3.68 | 74 | 0.27 |
| 2018 | 53 | 55 | 0.96 | 96 | 0.10 |
| 2019 | 1,783 | 54 | 33.02 | 51 | 2.56 |
| 2020 | 223 | 55 | 4.06 | 91 | 0.19 |

Table 2. Alewife juvenile abundance index, from the 11 core stations, Albemarle Sound area, NC, 1972-2020.

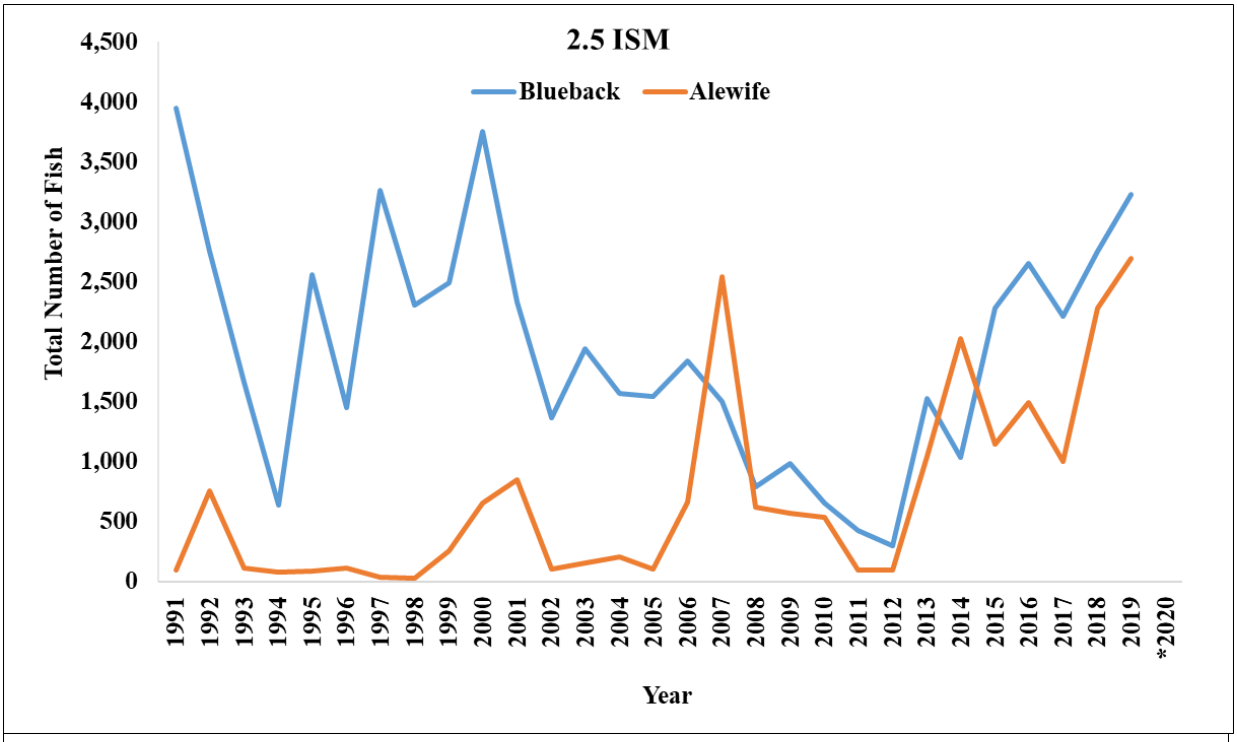
| Year | # caught | # samples | JAI | PSE | Geo. Mean |
|---|---|---|---|---|---|
| 1972 | 64 | 13 | 4.92 | 95 | 0.53 |
| 1973 | 320 | 39 | 8.21 | 52 | 0.76 |
| 1974 | 49 | 48 | 1.02 | 39 | 0.37 |
| 1975 | 410 | 50 | 8.20 | 68 | 0.71 |
| 1976 | 64 | 47 | 1.36 | 51 | 0.38 |
| 1977 | 391 | 50 | 7.82 | 42 | 1.66 |
| 1978 | 608 | 51 | 11.92 | 27 | 2.49 |
| 1979 | 160 | 36 | 4.44 | 64 | 1.03 |
| 1980 | 633 | 47 | 13.47 | 50 | 1.85 |
| 1981 | 249 | 50 | 4.98 | 96 | 0.26 |
| 1982 | 28 | 49 | 0.57 | 29 | 0.32 |
| 1983 | 105 | 50 | 2.10 | 68 | 0.36 |
| 1984 | 38 | 52 | 0.73 | 45 | 0.25 |
| 1985 | 200 | 51 | 3.92 | 72 | 0.46 |
| 1986 | 131 | 56 | 2.34 | 50 | 0.58 |
| 1987 | 1 | 55 | 0.02 | 100 | 0.01 |
| 1988 | 10 | 52 | 0.19 | 59 | 0.09 |
| 1989 | 3 | 55 | 0.05 | 74 | 0.03 |
| 1990 | 33 | 55 | 0.60 | 94 | 0.09 |
| 1991 | 0 | 55 | 0.00 | | 0.00 |
| 1992 | 1 | 55 | 0.02 | 100 | 0.01 |
| 1993 | 0 | 39 | 0.00 | | 0.00 |
| 1994 | 0 | 32 | 0.00 | | 0.00 |
| 1995 | 8 | 55 | 0.15 | 100 | 0.04 |
| 1996 | 219 | 55 | 3.98 | 37 | 0.86 |
| 1997 | 1 | 55 | 0.02 | 100 | 0.01 |
| 1998 | 69 | 55 | 1.25 | 75 | 0.17 |
| 1999 | 16 | 54 | 0.30 | 58 | 0.14 |
| 2000 | 23 | 55 | 0.42 | 45 | 0.19 |
| 2001 | 289 | 55 | 5.25 | 83 | 0.41 |
| 2002 | 7 | 55 | 0.13 | 50 | 0.08 |
| 2003 | 81 | 55 | 1.47 | 40 | 0.42 |
| 2004 | 115 | 55 | 2.09 | 58 | 0.40 |
| 2005 | 48 | 55 | 0.87 | 82 | 0.16 |
| 2006 | 1 | 55 | 0.02 | 100 | 0.01 |
| 2007 | 4 | 55 | 0.07 | 79 | 0.04 |
| 2008 | 0 | 55 | 0.00 | | 0.00 |
| 2009 | 0 | 55 | 0.00 | | 0.00 |
| 2010 | 227 | 55 | 4.13 | 40 | 0.67 |
| 2011 | 44 | 55 | 0.80 | 62 | 0.17 |
| 2012 | 38 | 55 | 0.69 | 44 | 0.24 |
| 2013 | 525 | 55 | 9.55 | 46 | 0.78 |
| 2014 | 0 | 55 | 0.00 | | 0.00 |
| 2015 | 392 | 55 | 7.13 | 63 | 0.40 |
| 2016 | 21 | 55 | 0.38 | 56 | 0.13 |
| 2017 | 46 | 55 | 0.84 | 82 | 0.13 |
| 2018 | 329 | 55 | 5.98 | 58 | 0.51 |
| 2019 | 4 | 54 | 0.07 | 70 | 0.04 |
| 2020 | 0 | 55 | 0.00 | | 0.00 |

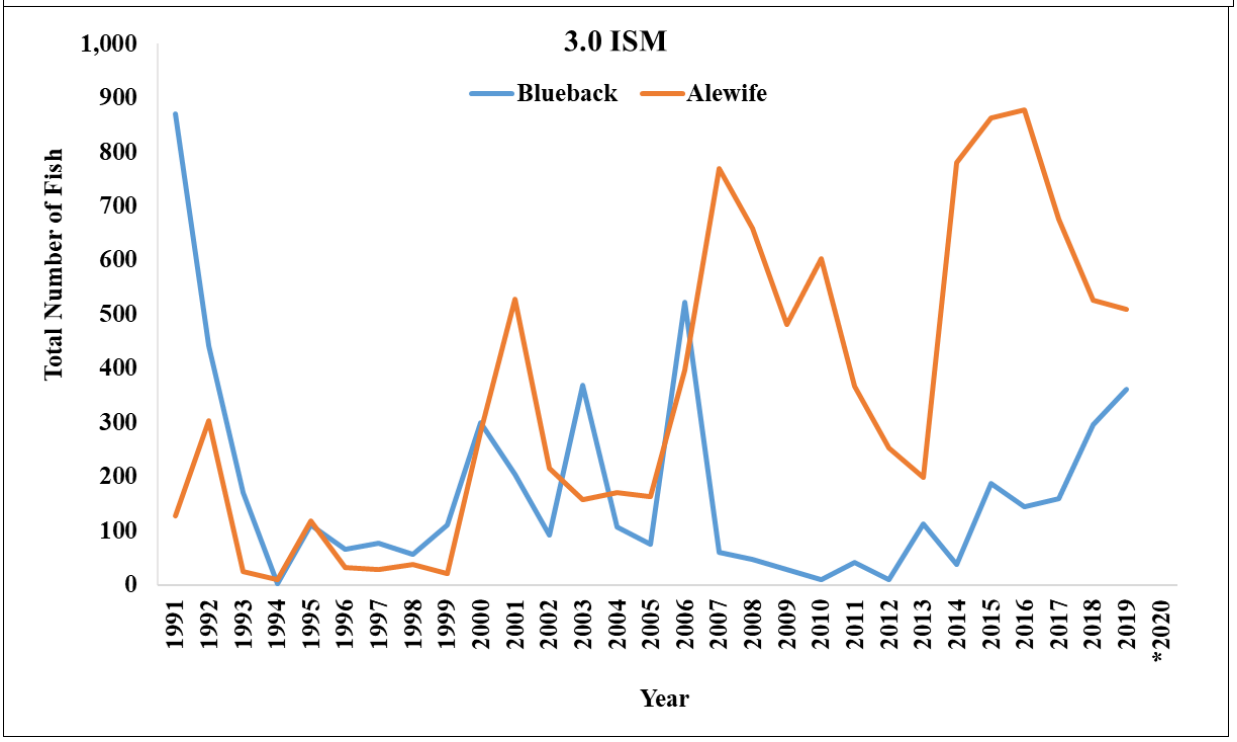
Description of work: Albemarle Sound Independent Gill Net Survey

Since 1990, DMF has been conducting an independent gill net survey (IGNS) throughout the Albemarle Sound area. The survey was designed for Striped Bass data collection, however, American Shad are captured during the survey and size, age, and sex data are collected. American shad are aged using the scale-age method. This method applies to all American shad ages reported by the DMF. Gill net mesh sizes from 2.5 through 7.0 ISM in half-inch increments and 8.0 and 10.0 ISM in whole mesh increments are utilized. The Albemarle Sound IGNS is conducted from November through May, but results for shad and river herring are only reported for January through May, for gill net mesh 2.5 and 3.0, because catches of these fish at other times and larger gill net mesh are rare. Areas fished, sampling effort and sampling frequency vary seasonally. Each unit of effort is one 40-yard net, fished for 24-hours. Gill nets are fished in 40-yard shots totaling 960 yards per set. A total of 2,778 units of effort were completed in 2019, for January through May.

During 2020 no index of abundance is available for river herring from the NCDMF Albemarle Sound IGNS. Sampling in 2020 was impacted by the COVID pandemic. Executive Order (EO) 116, issued on March 10, 2020, declared North Carolina under a State of Emergency and was soon followed by EO 120 which implemented a statewide Stay at Home Order for all non-essential State employees. Sampling is expected to resume in 2021.

- Source: NCDMF 2020 FMP Update for River Herring and previously ASMFC Compliance Report (consistent with table in Stock Assessment) as replacement for this table.
- Total number of river herring from the NC Albemarle Sound independent gill net survey, 1991-*2020. *January-February sampling only, not sufficient to determine index for 2020.


2.5 ISM
Blueback
Alewife
Total Number of Fish
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 *2020
Year


3.0 ISM
Blueback
Alewife
Total Number of Fish
1,000
900
800
700
600
500
400
300
200
100
0
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 *2020
Year

- Total number of river herring from the NC Albemarle Sound independent gill net survey, 1991-2020.

| | 2.5 ISM | | 3.0 ISM | |
|---|---|---|---|---|
| Year | Blueback | Alewife | Blueback | Alewife |
| 1991 | 3,946 | 95 | 871 | 127 |
| 1992 | 2,756 | 753 | 441 | 303 |
| 1993 | 1,667 | 115 | 171 | 24 |
| 1994 | 637 | 84 | 1 | 9 |
| 1995 | 2,561 | 89 | 111 | 118 |
| 1996 | 1,449 | 118 | 65 | 32 |
| 1997 | 3,261 | 35 | 77 | 29 |
| 1998 | 2,308 | 27 | 56 | 37 |
| 1999 | 2,489 | 260 | 111 | 21 |
| 2000 | 3,750 | 657 | 299 | 282 |
| 2001 | 2,330 | 852 | 204 | 528 |
| 2002 | 1,366 | 105 | 91 | 216 |
| 2003 | 1,944 | 152 | 368 | 158 |
| 2004 | 1,568 | 208 | 106 | 171 |
| 2005 | 1,542 | 104 | 75 | 163 |
| 2006 | 1,839 | 663 | 522 | 397 |
| 2007 | 1,506 | 2,540 | 60 | 770 |
| 2008 | 787 | 624 | 46 | 658 |
| 2009 | 982 | 569 | 29 | 481 |
| 2010 | 659 | 541 | 10 | 603 |
| 2011 | 424 | 100 | 41 | 366 |
| 2012 | 297 | 96 | 10 | 252 |
| 2013 | 1,529 | 1,047 | 113 | 199 |
| 2014 | 1,040 | 2,029 | 37 | 781 |
| 2015 | 2,283 | 1,150 | 187 | 863 |
| 2016 | 2,657 | 1,492 | 145 | 877 |
| 2017 | 2,213 | 1,002 | 160 | 675 |
| 2018 | 2,759 | 2,279 | 295 | 526 |
| 2019 | 3,228 | 2,693 | 362 | 509 |
| *2020 | 83 | 300 | 9 | 478 |

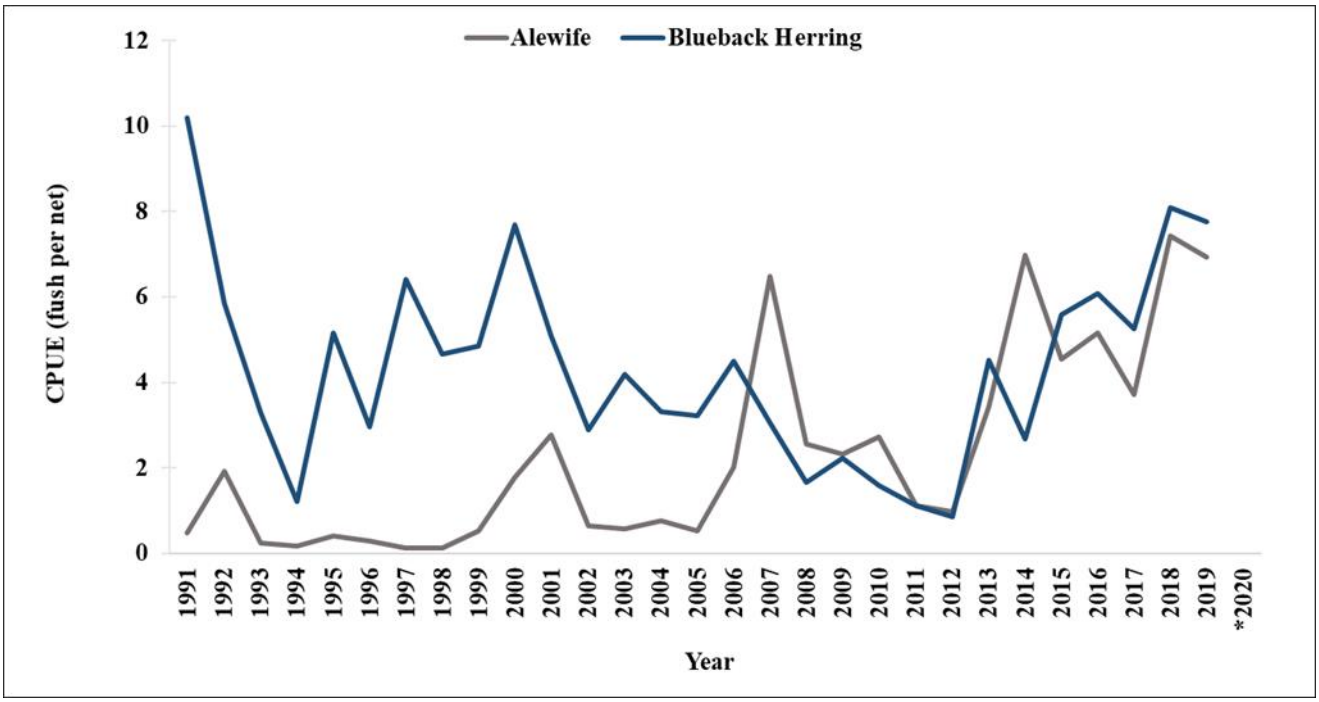
*January-February sampling only, not sufficient to determine index for 2020.

- River herring CPUE from the Albemarle Sound independent gill net survey (2.5 and 3.0 ISM combined), 1991-2020. *January-February sampling only, not sufficient to determine index for 2020.
- Source: NCDMF 2020 FMP Update for River Herring

| Alewife | | | | | Blueback Herring | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Effort | Sum | CPUE | PSE | Year | Effort | Sum | CPUE | PSE |
| 1991 | 472 | 222 | 0.47 | 16 | 1991 | 472 | 4,817 | 10.21 | 15 |
| 1992 | 548 | 1,056 | 1.93 | 18 | 1992 | 548 | 3,197 | 5.83 | 13 |
| 1993 | 558 | 139 | 0.25 | 27 | 1993 | 558 | 1,838 | 3.29 | 16 |
| 1994 | 527 | 93 | 0.18 | 22 | 1994 | 527 | 638 | 1.21 | 20 |
| 1995 | 517 | 207 | 0.40 | 17 | 1995 | 517 | 2,672 | 5.17 | 19 |
| 1996 | 512 | 150 | 0.29 | 59 | 1996 | 512 | 1,514 | 2.96 | 17 |
| 1997 | 521 | 64 | 0.12 | 19 | 1997 | 521 | 3,338 | 6.41 | 17 |
| 1998 | 506 | 64 | 0.13 | 16 | 1998 | 506 | 2,364 | 4.67 | 17 |
| 1999 | 536 | 281 | 0.52 | 42 | 1999 | 536 | 2,600 | 4.85 | 16 |
| 2000 | 525 | 938 | 1.79 | 15 | 2000 | 525 | 4,039 | 7.69 | 15 |
| 2001 | 498 | 1,380 | 2.77 | 11 | 2001 | 498 | 2,534 | 5.09 | 15 |
| 2002 | 505 | 321 | 0.64 | 11 | 2002 | 505 | 1,457 | 2.89 | 17 |
| 2003 | 552 | 310 | 0.56 | 13 | 2003 | 552 | 2,312 | 4.19 | 15 |
| 2004 | 504 | 379 | 0.75 | 12 | 2004 | 504 | 1,674 | 3.32 | 17 |
| 2005 | 503 | 267 | 0.53 | 12 | 2005 | 503 | 1,617 | 3.21 | 20 |
| 2006 | 526 | 1,060 | 2.02 | 11 | 2006 | 526 | 2,361 | 4.49 | 12 |
| 2007 | 511 | 3,310 | 6.48 | 11 | 2007 | 511 | 1,566 | 3.06 | 14 |
| 2008 | 499 | 1,282 | 2.57 | 10 | 2008 | 499 | 833 | 1.67 | 17 |
| 2009 | 452 | 1,050 | 2.32 | 10 | 2009 | 452 | 1,011 | 2.24 | 15 |
| 2010 | 419 | 1,144 | 2.73 | 14 | 2010 | 419 | 669 | 1.60 | 16 |
| 2011 | 418 | 466 | 1.11 | 14 | 2011 | 418 | 465 | 1.11 | 17 |
| 2012 | 355 | 348 | 0.98 | 13 | 2012 | 355 | 307 | 0.86 | 18 |
| 2013 | 363 | 1,246 | 3.43 | 18 | 2013 | 363 | 1,642 | 4.52 | 16 |
| 2014 | 402 | 2,810 | 6.99 | 15 | 2014 | 402 | 1,077 | 2.68 | 18 |
| 2015 | 443 | 2,013 | 4.54 | 11 | 2015 | 443 | 2,470 | 5.58 | 20 |
| 2016 | 460 | 2,369 | 5.15 | 11 | 2016 | 460 | 2,802 | 6.09 | 15 |
| 2017 | 451 | 1,677 | 3.72 | 10 | 2017 | 451 | 2,373 | 5.26 | 15 |
| 2018 | 377 | 2,805 | 7.44 | 19 | 2018 | 377 | 3,054 | 8.10 | 14 |
| 2019 | 462 | 3,202 | 6.93 | 13 | 2019 | 462 | 3,590 | 7.77 | 16 |
| *2020 | 145 | 778 | | | *2020 | 145 | 92 | | |

*January-February sampling only, not sufficient to determine index for 2020.

- January-May adult river herring index of abundance (2.5 and 3.0 inch stretch mesh) from the North Carolina Albemarle Sound independent gill net survey 1991-2020. *January-February sampling only, not sufficient to determine index for 2020.
- Source NCDMF 2020 FMP Update for River Herring



# Monitoring the Abundance of American Shad and River Herring in Virginia's Rivers

## 2020 Annual Report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| | |
|---|---|
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**Summary**

- This report describes the results of the twenty-third year of a continuing study to estimate the relative abundance and assess the status of American shad (*Alosa sapidissima*) stocks in Virginia by monitoring the spawning runs in the James, York and Rappahannock rivers in spring 2020, evaluating hatchery programs, and contributing to coast-wide assessments (ASMFC 2007, ASMFC 2020). We also report on two fishery-independent monitoring programs using anchor gillnets in the Rappahannock River (year 3) and the Chickahominy River (year 6; a major tributary of the James River), to determine relative abundance and stock structure for the adult spawning run of river herring (*A. pseudoharengus*, and *A. aestivalis*). Further, we report on the year 5 of a monitoring program for juvenile alosines by using nighttime surface trawls in the Chickahominy River and present an index of juvenile abundance from this survey. Additional objectives were to monitor bycatch of American shad in a permitted gill-net fishery and American shad and river herring in pound-net fisheries.
- Sampling for American shad occurred for eight weeks on the James River (5 March to 23 April 2020), thirteen weeks on the Rappahannock River (1 March to 23 May 2020), and six weeks on the York River (2 March to 6 April 2020). Three post-spawning American shad were observed on the Rappahannock River. No post-spawning fish were observed on the James or York rivers in 2020. Only pre-spawning females were included in the calculation of catch indices for each river. A total of 337 pre-spawning female American shad (466.8 kg total weight) were captured; this is an increase in number from the 2019 catch (154 pre-spawning females; 207.9 kg total weight).
- Total numbers and weights of pre-spawning female American shad in 2020 were highest on the Rappahannock River (n=310, 429.0 kg). Numbers of females were lower on the York River (n=21, 30.6 kg). The lowest catches of females were recorded on the James River (n=6, 7.2 kg). Numbers of males captured were: Rappahannock, 72; James, 0; York, 2. Total weight of males captured on all rivers was 86.8 kg. The total catch and weight of males were higher than in 2019 (n=9, 10.1 kg).
- Based on age estimates from scales, the 2014 (age 6) year class of female American shad were the most abundant on all rivers. Total instantaneous mortality rates of females calculated from age-specific catch rates were: James River, 0.88 ($r^2$=1.00); York River, 0.65 ($r^2$=1.0); and Rappahannock River, 1.17 ($r^2$=0.99). Total instantaneous mortality rates of males were not calculated because all year classes present were not equally catchable by the sampling gear.
- Otoliths of 4 American shad captured on the James River were scanned for hatchery marks. The proportion of the sample with hatchery marks on the James River was 25.0% (1 of 4 fish). Otoliths of 93 American shad captured on the Rappahannock River were scanned for hatchery marks. The presence of hatchery fish on the Rappahannock River was 4.3% (4 of 93 fish). On the York River, there is currently no stocking of hatchery fish, and no specimens were examined from the York River in 2020.
- The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2020 was: James River (including Chickahominy River), 0 (NA, 56); Chickahominy River, 0 (NA,

8); Rappahannock River, 8.13 (1.29, 32); York River (including Mattaponi and Pamunkey Rivers), 0.36 (0.62, 81); Mattaponi River, 0.73 (0.78, 42); and Pamunkey River, 0.06 (0.20, 34).

- Eleven species of fishes (total of 2,944 specimens) were counted as bycatch in the staked gill net monitoring gear. The total number of striped bass counted was 408 (James River, n=55; York River, n=19; Rappahannock River, n=334). Live striped bass captured in the gear were counted and released. A random subsample of dead striped bass was brought back to the laboratory for analysis. Sex, fork length, and total weight were recorded for each specimen. The proportions of dead striped bass on each river were: James River, 69.1%; York River, 26.3%; and the Rappahannock River, 55.1%.
- Seven Atlantic sturgeon were captured as bycatch in the American shad sampling (James River, n=0; York River, n= 1; Rappahannock River, n=6).
- A seasonal catch index for American shad was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2020 and for each year of the historical record of staked gill net catches on each river.
    - On the York River, the seasonal catch index in 2020 (0.75) decreased from the 2019 value (2.39). This is the lowest value of the 23-year time series. The geometric mean of the historical data during the 1980s on the York River is 3.22. The geometric mean of the current monitoring data is higher (4.01) but this mean is lower than the geometric mean of catch indexes from logbook records in the 1950s (17.44). These older data were adjusted for differences in the efficiency of multifilament and monofilament nets using the results of comparison trials in 2002 and 2003.
    - On the James River, the 2020 index (0.25) decreased from the 2019 value of 0.35. This is the lowest value of the 23-year time series. The geometric mean of the historical data during the 1980s on the James River is 6.40. The geometric mean of the current monitoring data is 3.06. In 2019 the hatchery prevalence was 28.6%. A correlation analysis among the catch index and hatchery prevalence from 1998-2019 was statistically significant ($r = 0.51$, df = 20, $p = 0.02$). The strength of the spawning run index on the James River continues to depend heavily on the presence of hatchery fish.
    - The catch index on the Rappahannock River in 2020 (10.62) increased from the 2019 value (3.01). With the exception of 2016 and 2019, since 2011 the annual index value has been above 4.0, with the highest value of the time series occurring in 2020. The geometric mean of the historical data during the 1980s on the Rappahannock River is 1.45. The geometric mean of the current monitoring data is higher (4.05).
- In 2020, gillnet sampling for river herring in the Chickahominy River occurred for nine weeks (29 January 2020 to 24 March 2020). The field season concluded early due to health concerns for personnel related to COVID-19. A catch index for pre-spawning alewife and blueback herring was calculated for each species. Catches of alewife peaked 3 March. After 11 March, post-spawning alewives were present in the sample. Catches of blueback herring peaked on 24 March, but this may not reflect the true peak due to the early cessation of

sampling. No post-spawning blueback herring were present in the sample. A total of 477 alewife (175 males; 294 pre-spawning females; 8 post-spawned females) and 114 blueback herring (50 males; 64 pre-spawning females; 0 post-spawned female) were captured.

- Using otolith-based ageing methods, the 2015-year class (age 5) of both female alewife and female blueback herring were dominant. The total instantaneous mortality rate of female alewife was 1.26. Total instantaneous mortality rate of female blueback herring was 1.12.

- The 2020 anchor gillnet seasonal catch indexes on the Chickahominy River, calculated by area under the CPUE curve: alewife, 1.54; blueback herring, 0.67. The index values were higher for alewife and blueback herring compared to the index values in 2019 (alewife, 0.44; blueback herring, 0.25).

- In 2020, the gillnet sampling season for river herring in the Rappahannock River occurred for eight weeks (4 February 2020 to 23 March 2020). The field season concluded early due to health concerns for personnel related to COVID-19. A total of 281 alewife (121 males; 159 pre-spawning females; 1 post-spawned female) and 133 blueback herring (53 males; 80 pre-spawning females; 0 post-spawned females) were captured. After 16 March, post-spawning alewives were present in the sample. Catches of alewife peaked on 16 March. Catches of blueback herring peaked on 23 March, but this may not reflect the true peak due to the early cessation of sampling.

- Using otolith-based ageing methods, the 2015-year class (age 5) of both female alewife and female blueback herring was dominant. The total instantaneous mortality rate of female alewife was 1.37. Total instantaneous mortality rate of female blueback herring was 0.66.

- The 2020 anchor gillnet seasonal catch indexes on the Rappahannock River, calculated by area under the CPUE curve: alewife, 1.85; blueback herring, 1.25. The index value for blueback herring was impacted by halting sampling during the peak of the run due to COVID-19. The index values were higher for alewife and lower for blueback herring compared to the index values in 2019 (alewife, 0.97; blueback herring, 3.08).

- The geometric mean catch (followed by standard deviation or and number of seine hauls in parentheses) of juvenile alewife captured in daylight seine hauls in 2020 was: James River, 0 (NA, 9); York River, 0 (NA, 55); Rappahannock River, 0.10 (0.32, 37). The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile blueback herring captured in daylight seine hauls in 2020 was: James River, 0.56 (1.40, 38); York River, 0.30 (0.88, 35); Rappahannock River, 0.99 (1.21, 22).

- Catches in nighttime surface trawls on the Chickahominy River in 2020, were dominated by blueback herring (total alewife = 29; total blueback herring = 8,301). The 2020 seasonal catch index (geometric mean of CPUE) was 40.8 (cruise specific catch index ranged from 19.3 – 64.3) for blueback herring. Mean fish/tow and seasonal catch index were not reported for alewife due to low catches at each sampling station.

## Preface

Concern about the decline in landings of American shad (*Alosa sapidissima*) along the Atlantic coast prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Management Program (ASMFC 1999). Similarly, as early as the 1970s a substantial decline in the stocks of river herring coast wide was noted, and resulted in the ASMFC to require moratoria on fisheries unless stocks within a jurisdiction were shown to be sustainable (ASMFC 2009). Legislation enables imposition of federal sanctions on fishing in those states that fail to comply with the FMPs. To be in compliance, coastal states are required to implement and maintain fishery-dependent and fishery-independent monitoring programs as specified by the FMPs. For Virginia, these requirements for American shad and river herring include spawning stock assessments, the collection of biological data on the spawning run (e.g., age-structure, sex ratio, and spawning history), estimation of total mortality, indices of juvenile abundance, biological characterization of permitted bycatch and evaluation of restoration programs by detection and enumeration of hatchery-released fish for American shad.

This annual report documents continued compliance with Federal law. Since 1998, scientists at the Virginia Institute of Marine Science have monitored the spawning run of American shad in the James, York and Rappahannock rivers. The information resulting from this program is reported annually to the ASMFC, has formed the basis for a significant number of technical papers published in the professional literature, formed the basis for a recent coast-wide stock assessment and peer review for American shad (ASMFC 2007a, 2007b) and is contributing substantially to our understanding of the status and conservation of this important species.

A number of individuals make significant contributions to the monitoring program and the preparation of this report. Commercial fishermen Raymond Kellum, Steve Kellum, George Trice, Hunter Sanders, and Jamie Sanders construct, set, and fish the sampling gear and offer helpful advice. They have participated in the sampling program since its beginning in 1998. Their contributions as authors of historic log books of commercial catches during the 1980s and as expert shad fishermen are essential elements of the monitoring program. We also extend our appreciation to several commercial fishers for their cooperation in our studies of bycatch of American Shad. In 2020, these individuals include: John Augustine, JC West, George Trice, John Dryden, RT Croswell, Walter Rogers, Karl Vandergrift, Gary Waxmunski, and Bobby Weagley. In 2020, the staff of the Virginia Institute of Marine Science who participated in the program were: B. Watkins, A. Magee, P. McGrath, and S. Muffelman. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. B. Watkins determined ages of adult shad. P. McGrath determined ages of adult river herring. B. Watkins determined hatchery origins of adult fish. Fish products from this program are donated to the Food Bank at Gleaning Baptist Church of Gloucester, Virginia. We offer thanks to the Hunters for the Hungry (Virginia Hunters Who Care) organization for their assistance.

## Introduction

This report describes the results of a continuing study to estimate the relative abundance and assess the status of American shad (*Alosa sapidissima*) stocks in Virginia by monitoring the spawning runs in the James, York and Rappahannock rivers in spring 2020, evaluating hatchery programs and contributing to coast-wide assessments (ASMFC 2007a; ASMFC 2020). We also report on a relatively new aspect of this program: a fishery-independent monitoring program to determine abundance and stock structure of river herring (*A. pseudoharengus*, and *A. aestivalis*) in Virginia by evaluating the adult spawning runs in the Chickahominy River, a major tributary of the James River, and the Rappahannock River. Further, a recently added objective of this study was to complement the monitoring of the adult spawning population of American shad and river herring in the James River system by monitoring juvenile alosines by using nighttime surface trawls in the Chickahominy River and calculate an index of juvenile abundance. Additional objectives were to monitor bycatch of American shad in a permitted gillnet fishery and American shad and river herring in pound net fisheries.

**American shad.** 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, especially in the York River. Data from the commercial fishery were the best available for assessing the status of individual stocks. Catch-per-unit-effort data were compiled from logbooks that recorded landings by commercial fishermen using staked gillnets 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) (Crecco 1998, ASMFC 1998, Olney & Hoenig 2001a).

Prior to 1998, there were no existing monitoring programs that provided direct assessment of American shad stock recovery in Virginia. The ban on in-river fishing 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 be lifted safely. To address this deficiency, VIMS initiated scientific monitoring to estimate catch rates relative to those recorded before the prohibition of in-river fishing in 1994 (Olney & Hoenig 2001a). 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 eight years of monitoring (1998-2005) formed the basis for recent stock assessments for American shad (ASMFC 2007; 2020). The conclusions of the 2007 assessment were that the James River stock remains at a low level of abundance and requires further protection and restoration; the Rappahannock River stock is stable with recent evidence of increasing abundance; in the York River, catch indexes have been trending downward but there is evidence of some recovery from the severe declines in the 1980s. The conclusions related to the adult mortality and abundance of American shad in Virginia's rivers resulting from the 2020 assessment were as follows: for the Rappahannock River and York River, mortality was considered sustainable, although no trend in abundance was detected since the 2007 assessment; and for the James River adult mortality was unknown (for the last three-year period mortality could be calculated, this was

considered sustainable), but as for the other rivers, there was no trend in adult abundance. Since 2017 (the last year of monitoring data to be incorporated into the 2020 assessment), catch indexes have remained at low levels in both the James and York rivers. The VMRC has not lifted the ban on recreational or commercial fishing, and asked that the monitoring program be continued.

**River herring.** River herring, including alewife (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*), were once the most valuable food fishes in Virginia (Atran et al. 1983). These species experienced decline in their value to the fisheries resources of Virginia, and as early as the 1970s a significant decline in the stocks of these fishes was noted. This range-wide decline of stocks culminated in the ASMFC requiring moratoria on fisheries unless stocks within a jurisdiction were shown to be sustainable (ASMFC 2009). Due in part to lack of available data to address the question of sustainability of river herring stocks in the Commonwealth, the VMRC implemented a ban on the possession of alewife and blueback herring to begin January 1, 2012. The ASMFC conducted a stock assessment for river herring that was completed in 2012 (ASMFC 2012), and which concluded that stocks coast-wide are at or near historically low levels. Due to this observed decline of river herring range-wide, the National Marine Fisheries Service (NMFS) received a petition from the Natural Resources Defense Council (NDRC) on August 5, 2011 (Federal Register, vol. 76, no. 212, Nov. 2, 2011) to list river herring, inclusive of both species, as Threatened under the Endangered Species Act (ESA). Although listing was not found to be warranted at the present time (Federal Register, vol. 78, no. 155, Aug. 8, 2013), this process highlighted the need for further data collection for many stocks of river herring, including those in Virginia.

**General alosine information needs.** In addition, there are other significant information needs relevant to American shad, river herring, or both in Virginia:

1. Extensive efforts are being made to rehabilitate the stocks of American shad through release of hatchery-raised fish. Evaluating the success of these programs is an ASMFC mandate and requires determination of the survival of the stocked fish to adulthood.
2. VMRC specifies a bycatch allowance of American shad in certain commercial fisheries. Bycatch of American shad currently exists in the Virginia commercial striped bass fishery, where mortality is presumed to be high. The VMRC regulation permits a limited number of commercial fishers to utilize this bycatch by selling fish in certain regions of each river. The ASMFC requires monitoring the biological characteristics, hatchery prevalence and magnitude of this harvest.
3. There is a need to evaluate mixed stock contributions to the pound net bycatch in Virginia's portion of Chesapeake Bay. Preliminary evidence using hatchery marks confirms that this bycatch includes adult shad from upper Bay stocks (Hoenig et al. 2008). Geochemical signatures in otoliths can be used to determine natal origins of American shad and estimate mixed stock contributions. This powerful technique has been validated in a recent study by Walther et al. (2008).
4. By the Treaty of 1677, Virginia tribal governments exercise their fishing rights in the York River and elsewhere. Brood stock is collected to support the activities of hatcheries on the Pamunkey and Mattaponi rivers. The total harvest of American shad is currently unknown but believed to be small. Detailed information concerning this harvest and its characteristics could aid future stock assessments.

The ongoing monitoring of American shad and river herring in Virginia waters is directly significant to recreational fisheries and the ecological health of the river systems that support these important fisheries for at least five reasons:

1. American shad fight well when angled using light tackle and were pursued by recreational fishermen in Virginia in the past, but the extent and success of this activity is not easily assessed. Recreational fishers catch and release shad on the James, Rappahannock, Mattaponi, Piankatank and Nottaway rivers; under moratorium, fishermen are not permitted to keep these fish. A recreational shad fishery in Virginia would constitute an important opportunity to expand or restore recreational fishing opportunities if the Chesapeake stocks are rehabilitated and managed carefully.
2. Until the moratorium took effect in 2012, river herring were recreationally harvested in Virginia's rivers. Lack of scientific data on the status of river herring stocks has been cited as a contributing factor for the inability to determine the sustainability of the stocks in Virginia, which led to the moratorium. This study addresses that shortcoming with the goal of informing management agencies for the objective of rebuilding river herring stocks to lift the moratorium.
3. American shad and river herring 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 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.
4. This study characterizes the bycatch associated with commercial fisheries for American shad and river herring in Virginia's rivers. This is important for determining the impact of reopened commercial fisheries for shad and river herring on other recreationally important species, especially striped bass, as well as protected species such as Atlantic sturgeon.
5. Considerable effort and sport fishing funds have been devoted to enhancement of shad stocks through hatchery programs. This monitoring program provides an opportunity to identify returning hatchery fish. This is important for determining benefits to recreational fishers from the program. From 2004 until 2014, a hatchery-release program for American shad began on the Rappahannock River. This restoration effort is designed specifically for enhancement of recreational fishing and restoration of historic spawning habitat.

## Background

American shad and river herring have supported recreational and commercial fisheries along the east coast of the United States and within the Chesapeake Bay since colonial times. Here we provide a brief review of the status and current regulations for American shad and river herring. See Atran et al. (1983), Loesch and Atran (1994), and Hilton et al. (2013) for further background on the stocks, fisheries, and management of these fishes in Virginia.

**American shad.** Concern about the significant decline in landings of American shad along the Atlantic coast prompted the development of an interstate fisheries management plan under the auspices of the ASMFC (ASMFC 1999). Prior to 1991, there were no restrictions on the American shad commercial fishery in Virginia's rivers and the Chesapeake Bay. A limited season (4 Feb - 30 Apr) 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 Mar - 15 Apr 1993). However, due to bad weather conditions, the season was extended through 30 Apr. A complete moratorium was established in 1994.

In 1997 and 1998, during a series of public hearings, commercial and recreational fishing interests asked that the in-river ban on shad fishing be lifted. This proposal was opposed by the VMRC staff, VIMS fishery scientists, 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. The initial results of the program provided the basis for the Commission to uphold the ban in December, 1998. The VMRC requested that VIMS continue its monitoring and stock assessment activities.

In 2003 and again in 2005, the ASMFC shad and river herring technical committee considered VMRC proposals for allowance of shad caught as bycatch. VMRC proposed to permit Virginia fishermen to retain American shad, caught as bycatch in Chesapeake Bay and tributary waters. The technical committee did not support either proposal. Members expressed concerns that the proposals included the catches of mixed stocks, had the potential to harvest substantial number of fish, and had the potential to impact other stocks which are under intensive restoration. A modified version of the 2006 proposal was subsequently approved by the Shad and River Herring Management Board. Since this date, bycatch allowances have been continually approved by the Management Board. In addition, VIMS has monitored bycatch of American shad in pound nets located off Reedville, Virginia annually since 2002, and at the mouth of the Rappahannock River since 2007. In this program, samples of up to 50 American shad are collected and returned to VIMS for biological analysis.

The current regulation (effective date January 1, 1994) states that: "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 4 VAC 20-530-10 ET SEQ) except as specified, related to a bycatch fishery allotment (as amended March 1, 2013).

Under Amendment 3 of the Interstate Fishery Management Plan for American Shad and River Herring (ASMFC 2010), Virginia is mandated to conduct the following, for the Rappahannock, York, and James rivers:

1) Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex;

2) composition of the spawning stock;
3) calculation of mortality and/or survival estimates where possible;
4) juvenile abundance survey (GM);
5) hatchery evaluation.

**River herring.** The most recent stock assessment for river herring concluded that stocks coast wide are severely depleted (ASMFC 2017). As early as the 1970s a substantial decline in the stocks of river herring coast wide was noted, and resulted in the ASMFC to require moratoria on fisheries unless stocks within a jurisdiction were shown to be sustainable (ASMFC 2009). Due in part to lack of available fishery-independent data to address the question of sustainability of river herring stocks in the Commonwealth, the VMRC voted to implement a ban on the possession of alewife and blueback herring to begin January 1, 2012.

The current regulation (effective date January 1, 2012) states, in part, that "It shall be unlawful for any person to catch and retain possession of any river herring from Virginia tidal waters." (VMRC Regulation 4 VAC-20-1260-30).

Amendment 2 of the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2009: table 15) mandates the following fishery-independent monitoring of river herring in Virginia (including the James, York, and Rappahannock rivers):

1) Annual spawning stock survey and representative sampling for biological data (excluding York River);
2) calculation of mortality and/or survival estimates;
3) calculation of juvenile abundance indices (JAI) as a geometric mean.

## Current Information

Historic and current catch data can be accessed through the VMRC website (http://www.mrc.state.va.us). Annual monitoring of the abundance of juvenile *Alosa* spp. (American shad, hickory shad, blueback herring and alewife) was conducted on the York River system with a push net developed in the late 1970s (Kriete and Loesch, 1980) until 2002. The data record extends back to 1979 but sampling was not conducted during 1987-1990. The push net survey was terminated in 2002 when it was determined that the survey results were highly correlated with those of the striped bass seine survey (Wilhite et al., 2003). Although fewer individual fish are collected each year in the seine survey as compared to the evening push net survey, the seine survey has larger geographic coverage (all three rivers in Virginia vs. the Mattaponi and Pamunkey Rivers only) and the data record is uninterrupted since 1979. A fishery-independent survey program for monitoring the spawning stocks of river herring in Virginia employing a drift gillnet was implemented on the Chickahominy River from 2014 to 2016. In 2015, an anchor gillnet fishery-independent survey was also implemented on the Chickahominy River to monitor the spawning stocks of river herring. Currently, there is a moratorium on both river herring species (i.e., no fishery-dependent data are available).

Since the alosine monitoring program at VIMS began in 1998, 27 papers on various aspects of the biology of American shad and the VIMS stock assessment program have appeared in peer-reviewed journals (Maki et al., 2001; Olney et al., 2001; Olney and Hoenig, 2001a; Maki et al., 2002; Bilkovic et al., 2002a, 2002b; Olney and McBride, 2003; Olney et al., 2003; Walter and Olney, 2003; Wilhite et al., 2003; Olney 2003b; Hoffman and Olney, 2005;

McBride et al., 2005; Maki et al., 2006; Olney et al., 2006a, b; Hoffman et al. 2007a, b; Hoffman et al. 2008, Walther et al. 2008; Hoenig et al. 2008; Aunins and Olney 2009; Tuckey and Olney, 2010; Latour et al. 2012; Upton et al. 2012; Hyle et al. 2014). Reprints of these papers are available on request. The 1998-2019 results of the monitoring program are reported by Olney & Hoenig (2000a, b, 2001b), Olney & Maki (2002), Olney (2003a, 2004, 2005), Olney & Delano (2006, 2007), Olney & Watkins (2008, 2009), Olney et al. (2010), and Hilton et al. (2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020).

VIMS' authors contributed to peer-reviewed sections of the most recent stock assessment for American shad (Olney 2007; Olney et al. 2007; Carpenter et al 2007; also contributing to the ongoing assessment) and river herring (Lee et al., 2012; updated by Hilton for the 2017 stock assessment). The current monitoring program has also served as the basis for several theses and dissertations, including a study of the reproductive biology of American shad in the Mattaponi River (Hyle, 2004) and a description of the spawning grounds of American shad in the James River (Aunins 2006). Two additional studies formed the basis for a thesis and a dissertation that were supported in part by the monitoring program: a validation of age determination of American shad using otolith isotopes as natural tags (Upton 2008) and a study of the population dynamics of juvenile *Alosa* spp. in Virginia rivers (Tuckey 2009). Finally, these monitoring data have been used in a recent revision of the on-line Chesapeake Bay Report presented annually by the Chesapeake Bay Program of the Environmental Protection Agency (http://www.chesapeakebay.net). Results of this project will also support a petition to ASMFC for a limited commercial fishery for river herring in the Chickahominy River. Bycatch of Atlantic sturgeon is recorded and these data are reported to ASMFC.

## Objectives

The primary objectives of the monitoring program (1) to continue a time series of relative abundance indices and biological structure of adult American shad during the spawning runs in the James, York and Rappahannock rivers and to establish a time series of relative abundance indices and biological structure of adult river herring in the Chickahominy and Rappahannock rivers; (2) to relate contemporary indices of abundance of American shad to historical logbook data collected during the period 1980-1992 and older data if available; (3) to assess the relative contribution of hatchery-reared and released cohorts of American shad to adult stocks; (4) to relate recruitment indexes (young-of-the-year index of abundance) of American shad and river herring to relative year-class strength and age-structure of spawning adults; (5) to determine the amount of bycatch of other species in the staked gill nets for American shad; and (6) to monitor the American shad bycatch fishery established by the VMRC. The results of this bycatch monitoring in 2020 are provided here as an appendix comprising a report on this fishery to the ASMFC (Appendix I).

## Methods

### *Collection and processing of adult American shad*

The 2020 sampling methods for the American shad monitoring program in the York and Rappahannock rivers followed those employed in 1998-2019 (see Appendix I for additional methods used to monitor the bycatch fishery), with the exception that effort was reduced from two to one day per week in 2015. In 1998, a sentinel fishery was developed that was as similar as possible 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 (Figures 1-3), and one of these locations on each river (the York and Rappahannock) was used to monitor catch rates by SGNs in 1998-2020. In 2020, the James River SGN was discontinued due to contractor health and logistical reasons; sampling on the James River was conducted using anchor gill nets by Mr. George Trice (Poquoson, Virginia) during the 2020 season. 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. One of these commercial fishermen, Mr. Raymond Kellum (Bena, Virginia), was the author of historical logbooks on the York River. Logbooks utilized for the James River were authored by Mr. Marc Brown (Rescue, Virginia). Authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders, Warsaw, Virginia) who had previous experience in SGN fishing but who had not participated in the shad fishery on the Rappahannock River in the 1980s. Scientists accompanied commercial fishermen during each sampling trip before the outbreak of COVID-19 and all catches were returned to the laboratory for analysis. After the outbreak of COVID-19 all samples were collected dockside to meet institutional social distancing guidelines.

One SGN, 900 ft (approximately 274 m) in length, was set on the York River (Figures 4). One SGN, 912 ft (approximately 277 m) in length, was set on the Rappahannock River (Figure 5). In the James River, two anchor gill nets (AGN), each 300 ft (~92 m) in length, were set. While this is inconsistent with past years for the James River, it was a necessary evolution of our approach to monitoring due to an unexpected health issue with our contracted fisherman immediately prior to the start of the sampling season. We attempted to continue SGN fishing in the James River but were unable to secure a new contractor. Staked gillnets have become infrequently used by commercial fisherman in the main rivers due to the logistical constraints (e.g., cutting down 30-ft tall trees for use as poles and bringing them into the river, and danger, having to hand drive poles into the sediment deep enough to withstand storms and high current). Current fisheries that use the fixed gear are minimal and further lower the number of fisherman utilizing staked gill nets. The availability of contractors with SGN experience continues to decline and has become absent in some regions. Anchor nets, which are both logistically easier to set and allow fisherman more flexibility are currently the most utilized gear for most gill-net fisheries in Chesapeake Bay. Locations of the sets were as follows: middle James River at river mile 36 (37° 11.0' N, 76° 42.3' W); middle York River near Clay Bank at river mile 14 (37° 20.8' N, 76° 37.7' W); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock, Virginia) at river mile 36 (37° 55.9' N, 76° 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 catch rates in the current monitoring program were comparable to logbook records, the 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 [9.14 m] each on the York River; 48 ft [14.63 m] each on the Rappahannock River). Each week, nets were fished for one day (i.e., a 24-h set) and then hung in a non-fishing position until the next sampling episode. Occasionally, weather or other circumstances prevented the regularly scheduled sampling on Sunday, and sampling was postponed, canceled or re-scheduled for another day. In 2020, sampling occurred for thirteen weeks on the Rappahannock River (1 March to 23 May 2020); six weeks on the York River (2 March to 6 April 2020); eight weeks on the James River (5 March to 23 April 2020). Surface water temperature and salinity were recorded at each sampling event.

Individual American shad collected from the monitoring sites were measured and weighed on an electronic fish measuring board interfaced with an electronic balance. The board recorded measurements (fork length (FL) and total length (TL)) to the nearest mm, received weight input to the nearest g from the balance, and allowed manual input of additional data (such as field data and comments) or subsample designations (such as gonad tissue and otoliths) into a data file for subsequent analysis.

Sagittal otoliths were removed from samples of adult American shad, placed in numbered tissue culture trays, and stored for subsequent screening for hatchery marks. To scan for hatchery marks, otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Otolith scanning was performed by B. Watkins (VIMS) in 2020. Scanning in previous years was performed by D. Hopler (VDGIF), J. Goins (VIMS), G. Holloman (VIMS), and A. Magee (VIMS).

Scales for age determination were removed from a mid-lateral area on the left side posterior to the pectoral-fin base of each fish. Scales were cleaned with a dilute bleach solution, mounted and pressed on acetate sheets, and read on a microfilm projector by one individual (B. Watkins, VIMS) using the methods of Cating (1953). Ages were determined by a different reader in 1998-2002 (K. Maki). To ensure consistency, B. Watkins has re-aged all scale samples collected during the monitoring program.

Catch data from each river were used to calculate a standardized catch index (the area under the curve of daily catch rate versus time of year). The catch index, the duration of the run in days, the maximum daily catch rate in each year and the mean catch rate in each year were compared to summaries of historical logbook data to provide a measure of the relative size of the current shad runs. In the historical data, catches are reported daily through the commercial season with occasional instances of skipped days due to inclement weather or damaged fishing gear. In monitoring years 1998-2014, catches on two successive days were separated by up to five days (usually Tuesday-Saturday) in each week of sampling. From 2015-2020, catches were separated by up to six days (usually Monday-Saturday) in each week of sampling. In some rare cases, catches are separated by more than six days. To compute the catch index during all monitoring years, we estimated catches on skipped days using linear interpolation between adjacent days of sampling.

### *Collection and processing of adult river herring*

Four anchor gill nets were set parallel to the current on the Chickahominy River approximately 2 miles [1.6-3.2 km] upstream from the mouth of the river. Two 2.5" [63.5 mm] stretched mesh (300' x 6') anchor gillnets and two 3.0" [76.2 mm] stretched mesh (300' x 8') anchor gillnets were constructed with top float lines and lead bottom lines. Additional larger floats are added every 50' to ensure that fishing occurs from the surface down. Two anchor gill nets were also set parallel to the current on the Rappahannock River near the Rappahannock River bridge (at Tappahannock, VA) at river mile 36 (37° 55.8' N, 76° 50.7' W). One net was a 2.5" [63.5 mm] stretched mesh (300' x 6') anchor gill net and the other was 3.0" [76.2 mm] stretched mesh (300' x 8') anchor gill net. Each week, the anchor gill nets were fished for one 24 h set on each river. Occasionally, weather or other circumstances prevented the regularly scheduled sampling on Tuesday and Wednesday, and sampling was postponed, canceled or re-scheduled for other days. In 2020, sampling for river herring on the Chickahominy and Rappahannock rivers ended early due to the COVID-19 pandemic. Sampling on the Chickahominy River occurred over nine weeks (29 January to 24 March). In 2020, sampling on the Rappahannock River occurred over eight weeks (4 February to 23 March). Surface water temperature and salinity were recorded at each sampling event.

Individual alewife and blueback herring were measured (FL and TL) to nearest mm and weighed to nearest g. Sagittal otoliths were removed, placed in numbered tissue culture trays, and stored for age determination. To determine ages, otoliths were submersed in water with the sulcus facing downward, and viewed under a stereomicroscope with reflected light and a magnification of 2.0x. Ages were determined by one individual (P. McGrath) using methods recommended by the ASMFC (ASMFC 2014). Digital imaging software was used in conjunction with the stereomicroscope for ageing and for archiving all images. Scales were collected for future use.

Catch data from anchor gillnets were used to calculate a standardized catch index (the area under the curve of daily catch rate for pre-spawning females versus time of year). In 2015, the 3.0" mesh was determined to be inefficient at catching blueback herring; therefore in 2015 and 2016, the catch indices for blueback herring were only calculated with catch data from 2.5" mesh. In 2017, blueback herring catches in the 3.0" mesh increased and in order to not exclude the larger females, catches from both 2.5" and 3.0" mesh were used in the catch index. The 2015 and 2016 catch indices for blueback herring were also recalculated to include the catch from the 3" mesh. In monitoring years 2015-2017, catch data occurred over two successive days and was separated by up to five days in each week of sampling. Since 2018, catches were separated by up to six days in each week of sampling. In some rare cases, catches were separated by more than six days. To compute the catch index, catches on skipped days were estimated using linear interpolation between adjacent days of sampling. The catch index, the duration of the run in days, the maximum daily catch rate in each year, and the mean catch rate in each year will serve as the starting point for future comparisons to determine annual relative abundance of river herring. Age composition and sex ratio, among other attributes of the spawning stock of each species, are reported. Mortality was estimated for pre-spawning females using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve.

### *Collection of other species*

In both American shad and river herring sampling, catches of all other species were recorded and enumerated on log sheets by observers on each river and released. In the American shad sampling, for striped bass (*Morone saxatilis*), separate records were kept of the number of live and dead fish in the nets and released (if alive) or returned to the laboratory (if dead). Random subsamples of dead striped bass from each river were analyzed for sex, fork length and total weight. Random subsamples of Atlantic menhaden (*Brevoortia tyrannus*) were collected weekly from each river and returned to the laboratory for processing. Individual specimens were measured (mm), weighed (g) and had scales removed for future age analysis.

### *Collection of juvenile alosines*

Juvenile alewife and blueback herring were captured in the Chickahominy River using the mamou trawl. The mamou trawl is a 6.7 m x 1.8 m floating surface trawl constructed of 35 mm high density polyethylene netting. The cod end is made from 36 mm netting with a 20 mm removable liner. The net consists of 15.2 m bridles connected to 36 x 18 floating mullet doors and 30.5 m tow lines. Tows were conducted using a 7.0 m skiff equipped with a 115 hp engine.

Eight weekly cruises were conducted in 2020 (6 July to 24 August). During each cruise, three stations were randomly chosen within each of four adjacent 9.3 river km long blocks. Stations were designated at every 1.9 river km, beginning approximately 1.2 km (c. 2 miles) below Walker's Dam and ending at the river mouth. Night-time sampling was conducted when juvenile *Alosa* spp. are most susceptible to surface trawling (Loesch et al. 1982). Each tow lasted 5 minutes and was conducted along the central axis of the river channel. All tows were performed with the prevailing current.

Alewife and blueback herring caught at each station were identified and counted. Ten randomly selected individuals of each species from each station were measured and weighed. The geometric mean of the catch per tow was calculated for each cruise and the season (seasonal catch index).

Data of catches of American shad and river herring from the VIMS Striped Bass Seine Survey are also reported, as this survey provides greater spatial coverage within the tributaries of the Chesapeake Bay.

## Results

### *Catches of American shad by staked gill nets in 2020*

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-9. Post-spawning females were not encountered on the James and York rivers in 2020. Three post-spawning females were encountered on the Rappahannock River. Post-spawning fish were identified macroscopically in the laboratory. Because the historic fishery was a roe fishery and spent or partially-spent fish were not routinely captured or marketed in the historic fishery, post-spawning fish were not included in the monitoring sample.

A total of 411 American shad (74 males; 337 females) were captured (Table 1). The total weight of the sample was 553.6 kg (male, 86.8 kg; female, 466.84 kg). Catches in 2020 were lowest on the James River (6 total fish, 0 males and 6 females) and York River (23 total fish, 2 males and 21 females). Catches on the Rappahannock River (382 total fish, 72 males and 310 females) were highest.

On the James River, catches of females occurred with no discernable peak between 5 March and 17 April (Table 2). Surface temperatures during this time ranged from 13.8ºC – 18.7ºC. On the York River, catches of females peaked between 5 March – 19 March when catch rates exceeded 0.01 fish/m or 0.02 kg/m. During that period, 81.0% (17 of 21) of all females were captured on the York River. Surface temperatures during this time ranged from 9.1 – 12.6ºC. The largest catch of pre-spawning female American shad on the York River (10 fish) occurred on 13 March when the surface temperature was 11.4ºC (Tables 2, 4). Catches of females on the Rappahannock River peaked on 15 March – 12 April when catch rates generally exceeded 0.10 fish/m or 0.14 kg/m. During that period on the Rappahannock River, 75.2% (233 of 310) of all females were captured. Surface temperatures during this time ranged from 11.8ºC – 14.8ºC. The largest catch of pre-spawning female American shad on the Rappahannock River (72 fish) occurred on 22 March when the surface temperature was 14.7ºC (Tables 2, 6). As in previous years of monitoring, numbers and catch rates of males were lower than catch rates of females throughout the period. Sex ratios (males: females) were: York River, 1:10.5; James River, 0:1.0 and Rappahannock River, 1:4.3. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish. Catches of males do not likely reflect true abundance.

The duration of the spawning run is 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. The 2020 spawning run duration was estimated to be a minimum of 44 days on the James River (5 March – 17 April; Table 3), 26 days on the York River (2 March – 27 March; Table 4), and 84 days on the Rappahannock River (1 March – 23 May; Table 6).

### *Biological characteristics of the American shad catch in 2020*

Age, mean length (mm TL) and mean weight (kg) of American shad in staked gill nets are summarized in Tables 8-9. Mean total length at age of males and females from all rivers ranged from 451.0–501.0 mm TL and 464.3–550.0 mm TL, respectively. Mean weight at age of males and females from all rivers ranged from 0.9-1.3 kg and 1.1–2.1 kg, respectively.

Using scale-based ageing methods, we estimated that the 2015-year class (age 5) of female American shad was the most abundant on the James River. The 2014-year class (age 6) of female American shad were the most abundant on the Rappahannock and York rivers (Table 8). On the James River, two age-classes of females were represented (2014-2015, ages 5-6), with the sample dominated by age-5 fish (75.0% of the total that was aged). On the York River, three age-classes of females were represented (2012, 2014, 2015, ages 5, 6, and 8). The sample was dominated by age-6 (64.3%) fish. On the Rappahannock River, six age-classes of females were taken (2011-2016, ages 4-9), with the sample dominated by age-6 fish (39.4%). Mean age of females in 2020 was 5.3 y (James River), 6.1 y (York River), and 5.7 y (Rappahannock River). These values are slightly lower than those observed in 2019 on the James and Rappahannock rivers and slightly higher on the York River. Six age-classes (2011-2016, ages 4-

9) of male American shad were collected on the Rappahannock River (Table 9). On the James and York Rivers, low sample sizes of male shad were observed in 2020.

Age-specific catch rates of American shad are reported in Tables 10 and 11 for females and males, respectively. Total instantaneous mortality (Z) of females was estimated using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve. Total instantaneous mortality rates of females were: James River, 0.88 ($r^2$=1.00); York River, 0.65 ($r^2$=1.00); and Rappahannock River, 1.17 ($r^2$=0.99). It is assumed that year classes above age-4 are equally catchable by the gear. Instantaneous mortality rates of males were not calculated because all year classes present are not equally catchable by the sampling gear.

Spawning histories of American shad collected in 2020 are presented in Tables 12 and 13. On the York River, fish (sexes combined) ranged in age from 4-8 years with 0 (virgin) to 3 spawning marks. On the Rappahannock River, fish (sexes combined) ranged in age from 4-9 years with 0-6 spawning marks. On the James River, fish (sexes combined) ranged in age from 5-6 years with 0 spawning marks. The following percentages of fish in each river had at least one prior spawn (termed "repeat spawners"): York River, 33.3% (10 virgins in a sample of 15); James River, 0.0% (4 virgins in a sample of 4) and Rappahannock River 38.9% (176 virgins in a sample of 288 fish).

### *Seasonal American shad catch indices, 1980-1992 and 1998-2020*

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2020 and for each year of the historical record of staked net catches on each river (Tables 14-19 and Figures 7-10). Seasonal catch indices in 2020 were: James River, 0.25; York River, 0.75; Rappahannock River, 10.62.

### *Evaluation of hatchery origin of American shad in 2020*

James River - Otoliths of 4 American shad (66.7% of the total catch) on the James River were processed for hatchery marks; the proportion with hatchery marks was 25.0% (1 of 4 fish). The biological attributes of these specimens are presented in Table 20. In most years since 2000, the prevalence of hatchery fish in the James River has been high (>20%); in 2006 and 2009 there were lower proportions of fish with hatchery tags (10.3% and 8.9% respectively); in 2013 the hatchery percentage of fish with hatchery marks was 60.5% on the James. The strength of the James River catch index continues to rely on the prevalence of hatchery fish (Figure 11). A correlation analysis among the catch index and hatchery prevalence from 1998-2020 was statistically significant ($r$ = 0.51, df = 21, $p$ = 0.01). In some years, fish with hatchery tags from rivers other than the James River were detected in the monitoring sample. These strays were not included in the estimates of hatchery prevalence and are as follows (year captured as an adult, number, river of release): 1999, n= 1, Patuxent River (Maryland); 2000, n= 7, Pamunkey River (Virginia) and Juniata River (Pennsylvania); 2001, n= 3, Pamunkey River, Juniata River, and the western branch of the Susquehanna River (Pennsylvania); 2002, n= 2, Pamunkey River, n= 2 unknown tag; 2005, n=3, tentatively Pamunkey River and Mattaponi River (Virginia); 2007, n=1, Pamunkey River (Virginia); 2008, n=1, Undetermined; 2009, n=1, Chemung River (New

York); 2010, n=2, Susquehanna River (Pennsylvania). In 2003, 2004, 2006, 2011-2020 there were no stray fish.

Most hatchery-reared adults taken on the James River in 2020 had OTC marks that indicated these specimens were released after 2010. These tags could not be easily differentiated microscopically, so we determined the year of release using scale-determined ages (Tables 20, 21). All of the fish in the sample were from the 2014-year class (1 of 1 fish). None of hatchery marked fish in the ageing sample were repeat spawners.

York and Rappahannock Rivers - Otoliths of American shad from the York River were not processed for hatchery marks. In 2020, 93 American shad (24.0 % of the total that were caught) from the Rappahannock river were scanned for the prevalence of hatchery marks. Four fish (4.3%) with hatchery marks were detected (Table 20, 22). Stocking of American shad in the Rappahannock River began in 2003 and ended in 2014.

***Catches of river herring by anchored gill nets in 2020***

Fishing days, numbers of river herring captured, catch rates (males and females) and length frequencies are reported in Tables 23-27 and 34-38. A total of 477 alewives (175 males; 294 pre-spawned females; 8 post-spawned females) and 114 blueback herring (50 males; 64 pre-spawned females; 0 post-spawned females) were captured on the Chickahominy River (Table 23). After 11 March, post-spawning alewives were mixed with pre-spawning alewives. No post-spawning blueback herring were present in the sample. A total of 281 alewives (121 males; 159 pre-spawned females; 1 post-spawned female) and 133 blueback herring (53 males; 80 pre-spawned females; 0 post-spawned females) were captured on the Rappahannock River (Table 34). After 25 March, post-spawning alewives were mixed with pre-spawning alewives. No post-spawning blueback herring were caught on the Rappahannock River. Post-spawning fish were identified macroscopically in the laboratory. Because the historical fishery was a roe fishery and spent or partially-spent fish were not routinely captured or marketed in the fishery, post-spawning fish were not included in the monitoring sample.

On the Chickahominy River, catches of pre-spawned alewife peaked between 5 February and 17 March, with catch rates typically exceeding 0.07 fish/m/day or 0.02 kg/m/day (Table 24). Catches of blueback herring peaked between 17 March and 24 March (last sampling event), with catch rates exceeding 0.01 fish/m/day or 0.01 kg/m/day (Table 26). Surface temperatures during these peaks ranged from 8.3ºC – 12.2ºC for alewife and from 12.2ºC – 13.8ºC for blueback herring. The largest catch of pre-spawned female alewife (98 fish) occurred on 3 March when surface temperatures were 8.9ºC and the largest catch of pre-spawned female blueback herring occurred on 24 March (44 fish) when surface temperatures were 13.8ºC. Sex ratio (males: females) for alewife was 1:1.73 and for blueback herring was 1:1.28. It is important to note that the monitoring gear is selective for mature female blueback herring and catches of male blueback herring do not likely reflect true sex ratio for that species.

On the Rappahannock River, catches of pre-spawned alewife peaked between 25 February and 23 March (last sampling event), with catch rates typically exceeding 0.06 fish/m/day or 0.02 kg/m/day (Table 35; Figure 12). Catches of blueback herring peaked between 10 March and 23 March (last sampling event), with catch rates exceeding 0.10 fish/m/day or 0.03 kg/m/day (Table 37; Figure 12). Surface temperatures during these peaks

ranged from 7.7ºC – 12.8ºC for alewife and from 9.5ºC – 12.8ºC for blueback herring. The largest catch of pre-spawned female alewife (34 fish) occurred on 10 March when surface temperatures were 9.5ºC and the largest catch of pre-spawned female blueback herring occurred on 23 March (28 fish) when surface temperatures were 12.8ºC. Sex ratio (males: females) for alewife was 1:1.32 and for blueback herring was 1:1.51.

***Biological characteristics of river herring caught in anchored gillnets in 2020***

Age, mean length (mm TL) and mean weight (kg) of river herring in anchored gill nets from the Chickahominy and Rappahannock Rivers are summarized in Table 28 and 39. Mean total length at age of pre-spawned female alewives and blueback herring from both rivers ranged from 271.5 – 322.0 mm TL and 274.0 – 312.5 mm TL, respectively. Mean weight at age of pre-spawned female alewives and blueback herring ranged from 0.19 – 0.36 kg and 0.20 – 0.31 kg, respectively.

Using otolith-based ageing methods, we estimated that the 2015-year class (age 5) of female alewife and blueback herring on both the Chickahominy and Rappahannock rivers was the most abundant (Tables 28 and 39, respectively). On the Chickahominy River, seven age-classes of female alewife were represented (2011 - 2017, ages 3 – 9), with the sample dominated by age-5 fish (50.0% of the total that was aged). Mean age of female alewives in 2020 was 4.88. Four age-classes of female blueback herring were represented (2013-2016, ages 4-7), with the sample dominated by age-5 fish (56.3% of the total that was aged). Mean age of female blueback herring in 2020 was 5.36. On the Rappahannock River, six age-classes of female alewife were represented (2012 - 2017, ages 3 – 8), with the sample dominated by age-5 fish (59.1% of the total that was aged). Mean age of female alewives in 2020 was 4.99. Six age-classes of female blueback herring were represented (2011-2016, ages 4 - 9), with the sample dominated by age-5 fish (38.8% of the total that was aged). Mean age of female blueback herring in 2020 was 6.03.

Age-specific catch rates of female alewives and blueback herring are reported in Tables 28 and 39. Total instantaneous mortality (Z) of females was estimated using Chapman-Robson method. On the Chickahominy River, total instantaneous mortality and survival (S) rates of females were: alewife, Z = 1.26 and S = 0.28; blueback herring, Z = 1.12 and S = 0.33. On the Rappahannock River, total instantaneous mortality and survival (S) rates of females were: alewife, Z = 1.37 and S = 0.25; blueback herring, Z = 0.66 and S = 0.52. It is assumed that year classes above age-4 are equally catchable by the gear.

Spawning histories of alewife and blueback herring collected in 2020 are presented in Tables 30-31 and 41-42. On the Chickahominy River, alewife (sexes combined) ranged in age from 3-9 years with 0 (virgin) to 4 spawning marks and blueback herring (sexes combined) ranged in age from 4-7 years with 0 (virgin) to 4 spawning marks. On the Rappahannock River, alewife (sexes combined) ranged in age from 3-9 years with 0 (virgin) to 5 spawning marks and blueback herring (sexes combined) ranged in age from 4-9 years with 0 (virgin) to 5 spawning marks. The following percentages of alewife in each river had at least one prior spawn (termed “repeat spawners”): Chickahominy River, 74.1% (107 virgins in a sample of 413); and Rappahannock River 72.0% (61 virgins in a sample of 218 fish). The following percentages of blueback herring in each river had at least one prior spawn (termed “repeat spawners”):

Chickahominy River, 83.5% (15 virgins in a sample of 91); and Rappahannock River 94.2% (5 virgins in a sample of 86 fish).

### *Seasonal river herring catch indices for 2020*

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for 2020 (Tables 32-33, 43-44; Figures 13-14). Seasonal catch indices in 2020 on the Chickahominy River were: alewife, 1.54; blueback herring, 0.67. The index values were higher for alewife and blueback herring compared to the index values in 2019 (alewife, 0.44; blueback herring, 0.25). On the Rappahannock River, seasonal catch indices in 2020 were: alewife, 1.85; blueback herring, 1.25. The index values were higher for alewife and lower for blueback herring compared to the index values in 2019 (alewife, 0.97; blueback herring, 3.08).

### *Juvenile abundance of American shad and river herring*

Tables 45 and 46 report index values of juvenile abundance of American shad based on seine surveys (1980-2020) on the James (including the Chickahominy), Chickahominy, Rappahannock, York (including the Mattaponi and Pamunkey rivers), Pamunkey, and Mattaponi rivers. The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2020 was: James River, 0 (NA, 56); Chickahominy River, 0 (NA, 8); Rappahannock River, 8.13 (1.29, 32); York River, 0.36 (0.62, 81); Mattaponi River, 0.73 (0.78, 42); and Pamunkey River, 0.06 (0.20, 34). In 2009, calculations for all years were adjusted to include fish greater than 72 mm, which had not been included in the indices in previous years.

The seine survey data on the James River (Table 43) showed below average recruitment of American shad in 2020 in all rivers except for the Rappahannock River In 2010, James River indices for all years were recalculated to include additional seine survey stations located in the upper James and Chickahominy rivers. Independent results from the Chickahominy River are also reported, although it is unknown whether fish captured in this river form a unique stock (i.e., distinct from that of the James River). Stocking of American shad took place on Chickahominy Lake in 2000 and on the Chickahominy River in 2004. Results from an independent survey below Bosher's Dam on the James River depict no measurable recruitment in most years (VDGIF, T. Gunter, pers. comm.). On the Rappahannock River, the highest JAI values in the time series were recorded in 2015, 2016, and 2018-2020 (4.19, 4.17, 4.65, 11.65, and 8.13, respectively). The Rappahannock River time series depicts no measurable recruitment in 1980-1981, 1985, 1988, 1991-1992, 1995, and 2002.

Within the York River system, except for 2003 and 2012, the juvenile index values based on the seine survey are consistently higher on the Mattaponi River than they are on the Pamunkey River (Table 44). In the time series, recruitment is highest (>7.0 on the Mattaponi River and >3.0 on the York River) in 1982, 1984-85, 1996, 2003 and 2004. Recruitment was low (<0.10) on both of these rivers in 2009; there was no measurable recruitment in the Pamunkey River in 1986-1989, 1992-1993, 1999, and 2007-2009.

Catches of river herring, mean length, mean weight, and the mean fish per tow from the nighttime surface trawls on the Chickahominy River in 2020 are reported in Table 47. Catches were dominated by blueback herring (total alewife = 29; total blueback herring = 8301). Mean

length of alewife ranged from 61.0 – 79.7 mm FL and mean weight ranged from 3.3 – 6.3 g. Mean length of blueback herring ranged from 36.3 – 47.4 mm FL and mean weight ranged from 0.6 – 1.2 g. Because of low catches at each sampling station, mean fish/tow and geometric means (cruise specific index) are not reliable for alewife. Mean fish/tow for blueback herring ranged from 67.0 – 108.8 fish per tow, and the geometric means ranged from 19.3 – 64.3. The cruise specific index of blueback herring peaked on the 10th of August.

Tables 48 and 49 report index values of juvenile abundance of alewife and blueback herring, respectively, based on seine surveys (1989-2020) on the James, York (includes the Mattaponi and Pamunkey rivers), and the Rappahannock rivers. The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile alewife captured in daylight seine hauls in 2020 was: James River, 0 (NA, 9); York River, 0 (NA, 55); Rappahannock River, 0.10 (0.32, 37). The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile blueback herring captured in daylight seine hauls in 2020 was: James River, 0.56 (1.40, 38); York River, 0.30 (0.88, 35); Rappahannock River, 0.99 (1.21, 22).

Indexes of juvenile abundance based on the seine survey data are variable, but are almost always higher for blueback herring than for alewife, and the Rappahannock River most often shows the highest abundance for both species. No measurable recruitment of alewife was seen in the James River in 1989-1992, 1995, 1999-2003, 2008, 2011-2012, and 2020 and in the York River in 1990-1993, 1995, 1998-2000, 2006-2009, 2012-2014, 2017, and 20202. In the Rappahannock River, indexes of juvenile alewife abundance have been relatively low (e.g., <0.1) in many years (1990-1992, 1995, 2002, 2004-2006, 2008, 2012), but there has always been measurable recruitment throughout the time series. The only instances of no measurable recruitment of blueback herring within the time series occurred in the York River, and in the years 1990, 1992-1993, 1995, 1998-1999, 2002, 2005-2006, 2009, 2012-2013.

***Bycatch of striped bass and other species in 2020***

Daily numbers and seasonal totals of striped bass and other species captured in staked or anchor gill nets are reported in Tables 50-52. Eleven species of fishes were counted as bycatch in the staked and anchor gill net monitoring gear for a total of 2,944 specimens. The most commonly encountered bycatch species were: gizzard shad (*Dorosoma cepedianum*), blue catfish (*Ictalurus furcatus),* menhaden (*Brevoortia tyrannus*), and striped bass (*Morone saxatilis*).

The total number of striped bass recorded was 421 (James River, n=55; York River, n=32; Rappahannock River, n=334). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 69.1%; York River, 46.9%; and the Rappahannock River, 54.4%. A subsample of 165 dead striped bass was selected from the York and Rappahannock rivers. Length of males and females ranged from 413 - 599 mm FL and 344 - 549 mm FL, respectively. Total weights of males and females ranged from 1.11 – 3.11 kg and 0.54 – 2.66 kg, respectively.

Atlantic sturgeon is taken as bycatch in the staked and anchor gill nets used to monitor abundance of adult American shad in the James, York, and Rappahannock rivers. In 2020, seven Atlantic sturgeon were caught as bycatch in this sampling (James River, n=0; York

River, n= 1; Rappahannock River, n=6; due to reduced effort sturgeon number data from 2015 to 2020 cannot be directly compared to previous years). The total numbers of Atlantic sturgeon captured in this survey from previous years were: 37 (1998), 24 (1999), 16 (2000), 8 (2001), 1 (2002), 3 (2003), 6 (2004), 25 (2005), 40 (2006), 30 (2007), 9 (2008), 7 (2009), 10 (2010), 12 (2011), 4 (2012), 11 (2013), 20 (2014), 10 (2015), 2 (2016). Most of these fish were taken in the James River during each year: 30 (1998); 22 (1999); 15 (2000); 7 (2001); 1 (2002); 3 (2003); 4 (2004); 22 (2005); 31 (2006); 22 (2007); 7 (2008); 6 (2009); 7 (2010); 11 (2011); 4 (2012); 6 (2013); 20 (2014), 9 (2015), 2 (2016), 1 (2017), 11 (2018), 9 (2019).

The total number of Atlantic menhaden recorded in the staked and anchor gill nets used to monitor abundance of adult American shad in 2020 was 652 (James River, n= 34; York River, n=16; Rappahannock River, n= 602). A portion (n=75) of this catch was returned to the laboratory and processed for length (mm) and weight (g). Scale samples were collected for future age analysis. Individual lengths ranged from 157 – 375 mm TL. Total weights ranged from 0.03 – 0.57 kg.

## Discussion

This monitoring program continues to be useful for assessment of stocks of American shad in Virginia. It is the only direct method available to determine the size of the spawning runs relative to what was obtained in the decades prior to the moratorium. The program also provides information for evaluating the hatchery-based restoration program, validating the juvenile index of abundance and for determining the amount of bycatch that could be expected in a commercial fishery if the in-river fishing ban is lifted.

In 1998, states were required to develop and submit restoration targets for stocks under moratorium. Virginia presented preliminary targets to the Plan Review Team of the ASMFC Shad and River Herring Management Board with the provision that these targets would be revised as appropriate historical data became available (see below). Criteria to achieve restoration targets were proposed as either: (1) a three-year period during which the catch index remains at or above the target level in the staked gill net monitoring of the spawning run; (2) a three-year period during which the average catch index is above the target level and the target level is exceeded in two of the years; or (3) a significant increasing trend over a five-year period with the target exceeded in the last two years.

Voluntary logbooks of catches from the York River exist in the archives of the Department of Fisheries Science (Table 17). These historical records from the 1950s form the basis for gear comparison trials conducted in 2002 and 2003 in the York River (Maki et al., 2006). Based on these comparisons, we have concluded that the multifilament nets of the type used in the 1950s have approximately half of the fishing power of monofilament nets used in the 1980s and the current monitoring. Thus, the older data have been adjusted upward (by a factor of 2.16) to make appropriate comparisons with current monitoring results.

Voluntary log books from the 1950s also exist for the James River. The most extensive data are those of Mr. J. C. Smith who fished staked gill nets on the upper James River in 1954-1957, just above the mouth of the Chickahominy River. Current monitoring on the James River is well below this location, complicating direct comparisons with Smith's log books. There are no historic records prior to 1980 in department archives for the Rappahannock River.

Using the information presented above and additional analysis, the ASMFC stock assessment subcommittee developed benchmarks for restoration of Virginia's stock of American shad (ASMFC 2007a). These benchmarks were reviewed and accepted by the ASMFC American shad stock assessment peer review panel in 2007 (ASMFC 2007b). These benchmarks have been upheld with the adoption of Amendment 3 to the Interstate Fishery Management Plan for American shad (ASMFC 2010).

For the York River, a restoration target of 17.44 (the geometric mean of the catch index values observed in 1953-1957) was accepted as an appropriate benchmark to assess the stocks since American shad abundance in the 1980s was insufficient to support the fishery. In the 1950s, shad abundance was higher (estimated at 131,000-218,000 total females annually using data from Nichols and Massmann, 1962), and landings were relatively stable in the face of a high fishing rate (50%). Thus, restoring the York River shad stocks to a 1950s level could allow for a sustainable fishery operating at a lower level of exploitation.

For the James River, an interim target of 6.40 (the geometric mean of the catch index values observed in 1980-1992) is available. However, American shad abundance in the 1980s was insufficient to support the fishery. The James River stock is dependent on hatchery inputs and there is strong evidence of persistent recruitment failure of wild stocks.

For the Rappahannock River, an interim restoration target of 1.45 (the geometric mean of the catch index values observed in 1980-1992) is available. Because effort of the historical fishery was lower on the Rappahannock than the other rivers, it is possible that this benchmark is artificially lower.

On the York River, the 2020 seasonal catch index (0.75) was the lowest catch index on the York in the 23 years of monitoring the American shad spawning stock. Since 2005 index values have been low, but stable. In years prior (1998-2004) index values were higher (5.42-14.71). The geometric mean of the historical data during the 1980s on the York River is 3.22. The geometric mean of the current monitoring data is higher (4.01), but this mean is still much lower than the benchmark based on 1950s data (17.44). In contrast to trends in the other two rivers, catch indices in the York River have been trending downward through the time series and, with the exception of 2014, are at all-time lows.

Our overall assessment of the York River stock is that it persists at a low level that is lower than its average abundance during the 1980s. As noted previously, the stock level was low during that period and was evidently incapable of supporting an active fishery. Since 2005, the catch index has shown no recovery to the higher levels seen earlier in the time series, and is cause for concern and continued monitoring. Although there is a moratorium on American shad harvest in the Chesapeake Bay, there are fish taken in the York River each year from several sources. Since 2005 there has been a limited bycatch fishery of American shad, results of which for 2020 are reported in Appendix I. The Mattaponi and Pamunkey tribal governments harvest American shad from the York River system but do not report landings to the VMRC, following the treaty of 1677. In past years there have also been losses to capture of brood stock on the Pamunkey River by the VDGIF. In comparison to other rivers in Virginia, there is currently no stocking of hatchery fish in the York River. The stock is currently well below the proposed 1950s target (Figure 9) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann, 1963). As a result, the stock requires continued protection.

On the James River, the seasonal catch index was 0.25. It was also below the geometric mean of the current monitoring data (3.06). This value is well below the peak catch index observed in the 1980s (29.20). The geometric mean of the historical data during the 1980s on the James River is 6.40. Prevalence of hatchery fish on the James River reached an all-time high of 60.5% in 2013. Our overall assessment for the James River is that the stock remains at historically low levels and is dependent on hatchery inputs (Figure 11). Due to budget constraints and absence of brood stock, stocking efforts of American shad on the James River have been reduced in recent years. In 2018, the stocking effort ceased operation on the James River. It is unclear how the change of gear in the 2020 season affected the catch and how the index from 2020 should be compared to previous years. However, we note that the 2020 index does not deviate greatly from the low index value found in 2019.

On the Rappahannock River, the 2020 index was 10.62, the highest recorded value for both current and historical data. The current geometric mean (4.05) is higher than the mean of the historical data (1.45). It should be noted that since the catch index for the Rappahannock River is low in the historical data relative to the York and James rivers, there is uncertainty about what an appropriate target level should be for this stock. There is little evidence of severe stock decline in the Rappahannock River, and this stock is considered to be low but stable (ASMFC 2007a). Stocking of American shad on the Rappahannock River occurred between 2003 and 2012, using the progeny of Potomac River brood stock. In the years since stocked hatchery fish would be expected to return (i.e., age 4 fish in 2007), the percent hatchery origin fish encountered in the Rappahannock River ranged from 0% (2007) to 8.9% (2016). Due to the low level of return, VDGIF has ceased stocking American shad in the Rappahannock River for the foreseeable future.

The anchor gill net survey on the Chickahominy River began in 2015 and was intended to monitor the relative abundance, stock structure, mortality, and biological characteristics of river herring in a major tributary of the James River that, prior to the moratorium, was the focus of a fishery. No historical data exist to allow comparison of those data collected in this survey, and thus the 2015 values will provide a reference point for future comparisons. This survey proved to be effective, although there is significant variation in levels of catches between species and sexes. Catches of adult blueback herring were significantly lower than adult alewife, although in summertime nighttime surface trawls, blueback herring dominated the catches in the Chickahominy River. This suggests that there is variation in species specific catchability, either because of gear (e.g., mesh size) or biological characteristics of the species (e.g., habitat use of juveniles). The 2020 indices were the highest values for both alewife and blueback herring during the six years monitoring herring on the Chickahominy River. Despite 2019, a positive trend is apparent for both alewife and blueback herring during the current 6-year monitoring period.

This year marked the third year of an adult spawning stock survey of river herring using anchor gillnets on the Rappahannock River. No historical data exist to allow comparison of those data collected in this survey, and thus these values will provide a reference point for future comparisons. The 2020 index was higher for alewife and lower for blueback herring then the 2019 indices. However, the 2020 blueback herring index was compromised by the early conclusion of sampling due to COVID-19. It will take additional years of sampling data before a trend can be realized for river herring in the Rappahannock River.

## Statement on the Impact of Constraints due to the COVID-19 Pandemic

The 2020 sampling season was altered due to safety precautions enacted because of COVID-19. The American shad survey continued as normal except scientists were no longer onboard with the commercial fisherman after 24 March. This resulted in bycatch not being recorded after March 24, except for Atlantic Sturgeon and Menhaden. The peak in catches for blueback herring was most likely not encountered due a premature end to the sampling season due to COVID-19.

Sampling for river herring on the Chickahominy and Rappahannock rivers concluded on the 23 and 24 of March, respectively. The impact of the shortened field season affected data in varying degrees. The following list is our best estimate of the impacts of a shortened field season collecting river herring: a slight underestimate of the index for alewife from the Chickahominy River; an underestimate of index for alewife from Rappahannock River; a large underestimate of blueback herring from both the Chickahominy and Rappahannock rivers; an inaccurate age composition for blueback herring; an inaccurate mortality estimate for blueback herring.

## Literature Cited


ASMFC. 1998. American shad stock assessment peer review report. Atlantic States Marine Fisheries Commission, March, 1998.

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

ASMFC. 2007a. American Shad Stock Assessment Report for Peer Review. Vols. I-III. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 Supplement.

ASMFC. 2007b. Terms of Reference & Advisory Report to the American Shad Stock Assessment Peer Review. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01

ASMFC. 2009. Amendment 2 to the interstate fishery management plan for shad and river herring. ASMFC, Washington, D.C. 166 p.

ASMFC. 2010. Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management). 158 pp.

ASMFC. 2012. River herring stock assessment report for peer review. Vol II., Section 15: Status of American shad in Virginia. Contributors: L.M. Lee, J.E. Olney, B. Watkins, E. J. Hilton, J. Cimino, and A. Weaver. Pages 489-548. Stock Assessment Report No. 12-02.

ASMFC. 2014. 2013 River Herring Ageing Workshop Report. 112 pp.

ASMFC. 2020. 2020 American Shad Benchmark Stock Assessment and Peer Review Report. Atlantic States Marine Fisheries Commission. 1067 p.

Atran, S.M., J.G. Loesch, and W.H. Kriete, Jr. 1983. An overview of the status of *Alosa* stocks in Virginia. VIMS Marine Resources Report No. 82-10. 47 p.

Aunins, A.W. 2006. Migratory and spawning behavior of American shad in the James River, Virginia. A thesis presented to the School of Marine Science, College of William and Mary, 99 pp.

Aunins, A.W. and J.E. Olney. 2009. Migration and spawning behavior of American shad in the James River, Virginia. Transactions of the American Fisheries Society. 138:1392-1404.

Bilkovic, D.M., C.H. Hershner and J.E. Olney. 2002a. Macroscale assessment of American shad spawning and nursery habitat in the Mattaponi and Pamunkey rivers, Virginia. North American Journal of Fisheries Management 22: 1176-1192.

Bilkovic, D.M., J.E. Olney and C.H. Hershner. 2002b. Spawning of American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*) in the Mattaponi and Pamunkey rivers, Virginia. Fishery Bulletin 100: 632-640.

Cating, J.P. 1953. Determining age of Atlantic shad from their scales. U.S. Fish Wildl. Serv. Fish. Bull. 54: 187-199.

Carpenter, A.C. and nine co-authors including K. Delano, J. Olney, and R. Latour. 2007. Status of the Potomac River stock. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement) 3:133-197.

Crecco, V. 1998. Stock assessment of American shad from selected Atlantic coast rivers. Report to the External Peer Review Panel, March 1998.

Hilton, E.J., R. Latour, B. Watkins, and A. Rhea. 2011. Monitoring relative abundance of American shad in Virginia's rivers. 2010 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-13, 15 April 2011.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2012. *Monitoring relative abundance of American shad in Virginia rivers.* 2011 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-14, 15 April 2012.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2013. *Monitoring relative abundance of American shad in Virginia rivers.* 2012 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-15, 15 April 2013.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2014. *Monitoring relative abundance of American shad in Virginia rivers.* 2013 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-16, 15 April 2014.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2015. *Monitoring relative abundance of American shad and river herring in Virginia rivers.* 2014 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-17, 15 April 2015.

Hilton, E. J., R. Latour, P.E. McGrath, B. Watkins, & A. Magee. 2016. *Monitoring relative abundance of American shad and river herring in Virginia rivers*. 2015 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-18, 15 April 2016.

Hilton, E. J., R. Latour, P.E. McGrath, B. Watkins, & A. Magee. 2017. *Monitoring relative abundance of American shad and river herring in Virginia's rivers.* 2016 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-19, 15 April 2017.

Hilton, E. J., R. Latour, P.E. McGrath, B. Watkins, & A. Magee. 2018. *Monitoring relative abundance of American shad and river herring in Virginia's rivers.* 2017 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-20, 15 April 2018.

Hilton, E. J., R. Latour, P.E. McGrath, B. Watkins, & A. Magee. 2019. *Monitoring relative abundance of American shad and river herring in Virginia's rivers.* 2018 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-21, 15 April 2019.

Hilton, E. J., R. Latour, P.E. McGrath, B. Watkins, & A. Magee. 2020. *Monitoring relative abundance of American shad and river herring in Virginia's rivers.* 2019 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-22, 24 January 2020.

Hoenig, J.M., R.J. Latour and J.E. Olney. 2008. Estimating stock composition of American shad (*Alosa sapidissima*) using mark-recovery data. North American Journal of Fisheries Management

Hoffman, J. and J.E. Olney**.** 2005. Cohort dynamics of juvenile American shad (*Alosa sapidissima*) in the Pamunkey River, Virginia. Transactions of the American Fisheries Society 134:1-18.

Hoffman J.C., Bronk D.A. and Olney J.E. 2007a. Contribution of allochthonous carbon to American shad production in the Mattaponi River, Virginia using stable isotopes. Estuaries and Coasts. 30(6):1034-1048.

Hoffman J.C., Bronk D.A. and Olney J.E. 2007b. Tracking nursery habitat use by young American shad using stable isotopes. Transactions of the American Fisheries Society 136: 1285-2197.

Hoffman J.C, K.E. Limburg, D.A. Bronk and J.E. Olney. 2008. Overwintering habitats of migratory juvenile American shad in Chesapeake Bay. Environmental Biology of Fishes 81(3):329-345.

Hyle, R. H. 2004. Reproductive biology of American shad, *Alosa sapidissima*, in the Mattaponi River. A thesis presented to the School of Marine Science, College of William and Mary, 88 pp.

Hyle, R.H., R.S. McBride, and J. E. Olney. 2014. Determinate versus indeterminate fecundity in American shad, an anadromous clupeid. Transactions of the American Fisheries Society 143:618–633.

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.

Latour, R. J., E. J. Hilton, P. D. Lynch, T. D. Tuckey, B. E. Watkins, and J. E. Olney. In press. Evaluating the current status of American shad (*Alosa sapidissima*) stocks in Virginia. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4: 302-311.

Loesch, J.G., and S.M. Atran. 1994. History of *Alosa* fisheries management: Virginia, a case study. Pages 1–6 *In*: J.E. Cooper, R.T. Eades, R.J. Klauda, and J.G. Loesch (editors), Anadromous *Alosa* Symposium. Tidewater Chapter, American Fisheries Society, Bethesda, Maryland.

Loesch, J.G., W.H. Kriete Jr. and E.J. Foell. 1982. Effects of light intensity on the catchability of juvenile anadromous *Alosa* species. Transactions of the American Fisheries Society 111: 41-44.

Maki, K. L., J. M. Hoenig and J. E. Olney. 2001. Estimating proportion mature at age when immature fish are unavailable for study, with application to American shad (*Alosa sapidissima*) in the York River, Virginia. J. North American Fisheries Management 21: 703-716.

Maki, K. L., J. M. Hoenig and J. E. Olney. 2002. Interpreting Maturation Data for American Shad in the Presence of Fishing Mortality - A Look at Historical Data from the York River, Virginia. J. North American Fisheries Management.

Maki, K.L., J.M. Hoenig, J.E. Olney and D.M. Heisey. 2006. Comparing historical catches of American shad in multifilament and monofilament nets: a step toward setting restoration targets for Virginia stocks. North American Journal of Fisheries Management 26: 282-288.

McBride, R., M. Hendricks, and J.E. Olney. 2005. Testing the validity of Cating's criteria for age estimation from a Pennsylvania River. Fisheries 30:10-18.

Olney, J.E. 2003a. Monitoring relative abundance of American shad in Virginia's rivers. 2002 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-5, 15 April 2003.

Olney, J.E. 2003b. Incorrect use of the names "Alosidae" and "Alosid" when referring to the shads in the subfamily Alosinae (Teleostei, Clupeidae). American Fisheries Society Symposium 35: xiii-xv.

Olney, J.E. 2004. Monitoring relative abundance of American shad in Virginia's rivers. 2003 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-6, 15 April 2004.

Olney, J.E. 2005. Monitoring relative abundance of American shad in Virginia's rivers. 2004 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-7, 15 April 2005.

Olney, J.E. 2007. Age determination in American shad. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement), 1: 38-41.

Olney, J. E. and J. M. Hoenig. 2000a. Monitoring relative abundance of American shad in Virginia's rivers. 1998 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-1, 24 January 2000.

Olney, J. E. and J. M. Hoenig. 2000b. Monitoring relative abundance of American shad in Virginia's rivers. 1999 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-2, 7 July 2000.

Olney, J.E. and J.M. Hoenig. 2001a. Managing a fishery under moratorium: assessment opportunities for Virginia's stocks of American shad (*Alosa sapidissima*). Fisheries 26(2): 6-12.

Olney, J. E. and J. M. Hoenig. 2001b. Monitoring relative abundance of American shad in Virginia's rivers. 2000 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-3, 29 April 2001.

Olney, J.E., S.C. Denny and J.M. Hoenig. 2001. Criteria for determining maturity stage in female American shad, *Alosa sapidissima*, and the mystery of partial spawning. Bull. Francais de la P□che et de la Pisciculture 362/363: 881-901.

Olney, J.E. and K.L. Maki. 2002. Monitoring relative abundance of American shad in Virginia's rivers. 2001 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-4, 28 April 2002.

Olney, J.E. and R.S. McBride. 2003. Intraspecific variation in batch fecundity of American shad *(Alosa sapidissima*): revisiting the paradigm of reciprocal trends in reproductive traits. American Fisheries Society Symposium 35: 185-192.

Olney, J.E., D.A. Hopler, Jr., T.P. Gunther Jr., K.L. Maki and J.M. Hoenig. 2003. Signs of recovery of American shad, *Alosa sapidissima*, in the James River, Virginia. American Fisheries Society Special Symposium 35: 323-329.

Olney, J.E. and K. Delano. 2006. Monitoring relative abundance of American shad in Virginia's rivers. 2005 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-8, 15 April 2006.

Olney, J.E., D.M. Bilkovic, C.H. Hershner, L.M. Varnell, H. Wang and R.L. Mann. 2006a. Six fish and 600,000 thirsty folks – a fishing moratorium on American shad thwarts a controversial municipal reservoir project in Virginia, USA. American Fisheries Society Symposium, 2006.

Olney, J.E., R.J. Latour, B.E. Watkins and D.G. Clarke. 2006b. Migratory behavior of American shad (*Alosa sapidissima*) in the York River, Virginia with implications for estimating in-river exploitation from tag recovery data. Transactions of the American Fisheries Society 135: 889-896.

Olney, J.E. and B.E. Watkins. 2008. Monitoring relative abundance of American shad in Virginia's rivers. 2007 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-10, 15 April 2008.

Olney, J.E. and B.E. Watkins. 2009. Monitoring relative abundance of American shad in Virginia's rivers. 2008 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-11, 15 April 2009.

Olney, J.E., B.E. Watkins and E.J. Hilton. 2010. Monitoring relative abundance of American shad in Virginia's rivers. 2009 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-12, 15 April 2010.

Olney, J.E. and K.D. Walter. 2007. Monitoring relative abundance of American shad in Virginia's rivers. 2006 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-9, 15 April 2007.

Olney, J.E., K.A. Delano, R.J. Latour, T.P. Gunter, Jr., and L.A. Weaver. 2007. Status of American shad stocks in Virginia. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement) 3:198-250.

Tuckey, T. 2009. Variability in juvenile growth, mortality, maturity and abundance of American shad and blueback herring in Virginia. Doctoral Dissertation, School of Marine Science, College of William and Mary, 175 pp.

Tuckey, T., and J. E. Olney. 2010. Maturity schedules of female American shad vary at small spatial scales in Chesapeake Bay. North American Journal of Fisheries Management 30: 1020-1031.

Upton, S. A. 2008. Novel use of a natural isotope to track recruitment and evaluate age determination for the 2002 year class of American shad in the York River, Virginia. Master's thesis, School of Marine Science, College of William and Mary, 75 pp.

Upton, S.A., B.D. Walther, S.R. Thorrold, and J.E. Olney. 2012. Use of a natural isotopic signature in otoliths to evaluate scale-based age determination for American shad. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 4: 346-357.

Walter, J.F. and J.E. Olney. 2003. Feeding behavior of American shad during the spawning migration in the York River, Virginia. American Fisheries Society Symposium 35: 201-209.

Walther, B.D., S.R. Thorrold and J.E. Olney. 2008. Geochemical signatures in otoliths record natal origins of American shad. Transactions of the American Fisheries Society 137:57-69

Wilhite, M.L., K.L. Maki, J.M. Hoenig and J.E. Olney. 2003. Towards validation of a

juvenile index of abundance for American shad in the York River, Virginia (USA). American Fisheries Society Symposium 35: 285-294.

Table 1. Summary of sampling dates, total number, and total weight of American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2020.

| Sampling Location | Sampling dates in 2020 | Total pre-spawn females | Total males | Total pre-spawn female weight (kg) | Total male weight (kg) | Total fish | Total weight (kg) |
|---|---|---|---|---|---|---|---|
| James River | 3/5 – 4/23 | 6 | 0 | 7.2 | 0 | 6 | 7.2 |
| York River | 3/2 – 4/6 | 21 | 2 | 30.6 | 2.2 | 23 | 32.8 |
| Rappahannock River | 3/1– 5/23 | 310 | 72 | 429.0 | 84.6 | 382 | 513.6 |
| Totals | | 337 | 74 | 466.8 | 86.8 | 411 | 553.6 |

Table 2. Daily temperature and number of American shad (both sexes combined) caught in staked gill nets on the James, York and Rappahannock rivers in 2020. Numbers in parentheses are the number of post-spawning fish caught. Abbreviations: N, number of shad caught; ND, no data. Highlighted cell are non-fishing days.

| | James | | York | | Rappahannock | |
|---|---|---|---|---|---|---|
| Date | Temp ˚C | N | Temp ˚C | N | Temp ˚C | N |
| 3/1/2020 | | | | | 6.5 | 27 |
| 3/2/2020 | | | 7.3 | 2 | | |
| 3/5/2020 | 14.9 | 1 | 9.1 | 4 | | |
| 3/9/2020 | | | | | 8.7 | 30 |
| 3/12/2020 | 16.3 | 3 | | | | |
| 3/13/2020 | | | 11.4 | 11 | | |
| 3/15/2020 | | | | | 11.8 | 55 |
| 3/19/2020 | 13.8 | 1 | 12.6 | 4 | | |
| 3/22/2020 | | | | | 14.7 | 86 |
| 3/26/2020 | 16.3 | 0 | | | | |
| 3/27/2020 | | | ND | 2 | | |
| 3/29/2020 | | | | | 14.8 | 30 |
| 4/1/2020 | 14.4 | 0 | | | | |
| 4/5/2020 | | | | | 13.1 | 56 |
| 4/6/2020 | | | ND | 0 | | |
| 4/8/2020 | 18.7 | 0 | | | | |
| 4/12/2020 | | | | | ND | 47 |
| 4/17/2020 | 16.8 | 1 | | | | |
| 4/19/2020 | | | | | 13.9 | 8 |
| 4/23/2020 | 15.8 | 0 | | | | |
| 4/25/2020 | | | | | 15.4 | 19 |
| 5/3/2020 | | | | | 16.7 | 11 (3) |
| 5/8/2020 | | | | | 16.3 | 6 |
| 5/17/2020 | | | | | 19.0 | 5 |
| 5/23/2020 | | | | | ND | 2 |

Table 3. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in anchor gill net monitoring on the James River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 3/5/2020 | 65 | 1 | 0.0044 | 1.1 | 0.0046 |
| 3/12/2020 | 72 | 3 | 0.0164 | 3.6 | 0.0200 |
| 3/19/2020 | 79 | 1 | 0.0050 | 1.1 | 0.0057 |
| 3/26/2020 | 86 | 0 | 0.0000 | 0.0 | 0.0000 |
| 4/1/2020 | 92 | 0 | 0.0000 | 0.0 | 0.0000 |
| 4/8/2020 | 99 | 0 | 0.0000 | 0.0 | 0.0000 |
| 4/17/2020 | 108 | 1 | 0.0055 | 1.4 | 0.0076 |
| 4/23/2020 | 114 | 0 | 0.0000 | 0.0 | 0.0000 |
| Totals | | 6 | | 7.2 | |

Table 4. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the York River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 3/2/2020 | 62 | 2 | 0.0076 | 2.83 | 0.0108 |
| 3/5/2020 | 65 | 4 | 0.0146 | 5.38 | 0.0196 |
| 3/13/2020 | 73 | 10 | 0.0365 | 15.17 | 0.0553 |
| 3/19/2020 | 79 | 3 | 0.0114 | 4.30 | 0.0164 |
| 3/27/2020 | 87 | 2 | 0.0073 | 2.89 | 0.0105 |
| 4/6/2020 | 97 | 0 | 0.0000 | 0.00 | 0.0000 |
| Totals | | 21 | | 30.57 | |

Table 5. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the York River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 3/2/2020 | 62 | 0 | 0.0000 | 0.00 | 0.0000 |
| 3/5/2020 | 65 | 0 | 0.0000 | 0.00 | 0.0000 |
| 3/13/2020 | 73 | 1 | 0.0036 | 0.91 | 0.0033 |
| 3/19/2020 | 79 | 1 | 0.0038 | 1.24 | 0.0047 |
| 3/27/2020 | 87 | 0 | 0.0000 | 0.00 | 0.0000 |
| 4/6/2020 | 97 | 0 | 0.0000 | 0.00 | 0.0000 |
| Totals | | 2 | | 2.15 | |

Table 6. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 3/1/2020 | 61 | 13 | 0.0510 | 21.43 | 0.0841 |
| 3/9/2020 | 69 | 15 | 0.0563 | 22.20 | 0.0833 |
| 3/15/2020 | 75 | 38 | 0.1367 | 55.94 | 0.2012 |
| 3/22/2020 | 82 | 72 | 0.2590 | 102.99 | 0.3705 |
| 3/29/2020 | 89 | 28 | 0.1007 | 37.53 | 0.1350 |
| 4/5/2020 | 96 | 54 | 0.1943 | 71.77 | 0.2582 |
| 4/12/2020 | 103 | 41 | 0.1609 | 55.36 | 0.2172 |
| 4/19/2020 | 110 | 8 | 0.0314 | 9.25 | 0.0363 |
| 4/25/2020 | 116 | 17 | 0.0612 | 21.41 | 0.0770 |
| 5/3/2020 | 124 | 11 | 0.0396 | 14.59 | 0.0525 |
| 5/8/2020 | 129 | 6 | 0.0235 | 7.34 | 0.0288 |
| 5/17/2020 | 138 | 5 | 0.0180 | 6.43 | 0.0231 |
| 5/23/2020 | 144 | 2 | 0.0072 | 2.74 | 0.0099 |
| Totals | | 310 | | 428.98 | |

Table 7. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 3/1/2020 | 61 | 14 | 0.0549 | 17.26 | 0.0677 |
| 3/9/2020 | 69 | 15 | 0.0563 | 17.66 | 0.0663 |
| 3/15/2020 | 75 | 17 | 0.0612 | 20.81 | 0.0748 |
| 3/22/2020 | 82 | 14 | 0.0504 | 16.05 | 0.0577 |
| 3/29/2020 | 89 | 2 | 0.0072 | 1.49 | 0.0054 |
| 4/5/2020 | 96 | 2 | 0.0072 | 1.95 | 0.0070 |
| 4/12/2020 | 103 | 6 | 0.0235 | 7.19 | 0.0282 |
| 4/19/2020 | 110 | 0 | 0.0000 | 0.00 | 0.0000 |
| 4/25/2020 | 116 | 2 | 0.0072 | 2.21 | 0.0079 |
| 5/3/2020 | 124 | 0 | 0.0000 | 0.00 | 0.0000 |
| 5/8/2020 | 129 | 0 | 0.0000 | 0.00 | 0.0000 |
| 5/17/2020 | 138 | 0 | 0.0000 | 0.00 | 0.0000 |
| 5/23/2020 | 144 | 0 | 0.0000 | 0.00 | 0.0000 |
| Totals | | 72 | | 84.62 | |

Table 8. Mean total length and mean weight of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2020. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

| River | Year class | Number | Mean total length (mm) | Standard deviation | Mean weight (kg) | Standard deviation |
|---|---|---|---|---|---|---|
| James River | 2015 | 3 | 464.3 | 14.2 | 1.1 | 0.094 |
| | 2014 | 1 | 480.0 | | 1.4 | |
| | NA | 2 | 477.5 | 43.1 | 1.2 | 0.268 |
| York River | 2015 | 3 | 470.7 | 19.1 | 1.2 | 0.180 |
| | 2014 | 9 | 500.1 | 18.4 | 1.5 | 0.201 |
| | 2012 | 2 | 550.0 | 22.6 | 1.9 | 0.204 |
| | NA | 7 | 484.7 | 20.9 | 1.4 | 0.177 |
| Rappahannock River | 2016 | 14 | 471.1 | 16.7 | 1.2 | 0.108 |
| | 2015 | 87 | 479.7 | 18.0 | 1.3 | 0.166 |
| | 2014 | 91 | 497.6 | 18.4 | 1.4 | 0.179 |
| | 2013 | 30 | 511.7 | 16.1 | 1.6 | 0.184 |
| | 2012 | 7 | 507.1 | 19.2 | 1.6 | 0.179 |
| | 2011 | 2 | 543.5 | 21.9 | 2.1 | 0.048 |
| | NA | 79 | 487.1 | 24.8 | 1.4 | 0.243 |

Table 9. Mean total length and mean weight of male American shad captured in staked gill nets in the York and Rappahannock Rivers, spring 2020. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

| River | Year class | Number | Mean total length (mm) | Standard deviation | Mean weight (kg) | Standard deviation |
|---|---|---|---|---|---|---|
| York River | 2016 | 1 | 451.0 | | 0.9 | |
| | NA | 1 | 501.0 | | 1.2 | |
| Rappahannock River | 2016 | 3 | 454.0 | 7.5 | 1.0 | 0.116 |
| | 2015 | 11 | 452.2 | 21.5 | 1.0 | 0.146 |
| | 2014 | 12 | 474.2 | 13.5 | 1.2 | 0.086 |
| | 2013 | 22 | 480.2 | 15.9 | 1.3 | 0.126 |
| | 2012 | 5 | 487.0 | 6.8 | 1.3 | 0.033 |
| | 2011 | 4 | 493.0 | 10.3 | 1.3 | 0.068 |
| | NA | 15 | 466.0 | 19.3 | 1.1 | 0.141 |

Table 10. Number, total weight, and seasonal catch rates by year class of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2020. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

| River | Year class | Number | Total weight (kg) | Total effort (days) | Seasonal catch rate (count/m/season) | Seasonal catch rate (kg/m/season) |
|---|---|---|---|---|---|---|
| James River | 2015 | 3 | 3.4 | 8.5 | 0.0019 | 0.0022 |
| | 2014 | 1 | 1.4 | 8.5 | 0.0006 | 0.0009 |
| | NA | 2 | 2.5 | 8.5 | 0.0013 | 0.0017 |
| York River | 2015 | 3 | 3.6 | 5.9 | 0.0018 | 0.0022 |
| | 2014 | 9 | 13.5 | 5.9 | 0.0055 | 0.0083 |
| | 2012 | 2 | 3.7 | 5.9 | 0.0012 | 0.0023 |
| | NA | 7 | 9.8 | 5.9 | 0.0043 | 0.0060 |
| Rappahannock River | 2016 | 14 | 17.0 | 12.6 | 0.0040 | 0.0048 |
| | 2015 | 87 | 113.2 | 12.6 | 0.0248 | 0.0322 |
| | 2014 | 91 | 129.3 | 12.6 | 0.0259 | 0.0369 |
| | 2013 | 30 | 47.0 | 12.6 | 0.0085 | 0.0134 |
| | 2012 | 7 | 11.2 | 12.6 | 0.0020 | 0.0032 |
| | 2011 | 2 | 4.2 | 12.6 | 0.0006 | 0.0012 |
| | NA | 79 | 107.2 | 12.6 | 0.0225 | 0.0305 |

Table 11. Number, total weight, and seasonal catch rates by year class of male American shad captured in staked gill nets in the York and Rappahannock Rivers, spring 2020. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

| River | Year class | Number | Total weight (kg) | Total effort (days) | Seasonal catch rate (count/m/season) | Seasonal catch rate (kg/m/season) |
|---|---|---|---|---|---|---|
| York River | 2016 | 1 | 0.9 | 5.9 | 0.0006 | 0.0006 |
| | NA | 1 | 1.2 | 5.9 | 0.0006 | 0.0007 |
| Rappahannock River | 2016 | 3 | 3.1 | 12.6 | 0.0009 | 0.0009 |
| | 2015 | 11 | 11.3 | 12.6 | 0.0031 | 0.0032 |
| | 2014 | 12 | 14.0 | 12.6 | 0.0034 | 0.0040 |
| | 2013 | 22 | 27.8 | 12.6 | 0.0063 | 0.0079 |
| | 2012 | 5 | 6.7 | 12.6 | 0.0014 | 0.0019 |
| | 2011 | 4 | 5.3 | 12.6 | 0.0011 | 0.0015 |
| | NA | 15 | 16.5 | 12.6 | 0.0043 | 0.0047 |

Table 12. Spawning histories of American shad (combined sexes) collected in spring, 2020 in the James and York rivers. Table entries are total numbers of fish that were aged (James River, n=4; York River, n=15). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the James River, the number in parentheses is the number of aged fish out of the total that had hatchery marks on their otoliths (James, n=1). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

| | | Age at Maturity | | | | |
|---|---|---|---|---|---|---|
| **James River** Year Class | Age at Capture | 3 | 4 | 5 | 6 | 7 |
| 2015 | 5 | - | - | **3 (1)** | - | - |
| 2014 | 6 | - | - | - | **1** | - |

| | | Age at Maturity | | | | |
|---|---|---|---|---|---|---|
| **York River** Year Class | Age at Capture | 3 | 4 | 5 | 6 | 7 |
| 2016 | 4 | | **1** | | | |
| 2015 | 5 | - | - | **3** | - | - |
| 2014 | 6 | - | - | 3 | **6** | - |
| 2012 | 8 | - | - | 2 | - | - |

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2020 in the Rappahannock River. Table entries are total numbers of fish that were aged (Rapp. River, n=288). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the Rappahannock River, the number in parentheses are the number of aged fish out of the total that had hatchery marks on their otoliths (Rapp, n=3). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

| | | Age at Maturity | | | | |
|---|---|---|---|---|---|---|
| **Rapp. River** Year Class | Age at Capture | 3 | 4 | 5 | 6 | 7 |
| 2016 | 4 | - | **17** | - | - | - |
| 2015 | 5 | - | 8 | **90** | - | - |
| 2014 | 6 | - | 8 (1) | 30 | **65** | - |
| 2013 | 7 | - | 13 (2) | 23 | 12 | **4** |
| 2012 | 8 | - | 2 | 5 | 5 | - |
| 2011 | 9 | 1 | 1 | 3 | 1 | - |

Table 14. Summary of historical catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia. Historical data are taken from the voluntary logbooks of Mr. M. Delano, Urbanna, Virginia.

| Year | Effort ($10^3$ m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | 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 |
| Geometric mean | | | | | **1.45** |

Table 15. Summary of recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia.

| Year | Effort ($10^3$ m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 1998 | 3.7 | ---- | 0.053 | 0.020 | 1.46 |
| 1999 | 5.8 | 42 | 0.055 | 0.026 | 1.30 |
| 2000 | 6.6 | 73 | 0.141 | 0.042 | 1.75 |
| 2001 | 6.6 | 72 | 0.167 | 0.070 | 5.77 |
| 2002 | 6.0 | 57 | 0.110 | 0.028 | 3.08 |
| 2003 | 7.3 | 72 | 0.311 | 0.094 | 7.10 |
| 2004 | 5.7 | 65 | 0.232 | 0.107 | 7.06 |
| 2005 | 5.7 | 65 | 0.164 | 0.054 | 3.69 |
| 2006 | 6.7 | 75 | 0.088 | 0.037 | 3.01 |
| 2007 | 5.8 | 64 | 0.130 | 0.042 | 2.60 |
| 2008 | 6.1 | 64 | 0.175 | 0.045 | 3.12 |
| 2009 | 5.6 | 50 | 0.259 | 0.093 | 5.36 |
| 2010 | 5.2 | 50 | 0.088 | 0.027 | 2.03 |
| 2011 | 6.8 | 85 | 0.216 | 0.074 | 6.51 |
| 2012 | 7.0 | 62 | 0.313 | 0.080 | 7.28 |
| 2013 | 7.0 | 78 | 0.289 | 0.080 | 6.98 |
| 2014 | 5.1 | 57 | 0.322 | 0.122 | 8.66 |
| 2015 | 2.7 | 63 | 0.200 | 0.053 | 5.08 |
| 2016 | 2.9 | 56 | 0.085 | 0.022 | 1.68 |
| 2017 | 2.0 | 47 | 0.173 | 0.071 | 4.14 |
| 2018 | 2.3 | 50 | 0.557 | 0.178 | 9.78 |
| 2019 | 2.4 | 50 | 0.106 | 0.052 | 3.01 |
| 2020 | 3.5 | 84 | 0.371 | 0.121 | 10.62 |
| Geometric mean | | | | | **4.05** |

Table 16. Historical catch and effort data of American shad captured by staked gill nets in the York River, Virginia. 1950s historical data are taken from the voluntary logbooks of Malvin Green, Aberdeen Creek, Virginia. The data were originally recorded as numbers of female shad per meter of net per day and were converted to weight (kg) of female shad per meter of net per day, assuming an average female weight of 1.45kg. Catch rates were multiplied by 2.16 to adjust for the lower fishing power of multifilament nets compared to current monofilament nets. 1980s historical data are taken from the voluntary logbooks of Mr. R. Kellum, Achilles, Virginia.

| Year | Effort ($10^3$m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 1953 | 36.0 | 56 | 0.549 | 0.443 | 14.88 |
| 1954 | 45.5 | 54 | 0.699 | 0.434 | 14.04 |
| 1955 | 40.1 | 55 | 0.310 | 0.270 | 8.70 |
| 1956 | 68.8 | 85 | 1.201 | 0.663 | 33.95 |
| 1957 | 56.2 | 65 | 0.955 | 0.667 | 26.14 |
| Geometric mean | | | | | **17.44** |
| 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 |
| Geometric mean | | | | | **3.22** |

Table 17. Summary of recent catch and effort data of American shad by staked gill nets in the York River, Virginia.

| Year | Effort ($10^3$m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 1998 | 6.6 | 78 | 1.080 | 0.190 | 14.71 |
| 1999 | 6.3 | 65 | 0.209 | 0.075 | 5.42 |
| 2000 | 7.1 | 76 | 0.276 | 0.086 | 7.52 |
| 2001 | 5.7 | 79 | 0.627 | 0.163 | 12.97 |
| 2002 | 6.7 | 70 | 0.306 | 0.073 | 7.47 |
| 2003 | 6.1 | 70 | 0.390 | 0.111 | 8.98 |
| 2004 | 5.2 | 65 | 0.448 | 0.157 | 9.72 |
| 2005 | 5.8 | 73 | 0.135 | 0.063 | 4.64 |
| 2006 | 5.5 | 62 | 0.146 | 0.042 | 2.85 |
| 2007 | 5.8 | 70 | 0.243 | 0.069 | 5.04 |
| 2008 | 5.4 | 65 | 0.228 | 0.050 | 3.28 |
| 2009 | 6.0 | 69 | 0.131 | 0.042 | 2.92 |
| 2010 | 6.0 | 44 | 0.227 | 0.055 | 4.19 |
| 2011 | 6.0 | 58 | 0.219 | 0.060 | 4.58 |
| 2012 | 6.0 | 66 | 0.206 | 0.045 | 3.17 |
| 2013 | 7.1 | 78 | 0.189 | 0.045 | 3.98 |
| 2014 | 5.7 | 70 | 0.611 | 0.139 | 10.06 |
| 2015 | 2.8 | 58 | 0.033 | 0.020 | 1.93 |
| 2016 | 2.6 | 58 | 0.062 | 0.023 | 1.54 |
| 2017 | 2.4 | 46 | 0.047 | 0.022 | 1.27 |
| 2018 | 2.2 | 50 | 0.043 | 0.021 | 1.36 |
| 2019 | 2.2 | 43 | 0.101 | 0.041 | 2.39 |
| 2020 | 1.6 | 26 | 0.055 | 0.019 | 0.75 |
| Geometric mean | | | | | **4.01** |

Table 18. Summary of historical catch and effort data of American shad by staked gill nets in the James River, Virginia. Historical data are taken from the voluntary logbooks of the Brown family, Rescue, Virginia.

| Year | Effort ($10^3$m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 1980 | 20.5 | 41 | 2.239 | 0.699 | 29.20 |
| 1981 | 67.7 | 41 | 0.547 | 0.130 | 5.20 |
| 1982 | 49.3 | 35 | 0.331 | 0.115 | 4.20 |
| 1983 | 94.0 | 57 | 1.274 | 0.297 | 16.50 |
| 1984 | 89.7 | 50 | 0.897 | 0.036 | 19.30 |
| 1985 | 91.3 | 45 | 0.295 | 0.103 | 4.90 |
| 1986 | 31.5 | 26 | 1.289 | 0.152 | 6.10 |
| 1987 | 30.1 | 30 | 0.352 | 0.085 | 2.70 |
| 1988 | 19.1 | 20 | 0.487 | 0.193 | 9.30 |
| 1989 | 31.5 | 30 | 0.331 | 0.176 | 6.40 |
| 1990 | 29.7 | 25 | 0.184 | 0.079 | 2.10 |
| 1991 | 28.3 | 40 | 0.138 | 0.062 | 1.90 |
| 1992 | 59.8 | 50 | 0.562 | 0.232 | 7.70 |
| Geometric mean | | | | | **6.40** |

Table 19. Summary of recent catch and effort data of American shad by staked gill nets in the James River, Virginia (* switched to anchor gill nets and therefore may not be directly comparable to previous years).

| Year | Effort ($10^3$m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 1998 | 4.6 | 50 | 0.198 | 0.051 | 2.57 |
| 1999 | 6.0 | 66 | 0.183 | 0.042 | 2.99 |
| 2000 | 7.1 | 70 | 0.279 | 0.086 | 6.61 |
| 2001 | 7.3 | 78 | 0.285 | 0.064 | 5.01 |
| 2002 | 6.5 | 71 | 0.205 | 0.054 | 5.62 |
| 2003 | 6.6 | 79 | 0.284 | 0.112 | 9.34 |
| 2004 | 5.9 | 78 | 0.234 | 0.090 | 7.41 |
| 2005 | 5.6 | 72 | 0.357 | 0.099 | 7.16 |
| 2006 | 4.6 | 54 | 0.078 | 0.032 | 1.74 |
| 2007 | 5.7 | 58 | 0.159 | 0.068 | 4.45 |
| 2008 | 5.2 | 58 | 0.069 | 0.025 | 1.51 |
| 2009 | 6.6 | 55 | 0.130 | 0.035 | 2.69 |
| 2010 | 6.9 | 57 | 0.513 | 0.082 | 6.90 |
| 2011 | 6.2 | 78 | 0.357 | 0.091 | 9.00 |
| 2012 | 5.1 | 72 | 0.294 | 0.076 | 6.06 |
| 2013 | 6.6 | 74 | 0.222 | 0.056 | 4.48 |
| 2014 | 5.1 | 60 | 0.251 | 0.113 | 7.35 |
| 2015 | 2.1 | 49 | 0.057 | 0.023 | 1.25 |
| 2016 | 2.5 | 56 | 0.032 | 0.015 | 0.96 |
| 2017 | 2.9 | 55 | 0.097 | 0.051 | 3.83 |
| 2018 | 2.0 | 43 | 0.049 | 0.022 | 1.30 |
| 2019 | 1.4 | 32 | 0.013 | 0.007 | 0.35 |
| 2020* | 1.5 | 44 | 0.020 | 0.005 | 0.25 |
| Geometric mean | | | | | **3.06** |

Table 20. Specimen number, river of capture, river of origin, sequence of hatchery marks, age, number of spawns, fork length (FL), total length (TL), total weight (TW), and sex of American shad with hatchery marks (James=1, Rapp=4) taken in staked gill net monitoring in the James and Rappahannock rivers, 2020. A total of 97 American shad were scanned for hatchery marks (James=4, Rapp=93). Data are sorted by river, age, and spawning history. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged; Sex: 1, Male; 2, Female.

| Specimen Number | River Capture | River Origin | Sequence | Age | Spawns | FL (mm) | TL (mm) | TW (g) | Sex |
|---|---|---|---|---|---|---|---|---|---|
| 20999 | James | James | 3 | 5 | 0 | 394 | 448 | 1013.9 | 2 |
| 20958 | Rappahannock | Rappahannock | 3 | 7 | 3 | 432 | 492 | 1443.4 | 1 |
| 20993 | Rappahannock | Rappahannock | 3 | 7 | 3 | 409 | 464 | 1288.4 | 1 |
| 21108 | Rappahannock | Rappahannock | 3 | 6 | 2 | 392 | 447 | 992.6 | 1 |
| 21304 | Rappahannock | Rappahannock | 3 | NA | NA | 413 | 471 | 1103.1 | 1 |

Table 21. Total numbers of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2020. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (E. Brittle). Abbreviation: NA; not aged.

| Hatchery Year Class | Hatchery Production (millions) | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total | % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 0.05 | | 1 | | | | | | | | | | | | | | | | | | | | | | 1 | 0.1 |
| 1993 | 0.5 | 7 | 2 | 1 | | | | | | | | | | | | | | | | | | | | | 10 | 1.0 |
| 1994 | 1.6 | 7 | 3 | 9 | | | 1 | | | | | | | | | | | | | | | | | | 20 | 1.9 |
| 1995 | 5.3 | | | 59 | 9 | 8 | 4 | 3 | | | | | | | | | | | | | | | | | 83 | 8.0 |
| 1996 | 5.8 | | | 53 | 62 | 43 | 10 | 4 | 1 | | | | | | | | | | | | | | | | 173 | 16.6 |
| 1997 | 5.9 | | | 2 | 27 | 78 | 57 | 5 | 4 | | 1 | | | | | | | | | | | | | | 174 | 16.7 |
| 1998 | 10 | | | | | 13 | 52 | 17 | 13 | | | | | | | | | | | | | | | | 95 | 9.1 |
| 1999 | 7.3 | | | | | | 14 | 29 | 7 | | | | | | | | | | | | | | | | 50 | 4.8 |
| 2000 | 8.9 | | | | | | 1 | 5 | 9 | | 1 | | | | | | | | | | | | | | 16 | 1.5 |
| 2001 | 9.3 | | | | | | | | 3 | 4 | 3 | | | | | | | | | | | | | | 10 | 1.0 |
| 2002 | 8.4 | | | | | | | | | 4 | 20 | 7 | 2 | | | | | | | | | | | | 33 | 3.2 |
| 2003 | 8.7 | | | | | | | | | | 12 | 8 | 1 | 1 | 2 | | | | | | | | | | 24 | 2.3 |
| 2004 | 6.6 | | | | | | | | | | 2 | 3 | 2 | 13 | 4 | | | | | | | | | | 24 | 2.3 |
| 2005 | 6.0 | | | | | | | | | | | | 1 | 18 | 22 | 2 | 1 | | | | | | | | 44 | 4.2 |
| 2006 | 7.0 | | | | | | | | | | | | | 11 | 35 | 5 | | 3 | | | | | | | 54 | 5.2 |
| 2007 | 6.5 | | | | | | | | | | | | | | 5 | 10 | 14 | 6 | | | | | | | 35 | 3.3 |
| 2008 | 6.2 | | | | | | | | | | | | | | | 4 | 19 | 13 | 2 | | | | | | 38 | 3.6 |
| 2009 | 3.8 | | | | | | | | | | | | | | | | 9 | 18 | 6 | | | | | | 33 | 3.2 |
| 2010 | 3.7 | | | | | | | | | | | | | | | | | 3 | 3 | 4 | 3 | | | | 13 | 1.2 |
| 2011 | 2.4 | | | | | | | | | | | | | | | | | | | 1 | 2 | 2 | | | 5 | 0.5 |
| 2012 | 5.4 | | | | | | | | | | | | | | | | | | | | 2 | 2 | | | 4 | 0.4 |
| 2013 | 4.8 | | | | | | | | | | | | | | | | | | | | | 1 | 2 | | 3 | 0.3 |
| 2014 | 3.3 | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 | 0.1 |
| 2015 | 3.5 | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 0.1 |
| 2016 | 1.01 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.0 |
| 2017 | 1.88 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.0 |
| 2018 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.0 |
| 2019 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.0 |
| 2020 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | |
| NA | -- | | | | | 12 | 3 | 5 | 3 | 1 | 9 | 2 | 2 | 11 | 15 | 7 | 9 | 16 | 1 | 1 | 2 | 2 | 0 | 0 | 101 | 9.7 |
| Total | 130.95 | 14 | 6 | 124 | 98 | 154 | 142 | 68 | 40 | 9 | 48 | 20 | 8 | 54 | 83 | 28 | 52 | 59 | 12 | 6 | 9 | 8 | 2 | 1 | 1045 | 100 |

Table 22. Total numbers of hatchery-marked American shad taken in staked gill nets in the Rappahannock River, 2007-2020. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (E. Brittle). Abbreviation: NA; not aged.

| Hatchery Year Class | Hatchery Production (millions) | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total | % Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | 1.4 | | | | | | | | | | | | | | | | |
| 2004 | 3.2 | | 1 | 2 | 1 | | | | | | | | | | | 4 | 9.5 |
| 2005 | 3.4 | | | 1 | | 1 | | 1 | | | | | | | | 3 | 7.1 |
| 2006 | 6.3 | | | | | 1 | 1 | | | | | | | | | 2 | 4.8 |
| 2007 | 4.5 | | | | | 1 | 5 | 1 | 1 | | | | | | | 8 | 19.0 |
| 2008 | 4.8 | | | | | | 1 | 2 | 1 | | | | | | | 4 | 9.5 |
| 2009 | 2.7 | | | | | | | | 4 | 1 | 1 | | | | | 6 | 14.3 |
| 2010 | 3.9 | | | | | | | | | 1 | 2 | | | | | 3 | 7.1 |
| 2011 | 4.1 | | | | | | | | | 1 | | 1 | 1 | | | 3 | 7.1 |
| 2012 | 6.0 | | | | | | | | | | | | 1 | | | 1 | 2.4 |
| 2013 | 4.3 | | | | | | | | | | | | | 1 | 2 | 3 | 7.1 |
| 2014 | 4.3 | | | | | | | | | | | | | | 1 | 1 | 2.4 |
| 2015 | 0.0 | | | | | | | | | | | | | | | 0 | 0.0 |
| 2016 | 0.0 | | | | | | | | | | | | | | | 0 | 0.0 |
| 2017 | 0.0 | | | | | | | | | | | | | | | 0 | 0.0 |
| 2018 | 0.0 | | | | | | | | | | | | | | | 0 | 0.0 |
| 2019 | 0.0 | | | | | | | | | | | | | | | 0 | 0.0 |
| 2020 | 0.0 | | | | | | | | | | | | | | | | |
| NA | -- | | | | | | 1 | | 1 | | 1 | | | | 1 | 4 | 9.5 |
| Total | 48.9 | 0 | 1 | 3 | 1 | 3 | 8 | 4 | 7 | 3 | 4 | 1 | 2 | 1 | 4 | 42 | 100.0 |

Table 23. Summary of catches of river herring in the Chickahominy River anchor gillnet survey, 2020 (# Females includes both pre- and post-spawn females).

| Date | # Alewife | | # Blueback | | Water Temp (C) |
|---|---|---|---|---|---|
| | 3" Mesh (# Females) | 2.5" Mesh (# Females) | 3" Mesh (# Females) | 2.5" Mesh (# Females) | |
| 1/29/2020 | 5 (2) | 16 (5) | 0 | 0 | 7.4 |
| 2/5/2020 | 40 (18) | 27 (7) | 0 | 0 | 8.3 |
| 2/12/2020 | 13 (7) | 36 (16) | 0 | 0 | 9.5 |
| 2/19/2020 | 22 (19) | 22 (12) | 0 | 0 | 9.1 |
| 2/26/2020 | 13 (11) | 25 (13) | 0 | 0 | 8.9 |
| 3/3/2020 | 51 (44) | 80 (54) | 0 | 2 (2) | 8.9 |
| 3/11/2020 | 22 (20) | 47 (25) | 0 | 6 (1) | 11.3 |
| 3/17/2020 | 13 (13) | 26 (20) | 2 (2) | 28 (15) | 12.2 |
| 3/24/2020 | 6 (6) | 13 (10) | 1 (0) | 75 (44) | 13.8 |
| Totals | 185 (140) | 292 (162) | 3 (2) | 111 (62) | |

Table 24. Dates of capture, number, total weight, and catch rates of pre-spawn female alewife taken in the 2.5" and 3" mesh anchor gillnets on the Chickahominy River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 1/29/2020 | 29 | 7 | 0.0194 | 1.74 | 0.0048 |
| 2/5/2020 | 36 | 25 | 0.0651 | 6.76 | 0.0176 |
| 2/12/2020 | 43 | 23 | 0.0667 | 5.96 | 0.0173 |
| 2/19/2020 | 50 | 31 | 0.0814 | 8.10 | 0.0213 |
| 2/26/2020 | 57 | 24 | 0.0641 | 5.83 | 0.0156 |
| 3/3/2020 | 63 | 98 | 0.2618 | 25.00 | 0.0668 |
| 3/11/2020 | 71 | 43 | 0.1340 | 10.94 | 0.0341 |
| 3/17/2020 | 77 | 31 | 0.0954 | 7.63 | 0.0235 |
| 3/24/2020 | 84 | 12 | 0.0326 | 2.78 | 0.0076 |
| | Totals | 294 | | 74.74 | |

Table 25. Dates of capture, number, total weight, and catch rates of male alewife taken in the 2.5” and 3” mesh anchor gillnets on the Chickahominy River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 1/29/2020 | 29 | 14 | 0.0389 | 2.91 | 0.0081 |
| 2/5/2020 | 36 | 42 | 0.1094 | 9.41 | 0.0245 |
| 2/12/2020 | 43 | 26 | 0.0754 | 5.59 | 0.0162 |
| 2/19/2020 | 50 | 13 | 0.0341 | 2.57 | 0.0067 |
| 2/26/2020 | 57 | 14 | 0.0374 | 2.83 | 0.0076 |
| 3/3/2020 | 63 | 33 | 0.0882 | 6.40 | 0.0171 |
| 3/11/2020 | 71 | 24 | 0.0748 | 4.75 | 0.0148 |
| 3/17/2020 | 77 | 6 | 0.0185 | 1.09 | 0.0034 |
| 3/24/2020 | 84 | 3 | 0.0082 | 0.61 | 0.0016 |
| | Totals | 175 | | 36.15 | |

Table 26. Dates of capture, number, total weight, and catch rates of pre-spawn female blueback herring taken in 2.5” and 3” mesh anchor gillnets on the Chickahominy River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 1/29/2020 | 29 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/5/2020 | 36 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/12/2020 | 43 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/19/2020 | 50 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/26/2020 | 57 | 0 | 0.0000 | 0.00 | 0.0000 |
| 3/3/2020 | 63 | 2 | 0.0053 | 0.37 | 0.0010 |
| 3/11/2020 | 71 | 1 | 0.0031 | 0.21 | 0.0006 |
| 3/17/2020 | 77 | 17 | 0.0523 | 3.87 | 0.0119 |
| 3/24/2020 | 84 | 44 | 0.1197 | 9.62 | 0.0262 |
| | Totals | 64 | | 14.07 | |

Table 27. Dates of capture, number, total weight, and catch rates of male blueback herring taken in the 2.5” and 3” mesh gillnets on the Chickahominy River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 1/29/2020 | 29 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/5/2020 | 36 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/12/2020 | 43 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/19/2020 | 50 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/26/2020 | 57 | 0 | 0.0000 | 0.00 | 0.0000 |
| 3/3/2020 | 63 | 0 | 0.0000 | 0.00 | 0.0000 |
| 3/11/2020 | 71 | 5 | 0.0156 | 0.90 | 0.0028 |
| 3/17/2020 | 77 | 13 | 0.0400 | 2.57 | 0.0079 |
| 3/24/2020 | 84 | 32 | 0.0870 | 5.92 | 0.0161 |
| | Totals | 50 | | 9.39 | |

Table 28. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of pre-spawn female alewife and blueback herring taken during an anchor gillnet survey in the Chickahominy River, spring 2020. The abbreviation NA is "not aged".

| Species | Year class | Number | Mean TL (mm) | Mean weight (kg) | Total weight (kg) | Seasonal catch rate (count/m/season) | Seasonal catch rate (kg/m/season) |
|---|---|---|---|---|---|---|---|
| Alewife | 2017 | 35 | 276.1 | 0.20 | 7.07 | 0.0108 | .0022 |
| | 2016 | 48 | 283.5 | 0.23 | 11.09 | 0.0148 | 0.0034 |
| | 2015 | 145 | 293.5 | 0.26 | 37.75 | 0.0448 | 0.0117 |
| | 2014 | 49 | 302.1 | 0.29 | 14.07 | 0.0152 | 0.0044 |
| | 2013 | 8 | 306.1 | 0.29 | 2.30 | 0.0025 | 0.0007 |
| | 2012 | 3 | 311.7 | 0.28 | 0.85 | 0.0009 | 0.0003 |
| | 2011 | 2 | 309.5 | 0.32 | 0.65 | 0.0006 | 0.0002 |
| | NA | 4 | 287.3 | 0.24 | 0.97 | 0.0012 | 0.0003 |
| Blueback herring | 2016 | 5 | 279.0 | 0.21 | 1.03 | 0.0036 | 0.0007 |
| | 2015 | 36 | 283.9 | 0.21 | 7.49 | 0.0260 | 0.0054 |
| | 2014 | 18 | 294.3 | 0.23 | 4.16 | 0.0130 | 0.0030 |
| | 2013 | 5 | 305.6 | 0.28 | 1.39 | 0.0036 | 0.0010 |

Table 29. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of male alewife and blueback herring taken during an anchor gillnet survey in the Chickahominy River, spring 2020. The abbreviation NA is "not aged".

| Species | Year class | Number | Mean TL (mm) | Mean weight (kg) | Total weight (kg) | Seasonal catch rate (count/m/season) | Seasonal catch rate (kg/m/season) |
|---|---|---|---|---|---|---|---|
| Alewife | 2017 | 38 | 266.9 | 0.18 | 6.77 | 0.0118 | 0.0021 |
| | 2016 | 41 | 270.5 | 0.19 | 7.83 | 0.0127 | 0.0024 |
| | 2015 | 78 | 282.0 | 0.22 | 17.25 | 0.0241 | 0.0053 |
| | 2014 | 12 | 286.6 | 0.24 | 2.94 | 0.0037 | 0.0009 |
| | 2013 | 2 | 285.5 | 0.25 | 0.49 | 0.0006 | 0.0002 |
| | NA | 4 | 282.0 | 0.22 | 0.87 | 0.0012 | 0.0003 |
| Blueback herring | 2016 | 6 | 268.7 | 0.18 | 1.05 | 0.0043 | 0.0008 |
| | 2015 | 24 | 273.3 | 0.18 | 4.41 | 0.0173 | 0.0032 |
| | 2014 | 13 | 280.8 | 0.20 | 2.54 | 0.0094 | 0.0018 |
| | 2013 | 4 | 288.3 | 0.21 | 0.83 | 0.0029 | 0.0006 |
| | NA | 3 | 280.3 | 0.18 | 0.55 | 0.0022 | 0.0004 |

Table 30. Spawning histories of male and female Alewife collected in spring 2020 in the Chickahominy River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=146; females, n=267). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

| | | Age at Maturity | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Males** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2017 | 3 | 1 | 3 | **28** | - | - | - | - |
| 2016 | 4 | - | 10 | 8 | **19** | - | - | - |
| 2015 | 5 | 1 | 12 | 21 | 26 | **6** | - | - |
| 2014 | 6 | - | - | 5 | 4 | - | - | - |
| 2013 | 7 | - | - | 1 | 1 | - | - | - |

| | | Age at Maturity | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Females** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 2017 | 3 | - | 1 | **29** | - | - | - | - | - |
| 2016 | 4 | 2 | 7 | 16 | **15** | - | - | - | - |
| 2015 | 5 | 1 | 17 | 38 | 74 | **9** | - | - | - |
| 2014 | 6 | - | 7 | 11 | 22 | 4 | **1** | - | - |
| 2013 | 7 | - | - | 1 | 6 | 1 | - | - | - |
| 2012 | 8 | - | - | - | 2 | 1 | - | - | - |
| 2011 | 9 | - | - | - | 2 | - | - | - | - |

Table 31. Spawning histories of male and female blueback herring collected in spring 2020 in the Chickahominy River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=35; females, n=56). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

| | | Age at Maturity | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Males** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2016 | 4 | - | - | - | **2** | - | - | - |
| 2015 | 5 | 1 | 4 | 5 | 8 | **2** | - | - |
| 2014 | 6 | - | 1 | 4 | 3 | 2 | - | - |
| 2013 | 7 | - | - | - | 1 | 1 | 1 | - |

| | | Age at Maturity | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Females** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2016 | 4 | - | 1 | - | **3** | - | - | - |
| 2015 | 5 | - | 5 | 3 | 16 | **8** | - | - |
| 2014 | 6 | - | 1 | 6 | 4 | 5 | - | - |
| 2013 | 7 | - | - | 1 | 2 | 1 | - | - |

Table 32. Summary of recent catch and effort data of pre-spawn female alewife by anchored gill nets in the Chickahominy River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

| Year | Effort ($10^3$ m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 2015 | 3.2 | 77 | 0.0421 | 0.0109 | 1.08 |
| 2016 | 9.1 | 85 | 0.0222 | 0.0070 | 0.60 |
| 2017 | 8.4 | 79 | 0.0337 | 0.0108 | 0.91 |
| 2018 | 4.1 | 78 | 0.0506 | 0.0144 | 1.03 |
| 2019 | 4.7 | 83 | 0.0155 | 0.0053 | 0.44 |
| 2020* | 3.2 | 56 | 0.0668 | 0.0232 | 1.54 |
| Geometric mean | | | | | **0.86** |

Table 33. Summary of recent catch and effort data of pre-spawn female blueback herring by anchored gill nets in the Chickahominy River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

| Year | Effort ($10^3$ m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 2015 | 3.2 | 29 | 0.0181 | 0.0091 | 0.37 |
| 2016 | 6.2 | 57 | 0.0191 | 0.0062 | 0.37 |
| 2017 | 5.5 | 56 | 0.0333 | 0.0082 | 0.44 |
| 2018 | 4.1 | 78 | 0.0381 | 0.0069 | 0.57 |
| 2019 | 4.7 | 70 | 0.0179 | 0.0037 | 0.25 |
| 2020* | 1.4 | 22 | 0.0262 | 0.0099 | 0.67 |
| Geometric mean | | | | | **0.42** |

Table 34. Summary of catches of river herring in the Rappahannock River anchor gillnet survey, 2020 (# Females includes both pre- and post-spawn females).

| Date | # Alewife | | # Blueback | | Water Temp (C) |
|---|---|---|---|---|---|
| | 3" Mesh (# Females) | 2.5" Mesh (# Females) | 3" Mesh (# Females) | 2.5" Mesh (# Females) | |
| 2/4/2020 | 21 (15) | 19 (6) | 0 | 6 (4) | 8.0 |
| 2/11/2020 | 4 (1) | 8 (0) | 0 | 1 (0) | 7.8 |
| 2/18/2020 | 8 (5) | 11 (3) | 0 | 0 | 7.9 |
| 2/25/2020 | 9 (9) | 10 (3) | 0 | 6 (4) | 7.7 |
| 3/2/2020 | 12 (11) | 20 (6) | 3 (2) | 2 (2) | 7.9 |
| 3/10/2020 | 27 (22) | 24 (12) | 6 (6) | 22 (15) | 9.5 |
| 3/16/2020 | 18 (16) | 44 (22) | 8 (7) | 20 (12) | 11.2 |
| 3/23/2020 | 14 (14) | 32 (15) | 5 (5) | 54 (23) | 12.8 |
| Totals | 113 (93) | 168 (67) | 22 (20) | 111 (60) | |

Table 35. Dates of capture, number, total weight, and catch rates of pre-spawn female alewife taken in the 2.5" and 3" mesh anchor gillnet monitoring on the Rappahannock River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 2/4/2020 | 35 | 21 | 0.1060 | 5.79 | 0.0292 |
| 2/11/2020 | 42 | 1 | 0.0055 | 0.25 | 0.0014 |
| 2/18/2020 | 49 | 8 | 0.0406 | 2.36 | 0.0120 |
| 2/25/2020 | 56 | 12 | 0.0609 | 3.25 | 0.0165 |
| 3/2/2020 | 62 | 17 | 0.0808 | 4.36 | 0.0207 |
| 3/10/2020 | 70 | 34 | 0.1812 | 8.96 | 0.0477 |
| 3/16/2020 | 76 | 37 | 0.2013 | 9.34 | 0.0508 |
| 3/23/2020 | 83 | 29 | 0.1371 | 6.85 | 0.0324 |
| | Totals | 159 | | 41.16 | |

Table 36. Dates of capture, number, total weight, and catch rates of male alewife taken in the 2.5” and 3” mesh anchor gillnets on the Rappahannock River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 2/4/2020 | 35 | 19 | 0.0959 | 4.24 | 0.0214 |
| 2/11/2020 | 42 | 11 | 0.0608 | 2.44 | 0.0135 |
| 2/18/2020 | 49 | 11 | 0.0558 | 2.25 | 0.0114 |
| 2/25/2020 | 56 | 7 | 0.0355 | 1.53 | 0.0078 |
| 3/2/2020 | 62 | 15 | 0.0713 | 2.79 | 0.0133 |
| 3/10/2020 | 70 | 17 | 0.0906 | 3.52 | 0.0187 |
| 3/16/2020 | 76 | 24 | 0.1306 | 4.47 | 0.0243 |
| 3/23/2020 | 83 | 17 | 0.0804 | 3.21 | 0.0152 |
| | Totals | 121 | | 24.46 | |

Table 37. Dates of capture, number, total weight, and catch rates of pre-spawn female blueback herring taken in the 2.5" and 3" mesh anchor gillnet monitoring on the Rappahannock River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 2/4/2020 | 35 | 4 | 0.0202 | 0.89 | 0.0045 |
| 2/11/2020 | 42 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/18/2020 | 49 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/25/2020 | 56 | 4 | 0.0203 | 0.93 | 0.0047 |
| 3/2/2020 | 62 | 4 | 0.0190 | 1.08 | 0.0051 |
| 3/10/2020 | 70 | 21 | 0.1119 | 5.45 | 0.0290 |
| 3/16/2020 | 76 | 19 | 0.1034 | 5.38 | 0.0292 |
| 3/23/2020 | 83 | 28 | 0.1324 | 6.53 | 0.0309 |
| | Totals | 80 | | 20.25 | |

Table 38. Dates of capture, number, total weight, and catch rates of male blueback herring taken in the 2.5" and 3" mesh anchor gillnet monitoring on the Rappahannock River, spring 2020.

| Date | Day of year | Number | Catch rate (count/m/day) | Total weight (kg) | Catch rate (kg/m/day) |
|---|---|---|---|---|---|
| 2/4/2020 | 35 | 2 | 0.0101 | 0.38 | 0.0019 |
| 2/11/2020 | 42 | 1 | 0.0055 | 0.18 | 0.0010 |
| 2/18/2020 | 49 | 0 | 0.0000 | 0.00 | 0.0000 |
| 2/25/2020 | 56 | 2 | 0.0101 | 0.41 | 0.0021 |
| 3/2/2020 | 62 | 1 | 0.0048 | 0.28 | 0.0013 |
| 3/10/2020 | 70 | 7 | 0.0373 | 1.51 | 0.0080 |
| 3/16/2020 | 76 | 9 | 0.0490 | 1.91 | 0.0104 |
| 3/23/2020 | 83 | 31 | 0.1466 | 5.66 | 0.0267 |
| | Totals | 53 | | 10.30 | |

Table 39. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of pre-spawn female alewife and blueback herring taken during anchor gillnet survey in the Rappahannock River, spring 2020.

| Species | Year class | Number | Mean TL (mm) | Mean weight (kg) | Total weight (kg) | Seasonal catch rate (count/m/season) | Seasonal catch rate (kg/m/season) |
|---|---|---|---|---|---|---|---|
| Alewife | 2017 | 12 | 271.5 | 0.19 | 2.29 | 0.0077 | 0.0015 |
| | 2016 | 20 | 280.9 | 0.22 | 4.49 | 0.0128 | 0.0029 |
| | 2015 | 94 | 293.5 | 0.26 | 24.70 | 0.0600 | 0.0158 |
| | 2014 | 24 | 298.0 | 0.29 | 6.88 | 0.0153 | 0.0044 |
| | 2013 | 8 | 307.0 | 0.31 | 2.44 | 0.0051 | 0.0016 |
| | 2012 | 1 | 322.0 | 0.36 | 0.36 | 0.0006 | 0.0002 |
| Blueback herring | 2016 | 1 | 274.0 | 0.20 | 0.20 | 0.0010 | 0.0002 |
| | 2015 | 31 | 285.3 | 0.22 | 6.85 | 0.0313 | 0.0069 |
| | 2014 | 29 | 299.3 | 0.26 | 7.65 | 0.0293 | 0.0077 |
| | 2013 | 9 | 304.1 | 0.28 | 2.49 | 0.0091 | 0.0025 |
| | 2012 | 4 | 311.0 | 0.30 | 1.19 | 0.0040 | 0.0012 |
| | 2011 | 6 | 312.5 | 0.31 | 1.87 | 0.0061 | 0.0019 |

Table 40. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of male alewife and blueback herring taken during an anchor gillnet survey in the Rappahannock River, spring 2020. The abbreviation NA is "not aged".

| Species | Year class | Number | Mean TL (mm) | Mean weight (kg) | Total weight (kg) | Seasonal catch rate (count/m/season) | Seasonal catch rate (kg/m/season) |
|---|---|---|---|---|---|---|---|
| Alewife | 2017 | 15 | 263.5 | 0.17 | 2.58 | 0.0096 | 0.0016 |
| | 2016 | 30 | 270.7 | 0.19 | 5.76 | 0.0191 | 0.0037 |
| | 2015 | 59 | 275.4 | 0.21 | 12.34 | 0.0376 | 0.0079 |
| | 2014 | 6 | 280.7 | 0.23 | 1.36 | 0.0038 | 0.0009 |
| | 2013 | 3 | 286.3 | 0.25 | 0.76 | 0.0019 | 0.0005 |
| | 2012 | 3 | 290.3 | 0.23 | 0.70 | 0.0019 | 0.0004 |
| | NA | 5 | 274.4 | 0.19 | 0.95 | 0.0032 | 0.0006 |
| Blueback herring | 2016 | 4 | 260.3 | 0.16 | 0.65 | 0.0040 | 0.0007 |
| | 2015 | 25 | 274.1 | 0.18 | 4.56 | 0.0252 | 0.0046 |
| | 2014 | 11 | 281.5 | 0.21 | 2.32 | 0.0111 | 0.0023 |
| | 2013 | 7 | 286.6 | 0.21 | 1.47 | 0.0071 | 0.0015 |
| | 2012 | 1 | 297.0 | 0.28 | 0.28 | 0.0010 | 0.0003 |
| | 2011 | 1 | 301.0 | 0.23 | 0.23 | 0.0010 | 0.0002 |
| | NA | 4 | 276.0 | 0.20 | 0.80 | 0.0040 | 0.0008 |

Table 41. Spawning histories of male and female Alewife collected in spring 2020 in the Rappahannock River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=94; females, n=124). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

Age at Maturity

| **Males** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 2017 | 3 | - | 1 | **13** | - | - | - | - |
| 2016 | 4 | - | 2 | 5 | **12** | - | - | - |
| 2015 | 5 | - | 5 | 13 | 21 | **10** | - | |
| 2014 | 6 | - | - | 2 | 4 | - | - | - |
| 2013 | 7 | - | - | 1 | 1 | 1 | - | - |
| 2012 | 8 | - | - | - | 1 | 1 | 1 | - |

Age at Maturity

| **Females** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 2017 | 3 | - | - | **9** | - | - | - | - |
| 2016 | 4 | - | 1 | 4 | **8** | - | - | - |
| 2015 | 5 | - | 7 | 21 | 37 | **9** | - | - |
| 2014 | 6 | 1 | 2 | 8 | 5 | 3 | - | - |
| 2013 | 7 | - | 1 | 2 | 3 | - | 1 | - |
| 2012 | 8 | - | - | - | - | 1 | - | - |
| 2011 | 9 | - | - | 1 | - | - | - | - |

Table 42. Spawning histories of male and female blueback herring collected in spring 2020 in the Rappahannock River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=31; females, n=55). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

| | | Age at Maturity | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Males** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2016 | 4 | - | - | 1 | **2** | - | - | - |
| 2015 | 5 | 2 | - | 7 | 3 | **3** | - | - |
| 2014 | 6 | - | 1 | 1 | 3 | 2 | - | - |
| 2013 | 7 | - | 1 | 1 | 1 | 1 | - | - |
| 2012 | 8 | - | 1 | - | - | - | - | - |
| 2011 | 9 | - | - | - | - | 1 | - | - |

| | | Age at Maturity | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Females** Year Class | Age at Capture | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2015 | 5 | - | 2 | 8 | 11 | - | - | - |
| 2014 | 6 | - | 7 | 7 | 4 | 4 | - | - |
| 2013 | 7 | 1 | - | 2 | - | 1 | - | - |
| 2012 | 8 | - | 1 | - | 2 | - | - | - |
| 2011 | 9 | - | - | - | 3 | 1 | 1 | - |

Table 43. Summary of recent catch and effort data of pre-spawn female alewife by anchored gill nets in the Rappahannock River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

| Year | Effort ($10^3$ m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 2018 | 4.6 | 77 | 0.950 | 0.0394 | 1.37 |
| 2019 | 2.2 | 71 | 0.0407 | 0.0126 | 0.97 |
| 2020* | 1.6 | 49 | 0.0508 | 0.0263 | 1.85 |
| Geometric mean | | | | | **1.35** |

Table 44. Summary of recent catch and effort data of pre-spawn female blueback herring by anchored gill nets in the Rappahannock River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

| Year | Effort ($10^3$ m*days) | Duration of run (days) | Highest catch rate (female kg/m/day) | Mean catch rate (female kg/m/day) | Area under the catch curve |
|---|---|---|---|---|---|
| 2018 | 3.8 | 63 | 0.2828 | 0.0710 | 2.33 |
| 2019 | 1.4 | 45 | 0.1294 | 0.0564 | 3.08 |
| 2020* | 1.6 | 49 | 0.0309 | 0.0129 | 1.25 |
| Geometric mean | | | | | **2.08** |

Table 45. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2020) on the James, Chickahominy and Rappahannock rivers. The index is the geometric mean catch per haul. Means are reported for five-year increments for years 1980 – 1999. Abbreviations are: SD, standard deviation; N, number of seine hauls.

| Year | James | SD | N | Chickahominy | SD | N | Rappahannock | SD | N |
|---|---|---|---|---|---|---|---|---|---|
| 1980 - 84 | 0.08 | 0.36 | 18 | 0 | | 5 | 0.32 | 2.77 | 4 |
| 1985 - 89 | 0.01 | 0.22 | 34 | 0 | | 8 | 0.16 | 0.49 | 16 |
| 1990 - 94 | 0.01 | 0.16 | 62 | 0 | | 10 | 0.08 | 0.35 | 32 |
| 1995 - 99 | 0.01 | 0.11 | 65 | 0 | | 10 | 0.17 | 0.46 | 33 |
| | | | | | | | | | |
| 2000 | 0 | | 70 | 0 | | 10 | 0.08 | 0.25 | 34 |
| 2001 | 0 | | 70 | 0 | | 10 | 0.34 | 0.43 | 35 |
| 2002 | 0 | | 69 | 0 | | 10 | 0 | | 35 |
| 2003 | 0.10 | 0.30 | 70 | 0 | | 10 | 0.59 | 0.66 | 28 |
| 2004 | 0.05 | 0.20 | 67 | 0 | | 10 | 0.81 | 0.94 | 35 |
| 2005 | 0 | | 66 | 0 | | 10 | 0.27 | 0.66 | 33 |
| 2006 | 0.21 | 0.44 | 64 | 0.23 | 0.34 | 10 | 0.11 | 0.30 | 34 |
| 2007 | 0.04 | 0.26 | 65 | 0 | | 10 | 0.40 | 0.50 | 34 |
| 2008 | 0.01 | 0.09 | 64 | 0 | | 10 | 0.02 | 0.12 | 35 |
| 2009 | 0.02 | 0.12 | 65 | 0.07 | 0.22 | 10 | 0.13 | 0.36 | 34 |
| 2010 | 0.02 | 0.12 | 65 | 0 | | 10 | 1.19 | 1.17 | 33 |
| 2011 | 0.15 | 0.39 | 59 | 0 | | 10 | 1.15 | 1.05 | 27 |
| 2012 | 0.01 | 0.09 | 57 | 0 | | 10 | 0.19 | 0.42 | 35 |
| 2013 | 0 | | 65 | 0 | | 10 | 0.35 | 0.61 | 35 |
| 2014 | 0.07 | 0.24 | 55 | 0.15 | 0.29 | 10 | 3.79 | 1.55 | 35 |
| 2015 | 0.25 | 0.57 | 59 | 0.56 | 0.94 | 10 | 4.19 | 1.52 | 28 |
| 2016 | 0.01 | 0.09 | 65 | 0 | | 10 | 4.17 | 1.63 | 35 |
| 2017 | 0 | | 65 | 0 | | 10 | 0.87 | 1.27 | 35 |
| 2018 | 0.03 | 0.16 | 63 | 0 | | 10 | 4.65 | 1.57 | 35 |
| 2019 | 0.13 | 0.33 | 65 | 0.07 | 0.22 | 10 | 11.65 | 1.75 | 35 |
| 2020 | 0 | | 56 | 0 | | 8 | 8.13 | 1.29 | 32 |

Table 46. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2020) on the Mattaponi, Pamunkey, and York rivers. The index is the geometric mean catch per haul. Means are reported for five-year increments for years 1980 – 1999. Abbreviations are: SD, standard deviation; N, number of seine hauls.

| Year | Mattaponi | SD | N | Pamunkey | SD | N | York | SD | N |
|---|---|---|---|---|---|---|---|---|---|
| 1980 - 84 | 7.21 | 1.01 | 17 | 0.42 | 0.60 | 12 | 2.41 | 1.15 | 30 |
| 1985 - 89 | 1.94 | 0.79 | 32 | 0.20 | 1.03 | 23 | 0.91 | 0.70 | 59 |
| 1990 - 94 | 0.59 | 0.77 | 46 | 0.04 | 0.22 | 36 | 0.28 | 0.62 | 87 |
| 1995 - 99 | 3.96 | 0.98 | 49 | 0.53 | 0.68 | 39 | 1.66 | 0.92 | 92 |
| | | | | | | | | | |
| 2000 | 5.77 | 1.31 | 39 | 0.08 | 0.26 | 31 | 1.83 | 1.33 | 74 |
| 2001 | 0.58 | 0.70 | 49 | 0.15 | 0.36 | 40 | 0.35 | 0.58 | 94 |
| 2002 | 0.23 | 0.50 | 48 | 0.02 | 0.11 | 40 | 0.12 | 0.37 | 93 |
| 2003 | 8.57 | 1.32 | 50 | 13.11 | 1.06 | 39 | 9.04 | 1.30 | 94 |
| 2004 | 7.52 | 1.39 | 47 | 0.10 | 0.29 | 38 | 2.21 | 1.45 | 90 |
| 2005 | 1.66 | 1.35 | 50 | 0.05 | 0.20 | 40 | 0.70 | 1.09 | 95 |
| 2006 | 0.93 | 0.92 | 48 | 0.09 | 0.35 | 37 | 0.47 | 0.76 | 90 |
| 2007 | 0.30 | 0.51 | 47 | 0 | | 36 | 0.15 | 0.39 | 88 |
| 2008 | 0.11 | 0.30 | 50 | 0 | | 40 | 0.06 | 0.23 | 95 |
| 2009 | 0.02 | 0.16 | 47 | 0 | | 40 | 0.01 | 0.12 | 92 |
| 2010 | 0.97 | 1.03 | 50 | 0.06 | 0.19 | 38 | 0.47 | 0.82 | 93 |
| 2011 | 1.16 | 1.39 | 48 | 0.27 | 0.55 | 35 | 0.67 | 1.11 | 88 |
| 2012 | 0.01 | 0.10 | 48 | 0.02 | 0.11 | 39 | 0.02 | 0.10 | 93 |
| 2013 | 0.12 | 0.36 | 50 | 0.05 | 0.20 | 40 | 0.10 | 0.32 | 95 |
| 2014 | 1.58 | 0.94 | 50 | 0.12 | 0.28 | 41 | 0.72 | 0.54 | 96 |
| 2015 | 2.96 | 1.22 | 49 | 0.89 | 0.88 | 40 | 1.69 | 1.13 | 94 |
| 2016 | 0.99 | 1.05 | 50 | 0.36 | 0.71 | 40 | 0.64 | 0.91 | 95 |
| 2017 | 0.60 | 0.82 | 50 | 0.13 | 0.49 | 40 | 0.36 | 0.70 | 95 |
| 2018 | 4.72 | 1.28 | 49 | 1.14 | 0.76 | 40 | 2.51 | 1.17 | 94 |
| 2019 | 2.65 | 1.13 | 50 | 0.40 | 0.80 | 40 | 1.28 | 1.09 | 95 |
| 2020 | 0.73 | 0.78 | 42 | 0.06 | 0.20 | 34 | 0.36 | 0.62 | 81 |

Table 47. Summary of catches of juvenile river herring in the Chickahominy River in 2020 during nighttime surface trawls. Cruise specific indexes are reported as geometric means of all stations. There were insufficient catches of alewife to present indexes of abundance.

| Date | Species | N | Mean FL (mm) | Mean WT (g) | Mean (fish/tow) | Cruise specific index (SD) |
|---|---|---|---|---|---|---|
| 7/6/2020 | Alewife | 1 | 67.0 | 4.1 | 0.08 | 1.1 (1.2) |
| | Blueback | 968 | 36.3 | 0.6 | 80.7 | 32.3 (6.0) |
| 7/14/2020 | Alewife | 6 | 61.0 | 3.3 | 0.5 | 1.3 (1.7) |
| | Blueback | 1117 | 36.8 | 0.6 | 93.1 | 46.2 (4.6) |
| 7/20/2020 | Alewife | 10 | 66.1 | 4.2 | 0.8 | 1.7 (1.6) |
| | Blueback | 1305 | 39.6 | 0.7 | 108.8 | 19.3 (8.7) |
| 7/27/2020 | Alewife | 2 | 72.0 | 4.6 | 0.2 | 1.1 (1.3) |
| | Blueback | 1134 | 41.5 | 0.8 | 94.5 | 52.1 (3.9) |
| 8/2/2020 | Alewife | 5 | 66.8 | 4.9 | 0.4 | 1.2 (1.6) |
| | Blueback | 877 | 42.4 | 0.9 | 73.1 | 42.8 (3.2) |
| 8/10/2020 | Alewife | 3 | 79.7 | 6.3 | 0.3 | 1.2 (1.4) |
| | Blueback | 1171 | 43.4 | 0.9 | 97.6 | 64.3 (3.3) |
| 8/17/2020 | Alewife | 2 | 68.0 | 3.9 | 0.2 | 1.1 (1.3) |
| | Blueback | 925 | 46.0 | 1.1 | 77.1 | 40.3 (3.3) |
| 8/24/2020 | Alewife | 0 | | | 0 | 0 |
| | Blueback | 804 | 47.4 | 1.2 | 67.0 | 46.8 (2.8) |
| **Season Totals** | **Alewife** | **29** | **67.1** | **4.4** | **0.3** | **1.2 (0.3)** |
| | **Blueback** | **8301** | **42.0** | **0.9** | **86.5** | **40.8 (4.3)** |

Table 48. Indexes of abundance of juvenile alewife collected in beach seine surveys (1989-2020) on the James, York, and Rappahannock rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

| Year | James | SD | N | York | SD | N | Rappahannock | SD | N |
|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.00 | | 10 | 0.05 | 0.33 | 54 | 1.01 | 1.07 | 36 |
| 1990 | 0.00 | | 10 | 0.00 | | 55 | 0.05 | 0.19 | 40 |
| 1991 | 0.00 | | 10 | 0.00 | | 54 | 0.02 | 0.12 | 35 |
| 1992 | 0.00 | | 10 | 0.00 | | 54 | 0.04 | 0.22 | 40 |
| 1993 | 0.07 | 0.22 | 10 | 0.00 | | 54 | 0.21 | 0.57 | 36 |
| 1994 | 0.07 | 0.22 | 10 | 0.12 | 0.54 | 54 | 0.22 | 0.52 | 39 |
| 1995 | 0.00 | | 10 | 0.00 | | 55 | 0.09 | 0.35 | 37 |
| 1996 | 0.66 | 1.07 | 10 | 0.11 | 0.40 | 53 | 0.61 | 1.08 | 37 |
| 1997 | 0.00 | | 10 | 0.01 | 0.09 | 55 | 0.28 | 0.80 | 40 |
| 1998 | 0.07 | 0.22 | 10 | 0.00 | | 51 | 0.12 | 0.47 | 33 |
| 1999 | 0.00 | | 10 | 0.00 | | 49 | 0.12 | 0.32 | 40 |
| 2000 | 0.00 | | 10 | 0.00 | | 51 | 0.17 | 0.50 | 39 |
| 2001 | 0.00 | | 10 | 0.24 | 0.65 | 54 | 0.41 | 0.90 | 40 |
| 2002 | 0.00 | | 10 | 0.01 | 0.10 | 53 | 0.02 | 0.11 | 40 |
| 2003 | 0.00 | | 10 | 0.04 | 0.24 | 54 | 0.25 | 0.61 | 39 |
| 2004 | 0.28 | 0.58 | 10 | 0.01 | 0.10 | 50 | 0.05 | 0.19 | 40 |
| 2005 | 0.44 | 1.16 | 10 | 0.02 | 0.15 | 55 | 0.03 | 0.18 | 37 |
| 2006 | 0.28 | 0.42 | 10 | 0.00 | | 50 | 0.04 | 0.16 | 39 |
| 2007 | 0.55 | 1.39 | 10 | 0.00 | | 48 | 0.30 | 0.77 | 39 |
| 2008 | 0.00 | | 10 | 0.00 | | 55 | 0.04 | 0.15 | 40 |
| 2009 | 0.30 | 0.63 | 10 | 0.00 | | 52 | 0.12 | 0.40 | 39 |
| 2010 | 0.07 | 0.22 | 10 | 0.23 | 0.61 | 53 | 0.36 | 0.74 | 38 |
| 2011 | 0.00 | | 10 | 0.05 | 0.21 | 49 | 0.98 | 1.32 | 39 |
| 2012 | 0.00 | | 10 | 0.00 | | 56 | 0.05 | 0.31 | 40 |
| 2013 | 0.12 | 0.35 | 10 | 0.00 | | 55 | 0.16 | 0.41 | 40 |
| 2014 | 0.23 | 0.47 | 10 | 0.00 | | 53 | 0.17 | 0.37 | 40 |
| 2015 | 3.29 | 1.66 | 10 | 0.07 | 0.23 | 55 | 0.25 | 0.53 | 40 |
| 2016 | 0.98 | 1.15 | 11 | 0.09 | 0.28 | 55 | 0.11 | 0.45 | 40 |
| 2017 | 0.20 | 0.57 | 10 | 0.00 | | 55 | 0.13 | 0.67 | 40 |
| 2018 | 2.98 | 1.54 | 10 | 0.06 | 0.34 | 54 | 0.52 | 1.03 | 40 |
| 2019 | 0.12 | 0.35 | 10 | 0.03 | 0.22 | 55 | 0.19 | 0.57 | 39 |
| 2020 | 0.00 | | 9 | 0.00 | | 55 | 0.10 | 0.32 | 37 |

Table 49. Indexes of abundance of juvenile blueback herring collected in beach seine surveys (1989-2020) on the James, York, and Rappahannock rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

| Year | James | SD | N | York | SD | N | Rappahannock | SD | N |
|---|---|---|---|---|---|---|---|---|---|
| 1989 | 0.5 | 0.89 | 45 | 0.32 | 0.69 | 35 | 8.93 | 1.63 | 22 |
| 1990 | 0.46 | 1.11 | 45 | 0.00 | 0.00 | 35 | 1.89 | 1.14 | 25 |
| 1991 | 0.26 | 0.64 | 45 | 0.04 | 0.16 | 35 | 0.15 | 0.45 | 21 |
| 1992 | 0.08 | 0.53 | 45 | 0.00 | 0.00 | 34 | 0.06 | 0.19 | 25 |
| 1993 | 0.72 | 1.37 | 45 | 0.00 | 0.00 | 34 | 2.05 | 1.39 | 21 |
| 1994 | 0.44 | 1.01 | 43 | 0.14 | 0.39 | 34 | 1.48 | 1.58 | 24 |
| 1995 | 0.03 | 0.15 | 43 | 0.00 | 0.00 | 35 | 0.40 | 0.50 | 23 |
| 1996 | 0.56 | 1.18 | 44 | 0.39 | 1.05 | 34 | 6.14 | 1.77 | 22 |
| 1997 | 0.18 | 0.80 | 45 | 0.06 | 0.26 | 35 | 1.51 | 1.54 | 25 |
| 1998 | 0.23 | 0.57 | 44 | 0.00 | 0.00 | 33 | 1.97 | 1.78 | 19 |
| 1999 | 0.03 | 0.14 | 49 | 0.00 | 0.00 | 32 | 0.46 | 0.89 | 25 |
| 2000 | 0.45 | 1.27 | 50 | 0.43 | 1.09 | 32 | 1.47 | 1.64 | 24 |
| 2001 | 0.42 | 1.07 | 50 | 0.27 | 0.92 | 34 | 3.30 | 1.43 | 25 |
| 2002 | 0.14 | 0.54 | 49 | 0.00 | 0.00 | 34 | 0.34 | 0.72 | 25 |
| 2003 | 0.74 | 1.28 | 50 | 0.82 | 1.10 | 34 | 3.22 | 1.62 | 25 |
| 2004 | 0.4 | 0.94 | 47 | 0.07 | 0.31 | 32 | 1.80 | 1.32 | 25 |
| 2005 | 0.47 | 1.02 | 46 | 0.00 | 0.00 | 35 | 1.29 | 1.53 | 23 |
| 2006 | 0.02 | 0.11 | 44 | 0.00 | 0.00 | 31 | 0.93 | 1.37 | 24 |
| 2007 | 0.51 | 1.09 | 45 | 0.11 | 0.44 | 30 | 1.30 | 1.03 | 24 |
| 2008 | 0.02 | 0.11 | 44 | 0.05 | 0.22 | 35 | 0.46 | 0.73 | 25 |
| 2009 | 0.16 | 0.64 | 45 | 0.00 | 0.00 | 33 | 0.65 | 1.19 | 24 |
| 2010 | 0.13 | 0.72 | 45 | 0.12 | 0.67 | 35 | 1.35 | 1.26 | 25 |
| 2011 | 1.15 | 1.49 | 39 | 0.26 | 0.10 | 30 | 9.14 | 2.12 | 24 |
| 2012 | 0.26 | 0.70 | 38 | 0.00 | 0.00 | 33 | 0.31 | 0.95 | 25 |
| 2013 | 0.08 | 0.37 | 40 | 0.00 | 0.00 | 35 | 0.45 | 1.07 | 25 |
| 2014 | 1.99 | 1.85 | 40 | 0.23 | 0.59 | 36 | 5.02 | 1.66 | 25 |
| 2015 | 2.82 | 1.84 | 40 | 1.41 | 1.59 | 35 | 15.84 | 2.20 | 25 |
| 2016 | 0.72 | 1.28 | 40 | 0.26 | 0.61 | 35 | 2.60 | 1.55 | 25 |
| 2017 | 0.87 | 1.38 | 40 | 0.20 | 0.57 | 35 | 0.69 | 0.99 | 25 |
| 2018 | 3.21 | 1.67 | 38 | 0.52 | 1.01 | 34 | 3.87 | 1.88 | 25 |
| 2019 | 3.85 | 1.82 | 40 | 0.09 | 0.31 | 35 | 2.66 | 1.59 | 25 |
| 2020 | 0.56 | 1.40 | 38 | 0.30 | 0.88 | 35 | 0.99 | 1.21 | 22 |

Table 50. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by anchor gill net in the James River, 2020. The abbreviation ND is “no data”.

| Date | Live SB | Dead SB | Total SB | Other species | Total |
|---|---|---|---|---|---|
| 3/5/2020 | 2 | 5 | 7 | 104 | 111 |
| 3/12/2020 | 6 | 7 | 13 | 256 | 269 |
| 3/19/2020 | 9 | 26 | 35 | 367 | 402 |
| 3/26/2020 | ND | ND | ND | ND | ND |
| 4/1/2020 | ND | ND | ND | ND | ND |
| 4/8/2020 | ND | ND | ND | ND | ND |
| 4/17/2020 | ND | ND | ND | ND | ND |
| 4/23/2020 | ND | ND | ND | ND | ND |
| Totals | 17 | 38 | 55 | 727 | 782 |

Table 51. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2020. The abbreviation ND is “no data”.

| Date | Live SB | Dead SB | Total SB | Other species | Total |
|---|---|---|---|---|---|
| 3/2/2020 | 6 | 5 | 11 | 50 | 61 |
| 3/5/2020 | 5 | 0 | 5 | 8 | 13 |
| 3/13/2020 | 3 | 6 | 9 | 7 | 16 |
| 3/19/2020 | 0 | 4 | 4 | 17 | 21 |
| 3/27/2020 | 3 | 0 | 3 | 14 | 17 |
| 4/6/2020 | ND | ND | ND | ND | ND |
| Totals | 17 | 15 | 32 | 96 | 128 |

Table 52. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2020. Abbreviations are: MEN, menhaden only; ND , no data.

| Date | Live SB | Dead SB | Total SB | Other species | Total |
|---|---|---|---|---|---|
| 3/1/2020 | 43 | 28 | 71 | 310 | 381 |
| 3/9/2020 | 72 | 56 | 128 | 215 | 343 |
| 3/15/2020 | 24 | 58 | 82 | 211 | 293 |
| 3/22/2020 | 6 | 37 | 43 | 517 | 560 |
| 3/29/2020 | ND | ND | ND | 90 (MEN) | ND |
| 4/5/2020 | ND | ND | ND | 20 (MEN) | ND |
| 4/12/2020 | 5 | 3 | 8 | 13 (MEN) | 21 |
| 4/19/2020 | 2 | 0 | 2 | 55 (MEN) | ND57 |
| 4/25/2020 | ND | ND | ND | 109 (MEN) | ND |
| 5/3/2020 | ND | ND | ND | 41 (MEN) | ND |
| 5/8/2020 | ND | ND | ND | 49 (MEN) | ND |
| 5/17/2020 | ND | ND | ND | 60 (MEN) | ND |
| 5/23/2020 | ND | ND | ND | 40 (MEN) | ND |
| Totals | 152 | 182 | 334 | 1730 | 2064 |

Figure 1. Number and location of staked gill nets on the James River in 1983.

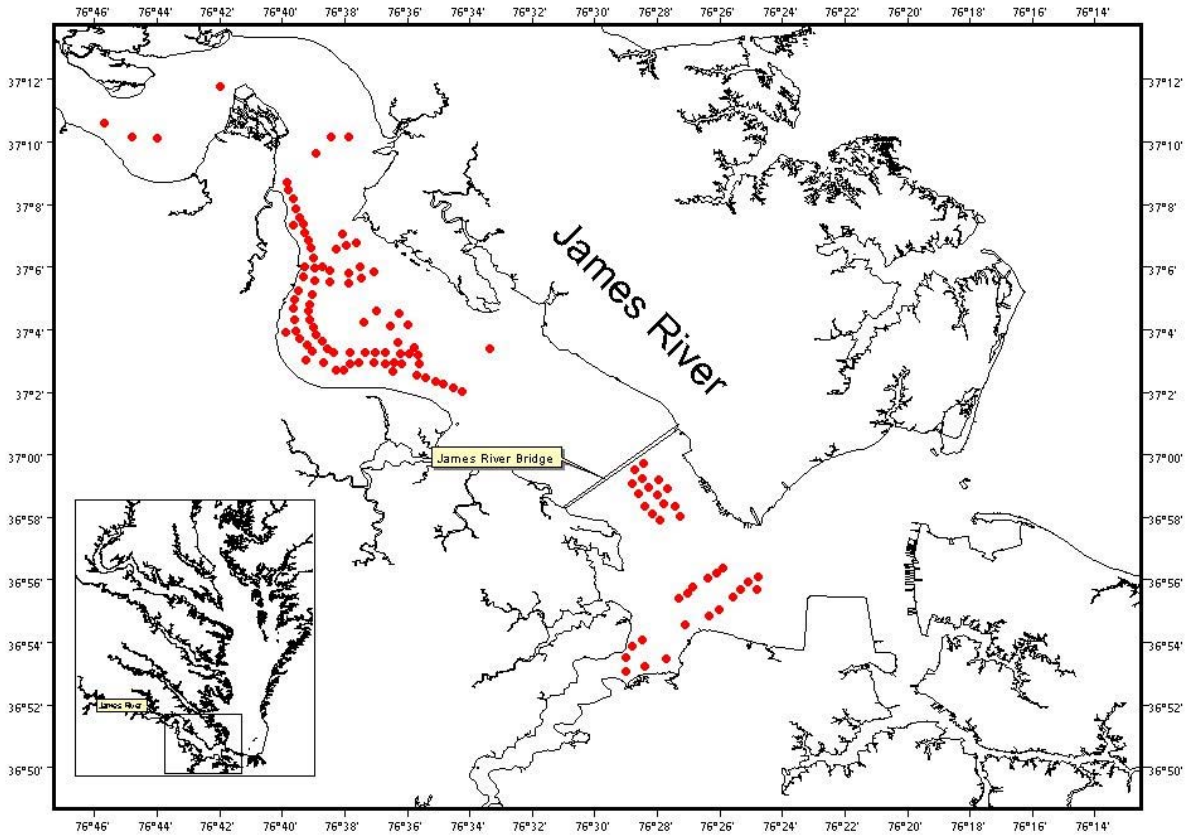


Figure 2. Number and location of staked gill nets on the York River in 1983.

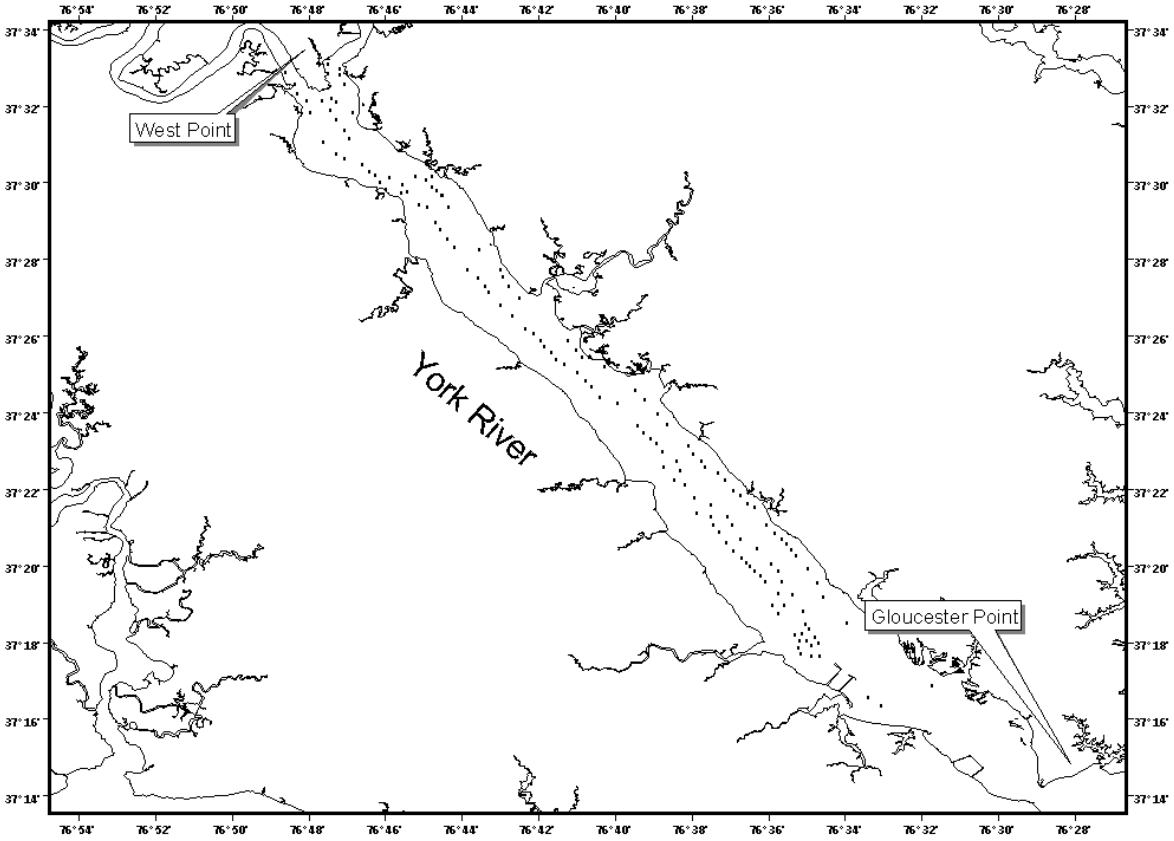


Figure 3. Number and location of staked gill nets on the Rappahannock River in 1983.

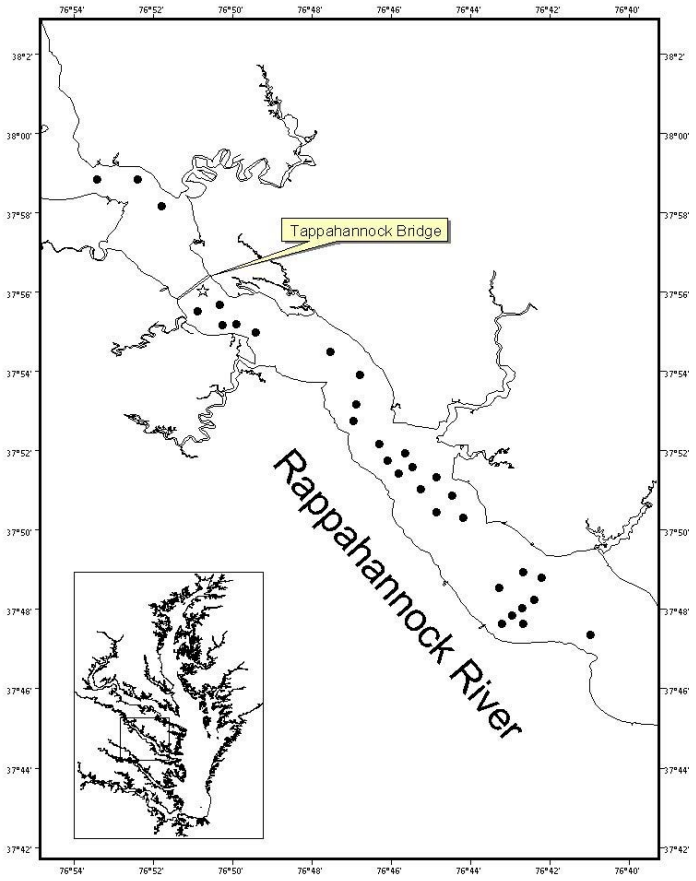


Figure 4. Location of the staked gill net fished by Mr. George Trice on the James River.

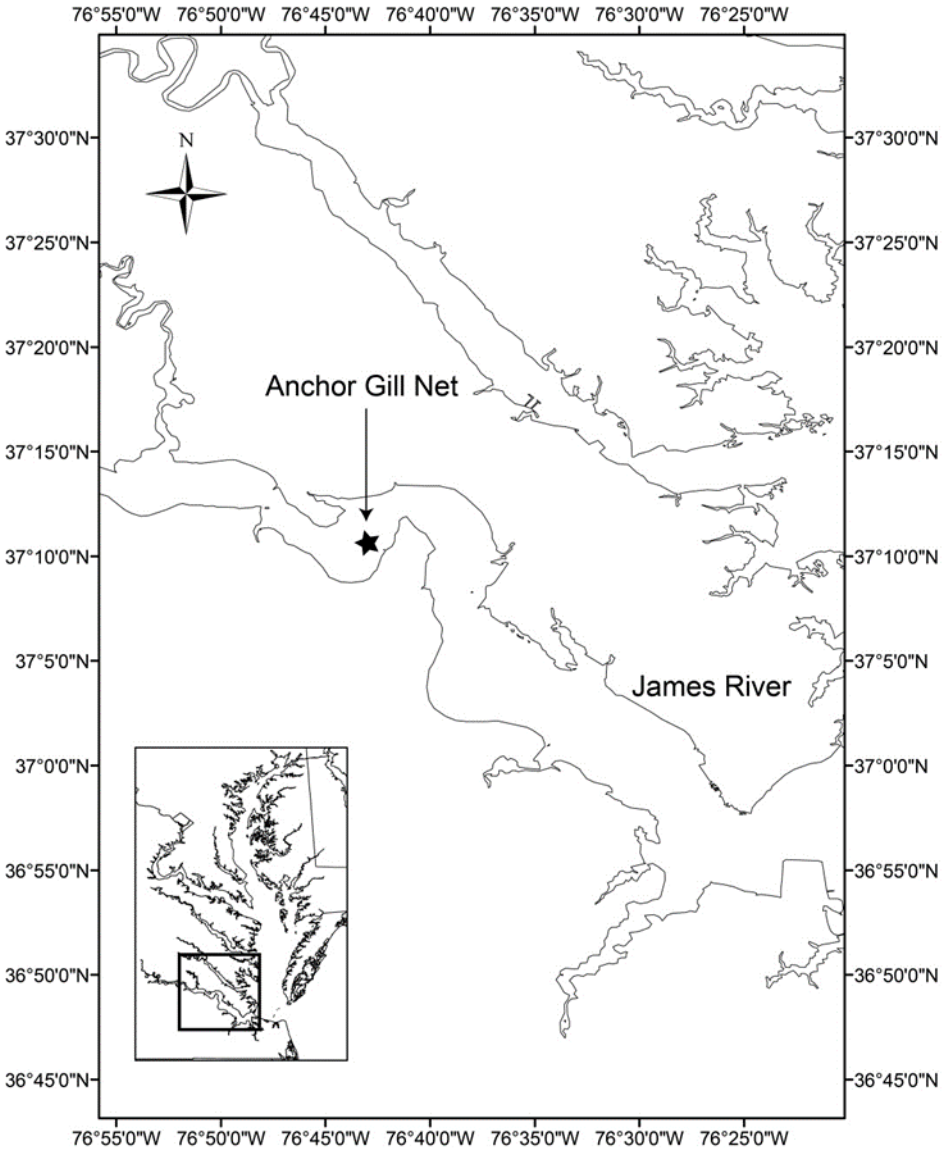


Figure 5. Location of the staked gill net fished by Mr. Raymond Kellum on the York River.

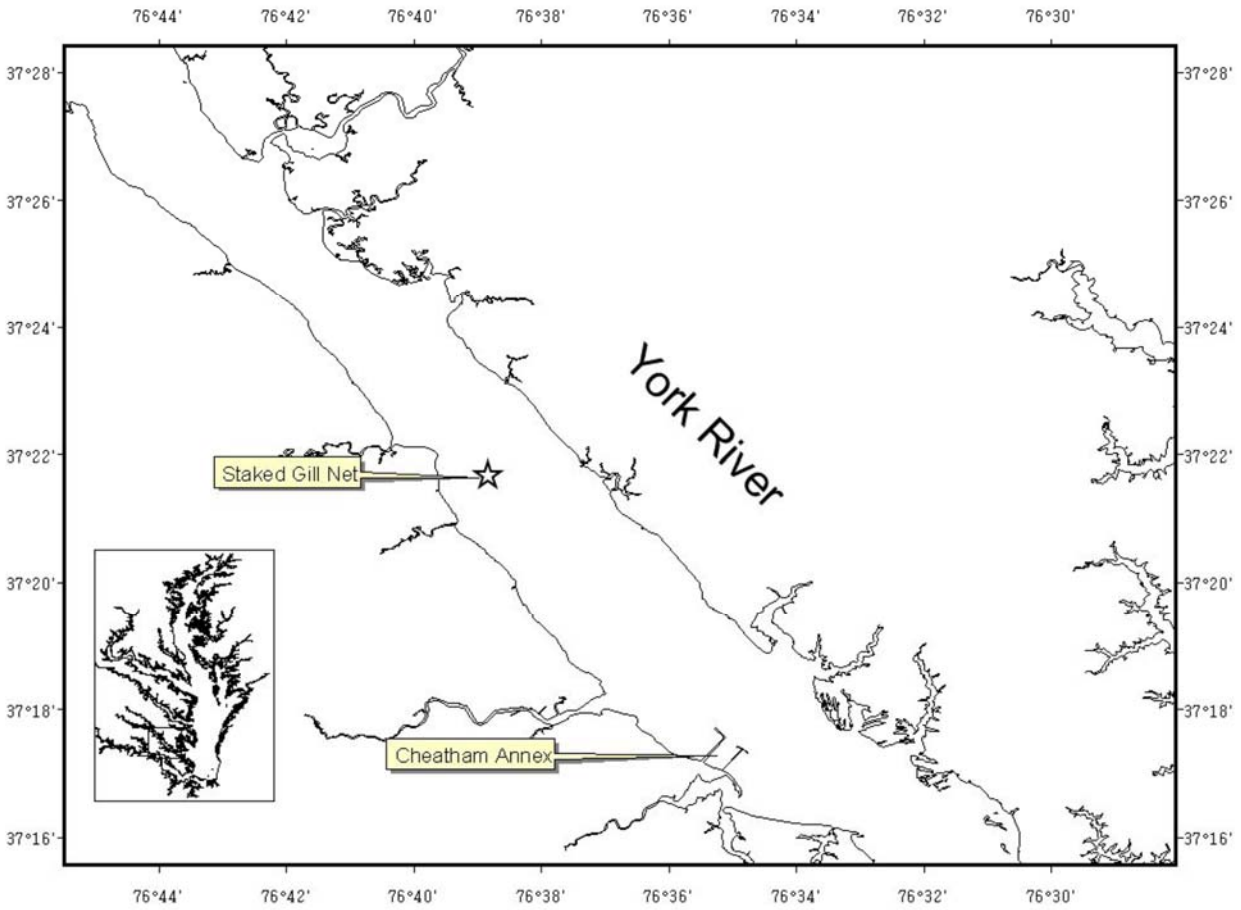


Figure 6. Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River.

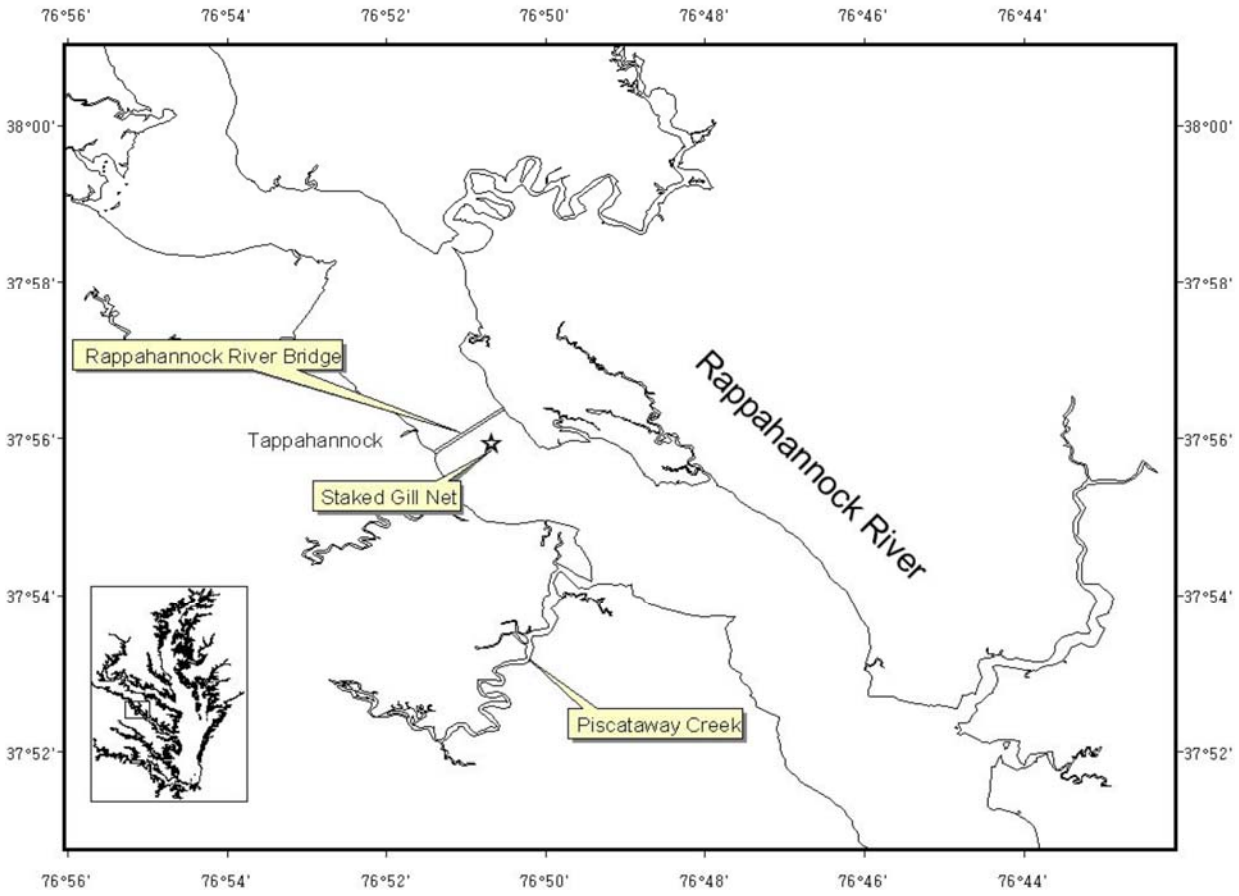


Figure 7. Recent (1998-2020) and historic values of the catch index of female American shad on the James River.

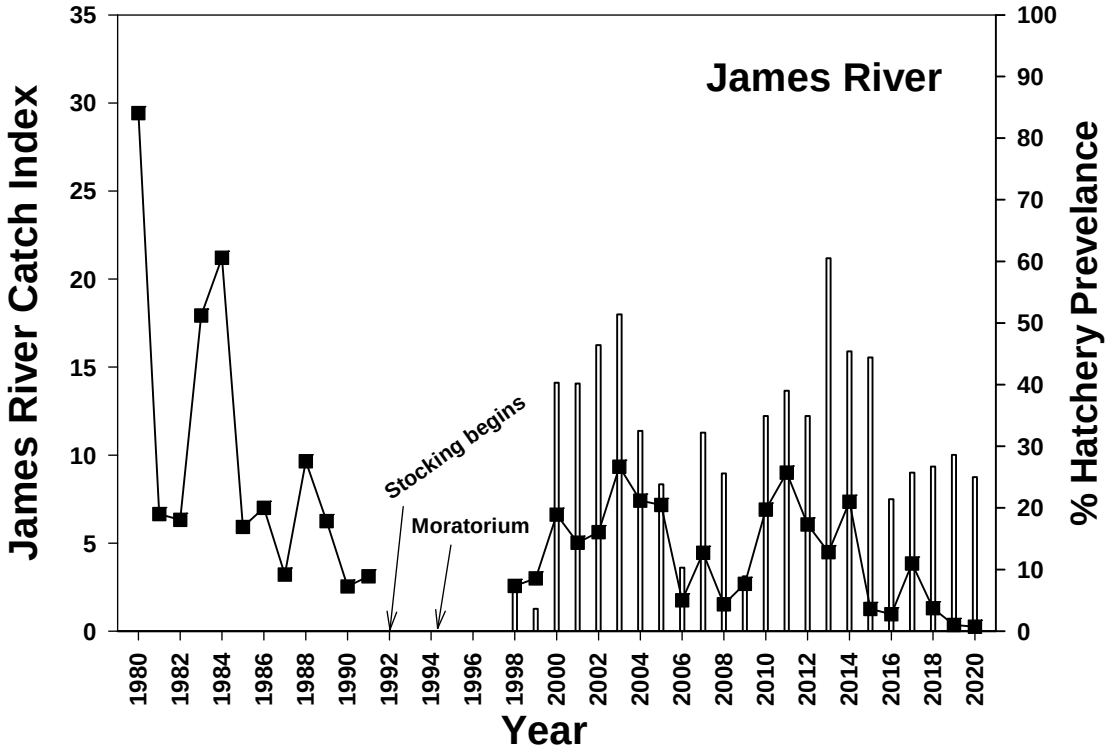


Figure 8. Recent (1998-2020) and historic values of the catch index of female American shad on the York River.

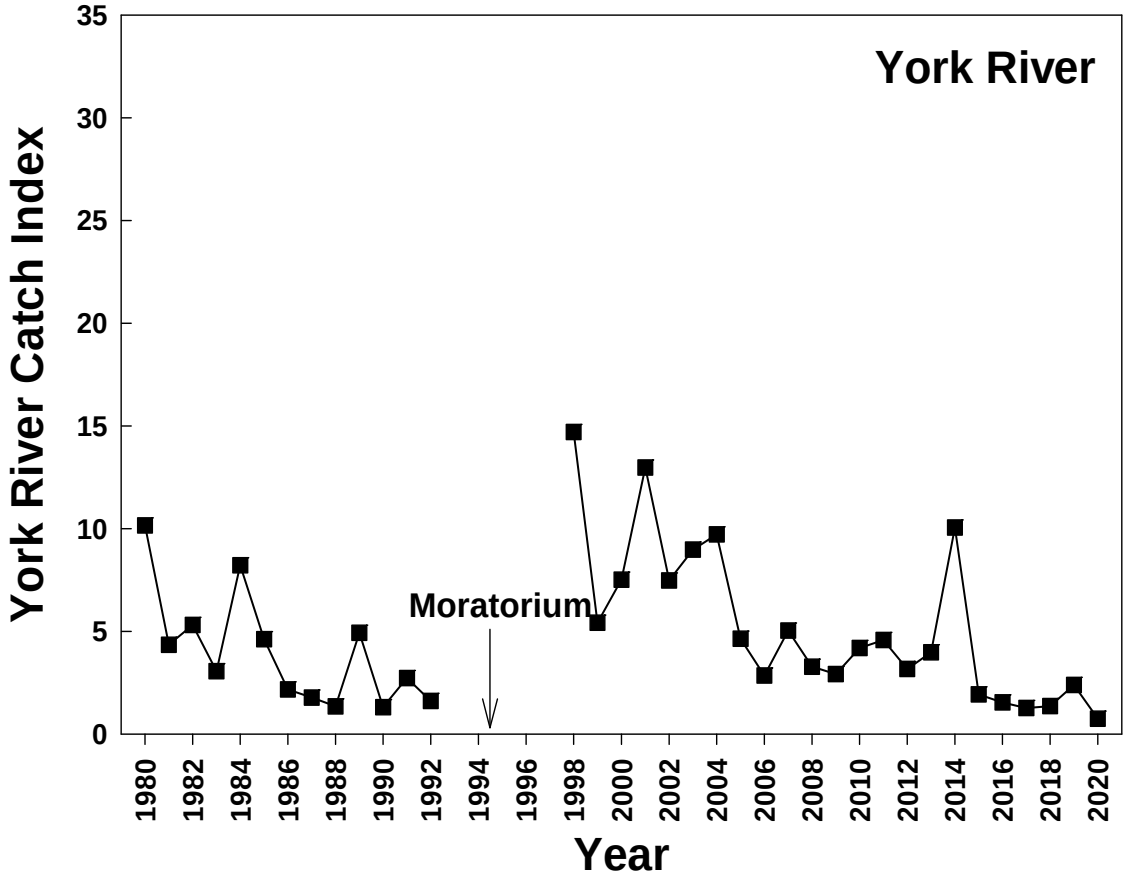


Figure 9. Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the geometric means of each data set (solid, 1950s; short dashes, current; long dashes, 1980s)

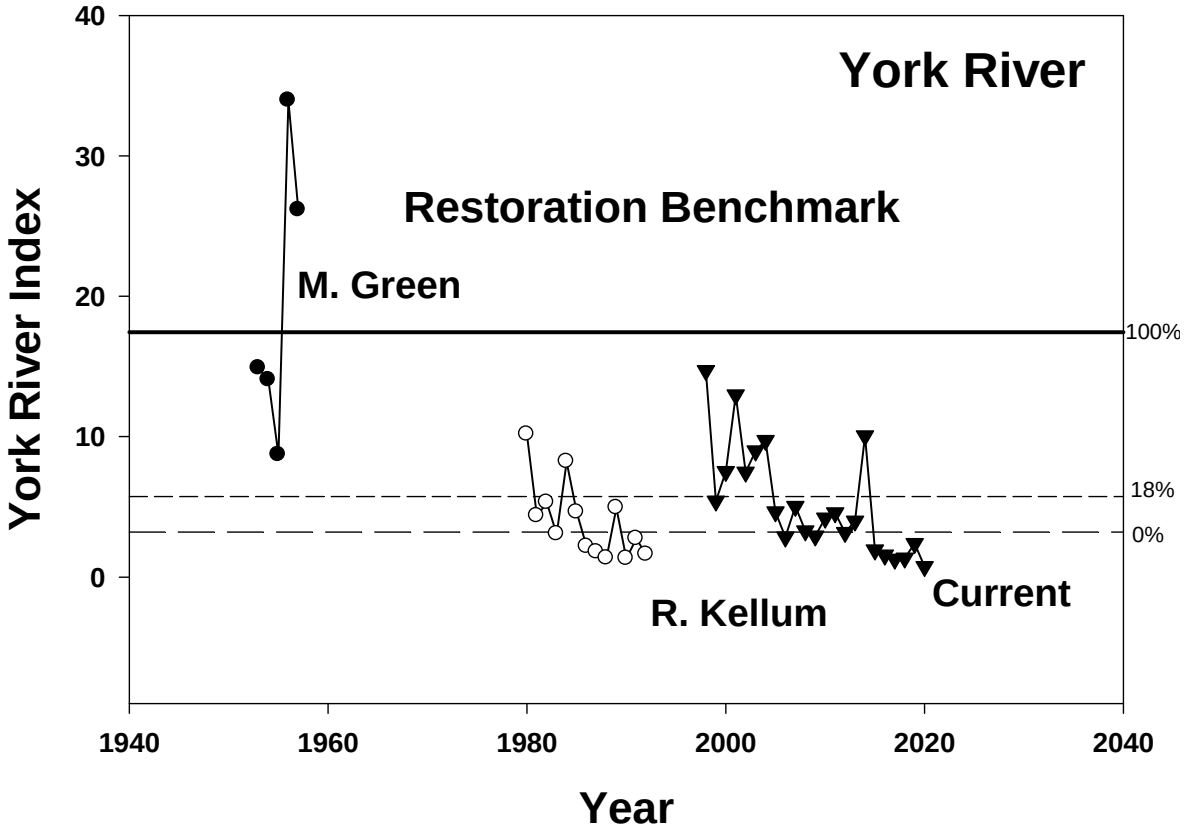


Figure 10. Recent (1998-2020) and historic values of the catch index of female American shad on the Rappahannock River.

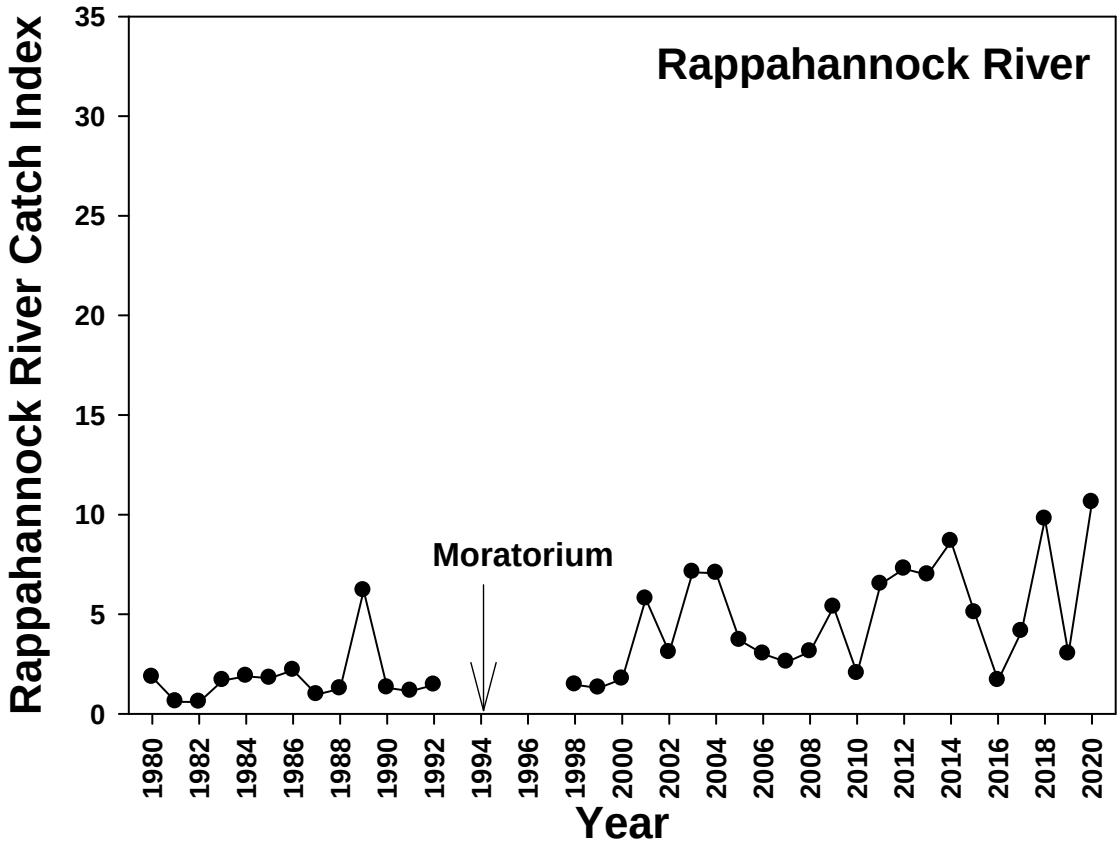


Figure 11. Comparison of the James River catch index to the percent of specimens with OTC hatchery marks.

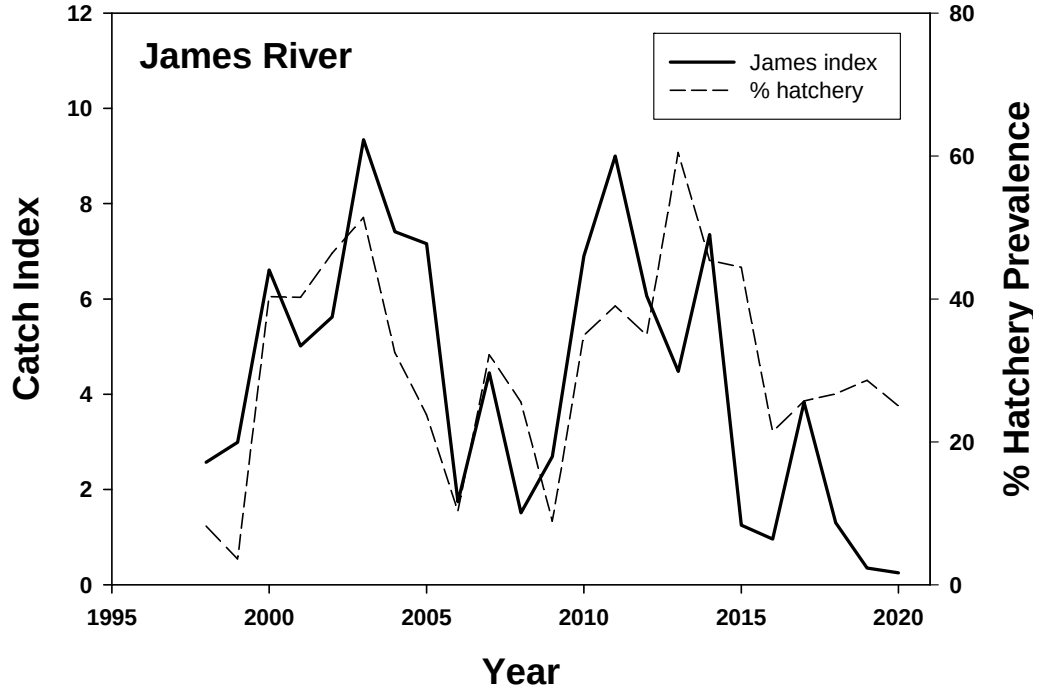


Figure 12. Anchor gill net catches of pre-spawned female river herring on the Rappahannock River in 2020.

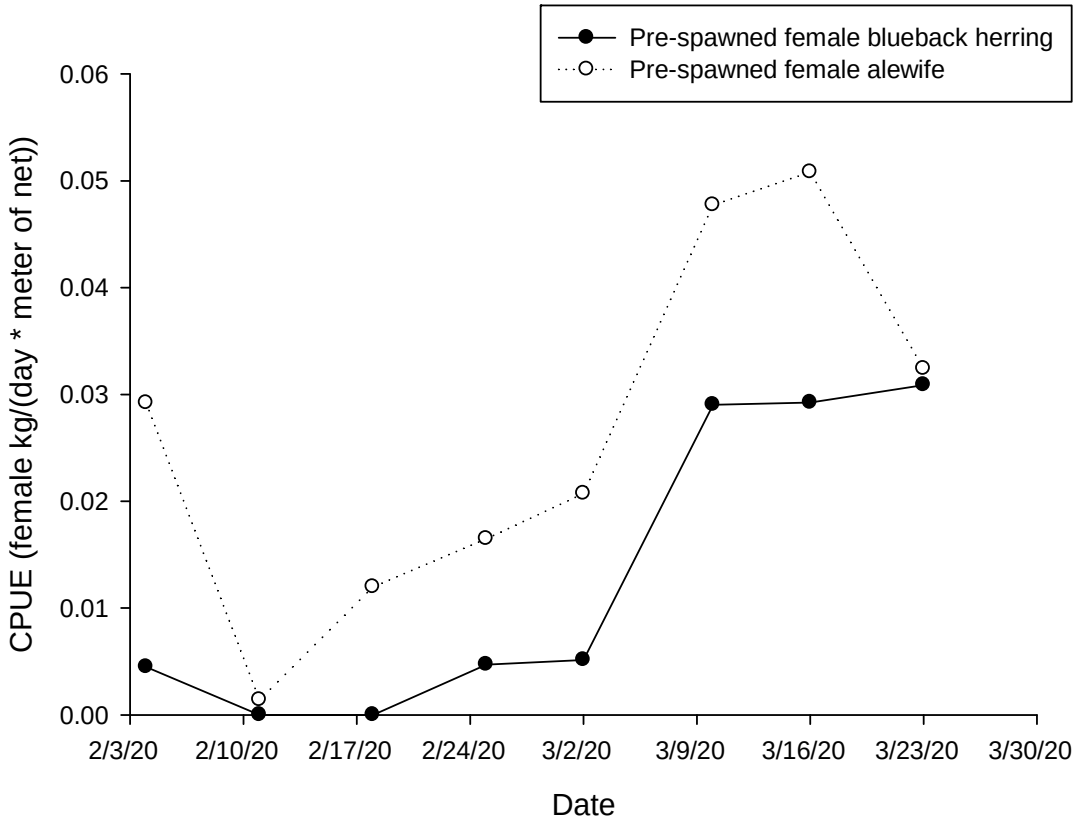


Figure 13. Recent (2015-2020) values of the catch index of female Alewife on the Chickahominy River.

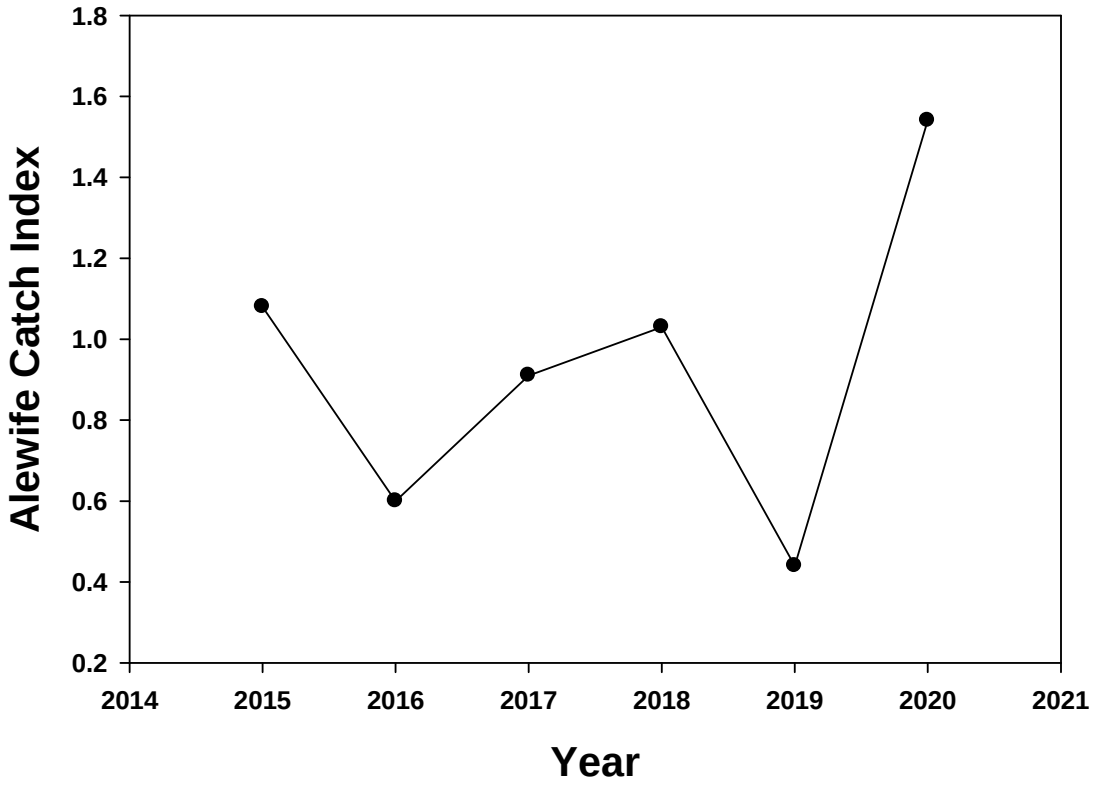
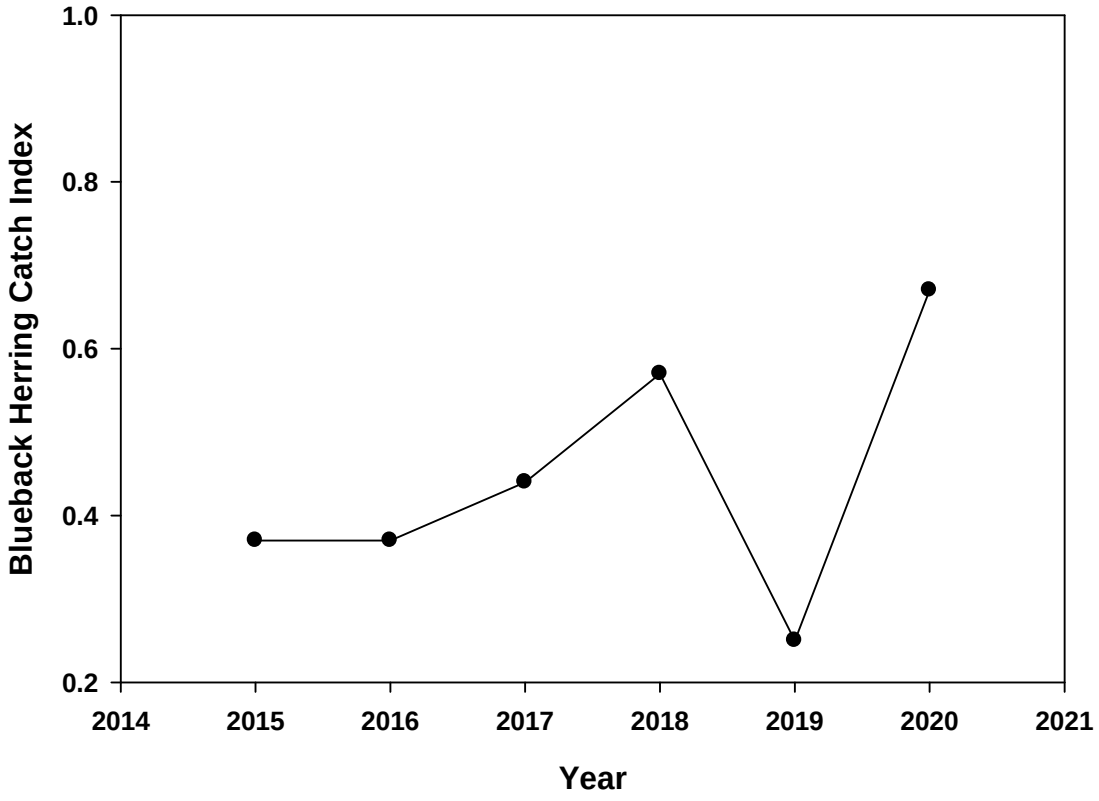


Figure 14. Recent (2015-2020) values of the catch index of female Blueback Herring on the Chickahominy River.



# Appendix 1

# Assessment of the 2020 Virginia by-catch of American shad and the status of the Virginia stocks

## Report to the Atlantic States Marine Fisheries Commission (ASMFC)

October 1, 2020

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## Background

In spring 2020, scientists at the Virginia Institute of Marine Science (VIMS) interviewed and obtained samples of by-catch of American shad from permitted fishers who had agreed to participate in the ASMFC required monitoring program. Total effort (number of trips) in the 2020 American shad by-catch fishery decreased compared to effort recorded in 2019 on the York and Rappahannock Rivers and increased on the James River (Table 1). A subsample of the by-catch of American shad (n=237), comprising fish from all three rivers, was obtained from eight cooperating fishers; these samples were processed for length, weight, sex, maturity stage, age, and the presence of hatchery (OTC) marks.

This report is a companion to a report of the 2020 by-catch prepared by the Virginia Marine Resources Commission (VMRC) and submitted separately.

## Biological Characterization of the 2020 Permitted Gill Net By-Catch in Virginia

### James River

27 American shad (2 males and 25 females) were collected from one cooperating fisher on the James River. The subsample ranged in size and age from 387-478 mm FL and 4-7 years, respectively. Virgin and repeat spawners were both present in the sample (82.4% and 17.6%, respectively). Otoliths of 20 fish from the James River subsample were scanned for hatchery marks. The proportion with positive OTC marks was 15.0%. Biological descriptions of the James River subsample are presented in Table 2.

### York River

102 American shad (20 males and 82 females) were collected from five cooperating fishers on the York River. The subsample ranged in size and age from 370-501 mm FL and 4-10 years, respectively. Virgin and repeat spawners were

present in the sample (55.1% and 44.9%, respectively). No otoliths of fish from the York River were scanned for hatchery marks. Biological descriptions of the York River subsample are presented in Table 2.

**Rappahannock River**

108 American shad (13 males and 95 females) were collected from two cooperating fishers on the Rappahannock River. The subsample ranged in size and age from 388-484 mm FL and 4-9 years, respectively. Virgin and repeat spawners were both present in the sample (66.3% and 33.7%, respectively). Otoliths of 58 fish from the Rappahannock River were scanned for hatchery marks. The proportion with positive OTC marks was 1.7%. Biological descriptions of the Rappahannock River subsample are presented in Table 2.

**By-Catch and Discards by Pound Nets in Virginia**

In addition to the permitted by-catch samples of American shad taken in gill nets, VIMS scientists examined pound-net samples from one pound-net fisher operating in the Great Wicomico River, a location in the upper western portion of Chesapeake Bay (Figure 1). The pound net fisher had a special permit to take American shad for scientific monitoring, but the catch was not permitted to be sold or retained as by-catch by the VMRC.

Samples of American shad were collected at intervals of approximately every two weeks. Fish in these samples were taken randomly from the total catch on a given day or represented the entire catch from a single fishing day. A total of 33 American shad were processed for length, weight, sex, maturity stage, and age. Laboratory scans for hatchery marks are still in the process of being completed. Biological information is recorded for each date of harvest in Table 3. Year-class composition from the pound net location is reported in Table 4.

Numbers of males sampled was higher than the number of females (15 females; 18 males). Sex ratios (females: males) were 1:1.20. Maturity stages were determined macroscopically for females in the laboratory (Table 3).

**Results of the 2020 Fishery-Independent Monitoring Studies**

The catch index values (the area under the curve of catch rate versus day of the year) of pre-spawning American shad in fishery-independent staked gill net monitoring is depicted in Figure 2.

On the Rappahannock River, the 2020 index was 10.62, which is an increase from the 2019 index (3.01). This is the highest index value for the Rappahannock River in the time series.

In 2020, the catch index on the James River was 0.25. This is a decrease from 2019 (0.35).

The 2020 York River index is 0.75. This is a decrease from 2019 (2.39). The index value is consistent with the last ten years of monitoring, which depicts a low, but stable population.

Table 1. Number of fishermen with American shad by-catch permits, active permits, and fishing activity reported by river system, 2006-2020. Permits are considered active if one or more pounds of American shad were reported.

†Due to COVID-19, 2020 data is only available through the VMRC Mandatory Harvest Reporting Program. Number of American shad kept is estimated by dividing the pounds reported by 3.57, the average fish weight according to the VMRC Biological Sampling Program.

This table contains confidential data that has been redacted.

| Water Body | Year | # Permit Holders | # Active Permits | Total Trips | # Shad Caught | # Shad Kept | % of Bycatch for Year |
|---|---|---|---|---|---|---|---|
| James River | 2020† | 8 | 5 | 19 | | 76 | |
| | 2019 | | | | | | |
| | 2018 | 10 | 3 | 18 | 32 | 32 | 2 |
| | 2017 | 12 | 3 | 72 | 277 | 277 | 48 |
| | 2016 | 14 | 4 | 107 | 24 | 22 | 26 |
| | 2015 | 14 | 8 | 58 | 31 | 21 | 8 |
| | 2014 | 14 | 9 | 54 | 114 | 112 | 15 |
| | 2013 | 10 | 4 | 55 | 150 | 139 | 32 |
| | 2012 | | | | | | |
| | 2011 | 9 | 3 | 25 | 42 | 42 | 32 |
| | 2010 | 9 | 0 | 0 | 0 | 0 | 0 |
| | 2009 | | | | | | |
| | 2008 | | | | | | |
| | 2007 | 16 | 7 | 58 | 119 | 52 | 19 |
| | 2006 | 32 | 5 | 27 | 24 | 23 | 9 |

| Water Body | Year | # Permit Holders | # Active Permits | Total Trips | # Shad Caught | # Shad Kept | % of Bycatch for Year |
|---|---|---|---|---|---|---|---|
| York River | 2020† | 15 | 8 | 93 | | 439 | |
| | 2019 | 11 | 8 | 128 | 257 | 254 | 25 |
| | 2018 | 10 | 6 | 143 | 288 | 284 | 22 |
| | 2017 | 9 | 5 | 45 | 148 | 146 | 25 |
| | 2016 | | | | | | |
| | 2015 | 10 | 9 | 36 | 302 | 279 | 76 |
| | 2014 | 8 | 5 | 85 | 453 | 453 | 61 |
| | 2013 | 12 | 6 | 116 | 212 | 203 | 47 |
| | 2012 | 13 | 5 | 71 | 207 | 207 | 94 |
| | 2011 | 11 | 4 | 51 | 88 | 87 | 67 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2010 | 9 | 5 | 43 | 229 | 208 | 84 |
| | 2009 | 11 | 6 | 97 | 302 | 288 | 100 |
| | 2008 | 10 | 6 | 85 | 89 | 89 | 60 |
| | 2007 | 15 | 8 | 104 | 199 | 199 | 73 |
| | 2006 | 31 | 5 | 198 | 233 | 228 | 90 |

| Water Body | Year | # Permit Holders | # Active Permits | Total Trips | # Shad Caught | # Shad Kept | % of Bycatch for Year |
|---|---|---|---|---|---|---|---|
| | 2020† | 7 | 7 | 49 | | 427 | |
| | 2019 | 9 | 9 | 99 | 1025 | 740 | 73 |
| | 2018 | 10 | 11 | 156 | 992 | 894 | 76 |
| | 2017 | 9 | 4 | 48 | 155 | 155 | 27 |
| | 2016 | 5 | 4 | 129 | 27 | 27 | 30 |
| | 2015 | 6 | 5 | 25 | 63 | 63 | 16 |
| | 2014 | 8 | 4 | 49 | 182 | 173 | 23 |
| Rappahannock | 2013 | 7 | 6 | 24 | 273 | 89 | 21 |
| River | 2012 | [redacted] | | | | | |
| | 2011 | | | | | | |
| | 2010 | | | | | | |
| | 2009 | 1 | 0 | 0 | 0 | 0 | 0 |
| | 2008 | [redacted] | | | | | |
| | 2007 | | | | | | |
| | 2006 | | | | | | |

Table 2. Biological descriptions by river and sex for American shad permitted by-catch samples processed at VIMS. Abbreviations: M, Male; F, Female; #, Number; Avg., Average; Yrs, Years; NA, Not applicable; Rap, Rappahannock.

| River | Sex | # | Avg. FL (mm) | Avg. Wt (g) | # Aged | Age Range (yrs) | % Repeat Spawner | % Post Spawner | # Hatchery Scanned | # Hatchery Origin |
|---|---|---|---|---|---|---|---|---|---|---|
| James | M | 2 | 388.0 | 968.4 | 2 | 5-6 | 0.0 | NA | 2 | 0 |
| | F | 25 | 435.3 | 1349.1 | 15 | 4-7 | 20.0 | 0.0 | 18 | 3 |
| | Combined | 27 | 431.8 | 1320.9 | 17 | 4-7 | 17.6 | 0.0 | 20 | 3 |
| | | | | | | | | | | |
| York | M | 20 | 410.0 | 1132.3 | 12 | 4-10 | 58.3 | NA | NA | NA |
| | F | 82 | 445.1 | 1533.1 | 57 | 5-9 | 42.1 | 0.0 | NA | NA |
| | Combined | 102 | 438.2 | 1454.5 | 69 | 4-10 | 44.9 | 0.0 | NA | NA |
| | | | | | | | | | | |
| Rap | M | 13 | 425.2 | 1302.7 | 11 | 5-9 | 90.9 | NA | 6 | 0 |
| | F | 95 | 442.4 | 1478.7 | 72 | 5-8 | 25.0 | 0.0 | 52 | 1 |
| | Combined | 108 | 440.3 | 1457.5 | 83 | 5-9 | 66.3 | 0.0 | 58 | 1 |

Table 3. Biological data of American shad (n=33) collected from a pound net fisher (1) located at the mouth of the Great Wicomico River. Abbreviations: TW, total weight; Avg, Average; P. Spent, Partially Spent.

| Date | Maturity Stage | # Females | TW (kg) | Avg Weight Per fish (g) | # Males | TW (kg) | Avg Weight Per fish (g) |
|---|---|---|---|---|---|---|---|
| 3/9/2020 | Maturing | 9 | 12.1 | 1353.5 | | | |
| | Hydrated | | | | | | |
| | P. Spent | | | | | | |
| | Spent | | | | | | |
| | Unstaged | | | | 10 | 8.8 | 876.8 |
| 3/24/2020 | Maturing | 6 | 7.9 | 1320.8 | | | |
| | Hydrated | | | | | | |
| | P. Spent | | | | | | |
| | Spent | | | | | | |
| | Unstaged | | | | 8 | 6.9 | 865.4 |
| Total | | 15 | 20.0 | 1337.2 | 18 | 15.7 | 871.1 |

Table 5. Year class composition of fish taken in pound nets in 2020, indicated as percent of aged catch from one pound net location in Chesapeake Bay.

| | Year Class | Great Wicomico |
|---|---|---|
| Males | 2016 | 36.4 |
| | 2015 | 36.4 |
| | 2014 | 27.2 |
| Females | 2015 | 36.4 |
| | 2014 | 45.4 |
| | 2013 | 9.1 |
| | 2012 | 9.1 |

Figure 1. Location of pound net operation with special American Shad by-catch permits.

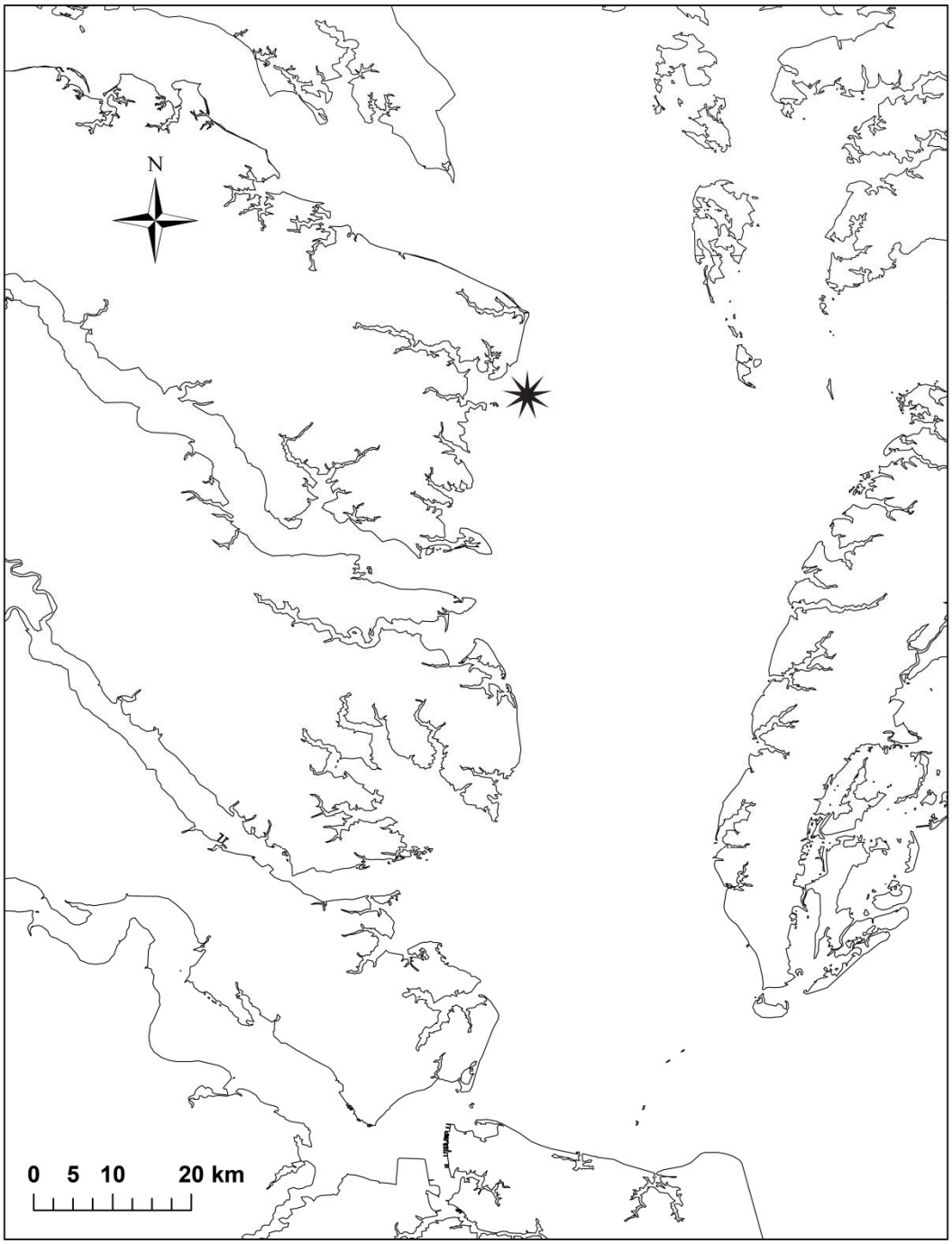

Figure 2. Time series of catch index from staked gill net monitoring in Virginia, 1998-2020. In 2020, the James River monitoring of American Shad switched gears to an anchor gill net (denoted by *).