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ADULT AMERICAN SHAD

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Project: Documentation and Quantification of Alosids Utilizing Fish Passage Facilities and Collection of Biological Data on Adult American Shad

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Introduction

Since the early 1820s the Lehigh River was closed to most migratory fishes, due to the construction of the Easton Dam (RM 0.0) at its confluence with the Delaware River. The Lehigh River's confluence with the Delaware River (RM 183.6) is located 50.3 miles up river from the tidewater line at Trenton, New Jersey (RM 133.3). In the spring of 1994 the lower 24.0 miles of the Lehigh River were reopened to migratory fishes through the operation of three vertical slot fishways at the Easton (RM 0.0, constructed 1993), Chain (RM 3.0, constructed 1993) and Hamilton Street Dams (RM 17.0, constructed 1983) (Fig. 1). As part of the Lehigh River American shad *Alosa sapidissima* restoration program, the Pennsylvania Fish and Boat Commission, since 1985, has annually stocked marked (tetracycline, OTC) fry immediately up river of the Cementon/Northampton Dam (RM 24.0) (Table 1). All fry stocked in the Lehigh River originated from Delaware River gametes taken from fish stripped at Smithfield Beach (RM 218.0).

In 1994 the Pennsylvania Fish and Boat Commission began operating the Easton and Chain Dam fishways during the spring and monitoring fish passage. In addition, efforts occurred to 1) collect adult American shad passing the Easton Dam for characterization of the spawning population and 2) collect outgoing juvenile American shad to determine origin and relative abundance. The agency also continued annual netting operations at Smithfield Beach on the Delaware River to collect and spawn American shad for restoration efforts in the Susquehanna and Delaware River basins. That effort provided the opportunity to collect biological data relative to the Delaware River spawning stock as part of the agency's commitment to the Atlantic States Marine Commission fisheries management plan for American shad. Prior to 1997 fishway operations, monitoring, Lehigh River sampling and the annual egg take were included as part of the F-57-R, Fisheries Management Project, Sport Fish Restoration Act. In 1997, 1998, 1999 and 2000 these activities were centered in project NA66FI0292, NA76FI0083, NA86FI0214, and NA96FI0220 *Documentation and Quantification of Alosids Utilizing Fish Passage Facilities and Collection of Biological Data on Adult American Shad*, for the Lehigh and Delaware Rivers. This report covers work done in 2001 under NA06FI0191.

Objective:

Documentation and quantification of alosids utilizing fish passage facilities at the Easton and Chain Dams, Lehigh River.

Fish passage at the Easton and Chain Dams were monitored via video from March 29 (Easton) and April 6 (Chain) through July 2, 2001 (Table 2). Recording time frames during this period are listed in Table 2. Minor periods of lost monitoring ranged less than 15 minutes on tape changing days not coinciding with draining and cleaning the fishways. Periods of lost time, other than tape changing, for each fishway are listed Table 3. Due to the highly fluctuating passage of American shad, no attempt was made to estimate passage that may have occurred during the down period events. The equipment used to provide night viewing and for monitoring American shad passage was previously described by Snyder (1997, 1998).

Diurnal movement through the fishway was summarized based on a 24-hour cycle for the entire survey period. Daily movement and monthly summaries (Easton: 1995-2001; Chain: 1996-2001) are also provided for the following discrete diurnal time periods: 0100-500, 0600-0900, 1000-1200, 1300-1500, 1600-1900, and 2000-0000 hours. These periods were chosen as the best ranges to describe daily movement activity (Snyder 2000).

Lehigh River adult American shad collected by Fisheries Management Areas 5 and 6 for origin analysis (stocked vs. wild) were taken during daytime electrofishing operations as described by Snyder (1997 and 1998). Staff aged a sample of American shad using scales and checked for repeat spawning marks. Annuli and repeat spawning marks were identified primarily using the criteria of Cating (1953). Figures 2 - 7 document scale aging for Ages III through VII, and provide examples of scale regeneration, repeat spawning single and double marks, and a time series of Age IV shad depicting scale re-absorption/erosion (scale sources Lehigh and Delaware Rivers).

Personnel from the PFBC's Division of Research examined otolith samples. A Fisheries Biologist from the Hudson River Unit, New York Department of Environmental Conservation (NYDEC), provided consultation and review of a sub-sample of scales as a quality control check. Otolith age information served as a second means to check scale ages.

Results:

Easton Fishway (RM 0.0)

American Shad

A minimum of 4,740 adult American shad passed in 2001 (Table 4, Fig. 8). Passage was observed on March 31, second day after monitoring began, and was documented through at least July 2. Greatest movement occurred from May 1 through May 6 when at least 1,379 shad passed (Table 5). The highest daily passage of 365 shad occurred on May 3. A total of 4,677 video frames of shad passage were recorded; of these, single passages accounted for 98.7 percent (N=4615), dual passages 1.3 percent (N=61), and tertiary passage < 0.1 percent (N=1). During late April through May, increases in mean daily river temperatures generally corresponded to periods of increased passage. Conversely decreases in mean daily river temperatures corresponded to periods of decreased shad passage (Fig. 8).

The unadjusted composite hourly passage from March 31 through July 2 was most noticeable from 0600 through 2000 hours, with peak usage occurring in the morning at 0800 hours (N=323), early after noon at 1100 hours (N=326), and late afternoon from 1400 to 1900 hours (N=2,446) (Table 6, Fig. 9). This data reflects the passage of 4,699 of the 4,740 shad that passed, as the passage of 41 shad from June 11 to June 13 recorded only the date not the time of passage. Daily usage and monthly summaries for six periods during the day (0100-0500, 0600-0900, 1000-1200, 1300-1500, 1600-1900, and 2000-0000 hours) are listed in Table 7. Diurnal usage patterns varied daily and seasonally. Monthly usage summaries showed that the greatest

movement of shad in May occurred from 1600-1900 hours (N=1404), and in June from 0600-0900 hours (N=152). Passage was least evident from 0100-0500 and 2000-0000 hours.

The adjusted composite hourly passage reflects the lost recorded time periods and their effect on the findings above (Table 2 & 6, and Fig. 9). Since the passage from late dusk to early dawn was not recorded (no lights) on taping days, May 11-14, 14-16, 16-18, and 28-30, all passage from these time frames were eliminated. Composite peak usage times were similar to those reported above for morning and early afternoon hours. Usage was greatest in the morning at 0800 hours (N=286), early afternoon at 1100 hours (N=274), and late afternoon 1700 to 1900 hours (N=1,101). Diurnal usage patterns were similar to those previously reported, with greatest usage occurring from 1600-1900 hours (N=1081).

Chain Dam Fishway (RM 3.0)

A minimum of 2,057 adult American shad passed in 2001 (Table 4, Fig. 10). The first shad passed on April 5 and passage continued through the end of the monitoring period on July 2, 2001. The greatest movements occurred from May 1 through May 6 and May 25 through May 30, when respectively 674 and 689 shad passed (Table 8). The highest daily passage recorded during these periods on May 3 (N=196) and May 25 (N=244). A total of 2,015 video frames of shad passage were recorded during this period, of these, single passage accounted for 98.2 percent (N=1979) of the total. Dual, tertiary, and pentad passage rates accounted for 1.6 percent (N=32), 0.2 percent (N=1), and <0.1 percent (N=1), respectively. From April 8 through July 2, 2001, the composite hourly passage was most noticeable from 0600 through 2000 hours, with the most active period ranging from 1200 through 1600 hours (Table 9). Daily usage and monthly summaries for six diurnal periods (0100-0500, 0600-0900, 1000-1200, 1300-1500, 1600-1900, and 2000-0000 hours) are listed in Table 10. Diurnal usage patterns varied daily. The greatest movement of shad in May occurred from 1300-1500 hours (N=619), followed by 1000-1200 (N=476), and 1600-1900 (N=472). Shad passage through the month of June was fairly uniform from 0600-0900 through 1600-1900. Least passage occurred during the 0100-0500 (N=14) and 2000-0000 (N=53) hour periods.

Cementon/Northampton Dam (RM 24.0)

This is the first year adult American shad have been documented immediately down river from the Cementon/Northampton Dam (RM 24.0; Fig 11). A total of 9 shad were caught during two electrofishing events (two fixed anode arrays from a flatbottom boat) that occurred on June 20 and 21, 2001. On June 20, one male shad was caught and no others were seen in 40 minutes of day boat electrofishing within 30 m from the dam. Additional sampling was conducted further downstream on June 21, 2001, to eliminate any suspicion as to the origin of the sole shad reported above. The following areas were surveyed: 1) RM 23.6 - 1.0 km down river from the Cementon/Northampton dam and 2) Hamilton Street Dam pool (RM 17.0) dam up river to the SR 0022 bridge). Electrofishing at RM 23.60 for 38 minutes yielded eight shad (1 female and 7 males). No adult shad were caught or seen in the Hamilton Street Dam pool during the 40 minutes of electrofishing.

Adult Origin (Wild or Hatchery Fry)

A total of 109 adult American shad were collected for origin determination (wild vs. hatchery) via otolith analysis. Adult shad were collected on May 24, 2001, in the tailrace area of the Chain Dam (RM 3.0; N=100), and June 20 and 21 down river of the Northampton/Cementon Dam (RM 24.0; N=9). Otolith analysis found 105 (40 females, 65 males) of the 109 shad were useful in origin determination. Hatchery reared shad accounted for 91 percent (N=96; 39 females, 57 males) of the total aged, based on the presence of detectable fluorophore marks on otoliths from oxytetracycline hydrochloride (OTC) solution treatment of hatchery fry (Table 11). All hatchery shad were derived from Delaware River shad gametes from the PFBC's Smithfield Beach spawning operation. Wild adult shad accounted for 9 percent (N=9; 1 female, 8 male) of the total collected. Otolith ages for stocked origin females ranged from IV to VII, with age VI being the most abundant. Stocked male shad ages ranged from IV to VI, with age V being the most abundant. Otolith age of the single female shad of wild origin was V. The eight male shad of wild origin otolith ages were IV (N=2), and V (N=6).

Adult Otolith Age Determination

Of the 109 adult American shad otoliths collected for origin determination, all were usable (Table 11). Females were represented by ages IV through VII, with age VI being the most dominant (N=31), followed by ages V (N=6), VII (N=2), and IV (N=1). The mean total length for females ages IV through VII was 513, 499, 551, and 558 mm (Table 12). Males were represented by ages IV through VI, with age V dominating the sample (N=32), followed by ages VI (N=19) and IV (N=18). The mean total length for males, ages IV through VI were 456, 479, and 507 mm. Furthermore, based on the OTC mark pattern 90 of the 109 shad were of known age (Age IV: 1 female, 15 male; V: 5 female, 22 male; and VI: 29 female, 18 male).

Adult Scale Age and Repeat Spawning Determination

Scale samples were collected on May 24, and June 20-21, 2001, from 109 adult shad collected for age and repeat spawning analysis. Age and repeat spawning data was obtained from 104 of the 109 shad sampled. Scale samples from five shad contained regenerated scales (Fig. 2), thus were unreadable for aging purposes. Of the 104 examined, 37 were female and 67 were male (Tables 13 and 14). Females were represented by ages IV through VII, with age V being the most abundant (N=20). Males were represented by ages III through VI, with age IV being the most abundant (N=37). The mean total and fork length for the respective ages of female and male shad are listed in Table 13.

The scale samples collected on May 24 exhibited signs of severe re-absorption/erosion. The lateral edges of the current years annulus were nearly gone and some incidences eroded back in to the previous annulus near the base of the posterior region of the scale. A scale time series from the Raubsville area of those collected on April 17 and May 11 and in the Lehigh River on May 24 shows the progressive stages of re-absorption (Figs. 4-4c). This time series shows that re-absorption is greater on the sides than through the crest of the scales anterior region. However,

depending of the duration of time spent in the area, even the scales crest for the current annulus can be re-absorbed.

However, not all shad caught during June 20 – 21 showed signs of severe scale re-absorption. Five of the six male shad exhibited minimal signs of erosion, as depicted in Figure 5a. The perimeter of the scale was similar to Figure 4, which showed a crisp current year annulus. This suggests that even during the late period of the shad run, there are some shad that have just entered the system.

Repeat spawning occurred in 3.8 percent (N=4, sexes combined, all were PFBC stocked) of the 104 shad sampled. Examples of repeat spawning marks are shown in Figures 5a (Age V w/one repeat), 6 (Age VI, w/two repeats), and 7 (Age VII w/two repeats). The repeat spawning rate by sex was 6.0 (4 of 67) male and 0 percent (0 of 37) for female shad (Table 14). All four repeat spawning marks were single marks. One regenerated scale from a male shad of PFBC hatchery origin contained at least one single repeat spawning mark (Fig. 2). Shad with regenerated scales were not included in the determination of the percentage of repeat spawning.

Scale analysis revealed a zone of aberration in 10 of the 36 Age V shad examined (6 female, 4 male) (Fig. 5b-c). The zone occurred in the transition region from age III to IV. In this region the aberration was narrow and visible on the both sides but did not follow through the crest of the anterior region of the scale. The right side exhibited a greater amount of disfiguration than the left. Nor did the zone thoroughly disfigure (break or offset) a majority of the transverse groove lines. The circuli in the lateral area of the anterior region at age III annulus were disfigured but not to the extent typically seen in a repeat spawning mark. A repeat spawning mark is a zone of chaotic line patterns resulting from the re-absorption process that occurs during their spawning run and is contiguous throughout the scale, this giving the appearance of an annulus (Figs. 2, 5a, 6, and 7).

Comparison of Scale, Otolith Ages to Known Age

All American shad

The comparison of scale and otolith ages by sex from 95 shad (36 females, 59 males) indicates an agreement of 27.8 and 30.5 percent, with a combined rate of 29.5 percent (Table 15). Differences in ages by + 1 year for females were 61.1 percent, and +1 and +2 years for males were 60.0 and 18.5 percent. Age differences by - 1 year were 11.1 percent for females.

American shad with Known Ages

Eighty-seven (32 females; 55 males) of the 92 shad with known ages had corresponding scale age data (Table 16). The comparison of known ages with corresponding scale ages indicates an overall agreement of 28.7 percent (N=25). Known female ages were IV (1997 year class), V (1996 year class), and VI (1995 year class) of which age V was the dominant cohort (N=22). Of the 32 female shad 22 sets differed by +1 year (68.8%), nine sets of otolith and scale ages agreed (28.1%), and one by -1 year (3.1%). Male ages ranged from III (1998 year class) to V (1996),

with most being age IV (N=32). The agreement rate for male shad was 29.1 percent (N=16), followed by +1 and +2 year(s) difference rates of 61.83 (N=34) and 9.1 percent (N=5). Of the 55 male shad 34 sets differed by +1 year (61.8%), 16 agreed (29.1%) and 5 differed by +2 years (9.1%).

Comparison of Read Otolith Ages and Known Age Shad based on Specific OTC pattern

The read otolith ages of 95 known aged shad (sexes combined) were compared to their known age based on the specific OTC tagging pattern used. They had an agreement rate of 100 percent.

Sex Ratio

The sex ratio (39 female: 61 male) of the 100 adult shad collected on May 24, 2001, during 17.9 minutes of electrofishing (two fix anode arrays from a flatbottom boat) was 1:1.6.

Discussion:

The 2001 American shad was the highest recorded in the 8-monitoring period (1994-2001) at the Easton Dam fishway (RM 0.0). A total of at least 4,740 shad had passed. Shad passage through the Easton Dam Fishway has fluctuated throughout the monitoring period (Snyder 2001). Passage in 2001 indicates that at least 1,447 shad passed over 1998's previous high of 3,293. While the passage of nearly 1,500 more shad may seem significant, it is still within the yearly fluctuation ranges previously recorded. Prior to the 2001 shad run, 1998's high of 3,293 was 1,199 higher than 2000's (N=2,094), 947 higher than 1999's (N=2,346), 1,865 higher than 1997's (N=1428), and 2,152 higher than 1996's (N=1,141). The 2001 shad run continues to support Snyder's (2000) premise that Lehigh run has leveled off citing the low and variable (overall an increasing trend) passage of shad and considering that the run has been and continues to be dominated by PFBC stocked shad.

Snyder (2000) noted that annual passage is affected by the yearly variations in the PFBC stocking program and subsequent recruitment, fluctuating river flows, and climatic events. Fluctuations in passage from 1994 through 2000, in addition to the above effects, were further compounded by the fishway's impaired ability to attract shad due to a malfunctioning attraction flow system (reduce flow and entrance chamber aeration). The attraction flow system was modified during the fall of 2000 by replacing the surface draw auxiliary flow intake with an inverted siphon system (Figure 12). This modification provided a more consistent volume of water, eliminated air entrainment (during normal operation) and subsequent aeration effects in the entrance chamber.

Attraction flow head differences necessary to attract American shad into the fishway ranged from a minimum of 15.2 cm (6.0 inches) to a maximum of 25.4 cm (10 inches). Prior to 2001 attraction flows head differences varied daily (Snyder 2000). Daily cleaning of the auxiliary flow system was required to maintain the best attraction flows possible. In 2001 aeration free attraction flows were maintained throughout most of the monitoring period (Table 17). No routine daily or weekly maintenance of the auxiliary flow system was necessary throughout the

entire spawning run. Minor changes in flow attraction flow adjustments were made by removing stop logs in response to changing depth in the Lehigh-Delaware river confluence. Aeration in the entrance chamber occurred from May 11 through May 23, when the auxiliary flow valve seal was torn upon re-installation. Aeration was abated on May 23 by PFBC staff and the gate seal was repaired on May 25. The stability and aeration free attraction flow (except as noted above) most likely played a role in the increase of shad through the Easton Dam Fishway. It is not known if the aeration period from May 11 through May 23 adversely affected passage.

However, just how much of an impact the modification had on passage is hard to discern. Since the Delaware shad run was the highest recorded since 1996, perhaps the Lehigh River component of stock was as well. Hydroacoustic monitoring in the Delaware River at Trenton, New Jersey in 2001 by Barnes-Williams Environmental Consultants for New Jersey Division of Fish and Game and the DRBC Fish and Wildlife Technical Committee conservatively estimated a run of $417,300 \pm 2,000$ shad. The estimated Delaware River shad run in 2000, 1999, 1998, and 1996 was $382,200 (\pm 2,700)$, $24,700 (\pm 300)$, $392,700 (\pm 2,500)$, and $524,300 (\pm 2,800)$. No monitoring occurred in 1997.

Record passage continued through the Chain Dam fishway (RM 3.0) that passed at least 2,057 shad. The 2001 passage was the highest recorded in the 6-year monitoring period (1996-2001). The highest recorded percentage of passage through the Chain Dam Fishway ($N=496$), as compared to Easton's passage ($N=1,141$) was in 1996 (a high water year) at 43.5 percent. This year recorded a similar passage rate of 43.4 percent. Passage rates in 1999, 1998, and 1997 were 20.4, 21.1 and 8.8 percent.

The significant increase in numerical passage is probably attributable to modifications made during the fall of 2000. The two major changes to the Chain Dam Fishway consisted of 1) angling the fishway entrance away from the shoreline approximately 45 degrees thereby projecting the attraction flow jet into the tailrace area (Fig. 13), and 2) installation of a restrictor plate in the auxiliary flow piping system to reduce aeration and increase water volume in the entrance chamber. Despite this change to the auxiliary flow system, the number of shad passing through the Chain Dam Fishway may continue to be adversely affected. Although modified, problems still exist with the attraction flow system. The minimum attraction flow criteria six inch head difference was maintained throughout most of the run (Table 17). While the restrictor plate eliminated the aeration problem when the auxiliary flow gate was full open, water flowing into the upstream end was moving at a faster than desirable rate. The increased draw caused vortexes along the anti-debris aluminum float and pulled debris under the float into the auxiliary flow chamber thus clogging the inverted debris rack system and reducing flow into and out of the entrance chamber. Lowering the auxiliary flow gate decreased flow into the system, minimized vortexes, and severely reduced accumulation of debris. While this accomplished the desired affect in regards to debris accumulation it reintroduced a significant aeration problem back into the entrance chamber. The above situation was further compounded near the end of May and into June when the aquatic weed bed immediately up river was dislodged by spawning carp. Dick Quinn (personnel communication) from the US Fish and Wildlife Service suggested placing a debris boom up river of the fishway, anchoring it on shore and angling it down river to catch and push debris away from the fishway.

A fourth dam (Cementon/Northampton) at RM 24.0 has been determined to be a barrier to American shad migration (Snyder 2000; Fig. 11). The USFWS (Dick Quinn) has recommended and developed plans for notching the dam. The owner of the dam was awaiting the modifications to the Easton and Chain Dams to increase passage and for the shad to reach the base of their dam. The modifications to the Easton and Chain Dams have been completed, and American shad were present immediately down river from this dam. A total of nine shad were caught immediately down river from the Cementon/Northampton Dam on June 20 (N=1) and 21 (N=8), 2001. Their presence demonstrates shad can pass through the Hamilton Street Fishway at RM 17.0. The low number of shad present immediately down river from the Northampton Dam suggests that although they are passing through the Hamilton Street Fishway (Fig 14) perhaps some modifications would be beneficial, such as angling the fishway attraction flow away from the shoreline, as was done at the Chain Dam approximately 45 degrees. As of this writing, the owner of the Cementon/Northampton Dam is considering the following options:

- 1) Pursue changing to a closed recirculation system at the plant thereby eliminating the need for the dam. If the system is financially feasible they will try to sell the dam or let someone/group take it over. However, they are considering the option that notching the dam is not part of the potential deal and would be left to the new owner. Another alternative considered is to remove the dam, but the company expects local opposition from users.
- 2) If the recirculation system is not financially feasible then the company will notch the dam.

The company's timeline for determination is reported to be by the end of 2001. Therefore, the earliest passage could occur would be in 2003.

Hourly usage at both fishways was similar despite dramatic increases in passage, particularly for the Chain Dam Fishway. Usage patterns were similar to those previously reported by Snyder (2000), with most passage occurring from 0600 through 2000 hours (Tables 6 and 9, Figures 2 and 4). Shad were least active from 2100 to 0500 hours. Daily passage was divided into six time periods 0100-0500, 0600-0900, 1000-1200, 1300-1500, 1600-1900, and 2000 to 0000 hours for the 2000 shad run. Hourly passage by day in 2001 at the Easton and Chain Dam fishways showed that passage was variable, and shad were least active during the period of 0100-0500 hours (Tables 7 and 10). Monthly summaries for the Easton Dam fishway showed for May the 1600-1900 hour period was the most active in 1995 through 2001 and more variable during the month of June (Tables 7 and 18). Since 1998 monthly summaries for the Chain Dam fishway showed for the month of May the 1300-1500 hour period was the most active (Tables 10 and 18).

Snyder (2000) suggested that preferred usage times may change due to the modifications to the fishways if the previously reported operational problems were affecting passage. The 2001 data shows that usage patterns did not change as the time frame 2100-0500 hours remained a period of significant inactivity. Hourly usage patterns were not expected to significantly change with the modifications, as passage through the fishways for all monitoring years reflected diurnal movement patterns similar to the hydroacoustic monitoring results of shad passing up river of the

Trenton bridge in the Delaware River (Barnes-Williams Environmental Consultants for New Jersey Division of Fish and Game and the DRBC's Fisheries and Wildlife Technical Committee).

The counts of eels are minimum values since they can swim through and underneath the fish crowder (Snyder 1999). As previously noted, accurate counts were not possible due to the nature of eels constantly moving upstream and downstream. However, their use of the fishways continues to be documented (Table 4).

The passage of gizzard shad in 2001 was the second highest recorded at both the Easton (N=392) and Chain Dam (N=416) fishways (Table 4). Their movement remains substantially lower than 1999's high of 1,263 and 958, respectively but still significantly higher than 1995 through 1998 for the Easton and 1996 through 1998 for the Chain Dam fishways. This high count of gizzard shad into the Lehigh River was not mirrored, as it was in 1999's catch data from the PFBC's American shad spawning operation in the Delaware River at Smithfield Beach (Snyder 2000, 1999).

Stock analysis continues to show that the shad from the stocking program are the mainstay of the Lehigh's shad run. Otolith analysis of adult shad sampled from 1995 through 2001 has shown that the preponderance of shad were PFBC hatchery stocked. The percentage of hatchery shad was 73 (24 of 33 shad) in 1995, 92 (36 of 39 shad) in 1996, 94 (51 of 54 shad) in 1997, 98 (52 of 53 shad) in 1998, 92 (95 of 102 shad) in 1999, 91 (91 of 100 shad) in 2000, and 91 percent (96 of 105 shad) in 2001. The makeup of the wild shad component is unknown. They are most likely returning naturally spawned Lehigh River shad and/or Delaware River shad that have strayed. Snyder (2000) reported that the high component of wild shad in 1995 (27%, 9 of 33) were strays from the Delaware River and not the result of natural reproduction in the Lehigh River, as the Easton Fishway first opened in 1994. Snyder (1998-2000) noted that even a small percentage of an increasing number passing into the Lehigh can be substantial. Based on the passage history of the Easton Fishway, and considering that the earliest age of return for male and female shad is generally age III and IV, then the most likely year we would expect to see returning natural Lehigh shad would be 1998. The estimated number of wild shad present in the 1998, 1999, 2000, and 2001 run, based on the percent of wild shad in the sample, is 66 (2% of 3,293), 165 (7% of 2,346), 188 (9% of 2,094) and 427 (9% of 4,740). This seemingly steady wild component of the Lehigh population further supports the previous statement that the Lehigh shad population has leveled off.

The changes to the Chain Dam fishway should increase the returning wild component of the run beginning in 2004. This will be achieved through time by allowing more shad to pass and spawn within the next 14 miles of river. The 2001 shad run marks the beginning of a significant number of shad passing through the Chain Dam fishway. Prior to the 2001 shad run the majority of spawning had taken place within the first 3.0 miles of river based on the low numbers adults passed through the Chain Dam fishway and subsequent young-of-the-year (YOY) sampling. A preponderance of YOY sampled were of PFBC hatchery origin. The 3.0 mile stretch of river between the Easton and Chain Dam, where most of the Lehigh adult shad remain, is not of sufficient length for shad to spawn, hatch and finally imprint to. The shad produced in this

stretch of river most likely emigrate during this developmental process and imprint on the Delaware or at least in the Delaware/Lehigh confluence area water.

This is the third year in American shad restoration history, based on OTC tagging by the Commission's Division of Research, that staff can distinguish the age year class of adult shad based upon the presence of specific OTC marks for otolith ages III (1998; N=6), IV (1997; N=36), V (1996; N=34), and VI (1995; N=11) (Table 16). Eighty-seven of the known otolith aged shad with corresponding scale ages had an overall agreement rate of 28.7 percent. Individual age class agreement rates for ages III, IV, V, and VI were 0 (N=6), 27.8 (10 of 36), 8.8 (3 of 34), and 100 (N=11) percent, respectively. This is a significant decrease in the overall agreement rate from 65.7 percent (N=76: Age III (N=1); IV (N=7); and V (N=68)) in 2000 and 85.7 percent (N=49: Age III (N=2); and IV (N=47)) in 1999.

The continual decrease in agreement rates from 1999 to 2001 is concerning. All scales ages were determined following Cating's (1953) usage of transverse groove counts in relationship to annulus marks. The tagging history supplied by the PFBC's Division of Research indicates that for the 2001 run some marked shad that could be of different ages since the same mark sequence was used on multiple years (Table 19). One male shad otolith age was III (1998) and had a scale age of V (1996), which corresponds to the same tagging pattern (Day "3, 9, 12" tag) used for 561,000 fry (Hudson/Delaware Egg Source) stocked in the West Branch of the Susquehanna River. There was no possible mixing of ages for the known otolith Age IV shad (1997, Day "5, 9, 13" tag) based on scale and read otolith ages. One female shad's otolith age was V (1996) with a scale age of IV (1997); both ages are possible since this tagging pattern (Day "5" tag) was used in 1997 in the Juniata River (486,000 fry; Susquehanna River Egg Source). Data from the 2000 shad run from known otolith age V (1995) shad based on a specific tagging pattern (Day "5" tag) in conjunction with scale ages indicated that for those with scales ages of +1 year (1994; N=15), may be valid, as this pattern was used to tag 996,000 fry (Hudson River Egg Source) stocked in the Juniata River. Those known otolith Age V shad with scales ages +1 year accounted for 22.1 percent (15 of 68) of the otolith Age V group. Therefore, if these 15 are removed from the overall estimate, the agreement rate increases to 82 percent (50 of 61). In comparing known otolith and corresponding scale ages for the 1999 shad run, two age IV (1995 year class, Day "5" tag) may have been from a previous stocking based on the scale age difference of +1 year (V, 1994), and their removal increases the agreement rate from 85.7 to 89.4 percent (42 of 47).

Known ages based on specific OTC tagging patterns may reflect known age periods. Known ages can only occur when the tag is used solely for one water and stocking year, or repeated in such a way that sufficient time has passed for recruitment out of the population. Tagging patterns as noted above, although separated by years and waters, leaves room for the influence of straying. Straying can begin in the ocean as the shad move up the coastline, and for the Delaware River it can also occur between the Delaware and Chesapeake Bays via the Chesapeake and Delaware (C&D) canal system. The frequency of straying albeit unknown is considered to be low, and at this time not believed to be a major factor in declination of agreement rates since 1999. This determination is based on the low number of shad with different scale and otolith ages whose origin could be from different stocking years.

This data continues the strong showing of the 1995 hatchery year class (Age VI) which accounted for 13 percent (11 of 87) of the shad with known otolith ages and corresponding scale ages in 2001, 77.0 percent (47 of 61) in 2000, and 96 percent (42 of 47) in 1999. As this database grows it will greatly aid in developing a guide for aging shad scales on a more accurate basis than in the past. The agreement rate of the 2001 shad run for read otolith ages with the known age based on a specific OTC tagging pattern used in 1998, 1997, 1996 and 1995 was 100 percent. In 2000 read otolith ages and known ages based on specific tagging pattern used in 1997 was 97.4 percent (Snyder 2000). Thus suggesting there is room for subjectivity in otolith reading as well. This is especially true when perhaps, even only remotely possible, shad with similar tagging patterns stocked in other years stray. Agreement rates also decline for the Smithfield Beach (RM 218.0) and the Raubsville Area (RM 176.6) of the Delaware River from 88.9 (8 of 9 shad) and 75 percent (9 of 12 shad) in 2000 to 28.6 (2 of 7 shad) to 58.3 (7 of 12 shad) in 2001, respectively. These lower agreement rates and possible decline may simply reflect their small sample size.

The stocking program has established a repeat spawning population for the Lehigh River. Repeat spawning rates have fluctuated since the first assessment in 1998. The lowest repeat spawning rate occurred in 1999 with a value of 3.1 percent (3 of 96 shad). The 2001 rate was slightly higher at 3.8 percent (5 of 109 shad), but considerably lower than the repeat spawning rates in 2000 (13.5 percent; 13 of 96 shad) and 1998 (12.5 percent, 6 of 48 shad). The incidence of repeat spawning in the Delaware River in the Raubsville (RM 176.6) area continues to remain above 1999's low value of 10.2 percent (15 of 147 shad) to 12.7 percent (17 of 134 shad) in 2001 and 15.2 percent (19 of 125 shad) in 2000. All values however are still lower than 1998's high of 22.4 percent (19 of 85 shad). While both the Lehigh River and the Delaware River – Raubsville area shad run experienced a decline in repeat spawning from 2000, the Delaware River at Smithfield Beach (RM 218.0) did not. Incidence rate of repeat spawning at Smithfield Beach decreased from 10 percent in 1997 (10 of 100) and 1998 (24 of 234 shad) to 4.4 percent (9 of 204 shad) in 1999, to 2.8 percent (9 of 327 shad) in 2000. In 2001 the repeat spawning rate increased to 5.8 percent (43 of 738 shad).

The rate of repeat spawning in the Lehigh as well as for the Smithfield Beach and Raubsville area of the Delaware River (Snyder 2001) may be underestimated. The scale time series for Age IV male shad clearly demonstrates rate and amount of re-absorption (4-4c). A concern when checking for repeat spawning, especially multiple marks, as previous repeat marks may be erased. Snyder (2001) suggested that repeat spawning rates for long-term shad may be underestimated, due to severe re-absorption masking/eliminating prior repeat marks. This also poses a problem for age determination, as complete annuli may be lost, thus underestimating the shad's age. The time series clearly indicates that for the Lehigh River scales should be collected no later than mid-May. Snyder (2001) noted that personnel from the NYDEC's Hudson River Unit could not believe the amount of scale re-absorption occurring on this portion of the Delaware and Lehigh Rivers. Shad collected in the Hudson River freshwater tidal zone exhibited minimal scale re-absorption for similar time frames.

Furthermore, repeat spawners may be underestimated for a different reason. The duration a shad stays in a spawning area is not known. If the shad stays for only a short time, or is a late arrival,

the amount of re-absorption may be minimal, such as was present in Figures 5b and 5c. These figures' scale samples from Age V shad (female and male) illustrate where something happened in the transition region for Age III to IV. These may be discounted as a repeat spawning mark since the disruption of circuli does not follow through the anterior region. The marks are only present on the lateral edges. The time series of scale re-absorption reveals a clear pattern. That is, the lateral edges show significantly more re-adsorption than the crest of the anterior region. Thus, it is entirely possible to erode only the lateral edges and not affect the crest of the scale if the shad did not spend a considerable time up river. This is not to say that other factors cannot be responsible for this anomaly. The intensity is not consistent within the age class, as some shad bear strong visible marks (Fig. 5b) and another shad will have only faint marks within the same region (Fig 5c). Strong marks of this type may reflect repeat spawning by short-term shad.

Shad collected down river from the Cementon/Northampton Dam on June 21, 2001, exhibited minimal signs of scale re-absorption (Fig. 5a). The scale's perimeter was similar to Figure 4, which was caught in the Raubsville area of the Delaware River on April 17, 2001. The crisp scale edges of Figure 5a indicate that this shad is a fairly recent immigrant up the Delaware River. Thus suggesting that shad do move throughout the spawning period, even from as far as the lower bay or even the ocean.

The sex ratio of adult American shad in the Lehigh River (female: male) continues to remain fairly stable from 1997 through 2001. Sex ratios in the following years were: 1997 (1:1.1; N=51), 1998 (1:1.5; N=50), 1999 (1: 1.7; N=104), 2000 (1:1.9; N=100), and 2001 (1:1.6, N=100). Snyder (2000, 1999, 1998 and 1997) suggests that the continued low and fairly stable sex ratio reflects a young developing population and perhaps differences in sample size.

Recommendations:

1. Continue time-lapsed video monitoring at both the Easton and the Chain Dam fishways in 2002.
2. Pursue installing a debris deflector up river of the Chain Dam to prevent clogging of the auxiliary flow racks.
3. Pursue possibility of re-orientating the attraction flow jet away from the shoreline at the Hamilton Street Dam fishway.
4. Repeat in river sampling to collect otoliths for origin determination. Sample by mid-May if possible to aid scale aging and reduce the affect of re-absorption.
5. Continue to monitor usage of the Hamilton Street Dam fishway (RM 17.0) and document the presence of adults at the base of the Cementon/Northampton Dam (RM 24.0) via day boat electrofishing in 2002.
6. Continue to pursue the cooperation of the private owner of the Cementon/Northampton Dam to begin notching the dam for shad passage in 2002-3.

7. In 2002 collect a minimum of 100 adult American shad above the Easton Dam for otolith assessment for origin and age determination (anticipating return of known age III, IV, V, and VI year old shad based on PFBC OTC tagging) and scales for age and repeat spawning analysis.

Objective:

Collect biological data on adult American shad taken during spawning operations at Smithfield Beach, Delaware River (RM 218.0).

American shad spawning operations commenced on May 6 and terminated on June 4, 2001. These netting and spawning operations although not covered nor funded by NA06FI0191 merit detailing relative to the biological data taken. Egg taking is part of the hatchery component of the restoration effort in the Lehigh and Schuylkill Rivers, tributaries to the Delaware River (1999-2001). Prior to 1999 and back through 1985, the egg taking effort also provided part of the hatchery component of the restoration effort in the Susquehanna, Lehigh, and Schuylkill Rivers.

Floating gillnets (4.5, 4.75, 5.0, 5.25, 5.5, 5.75 and 6.0 inch stretch mesh) were anchored on the upstream end and ran parallel to the current. Each net was 61 m (200 ft) long by 1.8 m (6.0 ft) deep. Sets were made just before dusk and removed by midnight. Operations began on May 6 and the river's temperature was 17.0° C (62.6° F). Netting began shortly after an early heat wave that extended from April 30 through approximately May 4, 2001. There was no early indication of spawning (splashing) during this period. This operation was conducted during moderate flows. Flows declined through the netting period. By the third week of netting nets set near Tocks Island, where the male collection area is, were beginning to bag over. The egg-take was terminated due to the low number of shad, particularly males, and eggs being collected and other operational commitments. The catch of male shad was extremely low, only two males were caught on June 3 and none on June 4, 2001. The river temperature on June 4 was 16.0° C (60.8° F).

Nets were set on twenty nights and 16 nets were set each night. Gillnetting occurred at Smithfield Beach each night during this period. However, on May 22 five gillnets were in the down river end of the Eshback pool near Buck Island (RM 231.2). The number of nets set per mesh size (stretch, inch) each night was: five for the 5.0 inch mesh; three for the 4.5 inch mesh; two each for the 4.75, 5.25, and 5.5 inch mesh; and one each for the 5.75 and 6.0 inch mesh. The five gillnets set on May 22 in the down river end of the Eshback pool consisted of two 5.0 inch mesh and one each of the 4.5, 4.75, and 5.5 inch mesh. Nightly catches of American shad were separated by gillnet size. Each different mesh size was color-coded and shad caught were identified by mesh size as per Snyder (1999).

Biological data was collected on every American shad netted and catches were sampled for scales and otoliths. Each netted shad after gamete removal was sexed, measured (total and fork length) to the nearest mm, and weighed in grams. Spawning readiness of female shad was classified into four categories: ripe, spent, immature, and gravid. Weights of immature, mature/gravid, and post-spawned ripe ovaries were also recorded. In 1997 heads (for otolith extraction) and scales were taken from each tenth fish, but no effort was made to distribute the effort throughout the spawn taking. During 1998 more fish were sampled, upwards to every eighth adult shad with specific attention given to sampling through the beginning, middle, and end of the effort. A total of 206 shad were sampled (57 males, 149 females) in 1999 for scales and otolith data, with roughly every fourth fish sampled, and scale samples without

corresponding otoliths were collected from five female shad. In 2000 a total of 337 shad were sampled (143 males, 194 females) for otolith and 333 for scale data (139 males, 194 females), roughly every 1.6 shad was sampled. A total of 925 shad were caught in 2001 from which scale samples were collected from 765 shad (568 females, 197 males), and otolith samples from 752 shad (556 females, 196 males), thus roughly every 1.2 shad was sampled

As with adult shad from the Lehigh River, the PFBC's Division of Research interpreted otolith ages and identified chemical (OTC) marks. The PFBC's Fisheries Management staff interpreted scale age and repeat spawning marks, as per Cating (1953). The NYDEC Hudson River Unit as a quality control check also examined a sample of scale ages and repeat spawning marks.

In addition, otolith and scale samples were collected from adult American shad in the Raubsville area of the Delaware River seven miles downstream from the confluence of the Lehigh River (RM 183.6). Samples were collected using day boat electrofishing on April 17, 20, and 26, and on May 2 and 11, 2001. Fifteen shad were collected each day from the Pennsylvania and New Jersey sides of the river, except on May 11 when only 10 were collected on the New Jersey side. This sampling is a continuation of an effort begun to determine the extent of hatchery origin adult American shad in the mainstem of the Delaware River downstream of the Lehigh River confluence and to supplement the biological data collected further upstream.

Results:

Delaware River - Smithfield Beach (RM 218.0) and Buck Island (RM 231.2)

Twenty nights of netting resulted in a catch of 925 adult American shad, 918 from Smithfield Beach and 7 from the Eshback pool (Table 20). Nightly catches ranged from a low of 11 to a high of 157 shad. Sex ratio (female to male) of the 918 adult shad caught at Smithfield Beach was 3.0:1. No sea lamprey *Petromyzon marinus* were attached to shad during this operation, although there were signs of a prior attachment on one shad. Due to the rigors of the operation all shad perished. Additional catch consisted of gizzard shad *Dorosoma cepedianum* (N=57), striped bass *Morone saxatilis* (N=4), walleye *Stizostedion vitreum* (N=1), channel catfish *Ictalurus punctatus* (N=13), white sucker *Catostomus commersoni* (N=7), and common carp *Cyprinus carpio* (N=2) (Table 21). All non-targeted species were released alive except for one female striped bass (662 mm TL, 3020 g).

This is the third year that American shad catch was enumerated by gillnet mesh size. Gillnet mesh data was collected from 925 (687 female and 238 male) adult AMS caught from May 6 to June 4, 2000 (20 nights) (Tables 22-23). The greatest catch of female shad per net per mesh size was the 5.0 (N=308) inch mesh, followed by the 5.25 (N=96), 4.5 (N=93), 5.5 (N=89), 4.75 (N=78), 5.75 (N=20) and 6.0 (N=3) inch mesh. For male shad the greatest catch per mesh size was the 4.5 inch net (N=141), followed by the 4.75 (N=48), 5.0 (N=41), 5.25 (N=6), and 5.5 (N=2) inch mesh nets. No male shad were caught in the 6.0 inch mesh net.

Female adult shad comprised 74.3 (N=687) percent of the total catch of American shad (Table 20). Total and fork lengths of female shad ranged from 465 to 606 mm and 410 to 551 mm,

respectively (Table 22). Weight ranged from 761 to 2,235 g for those American shad examined gonad state was considered to be "Ripe" (69.0%, N=474) for most, followed by "Mature/Gravid" (17.9%, N=123), "Spent" (7.4%, N=51) and "Immature" (5.7%, N=39; Table 24). Based on 591 of the 687 female shad caught the average ovarian weights for the above gonad states were 181.3 (N=396, Ripe after being artificially spawned); 282.0 (N=106, Mature/Gravid), 108.9 (N=51, Spent), and 162.1 (N=39, Immature) (Table 25).

Otolith analysis of 549 of the 555 female shad sampled consisted of six age classes (III through VIII), with age class V being the most abundant (N=270), followed by age classes VI (N=166), IV (N=77), VII (N=28), VIII (N=7) and III (N=1). There were six otoliths not read due to crystallization. The origin of the 146 female shad sub-sampled was 95.9 (N=140) percent wild and 4.1 (N=6) percent PFBC hatchery shad. Five of the six hatchery shad were of known age, Age VI. All five shad had a single OTC Day 5 tag, which was used in 1995 for fry stocked in the Lehigh, Juniata, and Susquehanna Rivers in Pennsylvania, in addition to the Potomac River in Maryland/District of Columbia, and the James River in Virginia. The egg source for the three Pennsylvania Rivers were from the Delaware and Hudson Rivers. The remaining tagged shad displayed the OTC daily tagging pattern of 3, 13, 17. This particular tagging pattern was used from 1989 through 1994, thus it cannot be identified to a specific stocking year.

Male shad made up 25.7 (N=238) percent of the catch (Table 20). Total and fork lengths ranged from 428 to 556 mm and 381 to 494 mm (Table 23). Weight ranged from 636 to 1581 g. Otolith analysis of 194 of the 196 males sampled consisted of five age classes (III through VII), with age class V (N=95) being the most abundant, followed by age classes IV (N=68), VI (N=28), VII (N=4), and III (N=3). Two male shad's otoliths were unreadable due to crystallization. The origin of the 52 male shad sub-sampled was 96.2 (N=50) percent wild and 3.8 (N=2) percent PFBC Hatchery shad. Both male were of known age, Age VI, identified by the single Day 5 OTC pattern referenced above.

The otolith ages of seven known age shad (sexes combined) when compared with the read otolith ages had an agreement rate of 28.6 percent (2 of 7 shad; all age V- 1995). The read otolith age for 5 of the 7 known aged shad differed by -1 year. Scale ages had an agreement rate of 42.9 percent (3 of 7) with known otolith ages, with the remaining four differing by -1 year. Scale and read otolith ages agreement rate was also 57.1 percent (4 of 7), with two differing by +1 year and one by -1 year.

Scale samples were collected from 749 adult American shad of which 738 were usable (545 females, 193 males) for age determination and repeat spawning analysis (Table 26). Eleven of the shad sampled had regenerated scales (Fig. 2). The combined sex repeat spawning rate was 5.8 percent (N=43) with most being single repeats (5.0%, N=37, Fig. 5a). Repeat spawning marks in female and male shad consisted of single, dual (Figs. 6 and 7) and tertiary (females only) marks. Scale analysis of 545 female shad yielded a repeat spawning rate of 4.6 percent (N=25). Repeat spawning occurred in age classes IV (N=2), V (N=8), VI (N=12) and VII (N=3). Single repeat spawning marks occurred in ages IV (N=2), V (N=8), VI (N=9) and VII (N=1). Dual and tertiary marks occurred in ages VI (N=3) and VII (N=1), and age VII (N=1), respectively. Male shad had a repeat spawning rate of 9.3 percent (18 of 193) that consisted of

single and dual marks. Single repeat spawning marks occurred in ages IV (N=4), V (N=11), and VI (N=1). Dual marks occurred in ages VI and VII with one each. Single repeat spawning marks, sexes combined) accounted for 86.0 percent (37 of 43) of the repeat spawning shad. Dual and tertiary repeat marks comprised 11.6 (5 of 43) and 2.4 percent (1 of 43) of the repeat spawning shad.

The comparison of scale and otolith ages by sex of 716 American shad (526 females and 190 males) indicates an agreement rate of 44.1 (N=232) and 48.9 (N=93) percent with an overall combined rate of 45.4 (N=325) percent (Table 27). Differences in ages between otolith and scale ages for female and male shad by one year were 47.5 (-1: 23.2%; +1: 24.5%) and 45.7 (-1: 26.8 %; +1: 18.9%) percent, respectively. Male shad exhibited the largest disparity between scale and otolith ages, ranging from -4 (N=1) and +2 (N=1) years. Female shad age differences ranged from -3 (N=1) to +2 (N=16) years.

Delaware River - Raubsville Area (RM 176.6)

The 2001 sampling involved taking 75 adult shad from the Pennsylvania side of the Delaware and 70 from the New Jersey side. Scales were collected from 145 American shad of which 134 were usable (56 female; 78 male) during five sampling times (Table 28). Sampling occurred on April 17, April 20, April 26, May 2, and May 11, 2001. The composite daily catch (PA and NJ combined) consisted of chiefly male shad, 60 percent (18 of 30 shad; April 17), 56.7 percent (17 of 30 shad; April 20 and 26), and 63.3 percent (19 of 30 shad; May 2). Similar numbers of both sexes were caught on May 11 (13 female; 12 male). The repeat spawning rate of female shad on the New Jersey and Pennsylvania sides of the Delaware River were 21.7 and 6.1 percent, respectively for a composite rate of 12.5 percent (7 of 56 females). For male shad the respective repeat spawning rates were 7.5 and 18.4, for a composite rate of 12.8 percent (10 of 78 males). The repeat spawning rate for both sexes combined was 12.7 percent (17 of 134 shad).

Otoliths were examined for 143 of the 145 adult shad in the Raubsville area with 69 caught on the New Jersey side and 74 caught on the Pennsylvania side of the Delaware River. The otoliths of two shad (one each side) were not readable due to crystallization. Wild origin shad accounted for 97.1 percent (67 of 69 shad) of those collected on the New Jersey side of the river. There were two PFBC hatchery shad (2.9%: female and male 1 each) on the New Jersey side. Both shad otoliths contained the OTC day tagging pattern of "3, 6, 9" which was used in 1996 (Age V), 1997 (Age IV), and 1998 (Age III; Table 19). The male hatchery shad was age IV based on scale and read otolith ages. The female shad had a scale age of V and a read otolith age of VI, in this case only the scale age agreed with the stocking year (1996).

However, on the Pennsylvania side 13.5 percent (10 of 74 shad) were returning PFBC Lehigh River stocked shad. All ten were of known age period. Six shad contained the Day "5" pattern that indicates that they were stocked in either 1994, 1995, 1997. The origin and stocking history of the Day "5" tagged shad was previously noted above and in Table 19. Comparing their scale (N=5; 4 female, 1 male) and read otolith (N=6; 5 female, 1 male) ages indicates that all are from the hatchery cohort (1995). Scale ages for five of the six shad were age V. Read otolith ages agreed with known stocked cohort for four of the six hatchery shad. The other two shad otoliths

were read as Age V, and one of the shad's age agreed with the scale age. The remaining four hatchery shad (2 female, 2 male) possessed the daily OTC tagging pattern of "3, 6, 9" which was used in 1996 (Age V), 1997 (Age IV) and 1998 (Age III). Three hatchery shad (2 female, 1 male) scale and read otolith ages agreed, Age V (1996). One male hatchery shad had a read otolith age of V with a scale age of IV (1997). Based on Day "3, 6, 9" tagging history both could be correct. The remaining male hatchery shad's aged at Age IV with both scale and read otolith ages in agreement.

The comparison of otolith and scale ages by sex (PA and NJ combined) of 132 shad (55 female; 77 male) indicates an agreement rate of 49.1 percent (27 of 55 female) and 55.8 percent (43 of 77 male), respectively (Table 29). Differences in ages by -1 and +1 year between otolith and scale ages were 30.9 (17 of 55) and 16.4 percent (9 of 55) for female, and 26.0 percent (20 of 77 female) and 13.0 percent (10 of 77) for male shad. Male shad exhibited the largest disparity between otolith and scale ages, ranging from -3 (N=1) and +2 (N=2) years. Female shad age differences ranged from -2 (N=1) to +1 (N=9) years.

Discussion:

This marks the fifth year of collecting biological data from spawn-taking operations at Smithfield Beach (RM 218.0). The percentage of repeat spawning increased from 1999 and 2000's low of 4.4 (9 of 204 shad) and 2.8 percent (9 of 325 shad) to 5.8 percent in 2001 (43 of 378 shad). It is still lower than the rates previously reported for 1996 (11.1%, 11 of 99), 1997 (10.0%, 10 of 100), and 1998 (10.3%, 24 of 234). The increase in repeat spawning rates for 2001 was not noted in the Raubsville area (RM 176.6) where repeat spawning declined slightly from 15.2 percent (19 of 124) to 12.7 percent (17 of 134 shad) in 2001. Prior to 2000 repeat spawning rates exhibited a significant decline from a high of 22.4 (19 of 85 shad) percent in 1998 to 10.3 (15 of 146 shad) percent in 1999. In 1999 Snyder (1999) noted that while the percent of repeat spawning decreased in both areas, the yearly proportional differences were similar. The percentage of repeat spawning in 1998, 1999, and 2001 in the Raubsville area was twice that for shad at Smithfield Beach. Snyder (2000) reported that the percentage of repeat spawning in 2000 increased 4.4 fold over that of Smithfield Beach. He noted that 2000's decline may be unduly influenced by the lower catch due to the sustained high flows and debris coated nets.

This progressive up river decline in repeat spawning rates may be related to their distance traveled, especially in the freshwater portion of the Delaware River (Snyder 1999). Snyder (2000) postulated that 1999's decline in repeat spawning at Smithfield Beach shad and those migrating further up river may have been affected more by 1999's severe drought conditions and its associated affects on an already physiologically stressed long river run shad. Furthermore, the continued decline in 2000 may reflect cumulative effects of the harsh conditions in 1999 and the prolonged high water conditions experienced in 2000. Snyder (2000) noted that the long-term effects on the egg-taking operation at Smithfield Beach are unknown but would have the greatest affect on those repeat shad that have imprinted on the Smithfield Beach area. Thus, one would expect a continual decline, and/or the elimination of repeat spawning in this area. Furthermore, it is not known what percentage of the shad caught at Smithfield Beach are shad that have imprinted and returned versus those just continuing their migration up river or strays that were

encountered in the netting area. Virgin returning shad that imprinted on the Smithfield Beach area were spawned further up river, thus the netting operation would at least affect this portion of the year's run.

Regardless of the source of repeat spawners, the resurgence in the rate of repeat spawning from 2000 to 2001 tends to belay the perception that the egg-taking operation is seriously compromising the Smithfield Beach fishery. Physiological stresses during their annual run may have more serious effects. The stresses of migrating this far up river or even as far as the Lehigh River area can be seen in a chronological review of the scales. Scale re-absorption/erosion is very similar to the times series provided in Figures 4-4c from the Delaware River - Raubsville and Lehigh River area. Repeat spawning rates for long-term shad in freshwater may be underestimated, due to severe re-absorption masking over previous repeat marks. If the shad stays up river long enough based on the amount of re-absorption documented herein, complete annuli may be lost. Personnel from the NYDEC's Hudson River Unit cannot believe the amount of scale re-absorption occurring in this portion of the Delaware and Lehigh Rivers. Shad collected in the Hudson River freshwater tidal zone exhibited minimal scale re-absorption.

Snyder (2001) suggested that repeat spawning may be underestimated due to the discounting of incomplete potential repeat marks. These areas of aberrations in scales reported by Snyder (2001, Figs 5b and c) for Age V shad in the Lehigh River were also present in the Delaware samples and occurred in other cohorts. Intensities of the marks varied as noted in Figures 5b and 5c. Strong marks on the lateral edge of the annulus, but not following through the crest of the anterior region, may reflect a short-term repeat spawning shad.

This is the first year where PFBC stocked shad were present in the Delaware River sample other than high water years. Snyder (2000) hypothesized that straying was related to high water events. Stocked PFBC shad were only present at Smithfield Beach during high water years (1996, 1998, and 2000), they were not present during low flow (drought) years of 1997 and 1999. Based on the presence of stocked shad in 2001 a moderately normal flow year, suggests that straying is significantly retarded during drought periods and not an artifact of high water events. Snyder (2000, 1999, 1998) postulated a second hypothesis that straying or a higher incidence of marked Lehigh River American shad observed in the Delaware River at Smithfield Beach is the result of a lower than expected migratory run of wild shad. Hydroacoustic population estimates indicated that the 2001 shad run was the highest since 1996, thus straying still occurred for a large Delaware River shad run. However, the point at which low flows cause population level straying to be reduced is not known.

Snyder (2000, 1999) stated that there was growing concern among state and federal agencies and anglers alike that the Delaware's spawning run of American shad had declined in 1999, but how much is still up to debate since some measures of abundance are not consistent. The catch rate (mean catch/night) at Smithfield Beach indicates that the run has declined from 1990 (15.9) through 1999 (2.6; Table 30). Snyder (2000) reported that the similarly in catch rates from 1999 to 2000 (2.8) might indicated that the run's apparent decline has leveled off. He further noted that 2000's catch rate may have been higher, if it wasn't for the sustained high flows affect on the netting gear. The 2001's mean catch per night rate 2.8 shad continues to support the belief

that the population has stabilized and is not exhibiting decline. Furthermore, the 2001 run showed an increase in the sex ratio (female: male) to 3.0:1 from a low of 1.4: 1 in 2000. Previous sex ratios were 3.4:1 in 1996, to 3.6:1 in 1997, to 4.3:1 in 1998, to 8.4:1 in 1999. The similarity in sex ratios for 2001 and 1996 may support the hydroacoustic estimates of an increased run. Shad sampling in the Raubsville area reported composite female to male ratios of 1:1.4 in 1998, 1.6:1 in 1999, 1:1.8 in 2000, and 1:1.3 in 2001. The Raubsville sample was collected in April and early May and is reflective of the early component of the shad run. Based on the Raubsville sampling, Snyder (2000) suggested that the nearly equal sex ratio in 2000 at Smithfield Beach may reflect the effects of the sustained high cool flows, perhaps delaying the movement of female shad up river and not the rebuilding of a declining run. The similarity in catch rates for 1999, 2000 and 2001 offer support for this assumption.

Snyder (1999) suggested that the decrease in the rate of repeat spawning at Smithfield Beach and the Raubsville area may indicate that the run is declining. In 2000 the rate of repeat spawning at Smithfield Beach again decreased to 2.8 from 4.4 percent in 1999, while in the Raubsville area the rate increased from 10.3 in 1999 to 15.2 percent. The repeat spawning rate in 2001 increased nearly two fold for the Smithfield Beach area from 2.8 in 2000 to 5.8 percent. However, in the Raubsville area the rate decreased from 15.2 in 2000 to 12.7 percent in 2001. Repeat spawning rates in the Lehigh River also declined in 1998 (Snyder) from 12.5 to 3.1 in 1999. Unlike the continued decline in the Delaware at Smithfield Beach, the Lehigh also increased in the rate of repeat spawning from 3.1 in 1999 to 13.5 percent in 2000. However, by 2001 the repeat spawning rate declined to 3.8 percent. Snyder (2000) postulated that the run in the lower river did not decline or perhaps if it did then the sustained high cool flows kept a greater portion of the shad down river from Smithfield Beach.

The decline in the 1999 Delaware River shad population referred to above was documented in the hydroacoustic monitoring study conducted by Barnes-Williams Environmental Consultants (Binghamton, NY) for the New Jersey Division of Game and Fish and the Delaware River Basin Fish & Wildlife Management Cooperative. The estimated Delaware shad run declined from 392,700 ($\pm 2,500$) in 1998 to 24,700 (± 300) in 1999. However, this decline was in question, as the Lehigh River shad run did not exhibit a similar reduction (Snyder 1999). The Delaware run continued to increase in 2000 to 382,200 ($\pm 2,700$) and 2001 (417,000 ($\pm 2,000$; conservative estimate) shad, which clearly indicates that the Delaware's run did not drastically decline as previously mentioned. This is also supported by the Lehigh's overall positive yearly passage results from 1994 through 2001, and that the 2001 passage was the high recorded at 4,740 shad (Snyder 2001). The Delaware River Basin Fish and Wildlife Technical Committee, American Shad Sub-Committee continues to examine ways to ground truth and validate the hydroacoustic estimates.

The scale age structure at Smithfield Beach for each sex was similar in ages IV through VII, with age V being the most abundant for both sexes (Table 31). The number of age IV males caught has steadily increased since 1999's low of 12. Age V male shad have also increased since 1999's catch of 45, however, catches in 2000 and 2001 were similar. The low catch of age IV female shad in 1999 was repeated in 2000 and 2001 as compared to 1998 and 1997 but similar to the

1996 catch. The catch of age V females significantly declined in 2000 but increased in 2001. Age VI female shad also increased slightly from 2000.

Recommendations:

Continue collecting biological data from the Smithfield Beach shad spawning operation, by gill net mesh size, for submission to the ASMFC Shad and River Herring Technical Committee Stock assessment Sub-Committee.

Continue the examination of otoliths for age and origin determination, and scales for repeat spawning determination.

Literature Cited:

- Cating, J. P. 1953. Determining Age of Atlantic shad from Their Scales. U.S. Fish and Wildlife Service Fishery Bulletin No. 85, Volume 54. Pp 187-199.
- Snyder, R. A. 2000. NA96FI0220. Documentation and Quantification of Alosids Utilizing Fish Passage Facilities and Collection of Biological Data on Adult American Shad. PFBC Files, 450 Robinson Lane, Bellefonte, PA.
1999. NA86FI0214. Documentation and Quantification of Alosids Utilizing Fish Passage Facilities and Collection of Biological Data on Adult American Shad. PFBC Files, 450 Robinson Lane, Bellefonte, PA.
1998. NA76FI0083. Documentation and Quantification of Alosids Utilizing Fish Passage Facilities and Collection of Biological Data on Adult American Shad. PFBC Files, 450 Robinson Lane, Bellefonte, PA.
1997. NA66FI0292. Documentation and Quantification of Alosids Utilizing Fish Passage Facilities and Collection of Biological Data on Adult American Shad. PFBC Files, 450 Robinson Lane, Bellefonte, PA.

Table 1. Number of marked (OTC, tetracycline) American shad fry stocked in the Lehigh River immediately up river of the Northampton Dam/Cementon Dam (RM 24.0) from 1985 through 2001.

Year	Number Stocked
1985	600,000
1986	550,000
1987	491,000
1988	340,400
1989	833,000
1990	2,088,000
1991	793,000
1992	353,000
1993	790,000
1994	642,000
1995	1,044,000
1996	993,000
1997	1,247,000
1998	948,000
1999	501,000
2000	447,900
2001	675,625

Table 2. Video recording periods for the 2001 American shad spawning run at the Easton (RM 0.00: March 29-July 2) and Chain Dam (RM 3.00: April 6 – July 2) fishways in the Lehigh River.

Recording Period	Hours	Recording Period	Hours
03/29 – 03/30	24	05/16 – 05/18	48
03/30 – 04/02	72	05/18 – 05/21	72
04/02 – 04/04	48	05/21 – 05/23	48
04/04 – 04/06	48	05/23 – 05/25	48
04/06 – 04/09	72	05/25 – 05/28	72
04/09 – 04/11	48	05/28 – 05/30	48
04/11 – 04/13	48	05/30 – 06/01	48
04/13 – 04/16	72	06/01 – 06/04	72
04/16 – 04/18	48	06/04 – 06/06	48
04/18 – 04/20	48	06/06 – 06/08	48
04/20 – 04/23	72	06/08 – 06/11	72
04/23 – 04/25	48	06/11 – 06/13	48
04/25 – 04/27	48	06/13 – 06/15	48
04/27 – 04/30	72	06/15 – 06/18	72
04/30 – 05/02	48	06/18 – 06/20	48
05/02 – 05/04	48	06/20 – 06/22	48
05/04 – 05/07	72	06/22 – 06/25	72
05/07 – 05/09	48	06/25 – 06/27	48
05/09 – 05/11	48	06/27 – 06/29	48
05/11 – 05/14	72	06/29 – 07/02	72
05/14 – 05/16	48		

Table 3. Periods of lost monitoring and/or periods of reduced visibility at the Easton and Chain Dam fishways during the 2000 American shad run. D/D = Dusk to Dawn.

Easton Dam Fishway					
Recording Date		Duration Hours	Lost Recording Hours	Percentage Lost Hours	Explanation
3/30	4/02	72	8.52	11.8	Fogged window 7.12 hrs (D/D), cleaning 1.4 hrs
4/02	4/04	48	1.22	2.3	Fishway lowered for cleaning 4/02
4/09	4/11	48	0.42	0.6	Fishway lowered for cleaning
4/11	4/13	48	0.44	0.9	Fogged window 0.7 hrs, cleaning glass 0.37
4/13	4/16	72	0.42	0.6	Fishway lowered for cleaning
4/20	4/23	72	0.80	1.2	Fishway lowered for cleaning 4/20 and 4/23
4/25	4/27	48	0.77	1.6	Fishway lowered for cleaning 4/27
4/27	4/30	72	0.66	0.9	Fishway lowered for cleaning 4/30
4/30	5/02	48	0.34	0.7	Tape Jumping
5/04	5/07	72	1.32	1.8	Fishway lowered for cleaning 5/04 and 5/07
5/09	5/11	48	0.55	1.1	Fishway lowered for cleaning 5/11
5/11	5/14	72	27.18	37.8	Lights not on D/D
5/14	5/16	48	18.05	37.6	Lights not on D/D
5/16	5/18	48	18.66	38.9	Lights not on D/D
5/18	5/21	72	0.43	0.6	Fishway lowered for cleaning 5/21
5/25	5/28	72	0.97	1.3	Tape change and light system check
5/28	5/30	48	21.68	45.2	Lights not on D/D 17.2 hrs, Fishway lowered for cleaning 0.73 hrs 5/29, tape stopped recording 3.75 hrs
6/01	6/04	72	0.42	0.6	Fishway lowered for cleaning 6/04
6/08	6/11	72	0.57	0.8	Fishway lowered for cleaning 6/11
6/22	6/25	72	1.20	1.7	Fishway lowered for cleaning 6/22
Chain Dam Fishway					
4/09	4/11	48	0.37	0.8	Fishway lowered for cleaning
4/13	4/16	72	0.82	1.1	Fishway lowered for cleaning 4/13 & 4/16
4/20	4/23	72	1.38	1.9	Fishway lowered for cleaning 4/20 & 4/23
4/25	4/27	48	1.35	2.8	Fishway lowered for cleaning 4/27
4/27	4/30	72	0.52	0.7	Fishway lowered for cleaning 4/30
5/04	5/07	72	1.93	2.7	Fishway lowered for cleaning 5/04 & 5/07
5/09	5/11	48	0.52	1.1	Fishway lowered for cleaning 5/11
5/18	5/21	72	0.72	1.0	Fishway lowered for cleaning 5/21
5/28	5/30	48	1.28	2.7	Fishway lowered for cleaning 5/29
6/01	6/04	72	0.52	7.2	Fishway lowered for cleaning 6/04
6/08	6/11	72	0.67	0.9	Fishway lowered for cleaning 6/11
6/22	6/25	72	1.50	2.1	Fishway lowered for cleaning 6/22

Table 4. Fishes that have been observed (video taped) migrating through the Easton (RM and Chain (RM 3.0) Dam fishways in the Lehigh River during the early spring and summer of 1994 through 2000.

Easton Dam Fishway								
Fish Species/Type	1994+	1995	1996	1997	1998	1999	2000	2001
American shad	87	873	1141	1428	3293	2346	2094	4740
Gizzard shad		51	23	15	45	1263	337	392
Striped bass		19	5	1	0	0	0	0
American eel		1	4	*	2*	4*	1*	*
Sea lamprey		6	27	38	22	181	253	894
Trout		109	43	79	193	111	231	267
Muskellunge		9	6	1	0	3	10	8
Chain pickerel		0	0	0	0	2	0	0
Walleye		3	2	0	1	1	0	1
Yellow perch		2	31	2	0	2	0	3
Bass		303	348	218	483	358	1149	377
Sunfish		368	289	130	210	140	1214	504
Crappie		0	2	2	0	0	0	0
Carp		338	1386	274	497	353	732	651
Quillback		0	0	0	11	9	17	21
Catfish		284	503	330	268	237	790	367
Minnows/Fallfish		0	4	11	63	221	67	279
Golden shiner		0	2	0	0	0	0	0
Sucker		1718	1607	435	209	2019	573	2292
Total	87	4041	5423	2964	5297	7250	7468	10796
% American shad		21.6	21.0	48.2	62.2	32.4	28.0	43.9

* No attempts were made to count elvers.

Chain Dam Fishway						
Fish Species/Type	1996	1997	1998	1999	2000	2001
American shad	496	126	694	479	645	2057
Gizzard shad	39	11	15	958	307	416
Striped bass	2	0	0	0	0	0
American eel	34	*	32*	*	13*	*
Sea lamprey	7	2	1	165	58	570
Trout	96	119	238	220	318	205
Muskellunge	1	1	0	1	4	0
Walleye	1	0	0	0	0	1
Yellow perch	90	10	5	19	75	59
Bass	557	389	823	765	1572	575
Sunfish	828	329	456	395	1409	1089
Crappie	0	6	0	0	0	0
Carp	1343	153	158	1201	137	193
Quillback				0	0	0
Catfish	545	427	279	215	592	318
Minnows/Fallfish	182	27	565	1079	1280	320
Golden shiner	6	0	2	0	0	0
Sucker	2899	852	326	2417	922	1143
Total	7126	2452	3594	7914	7332	6946
% American shad	7.0	5.1	19.3	6.1	8.8	29.6
% Easton's AMS passage	43.5	8.8	21.0	20.4	30.8	43.4

* No attempts were made to count elvers.

Table 5.

Daily passage of adult American shad in the Lehigh River, through the Easton Dam Fishway in 1995 (April 20-June 30), 1996 (April 27- July 11), 1997 (April 14-June 27), 1998 (April 6-June 30), 1999 (April 15-July 5), 2000 (March 31-July 5), and 2001 (March 31-July 2).

Easton Dam Fishway							
Date	1995	1996	1997	1998	1999	2000	2001
3/31						1	9
4/01						.	2
4/02						.	.
4/03						1	.
4/04						1	.
4/05						.	1
4/06				1		1	.
4/07				.		2	.
4/08				.		.	4
4/09				.		.	4
4/10				.		.	2
4/11				.		.	2
4/12				1		.	.
4/13				.		.	1
4/14			1	3		.	2
4/15			1	1	1	.	5
4/16			.	3	2	.	.
4/17			.	9	.	3	1
4/18			.	11		1	1
4/19			.	5	1	.	.
4/20	2		.	.	.	1	.
4/21	2		.	.	1	3	.
4/22	.		.	1	1	.	2
4/23	.		2	2	1	1	64
4/24	4		.	.	2	.	141
4/25	1		1	7	2	.	100
4/26	6		5	16	7	.	8
4/27	4	1	3	8	21	.	.
4/28	17	.	6	3	19	1	79
4/29	23	7	8	9	81	1	59
4/30	11	2	74	102	112	5	41
5/01	.	.	90	98	42	6	165
5/02	.	4	33	104	62	23	337
5/03	.	5	19	92	41	17	365
5/04	2	1	10	96	27	8	170
5/05	7	.	10	75	72	29	186
5/06	42	7	38	39	132	40	156
5/07	20	.	18	75	73	24	81
5/08	9	1	3	146	49	10	116
5/09	18	.	8	25	44	13	161
5/10	19	2	6	10	55	3	143
5/11	8	38	17	2	119	.	77
5/12	9	35	33	.	140	114	118
5/13	17	3	48	3	105	136	100
5/14	18	1	15	4	89	78	73
5/15	12	3	27	157	63	222	38
5/16	18	1	29	224	44	111	47
5/17	53	2	17	530	30	82	39
5/18	16	29	5	425	36	101	19
5/19	17	175	4	203	47	28	30

Table 5. (Cont'd)

Easton Dam Fishway							
Date	1995	1996	1997	1998	1999	2000	2001
5/20	11	162	32	125	82	.	67
5/21	16	122	28	86	162	3	30
5/22	22	47	50	21	67	5	34
5/23	10	28	31	5	19	2	67
5/24	26	1	31	4	14	4	331
5/25	30	23	73	5	6	3	138
5/26	8	21	56	26	29	3	115
5/27	13	9	74	26	92	.	39
5/28	20	2	57	15	100	15	116
5/29	6	3	18	58	37	80	199
5/30	47	8	6	101	22	79	62
5/31	31	1	7	58	41	38	41
6/01	84	11	55	62	44	17	32
6/02	28	8	33	55	39	53	12
6/03	15	12	38	43	19	51	41
6/04	2	6	7	10	2	32	43
6/05	19	19	61	8	.	6	41
6/06	31	19	9	6	.	16	50
6/07	11	9	3	5	5	8	44
6/08	13	6	16	1	12	25	35
6/09	6	17	3	.	11	126	23
6/10	.	62	50	.	3	86	27
6/11	.	47	56	2	2	14	14
6/12	15	4	39	1	1	.	26
6/13	13	.	21	1	.	7	28
6/14	8	59	5	.	4	14	16
6/15	.	6	9	.	.	28	16
6/16	1	21	3	2	1	39	19
6/17	5	21	4	7	1	26	6
6/18	.	37	4	42	.	17	23
6/19	3	9	.	9	.	23	9
6/20	6	5	2	1	.	21	13
6/21	7	3	4	2	.	18	8
6/22	2	2	1	6	1	55	5
6/23	1	6	5	2	1	22	.
6/24	.	1	6	1	2	5	3
6/25	.	.	3	2	1	5	1
6/26	1	2	6	2	1	11	6
6/27	1	.	1	1	.	29	1
6/28	4	2	.	1	.	16	3
6/29	.	1	.	.	.	18	1
6/30	2	.	.	1	.	3	3
7/01	.	1	.	.	.	.	1
7/02	.	.	.	.	.	.	1
7/03	.	.	.	.	.	1	.
7/04	.	.	.	.	1	.	.
7/05	.	.	.	.	3	1	.
7/06	.	.	.	.	.	.	.
...	.	.	.	.	.	.	.
7/11	.	1	.	.	.	.	.
Total	873	1141	1428	3293	2346	2094	4740

Table 6. Total hourly passage of adult American shad migrating through the Easton Dam (RM 0.0, 1995-2001) Dam Fishway in the Lehigh River during the early spring and summer.

Easton Dam Fishway								
Hours	1995	1996	1997	1998	1999	2000	2001	2001 ^a
0000	4	1	2	12	9	4	8	8
0100	2	2	1	6	3	4	1	1
0200	2	5	1	2	4	1	5	5
0300	3	3	2	3	5	1	10	10
0400	4	4	3	8	11	3	6	6
0500	.	11	6	21	38	19	41	33
0600	28	26	29	47	60	84	140	109
0700	34	55	41	82	75	149	217	190
0800	39	81	49	110	73	155	323	286
0900	37	55	29	88	105	162	173	170
1000	52	65	55	128	132	149	221	194
1100	52	66	83	171	115	129	326	274
1200	60	49	96	137	168	103	257	201
1300	65	58	122	173	190	151	313	254
1400	65	61	123	240	208	149	353	293
1500	63	84	136	353	219	125	356	307
1600	61	91	175	410	260	149	382	310
1700	85	101	142	425	260	175	483	401
1800	67	109	158	401	223	169	441	351
1900	69	116	106	272	151	128	431	351
2000	44	65	45	145	20	63	178	150
2100	20	21	13	36	10	14	17	17
2200	13	8	5	18	5	6	8	8
2300	4	4	6	5	2	2	9	9
Total	873	1141	1428	3293	2346	2094	4699	3938

2001* – less 41 shad as only the date was recorded not actual time of passage.

2001^a – less 41 shad, and those periods where passage at night was not recorded
May 11-14, 14-16, 16-18, and 28-30, 2001.

Table 7. Daily and monthly passages of adult American shad through the Easton Dam Fishway in the Lehigh River per the following six diurnal periods: 0100-0500; 0600-0900; 1000-1200; 1300-1500; 1600-1900; 2000-0000 hours in 1995 (April 20-June 30), 1996 (April 27-July 11), 1997 (April 14-June 27), 1998 (April 6-June 30), 1999 (April 15-July 5), 2000 (March 31-July 5; April 5-July 5) and 2001 (March 31-July 2; April 8-July 2).

Date	Easton Dam Fishway																				
	0100-0500							0600-0900							1000-1200						
	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001
3/31																					
March Summary																					
4/01																					
4/02																					
4/03																					
4/04																					
4/05														1							
4/06						1								.							
4/07						1								.							
4/08						.	2							.							
4/09						.	1							.							
4/10						.	1							.							
4/11						.	.							.							
4/12						.	.							.							
4/13						.	.							.							
4/14						.	.							1							1
4/15						.	.							2							.
4/16					1	.	.							.							.
4/17					.	.	.				1		1	.				1			.
4/18				1	.	.	.				.		1	.				2			.
4/19				.	.	.	.				.		.	.				2			.
4/20				.	.	.	.				.		.	.				.			.
4/21				.	.	1	.				.		.	.	1			.		2	.
4/22				.	.	.	.				.		.	.	.			.		.	.
4/23				.	.	.	.				.		.	4	.		1	1		.	1
4/24				.	.	.	.				.	1	.	12	.		.	.		.	29
4/25				.	.	.	.				.	.	.	25	.		.	.		.	27
4/26				.	.	.	.				3	.	.	3	1		.	4	1	.	1
4/27				.	.	.	.	2		1	.	1	.	.	1		1	1	2	.	.
4/28	1			.	.	.	.	.		1	.	2	.	5	1		2	1	2	.	13
4/29	.			.	2	.	2	3		.	1	5	1	13	5	1	.	.	8	.	4
4/30	.			2	4	.	4	1	1	4	5	20	.	9	1	.	4	11	20	.	1
April Summary	1	0	0	3	7	3	10	6	1	6	10	33	3	75	10	1	8	23	74	2	77

Table 7. (Cont'd)

Easton Dam Fishway																					
Date	0100-0500							0600-0900							1000-1200						
	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001
5/01	.	.	1	1	.	.	1	.	.	14	8	1	.	10	.	.	15	19	4	.	14
5/02	.	.	.	.	1	1	1	.	1	15	14	7	.	47	.	.	8	19	6	2	46
5/03	.	.	.	.	.	.	3	.	2	3	6	4	1	82	.	2	1	11	10	1	55
5/04	.	.	.	.	.	1	2	1	.	3	9	3	1	69	.	.	.	20	.	1	14
5/05	.	.	.	.	.	1	2	.	.	1	8	1	3	23	1	.	1	6	3	.	46
5/06	.	.	1	3	3	3	.	6	.	3	4	25	7	36	7	.	4	23	21	2	23
5/07	.	.	.	.	1	.	.	4	.	1	.	15	8	20	1	.	3	11	23	2	6
5/08	.	.	.	1	.	.	4	3	.	1	7	4	.	21	1	.	.	15	11	3	21
5/09	.	.	.	1	2	.	2	4	.	.	3	6	2	26	1	.	.	2	14	1	12
5/10	.	.	.	.	.	.	3	3	.	2	1	1	3	25	1	.	2	.	3	.	25
5/11	.	.	.	2	6	.	4	2	.	.	.	13	.	5	1	1	.	.	18	.	7
5/12	.	.	.	.	5	.	2	.	25	.	.	23	.	10	1	8	1	.	17	27	28
5/13	.	.	.	.	1	.	.	1	2	11	.	24	42	11	.	1	13	2	24	35	16
5/14	1	1	.	.	4	3	.	.	.	3	.	19	35	5	4	.	.	1	15	31	11
5/15	.	1	.	.	3	.	1	.	.	1	7	4	44	3	.	.	2	8	10	35	8
5/16	1	.	.	2	1	2	.	1	.	2	21	5	42	10	.	.	4	28	10	14	7
5/17	1	.	1	1	1	.	.	9	.	6	59	1	8	6	8	1	1	82	4	7	7
5/18	1	.	.	13	1	2	.	4	.	1	34	.	28	4	1	.	.	52	8	15	4
5/19	.	1	.	.	.	.	.	3	16	.	33	6	16	3	4	19	1	25	11	5	1
5/20	.	3	.	2	.	.	1	1	36	1	15	4	.	8	2	17	2	12	8	.	9
5/21	1	1	1	1	2	.	2	3	34	6	18	33	.	3	3	19	7	8	43	.	2
5/22	.	4	1	.	1	.	.	1	14	1	9	15	.	10	.	4	6	3	14	.	4
5/23	3	.	.	.	3	.	.	1	4	4	.	2	.	7	4	4	8	1	6	1	10
5/24	1	.	.	.	2	.	6	1	1	3	1	.	.	62	.	.	5	.	2	.	68
5/25	3	.	1	.	.	.	3	7	.	2	.	.	1	44	5	4	4	.	.	.	14
5/26	.	2	.	.	1	.	1	.	6	9	1	2	3	12	2	3	11	.	11	.	40
5/27	.	.	1	.	.	.	.	2	1	7	2	2	.	1	2	4	7	7	6	.	8
5/28	.	1	1	.	2	.	1	9	.	8	2	27	.	11	3	.	4	1	17	1	20
5/29	.	.	.	1	4	1	.	.	.	6	8	4	13	36	.	.	7	3	6	11	50
5/30	.	.	.	3	1	.	2	3	.	4	10	4	28	7	7	3	.	19	4	10	12
5/31	.	1	.	.	1	2	.	1	.	.	5	1	9	9	12	.	1	4	8	8	10
May Summary	12	15	8	31	46	16	41	70	142	118	285	256	294	626	71	90	118	382	337	212	598

Table 7. (Cont'd)

Easton Dam Fishway																					
Date	0100-0500							0600-0900							1000-1200						
	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001
6/01	2	.	.	2	1	.	.	27	.	3	9	7	4	9	26	.	10	18	13	2	8
6/02	.	1	.	1	1	1	.	5	2	.	.	6	10	4	7	2	17	2	9	9	.
6/03	.	1	.	.	.	2	.	4	2	.	2	4	18	7	6	3	13	1	9	10	9
6/04	.	.	.	.	.	1	.	1	.	1	.	.	7	7	1	4	5	1	.	7	17
6/05	1	.	1	.	.	.	.	1	3	2	2	.	1	11	2	2	10	2	.	1	9
6/06	.	.	.	1	.	.	.	7	.	1	.	.	2	14	5	3	1	1	.	3	9
6/07	.	.	.	.	.	1	2	2	3	.	2	.	1	10	3	1	1	1	1	1	9
6/08	.	1	.	.	.	.	3	5	.	3	.	5	4	5	3	.	2	.	2	1	14
6/09	1	1	.	.	2	.	.	3	.	.	.	1	38	8	2	1	2	.	6	23	5
6/10	.	.	1	.	.	.	1	.	6	.	.	1	27	13	.	19	9	.	.	17	6
6/11	.	3	.	.	.	.	.	.	8	.	.	.	9	2	.	10	15	2	.	5	7
6/12	.	.	1	1	.	.	.	.	4	2	.	.	.	.	8	.	14	.	1	.	.
6/13	.	.	.	.	.	.	.	1	.	3	.	.	.	.	7	.	7	1	.	1	9
6/14	.	.	.	.	1	1	.	3	15	3	.	1	3	11	4	11	2	.	1	4	5
6/15	.	.	.	.	.	.	.	.	1	.	.	.	10	6	.	.	1	.	.	11	2
6/16	1	.	.	.	.	.	.	.	7	.	.	.	22	11	.	5	1	.	1	11	3
6/17	.	.	.	.	.	.	.	2	2	1	2	.	8	4	.	10	.	.	.	1	1
6/18	.	1	2	1	.	.	.	.	14	1	8	.	7	6	.	8	.	9	.	.	6
6/19	.	.	.	.	.	.	1	.	2	.	1	.	9	3	.	6	.	4	.	7	4
6/20	.	.	.	.	.	.	1	5	1	.	.	.	1	8	.	.	1	1	.	8	1
6/21	1	.	.	.	.	1	2	1	.	1	1	.	6	2	4	2	1	.	.	.	2
6/22	.	.	.	.	.	.	1	1	1	.	1	.	28	4	.	.	.	.	1	18	.
6/23	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	1	.	.	.	7	.
6/24	.	.	.	.	.	.	.	.	1	2	1	2	.	.	.	.	.	.	.	1	1
6/25	.	.	.	.	.	.	.	.	.	.	1	1	1	.	.	.	1	.	.	1	.
6/26	.	1	.	.	.	.	1	.	.	1	.	.	2	2	.	1	.	2	1	4	.
6/27	.	.	.	.	.	.	.	.	.	.	1	.	9	.	1	.	.	.	.	7	.
6/28	.	.	.	.	.	.	.	.	2	.	.	.	8	3	2	.	.	.	.	2	.
6/29	.	1	.	.	.	1	.	.	.	.	.	.	9	.	.	.	.	.	.	2	.
6/30	1	.	.	.	.	.	1	.	.	.	1	.	1	2	.	.	.	.	.	1	.
June Summary	7	10	5	6	5	8	13	68	74	24	32	28	255	152	82	92	113	45	45	165	127
7/01					.								.						.		
7/02					.								.						.		
7/03					.								.						.		
7/04					.								.						1		
7/05					3								1								
...																					
7/11																					
July Summary	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Total Passage	20	25	13	40	61	27	64	144	217	148	327	313	553	853	163	183	239	450	416	379	802

Table 7. (Cont'd)

Easton Dam Fishway																					
Date	1300-1500							1600-1900							2000-0000						
	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001
3/31							1							2						1	6
March Summary							1							2						1	6
4/01														1						.	1
4/02														.							.
4/03													1	.						.	.
4/04													2	.						1	.
4/05													.	.						.	.
4/06											1			.						.	.
4/07											.		1	.						.	.
4/08											.		.	.						.	2
4/09											.		.	2						.	1
4/10							1				.		.	.						.	.
4/11							.				.		.	2						.	.
4/12				1							.		.	.						.	.
4/13				.			1				.		.	.						.	.
4/14				2			.				1		.	.			1			.	.
4/15				1			3			1	.	1	.	.			.			.	.
4/16				1			.			.	1	.	.	.			.	1	1	.	.
4/17				3		1	.			.	1	.	1	1			.	3	.	.	.
4/18				3		.	.			.	5	.	.	.			.	.	.	.	1
4/19				2		.	.			.	1	1	.	.			.	.	.	.	.
4/20				.		.	.	1		.	.	.	1	.			.	.	.	.	.
4/21	1			.	1	.	.	.		.	.	.	.	.			.	.	.	.	.
4/22	.			.	1	.	1	.		.	1	.	.	.			.	.	.	.	1
4/23	.			.	.	1	18	.		1	1	1	.	38			.	.	.	.	3
4/24	2			.	1		33	.		.	.	.	.	64	3		.	.	.	.	3
4/25	.		1	2	.	.	17	.		.	5	2	.	29	2		.	.	.	.	2
4/26	.		2	4	.	.	3	4		2	5	4	.	1	4		1	.	2	.	.
4/27	1		1	1	6	.	.	.	1	.	2	12	.	.	.		.	4	.	.	.
4/28	6		2	.	9	.	18	8	.	1	2	6	1	41	2		.	.	.	.	2
4/29	7	1	2	2	28	.	14	7	5	5	6	35	.	22	.		1	.	3	.	4
4/30	4		20	21	28	1	4	5	1	43	55	35	4	23	2		3	8	5	.	.
April Summary	21	1	28	43	74	3	113	25	7	53	87	97	11	224	13	0	6	16	11	1	20

Table 7. (Cont'd)

Date	Easton Dam Fishway																				
	1300-1500							1600-1900							2000-0000						
	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001
5/01	.	.	13	24	16	1	28	.	.	39	40	21	5	104	.	.	8	6	.	.	8
5/02	.	.	2	27	12	8	88	.	3	6	41	35	11	139	.	.	2	3	1	1	16
5/03	.	.	6	27	12	5	74	.	1	8	47	14	8	130	.	.	1	1	1	2	21
5/04	.	.	4	34	6	2	21	1	1	2	29	15	3	58	.	.	1	4	3	.	6
5/05	5	.	2	21	14	2	37	.	.	6	36	49	20	70	1	.	.	4	5	3	8
5/06	9	1	8	9	43	5	29	18	4	21	.	38	21	56	2	2	1	.	2	2	13
5/07	4	1	4	13	19	4	21	11	.	9	47	14	8	27	.	.	1	4	1	2	7
5/08	.	.	.	42	14	5	19	5	.	2	78	20	2	44	.	.	.	3	.	.	7
5/09	3	.	5	5	12	1	29	10	.	2	13	10	8	76	.	.	1	1	.	1	16
5/10	2	.	.	3	9	.	34	12	1	2	6	42	.	53	1	1	.	.	.	.	3
5/11	1	2	5	.	30	.	14	3	28	9	.	50	.	45	1	7	3	.	2	.	2
5/12	4	1	9	.	40	36	23	4	1	23	.	50	49	54	.	.	.	.	5	2	1
5/13	2	.	14	1	24	25	27	10	.	9	.	30	30	43	4	.	1	.	2	4	3
5/14	2	.	2	1	22	2	17	8	.	10	1	27	7	35	3	.	.	1	2	.	5
5/15	4	1	5	50	21	79	17	8	1	9	72	24	60	9	.	.	.	20	1	4	.
5/16	2	.	8	36	7	18	8	13	.	12	120	20	28	20	1	1	3	17	1	7	2
5/17	10	1	4	106	8	19	12	21	.	5	249	15	43	12	4	.	.	33	1	5	2
5/18	5	1	2	109	9	20	1	5	23	1	199	18	32	7	.	5	1	18	.	4	3
5/19	5	17	1	42	15	7	6	5	96	1	97	14	.	15	.	26	1	6	1	.	5
5/20	3	43	5	27	20	.	16	4	52	21	60	50	.	26	1	11	3	9	.	.	7
5/21	3	9	3	13	38	2	4	4	51	9	35	45	.	14	2	8	2	11	1	1	5
5/22	6	10	14	3	18	3	9	8	12	24	6	18	1	11	7	3	4	.	1	1	.
5/23	.	11	6	.	2	.	15	1	8	12	3	6	.	31	1	1	1	1	.	1	4
5/24	7	.	8	.	7	.	85	11	.	12	1	3	4	98	6	.	3	2	.	.	12
5/25	8	10	26	2	1	.	40	3	9	38	3	5	2	35	4	.	2	.	.	.	2
5/26	6	4	14	1	9	.	26	.	6	19	15	6	.	33	.	.	3	9	.	.	3
5/27	.	1	12	3	30	.	9	9	2	40	10	53	.	18	.	1	7	4	1	.	3
5/28	8	1	6	3	22	2	28	.	.	34	4	30	9	51	.	.	4	5	2	3	5
5/29	.	.	4	5	12	9	51	6	3	1	34	10	44	54	.	.	.	7	1	2	8
5/30	13	1	.	23	5	11	17	22	2	2	43	8	25	21	2	2	.	3	.	5	3
5/31	6	.	2	11	18	4	6	10	.	4	33	13	14	15	2	.	.	5	.	1	1
May Summary	118	115	194	641	515	270	811	212	304	392	1322	753	434	1404	42	68	53	177	34	51	181

Table 7. (Cont'd)

Easton Dam Fishway																					
Date	1300-1500							1600-1900							2000-0000						
	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001	1995	1996	1997	1998	1999	2000	2001
6/01	7	2	25	19	10	7	8	13	6	17	9	13	1	7	9	3	.	5	.	3	.
6/02	7	1	6	18	5	13	2	5	1	8	27	18	10	6	4	1	2	7	.	10	.
6/03	2	3	15	8	2	13	16	1	3	10	27	4	5	9	2	.	.	5	.	3	.
6/04	.	.	.	2	2	9	10	.	2	1	6	.	6	7	.	.	.	1	.	2	2
6/05	6	12	14	.	.	.	12	8	2	30	4	.	4	9	.	.	4	.	.	.	.
6/06	9	5	3	2	.	9	8	8	8	4	2	.	2	16	2	3	.	.	.	.	3
6/07	3	1	2	1	3	4	7	2	3	.	1	1	1	15	1	1	.	.	.	.	1
6/08	2	1	8	1	2	2	2	2	3	3	.	2	16	8	1	1	.	.	.	2	3
6/09	.	4	1	.	2	29	7	.	8	.	.	.	32	3	.	3	.	.	.	4	.
6/10	.	13	22	.	.	5	3	.	16	18	.	2	31	.	.	8	.	.	.	6	4
6/11	.	15	24	.	2	.	2	.	9	17	.	.	.	.	.	2	.	.	.	.	.
6/12	6	.	14	.	.	.	.	1	.	7	.	.	.	.	.	.	1	.	.	.	.
6/13	3	.	4	.	.	1	2	1	.	6	.	.	4	5	1	.	1	.	.	1	.
6/14	.	11	.	.	.	2	.	1	17	.	.	1	4	.	.	2	.	.	.	.	.
6/15	.	.	5	.	.	7	5	.	4	3	.	.	.	3	.	1	.	.	.	.	.
6/16	.	2	.	2	.	1	3	.	6	1	.	.	5	1	.	1	1	.	.	.	1
6/17	3	3	.	1	1	7	.	.	5	2	4	.	9	.	.	1	1	.	.	1	1
6/18	.	7	1	12	.	5	4	.	6	.	10	.	2	7	.	1	.	2	.	3	.
6/19	1	1	.	2	.	6	.	1	.	.	2	.	.	1	1	.	.	.	.	1	.
6/20	1	.	1	.	.	3	1	.	2	.	.	.	9	2	.	2	.	.	.	.	.
6/21	1	.	2	1	.	3	2	.	1	.	.	.	8	.	.	.	.	.	.	.	.
6/22	.	.	1	.	.	4	.	1	1	.	2	.	5	.	.	.	.	3	.	.	.
6/23	.	2	3	.	.	2	.	.	2	2	2	.	2	.	1	1	.	.	1	1	.
6/24	.	.	2	.	.	3	1	.	.	2	.	.	1	1	.	.	.	.	.	.	.
6/25	.	.	.	.	.	1	1	.	.	2	1	.	2	.	.	.	.	.	.	.	.
6/26	.	.	3	.	.	3	1	1	.	2	.	.	1	1	.	.	.	.	.	1	1
6/27	.	.	.	.	.	7	.	.	.	1	.	.	6	.	.	.	.	.	.	.	1
6/28	2	.	.	1	.	3	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
6/29	.	.	.	.	.	3	.	.	.	.	.	.	3	.	.	.	.	.	.	.	1
6/30	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
June Summary	53	83	156	70	29	153	97	45	105	136	97	42	172	101	23	31	10	23	1	38	18
7/01									1					1							
7/02							1														
7/03													1								
7/04																					
7/05																					
...																					
7/11		1																			
July Summary	0	1	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Total Passage	192	200	378	754	618	426	1023	282	417	581	1506	892	616	1732	78	99	69	216	46	91	225

Table 8.

Daily passage of adult American shad in the Lehigh River, through the Chain Dam Fishway 1996 (May 11-July 3), 1997 (April 26-July 2), 1998 (April 13-July 4), 1999 (May 1-July 6), 2000 (April 5-July 5) and 2001 (April 8-July 2).

Chain Dam Fishway						
Date	1996	1997	1998	1999	2000	2001
4/08						1
4/09						1
4/10						16
4/11						6
4/12						2
4/13			3			.
4/14			.			1
4/15			.			.
4/16			1			.
4/17			.			.
4/18			.			.
4/19			1			.
4/20			1			.
4/21			.		1	.
4/22			.		.	.
4/23			1		.	.
4/24			.		.	3
4/25			2		.	3
4/26		2	.		.	1
4/27		.	1		.	3
4/28		.	.		.	8
4/29		1	1		.	3
4/30		2	2		.	10
5/01		.	2	1	.	48
5/02		.	13	6	.	154
5/03		.	9	4	1	196
5/04		1	11	.	1	139
5/05		.	9	.	2	101
5/06		.	15	.	6	36
5/07		.	34	1	2	9
5/08		.	4	1	11	8
5/09		.	9	1	.	13
5/10		1	3	29	1	21
5/11	1	.	2	6	10	86
5/12	2	3	.	76	11	10
5/13	.	.	1	26	11	40
5/14	.	1	.	40	27	19
5/15	.	.	1	23	26	8
5/16	.	.	73	5	80	63
5/17	.	1	113	2	23	34
5/18	3	.	100	1	91	2
5/19	6	5	35	10	45	4
5/20	26	12	5	24	.	93
5/21	31	5	67	69	2	.
5/22	38	3	44	39	2	4
5/23	14	1	8	11	.	5
5/24	4	.	38	2	1	7
5/25	4	1	.	6	1	244
5/26	3	9	3	5	2	78

Table 8. (Cont'd)

Chain Dam Fishway						
Date	1996	1997	1998	1999	2000	2001
5/27	1	2	1	9	8	59
5/28	2	33	1	2	5	94
5/29	2	3	.	12	2	111
5/30	1	1	4	.	4	103
5/31	10	.	.	.	7	12
6/01	4	1	4	.	8	11
6/02	8	1	1	7	16	40
6/03	9	.	6	5	1	23
6/04	1	4	1	3	.	6
6/05	15	3	4	3	1	19
6/06	6	5	.	.	2	8
6/07	6	1	2	.	.	4
6/08	4	.	.	.	5	.
6/09	1	.	.	3	25	1
6/10	66	.	6	3	22	.
6/11	35	8	2	2	16	1
6/12	9	1	2	9	90	1
6/13	10	5	.	2	6	21
6/14	34	.	.	6	1	3
6/15	15	1	.	2	.	15
6/16	12	.	4	3	9	8
6/17	5	1	12	.	2	5
6/18	40	.	2	.	.	.
6/19	8	.	1	1	5	1
6/20	3	3	4	.	4	.
6/21	4	3	3	.	6	.
6/22	10	.	9	.	5	.
6/23	26	.	3	.	11	.
6/24	5	.	2	.	5	1
6/25	5	.	2	.	2	1
6/26	.	.	3	.	1	1
6/27	2	.	.	.	6	2
6/28	.	.	.	.	7	.
6/29	1	.	1	.	3	.
6/30	2	.	.	2	1	23
7/01	1	.	.	1	2	.
7/02	.	2	1	.	.	3
7/03	1	.	.	.	.	.
7/04	.	.	1	2	.	.
7/05	.	.	.	13	.	.
7/06	.	.	.	1	.	.
Total	496	126	694	479	645	2057

Table 9.

Total hourly passage of adult American shad migrating through the Chain Dam (RM 3.0, 1996-2001) fishway in the Lehigh River during the early spring and summer.

Chain Dam Fishway						
Hours	1996	1997	1998	1999	2000	2001
0000	.	.	2	1	.	.
0100	2	.	1	2	.	.
0200	.	1	.	1	.	1
0300	2	2	1	1	1	3
0400	3	.	.	1	.	1
0500	5	2	4	10	1	9
0600	22	2	8	16	11	31
0700	54	1	13	20	36	38
0800	40	3	11	45	51	70
0900	57	3	29	44	40	90
1000	35	4	24	41	32	159
1100	31	1	21	40	42	155
1200	33	2	47	27	53	219
1300	31	13	53	39	65	214
1400	20	18	70	49	79	227
1500	31	18	89	50	87	244
1600	27	18	101	41	58	208
1700	24	8	73	19	38	153
1800	22	8	59	22	19	100
1900	28	12	49	8	21	84
2000	23	8	34	1	10	39
2100	2	2	2	1	1	6
2200	2	.	1	.	.	3
2300	2	.	2	.	.	3
Total	496	126	694	479	645	2057

Table 10. Daily and monthly passages of adult American shad through the Chain Dam Fishway in the Lehigh River per the following six diurnal periods: 0100-0500; 0600-0900; 1000-1200; 1300-1500; 1600-1900; 2000-0000 hours in 1996 (May 11-July 11), 1997 (April 14-June 27), 1998 (April 6-June 30), 1999 (April 15-July 5), 2000 (March 31-July 5; April 5-July 5) and 2001 (March 31-July 2; April 8-July 2).

Date	Chain Dam Fishway																	
	0100-0500						0600-0900						1000-1200					
	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
4/08												1						
4/09												.						
4/10												2						1
4/11						1						1						2
4/12						.						1						.
4/13						.						.						.
4/14						.						1						.
4/15						.						.						.
4/16						.						.						.
4/17						.						.						.
4/18						.						.						.
4/19						.						.			1			.
4/20						.						.			.			.
4/21						.					1	.			.			.
4/22						.					.	.			.			.
4/23						.					.	.			.			.
4/24						.					.	.			.			.
4/25			1			.			1		.	.			.			.
4/26			.			.			.		.	.			.			.
4/27			.			.			.		.	.			.			.
4/28			.			.			.		.	.			.			1
4/29			.			.			.		.	.			.			.
4/30			.			.			.		.	.			.			.
April Summary	0	0	1	0	0	1	0	0	1	0	1	6	0	0	1	0	0	4

Table 10. (Cont'd)

Chain Dam Fishway																		
Date	0100-0500						0600-0900						1000-1200					
	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
5/01			.			.			.		.	1			.		.	9
5/02			.			1			.		.	14			2	2	.	15
5/03			.			1			.		.	16			1	.	1	81
5/04			.			.		1	2		.	33			.	.	.	21
5/05			.			1		.	2		.	22			.	.	1	55
5/06			.			.		.	.		1	2			2	.	.	14
5/07			.			.		.	9		1	.			2	.	.	1
5/08			.	1	1	.		.	2		4	.			1	.	1	4
5/09			1	.	.	.		.	.		.	.			1	1	.	9
5/10			.	.	.	.		.	.	3	.	2			.	7	.	4
5/11			.	.	.	1		.	.	3	.	10			.	1	1	23
5/12			.	1	.	.		.	.	29	3	2	1		.	22	.	2
5/13			.	.	.	.		.	.	6	1	4	.		.	14	4	17
5/14			.	.	.	.		.	.	.	9	4	.		.	10	4	5
5/15			.	.	.	.		.	.	1	1	1	.		.	1	1	2
5/16			.	.	.	1		.	.	3	15	3	.		3	.	25	13
5/17		1	.	.	.	2		.	7	.	1	5	.		21	.	4	10
5/18		.	2	.	.	1	1	.	23	1	1	1	.		16	.	16	.
5/19	1	.	.	.	.	.	.	.	2	3	22	.	1		5	2	5	1
5/20	1	1	.	.	.	.	2	.	1	.	.	11	3		3	4	.	33
5/21	2	.	.	5	.	.	.	2	4	36	.	.	4		6	7	.	.
5/22	1	.	1	3	.	.	11	.	3	15	.	.	6		2	13	.	.
5/23	1	1	.	.	.	.	4	.	.	1	.	.	5		.	.	.	.
5/24	.	.	.	.	.	.	2	.	1	.	1	1	2		4	.	.	2
5/25	.	.	.	.	.	.	.	.	.	.	.	2	.		.	.	.	79
5/26	.	.	.	.	.	.	.	.	2	.	.	7	.	1	.	2	.	14
5/27	.	.	.	.	.	.	.	1	.	5	1	.	.		.	2	2	2
5/28	.	.	1	.	.	.	.	.	.	.	.	5	.	2	.	1	1	7
5/29	.	.	.	.	.	1	.	.	.	.	1	18	2	1	.	2	1	8
5/30	.	.	.	.	.	1	1	.	.	.	.	14	.	1	1	.	.	42
5/31	.	.	.	.	.	1	4	.	.	.	.	1	.	.	.	.	1	3
May Summary	6	3	5	10	1	11	25	4	58	106	62	179	24	5	70	91	68	476

Table 10. (Cont'd)

Chain Dam Fishway																		
Date	0100-0500						0600-0900						1000-1200					
	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
6/01	1	.	.	.	.	.	3	.	.	.	2	2	.	.	1	.	4	4
6/02	1	.	.	.	.	.	4	.	.	.	5	3	.	.	.	2	5	12
6/03	.	.	.	2	.	.	2	.	.	1	1	2	4	.	.	1	.	6
6/04	.	.	.	1	.	.	.	.	.	1	.	1	.	.	.	.	.	.
6/05	.	.	.	.	.	.	4	.	.	2	.	2	9	.	3	1	1	4
6/06	.	.	.	.	.	.	.	1	.	.	.	5	2	.	.	.	.	2
6/07	.	.	.	.	.	.	2	1	.	.	.	.	2	.	.	.	.	2
6/08	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.
6/09	.	.	.	1	.	.	1	.	.	1	6	.	.	.	.	1	5	1
6/10	.	.	.	.	1	.	24	.	.	.	3	.	13	.	2	2	1	.
6/11	1	1	.	.	.	.	11	1	1	1	9	.	6	.	.	1	5	.
6/12	.	.	.	.	.	.	7	.	.	5	26	1	2	.	.	3	19	.
6/13	.	.	.	.	.	1	.	1	.	.	2	8	.	.	.	1	3	4
6/14	.	.	.	.	.	.	10	.	.	.	.	2	12	.	.	5	1	1
6/15	.	.	.	.	.	.	4	.	.	1	.	.	2	.	.	.	.	10
6/16	.	.	.	.	.	.	9	.	.	3	2	.	2	.	.	.	.	4
6/17	.	.	.	.	.	.	5	.	.	.	2	2	.	.	.	.	.	1
6/18	.	.	.	.	.	.	28	.	.	.	.	.	2	.	.	.	.	.
6/19	2	.	.	.	.	.	4	.	.	.	.	1	2	.	.	.	3	.
6/20	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2	.	1	.
6/21	.	1	.	.	.	.	1	1	.	.	5	.	1	1	.	.	.	.
6/22	.	.	.	.	.	.	6	.	.	.	3	.	1	.	1	.	.	.
6/23	.	.	.	.	.	.	16	.	.	.	1	.	5	.	2	.	3	.
6/24	.	.	.	.	.	.	4	.	.	.	.	.	1	.	.	.	4	.
6/25	1	.	.	.	.	.	1	.	.	.	.	.	3	.	.	.	.	.
6/26	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
6/27	.	.	.	.	.	.	2	.	.	.	4	1	.	.	.	.	1	1
6/28	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	1	.
6/29	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.
6/30	.	.	.	.	.	1	.	.	.	1	1	10	.	.	.	.	.	1
June Summary	6	2	0	4	1	2	149	5	2	16	75	40	72	2	13	17	57	53
7/01				.						1		.	1					
7/02				.						.		3	.					
7/03				.						.			1					
7/04				.						2								
7/05				.														
7/06				1														
July Summary	0	0	0	1	0	0	0	0	0	3	0	3	2	0	0	0	0	0
Total Passage	12	5	6	15	2	14	174	9	61	125	138	228	98	7	84	108	125	533

Table 10. (Cont'd)

Chain Dam Fishway																		
Date	1300-1500						1600-1900						2000-0000					
	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
4/08																		
4/09																		1
4/10						2						10						1
4/11						2						.						.
4/12						.						.						1
4/13						.			3			.						.
4/14						.			.			.						.
4/15						.			.			.						.
4/16						.			.			.			1			.
4/17						.			.			.			.			.
4/18						.			.			.			.			.
4/19						.			.			.			.			.
4/20						.			1			.			.			.
4/21						.			.			.			.			.
4/22						.			.			.			.			.
4/23						.			1			.			.			.
4/24						3			.			.			.			.
4/25						1			.			2			.			.
4/26		1				1		1	.			.			.			.
4/27		.				1		.	1			2			.			.
4/28		.				4		.	.			3			.			.
4/29		.				2		1	1			1			.			.
4/30		.				3		2	1			5			.			.
April Summary		1				19		4	9			23			1			5

Table 10. (Cont'd)

Date	1300-1500						Chain Dam Fishway						2000-0000					
	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
5/01		.	.	1		16		.	2		.	22			.			.
5/02		.	2	1		64		.	8	3	.	58			1			2
5/03		.	1	2		76		.	7	2	.	22			.			.
5/04		.	2	.		57		.	6	.	.	26			1		1	2
5/05		.	1	.	1	18		.	6	.	.	4			.		.	1
5/06		.	.	.	2	12		.	10	.	3	8			3		.	.
5/07		.	8	1	.	.		.	14	.	1	8			1		.	.
5/08		.	1	.	.	1		.	.	.	5	3			.		.	.
5/09		.	5	.	.	2		.	2	.	.	2			.		.	.
5/10		1	2	7	.	6		.	1	12	1	4			.		.	5
5/11		.	.	2	4	39	1	.	2	.	4	11			.		1	2
5/12		2	.	13	7	2	1	1	.	10	1	2			.	1	.	2
5/13		.	.	2	.	8	.	.	1	4	6	9			.	.	.	2
5/14		.	.	19	10	7	.	1	.	11	4	3			.	.	.	.
5/15		.	1	12	11	3	.	.	.	8	11	2			.	1	2	.
5/16		.	16	2	26	20	.	.	49	.	14	24			5	.	.	2
5/17		.	35	2	15	5	.	.	45	.	3	9			5	.	.	3
5/18	1	.	28	.	48	.	1	.	29	.	26	.			2	.	.	.
5/19	1	3	18	4	14	2	2	1	9	1	4	1	1	1	1	.	.	.
5/20	5	9	.	19	.	29	11	2	1	1	.	19	4	.	.	.	.	1
5/21	4	.	40	11	.	.	7	3	14	10	2	.	14	.	3	.	.	.
5/22	6	1	18	4	.	1	13	.	17	4	2	3	1	2	3	.	.	.
5/23	2	.	1	8	.	.	2	.	7	2	.	5	.	.	.	.	.	.
5/24	.	.	13	.	.	1	.	.	15	2	.	3	.	.	5	.	.	.
5/25	2	.	.	4	1	109	2	1	.	2	.	53	.	.	.	.	.	1
5/26	.	6	1	2	.	19	3	2	.	1	2	32	.	.	.	.	.	6
5/27	1	1	1	.	3	20	.	.	.	2	2	36	.	.	.	.	.	1
5/28	.	9	.	1	2	43	2	.	.	.	2	35	.	4	.	.	.	4
5/29	.	2	.	7	.	29	.	18	.	3	.	46	.	.	.	.	.	9
5/30	.	.	1	.	4	25	.	.	2	.	.	20	.	.	.	.	.	1
5/31	3	.	.	.	3	5	3	.	.	.	3	2	.	.	.	.	.	.
May Summary	25	34	195	124	151	619	48	29	247	78	96	472	20	7	30	2	4	44

Table 10. (Cont'd)

Date	Chain Dam Fishway																	
	1300-1500						1600-1900						2000-0000					
	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001	1996	1997	1998	1999	2000	2001
6/01	.	.	2	.	2	3	.	.	1	.	.	2	.	1	.	.	.	.
6/02	.	.	.	1	2	15	3	.	1	4	3	10	.	1	.	.	1	.
6/03	1	.	4	.	.	8	2	.	2	.	.	7	.	.	.	1	.	.
6/04	.	1	.	1	.	3	1	3	1	.	.	2	.	.	.	.	.	.
6/05	.	1	1	.	.	9	2	1	.	.	.	4	.	1	.	.	.	.
6/06	1	.	.	.	.	.	3	4	.	.	2	1	.	.	.	.	.	.
6/07	2	.	.	.	.	2	.	.	2	.	.	.	.	.	.	.	.	.
6/08	1	.	.	.	2	.	1	.	.	.	2	.	.	.	.	.	1	.
6/09	.	.	.	.	9	.	.	.	.	.	2	.	.	.	.	.	3	.
6/10	17	.	4	1	9	.	8	.	.	.	7	.	4	.	.	.	1	.
6/11	15	5	1	.	1	.	2	1	.	.	1	1	.	.	.	.	.	.
6/12	.	1	1	1	33	.	.	.	1	.	11	.	.	.	.	.	1	.
6/13	3	2	.	1	1	2	5	2	.	.	.	5	2	.	.	.	.	1
6/14	4	.	.	1	.	.	7	.	.	.	.	.	1	.	.	.	.	.
6/15	6	1	.	.	.	.	3	.	.	1	.	5	.	.	.	.	.	.
6/16	.	.	3	.	3	1	1	.	1	.	4	2	.	.	.	.	.	1
6/17	.	.	2	.	.	.	.	1	10	.	.	1	.	.	.	.	.	1
6/18	2	.	.	.	.	.	6	.	.	.	.	.	2	.	1	.	.	.
6/19	.	.	.	1	.	.	.	.	.	.	2	.	.	.	.	.	.	.
6/20	2	1	2	.	2	.	.	1	.	.	1	.	.	.	.	.	.	.
6/21	2	.	1	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
6/22	2	.	3	.	.	.	1	.	3	.	2	.	.	.	2	.	.	.
6/23	1	.	.	.	7	.	4	.	.	.	.	.	.	.	1	.	.	.
6/24	.	.	1	.	1	1	.	.	.	.	.	.	.	.	1	.	.	.
6/25	.	.	.	.	.	1	.	.	1	.	2	.	.	.	1	.	.	.
6/26	.	.	1	.	1	.	.	.	.	.	.	1	.	.	1	.	.	.
6/27	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
6/28	.	.	.	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.
6/29	.	.	.	.	.	.	.	.	1	.	2	.	.	.	1	.	.	.
6/30	.	.	.	.	.	3	2	.	.	1	.	7	.	.	.	.	.	1
June Summary	59	12	26	7	78	48	51	13	24	6	42	48	9	3	9	1	7	4
7/01				.						.	2							
7/02		2		.					1	.								
7/03				.						.								
7/04				.					1	.								
7/05				7						6								
7/06																		
July Summary	0	2	0	7	0	0	0	0	2	6	2	0	0	0	0	0	0	0
Total Passage	84	49	221	138	229	686	99	46	282	90	140	543	29	10	40	3	11	53

Table 11. Otolith analysis for origin and age determination (hatchery vs. wild) from adult American shad collected in the Lehigh River in 2001 (N=109; 40 females:65 males), 2000 (N=100; 35 females: 65 males), and 1999 (N=103; 38 females:65 males). Hatchery origin is determined by the presence of florescent rings from the PFBC's OTC (tetracycline) treatment of stocked fry.

Otolith Age	Hatchery Origin					
	1999		2000		2001	
	Female	Male	Female	Male	Female	Male
Unknown	0	3	0	0	0	0
3	0	2	0	1	0	0
4	6	44	1	4	1	15
5	16	6	23	50	5	23
6	13	4	9	1	31	19
7	1	0	1	0	2	0
8	0	0	0	1	0	0
Total	36	59	34	57	39	57
Wild Origin						
3	0	1	0	0	0	0
4	0	5	0	3	0	2
5	1	0	0	4	1	6
6	1	0	1	1	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
Total	2	6	1	8	1	8
Grand Total	38	65	35	65	40	65

Table 12. Average total length by sex and otolith age for 109 adult American shad (40 females and 69 males) caught in the Lehigh River on May 24 (100 Chain Dam Tailrace) and June 20-21, 2001 (9 Northampton/Cementon Dam Tailrace).

Female					
Total Length (mm)					
Otolith Age	Mean	Std. Dev.	Min.	Max.	N
4	513	...	513	513	1
5	499.2	16.6	474	522	6
6	551.4	21.4	509	592	31
7	558.0	4.2	555	561	2
Male					
3	...	...	...	...	...
4	455.8	28.8	423	508	18
5	479.3	24.2	422	520	32
6	506.8	24.3	432	542	19
7	...	...	...	...	...

Table 13. Average total length by sex and scale age for 109 adult American shad (40 females and 69 males) caught in the Lehigh River on May 24 (N=100 Chain Dam Tailrace) and June 20-21, 2001 (N=9, Northampton/Cementon Dam Tailrace). Not included in the total was data from shad due to scale regeneration (1 female and 2 males) and unreadable scales (2 females).

Female					
Total Length (mm)					
Scale Age	Mean	Std. Dev.	Min.	Max.	N
4	494.6	13.8	474	512	5
5	539.7	19.7	509	575	20
6	565.5	15.3	552	589	8
7	572.0	15.9	555	555	4
Male					
3	442.0	30.7	422	510	7
4	477.7	28.4	423	539	39
5	459.3	24.8	432	542	18
6	517.7	14.6	506	534	3

Table 14. Scale analysis for age and repeat spawning from 104 of the 109 (40 females; 69 males) adult American shad collected in the Lehigh River's Chain Dam tailrace on May 24 (N=100) and June 20-21, 2001 (N=9).

Virgin shad		
Scale Age	Female	Male
Unageable	3	1
3	...	7
4	5	37
5	20	16
6	8	3
7	4	...
Total	40	64
Repeat Spawning		
	Female	Male
	1 Mark	1 Mark
Unageable	...	1
3	...	...
4	...	2
5	...	2
6	...	...
7	...	...
Total	0	5

Table 15. Comparison of scale and otolith ages for 95 (36 females, 59 males) of the 109 adult American shad caught in the Lehigh River's Chain Dam tailrace on May 24 (N=100) and Northampton/Cementon Dam tailrace and first down river pool on June 20-21, 2001 (N=9).

Female Otolith Age Difference					Male Otolith Age Difference			
Scale Age	-1	=	+1	+2	-1	=	+1	+2
3	...	...	...	...	...	...	5	1
4	...	...	4	...	...	11	20	4
5	1	1	18	...	...	4	11	...
6	...	8	...	...	...	3	...	...
7	3	1	...	...	...	...	...	...
Total	4	10	22	...	...	18	36	5
% Total	11.1	27.8	61.1	...	...	30.5	61.0	8.5
Percentage					Percentage			
3	...	...	...	...	...	...	83.3	16.7
4	...	...	4.0	...	...	31.4	57.1	11.4
5	10.0	10.0	90.0	...	...	26.7	73.3	...
6	...	100.0	...	...	...	100	...	...
7	75.0	100.0	25.0	...	...	...	...	...

Table 16. Comparison of known otolith ages with scale ages from 87 (32 females, and 55 males) of the 109 American shad caught in the Lehigh River's Chain Dam tailrace on May 24 (N=100) and in the Northampton/Cementon Dam tailrace and first down river pool on June 20-21, 2001 (N=9).

Female Scale Age Difference					Male Scale Age Difference			
Otolith Age	-1	=	+1	+2	-1	=	+1	+2
3	...	...	...	...	...	...	5	1
4	...	...	4	...	...	10	18	4
5	1	1	18	...	...	3	11	...
6	...	8	...	...	...	3	...	...
Total	1	9	22	...	...	16	34	5
% Total	3.1	28.1	68.8	...	...	29.1	61.8	9.1

Table 17. Attraction flow head differences (cm) from the Easton and Chain Dam fishways after modifications during the 2001 American shad run. American shad minimum and maximum attraction flow head differences are 15.2 (6 inches) and 25.4 cm (10 inches).

Date	Easton Dam Fishway	Chain Dam Fishway
3/29	26.7	...
3/30	12.7	...
...	...	...
4/02	3.81	...
...	...	...
4/06	12.7	30.5
4/07	...	...
4/08	...	...
4/09	5.1	22.9
4/10	...	...
4/11	...	22.9
4/12	...	...
4/13	...	...
4/14	...	...
4/15	...	...
4/16	15.2	22.9
4/17	...	...
4/18	15.2	22.9
4/19	...	...
4/20	...	22.9
4/21	...	...
4/22	...	...
4/23	40.6	22.9
4/24	...	...
4/25	45.7	30.5
4/26	...	...
4/27	17.8	30.5
4/28	...	...
4/29	...	...
4/30	22.9	30.5
5/01	...	...
5/02	22.9	22.9
5/03	...	...
5/04	25.4	...
5/05	...	...
5/06	...	...
5/07	...	...
5/08	...	...
5/09	27.9	22.9
5/10	...	...
5/11	15.2	22.9
5/12	...	...
5/13	...	...
5/14	12.7	20.5

Table 17. (Cont'd)

Date	Easton Dam Fishway	Chain Dam Fishway
5/15	...	...
5/16	...	...
5/17	...	...
5/18	...	22.9
5/19	...	...
5/20	...	...
5/21	...	...
5/22	...	...
5/23	25.4	15.2
5/24	...	...
5/25	22.9	15.2
5/26	...	...
5/27	...	...
5/28	10.2	...
5/29	...	...
5/30	15.2	...
5/31	...	...
6/01	20.3	22.9
6/02	...	...
6/03	...	...
6/04	11.4	22.9
6/05	...	...
6/06	12.7	22.9
6/07	...	...
6/08	...	15.2
6/09	...	...
6/10	...	...
6/11	...	15.2
6/12	...	...
6/13	...	10.2
6/14	...	...
6/15	30.5	22.9
6/16	...	...
6/17	...	...
6/18	12.7	7.6
6/19	...	...
6/20	20.3	7.6
6/21	...	...
6/22	20.3	7.6
6/23	...	...
6/24	...	...
6/25	...	15.2
6/26	...	...
6/27	...	15.2
6/28	...	...
6/29	25.4	15.2

Table 18. Adult American shad passage by month (April-June) through the Easton (1995-2001) and Chain (1996-2001) Dam Fishways in the following six diurnal periods: 0100-0500; 0600-0900; 1000-1200; 1300-1500; 1600-1900; 2000-0000 hours.

Easton Dam Fishway							
Year	Month	Diurnal Period					
		0100-0500	0600-0900	1000-1200	1300-1500	1600-1900	2000-0000
2001	April	10	75	77	113	224	20
	May	41	626	598	811	1404	181
	June	13	152	127	97	101	19
2001 ^a	April	10	75	77	113	224	20
	May	32	529	464	641	1081	153
	June	13	152	127	97	101	18
2000	April	3	3	2	3	11	1
	May	16	294	212	270	434	51
	June	8	255	165	153	172	38
1999	April	7	29	33	74	97	11
	May	46	256	337	515	753	34
	June	5	28	45	29	2	1
1998	April	3	10	23	43	87	16
	May	31	285	382	641	1322	177
	June	6	32	45	70	97	23
1997	April	.	6	8	28	53	6
	May	8	118	118	194	392	53
	June	5	24	113	156	132	10
1996	April	.	1	1	2	6	.
	May	15	142	87	116	307	67
	June	10	74	93	83	104	31
1995	April	1	6	10	21	25	13
	May	12	70	71	118	212	42
	June	7	68	82	53	45	23
Chain Dam Fishway							
2001	April	1	6	4	19	23	5
	May	11	179	476	619	472	44
	June	2	40	53	48	48	4
2000	April	0	1	0	0	0	0
	May	1	62	68	151	96	4
	June	1	75	57	78	42	7
1999	April	0	0	0	0	0	0
	May	10	106	91	124	78	2
	June	4	16	17	7	6	1
1998	April	1	1	1	0	9	1
	May	5	58	70	195	247	30
	June	0	2	13	26	24	9
1997	April	0	0	0	1	4	0
	May	3	4	5	34	29	7
	June	2	5	2	12	13	3
1996	April	0	0	0	0	0	0
	May	6	25	24	25	48	20
	June	6	149	72	59	51	9

Easton 2001 - less 41 shad from June 11-13 where time of day was not recorded.

Easton 2001^a - less the 41 shad, and 761 shad from May 11-14, 14-16, 16-18, and 28-30 where night monitoring did not occur.

Table 19. Daily tagging (OTC) pattern history of American shad stocked in the Lehigh River from 1993 to 1998 in relation to the 2001 adult assessment and corresponding waters with the same daily tagging pattern. Tagging information provided by the Pennsylvania Fish and Boat Commission's Division of Research.

Age Class	Tagging Year	Tagging Pattern Day(s)	Other Year(s) Used	Age Class	Number Of Fry Stocked	Number Of Fingerling	Water Stocked	River Egg Source
7	1994	3,13,17			642,000	-	Lehigh R.	Delaware
					785,000	99,500	Juniata R.	Delaware
			1993	8	790,000	-	Lehigh R.	Delaware
					2,499,000	44,000	Juniata R.	Delaware
6	1995	5			1,044,000	-	Lehigh R.	Delaware
					8,339,000	-	Juniata R.	Hudson/Delaware
					731,000	-	Susquehanna R.	Hudson/Delaware
					5,05,000	-	James R.	Pamunkey R.
					1,175,000	-	Potomac R.	Potomac R.
			1997	4	236,000	-	Juniata R.	Hudson/Delaware.
					2,801,000	-	Susquehanna R.	Hudson/Delaware
			1994	7	996,000	-	Juniata R.	Hudson
5	1996	3,6,9			993,000	-	Lehigh R.	Delaware
					43,000	-	Standing Ck.	Delaware
			1998	3	565,000	-	Juniata R.	Hudson
			1997	4	486,000	-	Juniata R.	Susquehanna
4	1997	5,9,13			1,247,000	-	Lehigh R.	Delaware
			1994	7	2,004,000	-	Juniata R.	Hudson
3	1998	3,9,12			948,000	-	Lehigh R.	Delaware
					321,000	-	W. Conewgo Ck.	Hudson
			1996	5	561,000		W. Br. Susquehanna R.	Hudson/Delaware

Table 20. Nightly summary of 925 American shad caught from May 6 through June 4, 2001 (20 nights). Netting during this period at Smithfield Beach (RM 218.0) caught a total of 918 shad. A single night netting on May 22 at Eshback Access near Buck Island (RM 231.2) caught an additional 7 shad. American shad were caught by floating gillnets of various constant mesh sizes (4.5, 4.75, 5.0, 5.25, 5.5, and 6.0 inch stretch) in the Delaware River at Smithfield Beach (RM 218.0), and the volume and number of eggs shipped and their viability. Nights worked were from Sunday through Thursday night. River flows were low and stable throughout the netting period. This table was adapted in part from the PFBC's Division of Research. On May 22, 2001 two sites were netted Smithfield Beach (11 nets) and Eshback Access Pool area immediately up river Buck Island (RM 231.1; 5 nets).

Date	River Temp C	Total No of Nets Set/Night	Number of Nets set per Mesh Size (inch stretch)						Duration Set/Net Hours	Total No. of Net Hours	No. of Males Caught	No. of Females Caught	Total AMS	Volume of Eggs (liters)	No. of Eggs (million)	Percent Viability
			4.5	4.75	5.0	5.25	5.5	6.0								
5/06	17.0	16	3	2	5	2	1	1	4.50	72.00	57	100	157	24.1	1,177,149	5.7
5/07	17.0	16	3	2	5	2	1	1	3.50	56.00	18	43	61	11.8	606,116	19.0
5/08	18.0	16	3	2	5	2	1	1	3.50	56.00	16	56	72	13.5	519,140	44.5
5/09	18.0	15	3	2	5	2	1	1	4.25	68.00	16	38	54	13.0	511,736	12.5
5/10	19.1	14	3	2	5	2	1	1	5.25	84.00	17	38	55	9.6	357,510	26.3
5/13	20.0	15	3	2	5	2	1	1	5.25	84.00	21	56	77	13.3	702,170	15.0
5/14	19.0	16	3	2	5	2	1	1	4.75	76.00	16	28	44	4.9	243,896	29.6
5/15	19.0	16	3	2	5	2	1	1	4.25	68.00	6	29	35	9.5	518,738	34.7
5/16	19.0	16	3	2	5	2	1	1	4.25	68.00	3	39	42	3.9	230,915	7.5
5/17	17.0	16	3	2	5	2	1	1	4.92	78.72	6	15	21	4.6	184,784	0.2
5/20	18.5	16	3	2	5	2	1	1	4.42	70.72	1	36	37	R	.	.
5/22 ^S	17.0	11	2	1	3	1	1	1	3.92	43.12	4	12	16	R	.	.
5/22 ^E	17.0	5	1	1	2	1	0	0	2.00	10.00	5	2	7	R	.	.
5/23	16.5	16	3	2	5	2	1	1	4.00	64.00	4	9	13	R	.	.
5/24	18.0	16	3	2	5	2	1	1	4.50	72.00	11	26	37	6.3	221,275	0
5/28	16.0	16	3	2	5	2	1	1	3.75	60.00	4	12	16	1.1	41,993	30.7
5/29	16.0	15	3	2	5	2	1	1	4.50	72.00	14	54	68	8.6	389,055	13.1
5/30	16.0	16	3	2	5	2	1	1	4.50	72.00	13	40	53	11.0	407,120	38.2
5/31	16.0	16	3	2	5	2	1	1	4.00	64.00	4	26	30	4.2	139,862	58.3
6/03	17.0	16	3	2	5	2	1	1	3.75	60.00	2	17	19	2.7	96,850	55.3
6/04	16.0	16	3	2	5	2	1	1	4.00	64.00	0	11	11	NS	.	.
Total ^S			59	39	98	39	20	20	85.76	1352.56	233	685	918	142.1	6,348,308	20.5
Mean ^S									4.29	67.6						
Total ^E			1	1	2	1	0	0	2.00	10.00	5	2	7	.	.	.
Total			60	40	100	40	20	20	87.76	1362.56	238	687	925	142.1	6,348,308	20.5
Mean									4.18	64.88						

R – shipment of fertilized eggs was < 5 liters water hardened, eggs released to Delaware River at Smithfield Beach spawning site.

NS – No shipment, no males were caught.

Table 21. Summary of 3 non-targeted species caught during the American shad spawn-taking from May 7 to May 11, May 14, May 17 and 18, May 30 and 31, and June 1 and 4, 2000 in the Delaware River at Smithfield Beach (RM 218.0). All by catch species were released alive. GZS=Gizzard shad; WE=Walleye, and WC=White.

Date	GZS	STB	WE	CC	WSKR	CARP
5/06	1	.	.	1	1	.
5/07	3	.	.	1	1	.
5/08	2	.	.	2	.	.
5/09	5	.	.	1	.	.
5/10	11	.	.	1	.	.
5/13	3	1	.	.	.	.
5/14	.	.	.	.	.	.
5/15	6	2	.	.	1	.
5/16	6	.	1	.	1	.
5/17	4	1	.	3	.	.
5/20	13	.	.	.	2	1
5/22 ^S	2	.	.	3	1	.
5/22 ^E	.	.	.	.	.	1
5/23	.	.	.	.	.	.
5/24	.	.	.	1	.	.
5/28	1	.	.	.	.	.
5/29	.	.	.	.	.	.
5/30	.	.	.	.	.	.
5/31	.	.	.	.	.	.
6/01	.	.	.	.	.	.
6/04	.	.	.	.	.	.
Total^S	57	4	1	13	7	1
Total^E	.	.	.	.	.	1

^S=Smithfield Beach, main spawning site

^E=Eshback Access pool down river end, trail site.

Table 22. Average total and fork length (mm), and weight (g) by sex by constant gillnet mesh size (stretch inches) for 687 female adult American shad caught in the Delaware River at Smithfield Beach (RM 218.0 from May through June 4, 2001 in 20 nights of netting, and Eshback (RM 231.2, N=2, May 22, 2001).

May 6 – 10, 2001													
Mesh Size (inches)	N	Total Length (mm)				Fork Length (mm)				Weight (g)			
		Mean	Std. Dev.	Min	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
4.5	24	538.4	27.4	496	600	478.3	24.1	431	530	1433.1	342.5	941	2158
4.75	31	534.9	21.1	502	577	476.1	19.6	446	512	1356.9	207.7	1015	1850
5.0	110	543.4	20.0	479	600	484.2	18.8	430	551	1499.3	222.2	854	2099
5.25	41	551.7	18.5	509	600	490.7	18.1	450	534	1632.7	232.6	1159	2028
5.5	54	555.2	22.3	517	602	493.7	19.6	455	540	1652.1	176.4	1247	2066
5.75	12	557.8	21.5	515	584	497.0	18.3	460	520	1749.6	239.9	1134	2005
6.0	3	560.3	31.1	535	595	497.0	27.6	475	528	1811.0	326.6	1563	2181
May 13 – 17, 2001													
4.5	26	537.3	17.8	504	577	476.5	15.8	445	510	1263.3	209.2	933	1949
4.75	14	537.7	19.2	513	581	477.1	17.4	454	520	1357.4	243.5	1096	1921
5.0	67	545.4	23.9	490	606	482.9	22.7	433	540	1438.4	228.6	1027	2355
5.25	29	550.8	21.9	501	592	487.3	20.9	437	525	1548.6	285.9	861	2253
5.5	24	553.2	21.2	520	592	491.0	18.8	460	524	1721.7	179.3	1345	2006
5.75	7	564.7	22.6	533	587	500.3	21.2	471	520	1832.3	290.0	1231	2146
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
May 20, 22 – 24, 2001													
4.5	16	538.9	21.4	492	583	477.5	17.8	440	514	1164.5	259.8	876	1971
4.75	10	540.2	19.5	515	566	478.5	16.2	457	505	1318.0	205.0	1047	1797
5.0	43	553.1	20.6	500	593	490.0	17.4	452	524	1441.8	225.1	1062	1987
5.25	10	557.9	20.6	523	581	493.0	18.3	463	516	1558.3	167.3	1260	1895
5.5	5	551.6	16.1	534	564	487.0	12.6	470	498	1549.8	143.2	1297	1646
5.75	1	585.0	...	585	585	516.0	...	516	516	2149.0	...	2149	2149
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
May 28 – 31, 2001													
4.5	26	530.5	18.4	494	568	470.0	15.9	440	500	1060.9	194.0	797	1464
4.75	23	541.8	21.8	501	576	480.3	19.1	444	510	1187.3	156.4	927	1522
5.0	75	549.5	22.8	465	600	486.6	20.0	410	530	1292.0	238.9	900	2175
5.25	13	551.8	24.1	491	592	489.7	22.0	440	525	1340.2	152.7	1023	1582
5.5	3	564.7	32.9	540	602	499.0	28.8	479	532	1553.0	240.0	1284	1745
5.75	0	...	...	...	...	...	...	...	...	...	...	...	...
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
June 3 – 4, 2001													
4.5	1	509	...	509	509	450	...	450	450	799	...	799	799
4.75	0	...	...	...	...	...	...	...	...	...	...	...	...
5.0	13	548.1	21.8	505	585	486.0	19.6	445	515	1249.2	269.8	926	1813
5.25	3	544.0	33.6	506	570	452.0	44.1	410	498	1246.3	420.4	761	1496
5.5	3	561.0	16.4	543	575	498.3	12.6	485	510	1674.0	138.1	1529	1804
5.75	0	...	...	...	...	...	...	...	...	...	...	...	...
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
Summary													
4.5	93	535.6	21.5	492	600	475.1	18.6	431	530	1228.5	290.5	797	2158
4.75	78	538.1	20.6	501	581	477.8	18.4	444	520	1302.0	210.8	927	1921
5.0	306	546.9	21.9	465	606	485.4	19.9	410	551	1417.0	244.8	854	2355
5.25	96	551.9	20.7	491	600	488.6	21.2	410	534	1547.9	260.9	761	2253
5.5	89	555.0	21.6	517	602	492.9	19.0	455	540	1662.5	178.8	1247	2066
5.75	20	561.6	21.7	515	587	499.1	18.8	460	520	1798.5	261.3	1134	2149
6.0	3	560.3	31.1	535	595	497.0	27.6	475	528	1811.0	326.6	1563	2181

Table 24. Summary of 687 female American shad by gonad state caught by floating gillnets of various mesh sizes in 20 nights of netting from May 6 to May 10, 14-17, 20, 22-24, 28-31, and June 3 and 4, 2001 in the Delaware River at Smithfield Beach (RM 218.0) and Eshback (RM 231.2, May 22 only, N=2). Gonad State categories are Immature, Mature/Gravid, Ripe and Spent.

Date	Immature	Mature/Gravid	Ripe	Spent	Total
5/06	11	28	57	4	100
5/07	2	3	38	.	43
5/08	3	14	38	1	56
5/09	2	3	33	.	38
5/10	1	8	29	.	38
5/13	3	13	40	.	56
5/14	2	7	15	4	28
5/15	.	2	26	1	29
5/16	.	9	25	5	39
5/17	1	4	10	.	15
5/20	.	5	27	3	35
5/22	2	4	6	3	15
5/23	1	2	6	.	9
5/24	1	7	16	2	26
5/28	.	4	6	2	12
5/29	5	5	35	9	54
5/30	4	1	30	5	40
5/31	1	3	25	5	34
6/03	.	1	4	4	9
6/04	.	.	8	3	11
Total	39	123	474	51	687
Percent	5.7	17.9	69.0	7.4	

Table 25. Average ovarian weight by the gonad state of 591 of the 687 female American shad caught by constant mesh gillnets set in the Delaware River at Smithfield Beach (RM 218.0, N=685) from May 6 through June 4, 2001, and Eshback (RM 231.2, N=2, May 22). Ripe female ovarian weights are after artificial striping has occurred.

Gonad State	Number Sampled	Mean Weight	Std. Dev.	Minimum Weight (g)	Maximum Weight (g)
Immature	39	162.1	36.6	94	227
Mature/Gravid	106	282.0	94.5	84	539
Ripe	396	181.3	64.4	42	385
Spent	50	108.9	53.2	6	259

Table 26.

Scale age and repeat spawning by sex for 738 American shad (545 females and 193 males) netted in the Delaware River at Smithfield Beach (RM 218.0, N=731) during the period of May 6-10; 13-17, 20-24, 28-31, and June 3 and 4, 2001 and Eshback (RM 231.2, N=7, May 22, 2001).

May 6 – 10								
Female					Male			
Scale Age	Virgin	Single Repeat Mark	Dual Repeat Marks	Tertiary Repeat Marks	Virgin	Single Repeat Mark	Dual Repeat Marks	Tertiary Repeat Marks
3	.	.	.	.	1	.	.	.
4	14	.	.	.	28	3	.	.
5	84	3	.	.	40	4	.	.
6	40	5	1	.	3	1	1	.
7	6	1	.	.	.	.	1	.
Total	144	9	1	0	72	8	2	0
May 13 – 17								
3	.	.	.	.	.	.	.	.
4	17	2	.	.	26	1	.	.
5	80	.	.	.	19	5	.	.
6	51	2	1	.	.	.	.	.
7	.	.	.	1	.	.	.	.
Total	148	4	1	1	45	6	0	0
May 20 – 24								
3	.	.	.	.	.	.	.	.
4	10	.	.	.	9	.	.	.
5	40	4	.	.	14	1	.	.
6	26	.	1	.	1	.	.	.
7	1	.	.	.	.	.	.	.
Total	77	4	1	0	24	1	0	0
May 28 – 31								
3	.	.	.	.	2	.	.	.
4	14	.	.	.	9	.	.	.
5	75	1	.	.	20	1	.	.
6	40	2	.	.	2	.	.	.
7	2	.	1	.	.	.	.	.
Total	131	3	1	0	33	1	0	0
June 3 – 4								
3	.	.	.	.	.	.	.	.
4	1	.	.	.	1	.	.	.
5	6	.	.	.	.	.	.	.
6	13	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.
Total	20	0	0	0	1	0	0	0
Summary								
3	.	.	.	.	3	.	.	.
4	56	2	.	.	73	4	.	.
5	285	8	.	.	93	11	.	.
6	170	9	3	.	6	1	1	.
7	9	1	1	1	.	.	1	.
Grand Total	520	20	4	1	175	16	2	0
%	95.4	3.7	0.7	0.2	90.7	8.3	1.0	0
Sexes Combined								
Total	695	36	6	1				
%	94.2	4.9	0.8	0.1				

Table 27. Comparison of otolith and scale ages of 716 adult American shad (526 females and 190 males) caught at Smithfield Beach (524 females and 185 males) from May 6-10, 13-17, 20-24, 28-31, and June 3 and 4, 2001, and Eshback (RM 231.2, 2 females and 5 males, May 22, 2001).

Female Scale Age Difference								
Otolith Age	-4	-3	-2	-1	=	+1	+2	Total
3	.	.	.	.	.	.	1	1
4	.	.	.	1	14	46	12	73
5	.	.	.	32	147	73	3	255
6	.	.	10	75	70	9	.	164
7	.	.	11	14	1	.	.	26
8	.	1	6	.	.	.	.	7
Total	0	1	27	122	232	128	16	526
%	.	0.2	5.1	23.2	44.1	24.3	3.1	
Male Scale Age Difference								
3	.	.	.	.	.	2	1	3
4	.	.	.	1	34	29	.	64
5	.	.	.	33	56	5	.	94
6	.	1	5	17	2	.	.	25
7	1	1	1	.	1	.	.	4
Total	1	2	6	51	93	36	1	190
%	0.5	1.1	3.2	26.8	48.9	18.9	0.5	
Combined Scale Age Difference								
Total	1	3	33	173	325	164	17	716
%	0.1	0.4	4.6	24.2	45.4	22.9	2.4	

Table 28. Scale and repeat spawning by sex for 134 (56 female; 78 male) of the 145 American shad collected by day boat electrofishing on the New Jersey (27 female; 43 male) and Pennsylvania (35 female; 40 male) sides in the vicinity of the Raubsville area of the Delaware River (RM 176.6) on April 17, April 20, April 26, May 2 and May 11, 2001.

Female - New Jersey Side																		
Scale Age	April 17			April 20			April 26			May 2			May 11			Total		
	Virgin	One Repeat Mark	Two Repeat Marks	Virgin	One Repeat Mark	Two Repeat Marks	Virgin	One Repeat Mark	Two Repeat Marks	Virgin	One Repeat Mark	Two Repeat Marks	Virgin	One Repeat Mark	Two Repeat Marks	Virgin	Repeat	Percent Repeat
4	2	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3	0	0
5	3	.	.	.	1	.	4	.	.	2	2	.	2	.	.	11	3	21.4
6	.	.	.	2	1	.	.	.	.	1	.	.	1	1	.	4	2	33.3
Total	5	0	0	2	2	0	5	0	0	3	2	0	3	1	0	18	5	21.7
Female - Pennsylvania Side																		
4	.	.	.	2	.	.	1	.	.	1	.	.	2	.	.	6	0	0
5	6	.	.	5	.	.	4	2	.	1	.	.	3	.	.	19	2	9.5
6	1	.	.	2	.	.	1	.	.	1	.	.	1	.	.	6	0	0
Total	7	0	0	9	0	0	6	2	0	3	0	0	6	0	0	31	2	6.1
Female Pennsylvania and New Jersey Sides																		
4	2	.	.	2	.	.	2	.	.	1	.	.	2	.	.	9	0	0
5	9	.	.	5	1	.	8	2	.	3	2	.	5	.	.	30	5	14.3
6	1	.	.	4	1	.	1	.	.	2	.	.	2	1	.	10	2	16.7
Total	12	0	0	11	2	0	11	2	0	6	2	0	9	1	0	49	7	12.5
Male - New Jersey Side																		
3	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	0	0
4	5	1	.	6	.	.	7	.	.	3	.	.	2	.	.	23	1	4.2
5	1	1	.	3	.	.	1	.	.	4	.	.	2	.	.	11	1	8.3
6	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	1	1	50.0
Total	7	2	0	10	0	0	9	0	0	7	1	0	4	0	0	37	3	7.5
Male- Pennsylvania Side																		
3	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	2	0	0
4	2	.	.	2	.	.	2	.	.	4	1	.	7	.	.	17	1	5.6
5	3	.	.	2	1	.	1	2	.	3	2	.	1	.	.	10	5	33.3
6	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	2	1	33.3
Total	8	0	0	4	2	0	4	2	0	7	3	0	8	0	0	31	7	18.4
Male New Jersey and Pennsylvania Sides																		
3	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	4	0	0
4	7	1	.	8	.	.	9	.	.	7	1	.	9	.	.	40	2	4.8
5	4	1	.	5	1	.	2	2	.	7	2	.	3	.	.	21	6	22.2
6	2	.	.	1	1	.	.	.	.	.	1	.	.	.	.	3	2	40.0
Total	15	2	0	14	2	0	13	2	0	14	4	.	12	0	0	68	10	12.8
Combined Sexes and New Jersey and Pennsylvania Sides																		
3	2	.	.	.	.	.	2	.	.	.	.	.	.	.	.	4	0	0
4	9	1	.	10	.	.	11	.	.	8	1	.	11	.	.	49	2	3.9
5	13	1	.	10	2	.	10	4	.	10	4	.	8	.	.	51	11	17.7
6	3	.	.	5	2	.	1	.	.	2	1	.	2	1	.	13	4	23.5
Total	27	2	0	25	4	0	24	4	0	20	6	0	21	1	0	117	17	12.7

Table 29. Comparison of otolith and scale ages from 132 (55 females; 77 males) of the 145 adult American shad (46 females; 78 males) caught in the vicinity of the Raubsville area (RM 176.6) in the Delaware River on April 17, April 20, April 26, May 2 and May 11, 2001.

Female							
Otolith Age	-3	-2	-1	=	+1	+2	Total
4	.	.	.	3	4	.	7
5	.	.	6	19	5	.	30
6	.	1	11	5	.	.	17
7	.	1	.	.	.	.	1
Total	0	2	17	27	9	0	55
%	0	3.6	30.9	49.1	16.4	0	
Male							
3	.	.	.	1	1	.	2
4	.	.	3	26	6	2	37
5	.	.	13	16	3	.	32
6	.	1	4	.	.	.	5
7	1	.	.	.	.	.	1
Total	1	1	20	43	10	2	77
%	1.3	1.3	26.0	55.8	13.0	2.6	
Sexes Combined							
3	.	.	.	1	1	.	2
4	.	.	3	29	10	2	44
5	.	.	19	35	8	.	62
6	.	2	15	5	.	.	22
7	1	1	.	.	.	.	2
Total	1	3	27	70	19	2	132
%	0.8	2.3	20.4	53.0	14.4	1.5	

Table 30. Catch rate statistics for adult American shad, mean catch per night, for the PFBC's Delaware River spawn-take from 1990 through 2001.

Catch Rate Statistics		
Year	Mean Catch per Night	SE
1990	15.9	2.2
1991	9.7	1.7
1992	13.0	1.7
1993	5.0	0.8
1994	4.9	0.8
1995	5.8	0.7
1996	3.7	1.8
1997	3.7	0.5
1998	5.0	0.9
1999	2.6	0.3
2000	2.8	0.6
2001	2.8	0.4

Table 31. Catch frequency by age for female and male shad caught during the egg-taking operations at Smithfield Beach area (RM 218.0) from 1996 through 2001.

Females						
Year	Age					Total
	3	4	5	6	7	
2001	0	58	293	182	12	545
2000	0	42	120	141	13	316
1999	0	39	334	252	13	638
1998	7	179	656	166	14	1022
1997	0	282	315	349	50	996
1996	0	37	473	137	0	647
Males						
2001	4	95	128	10	1	238
2000	0	42	143	36	3	223
1999	0	12	45	19	0	76
1998	3	87	123	22	0	235
1997	33	96	96	48	0	273
1996	0	63	154	10	0	227



Figure 1. Location of the lowhead dams in the Lehigh River: Easton (RM 0.0; solid triangle; fishway w/windows), Chain (RM 3.0; solid circle; fishway w/window), Hamilton Street (RM 17.0; solid square; fishway w/no window), and Northampton/Cementon Dam (RM 24.0; solid diamond; no passage facility).



Figure 1 continued. Location of the lowhead dams in the Lehigh River: East (RM 0.0; solid triangle; fishway w/windows), Chain (RM 3.0; solid circle; fishway w/window), Hamilton Street (RM 17.0; solid square; fishway w/no window), and Northampton/Cementon Dam (RM 24.0; solid diamond; no passage facility).

Repeat Spawning Mark

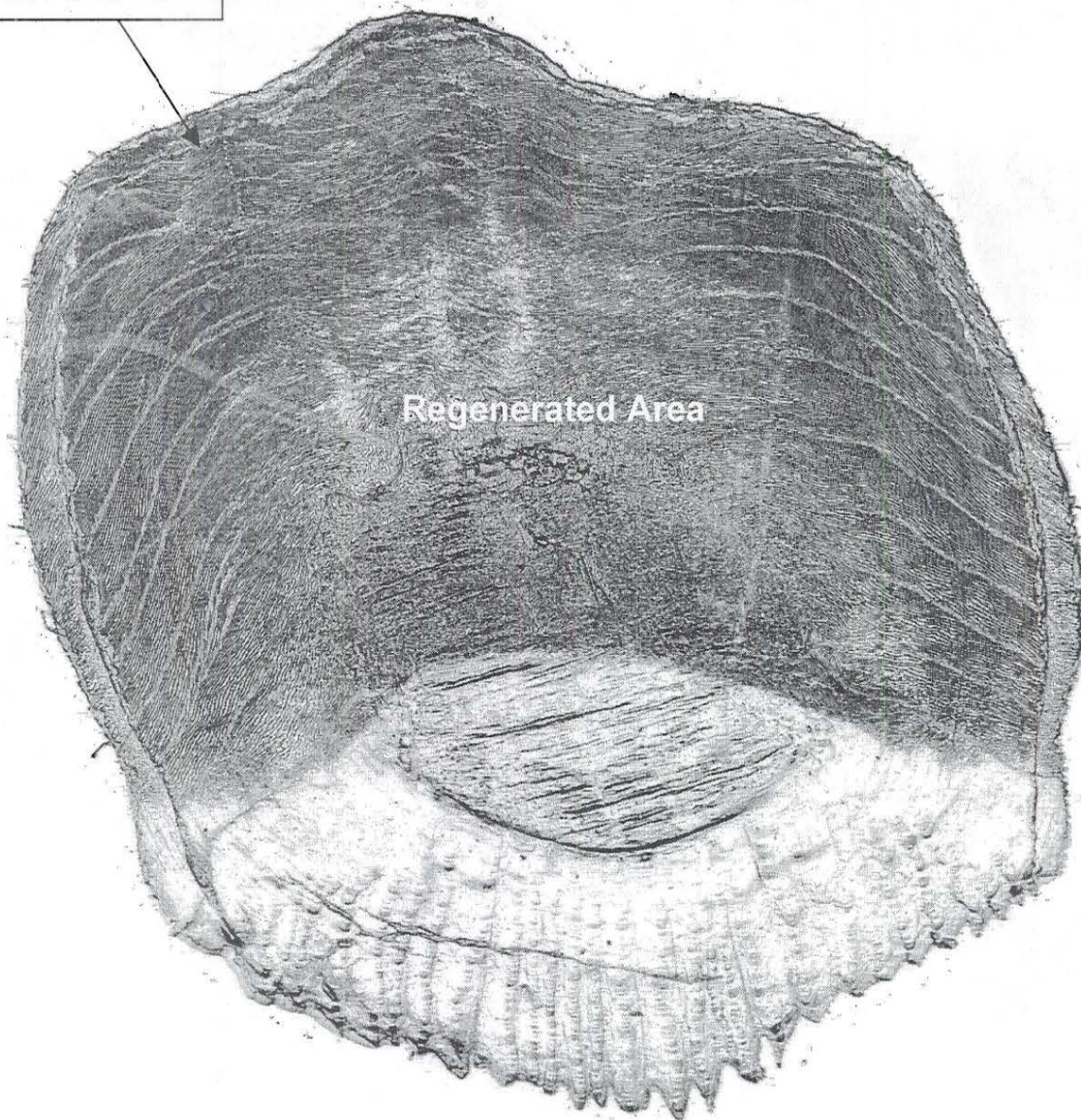


Figure 2. Regenerated scale from a male American shad (TL 470 mm) of unknown age caught on May 24, 2001 in the Chain Dam tailrace of the Lehigh River depicting a repeat spawning mark.



Figure 3. Scale from a 3 year old male American shad (TL 436 mm) caught on April 17, 2001 in the Raubsville area of the Delaware River depicting minimal re-absorption erosion along the edge of the anterior region. FWZ – Freshwater Zone Mark.

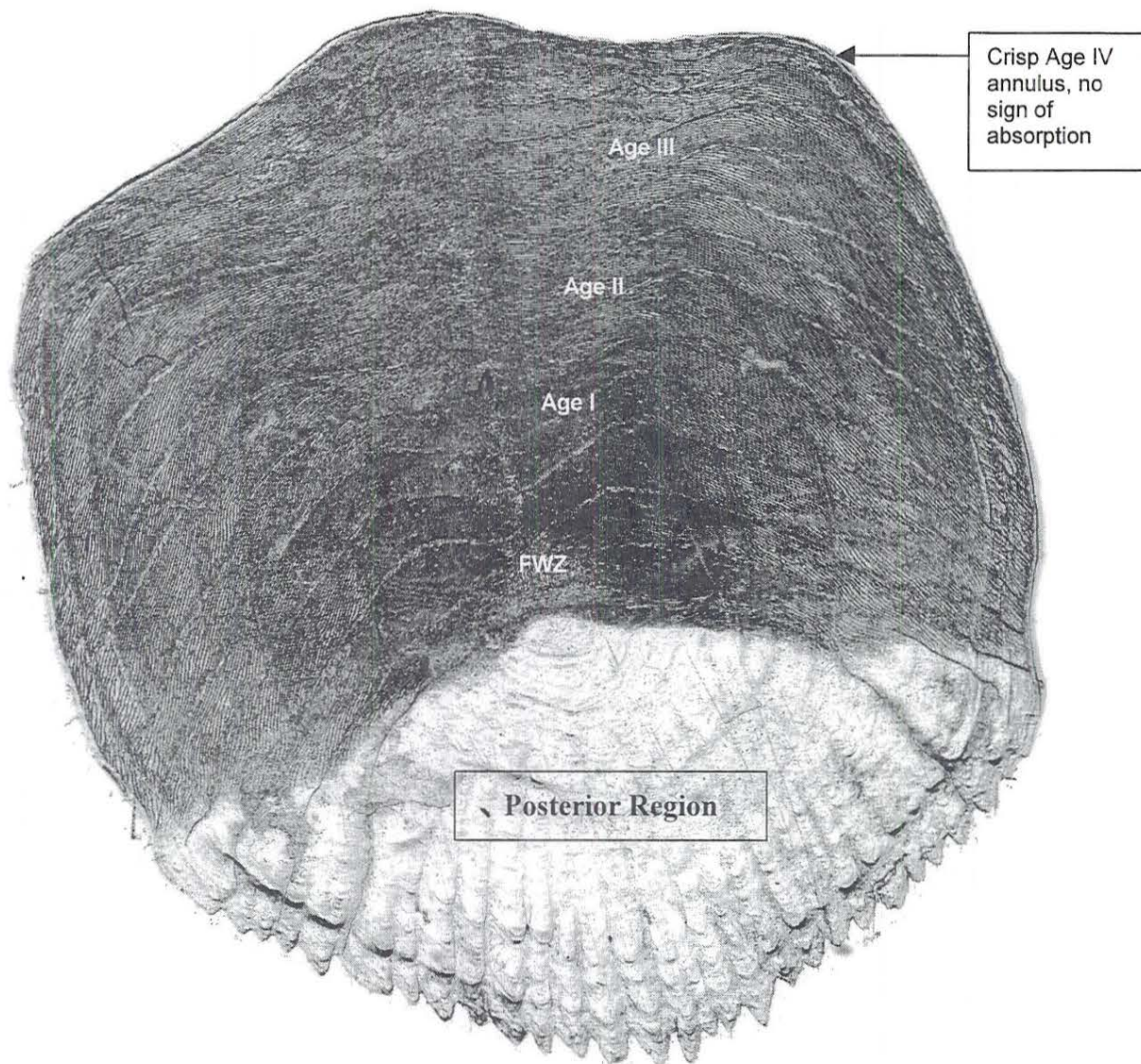


Figure 4. Scale from a 4 year old male American shad (TL 482 mm) caught on April 17, 2001 in the Raubsville, Pennsylvania reach of the Delaware River depicting minimal re-absorption around the perimeter of the scale, i.e. the crisp current annual mark. FWZ – Freshwater Zone mark.

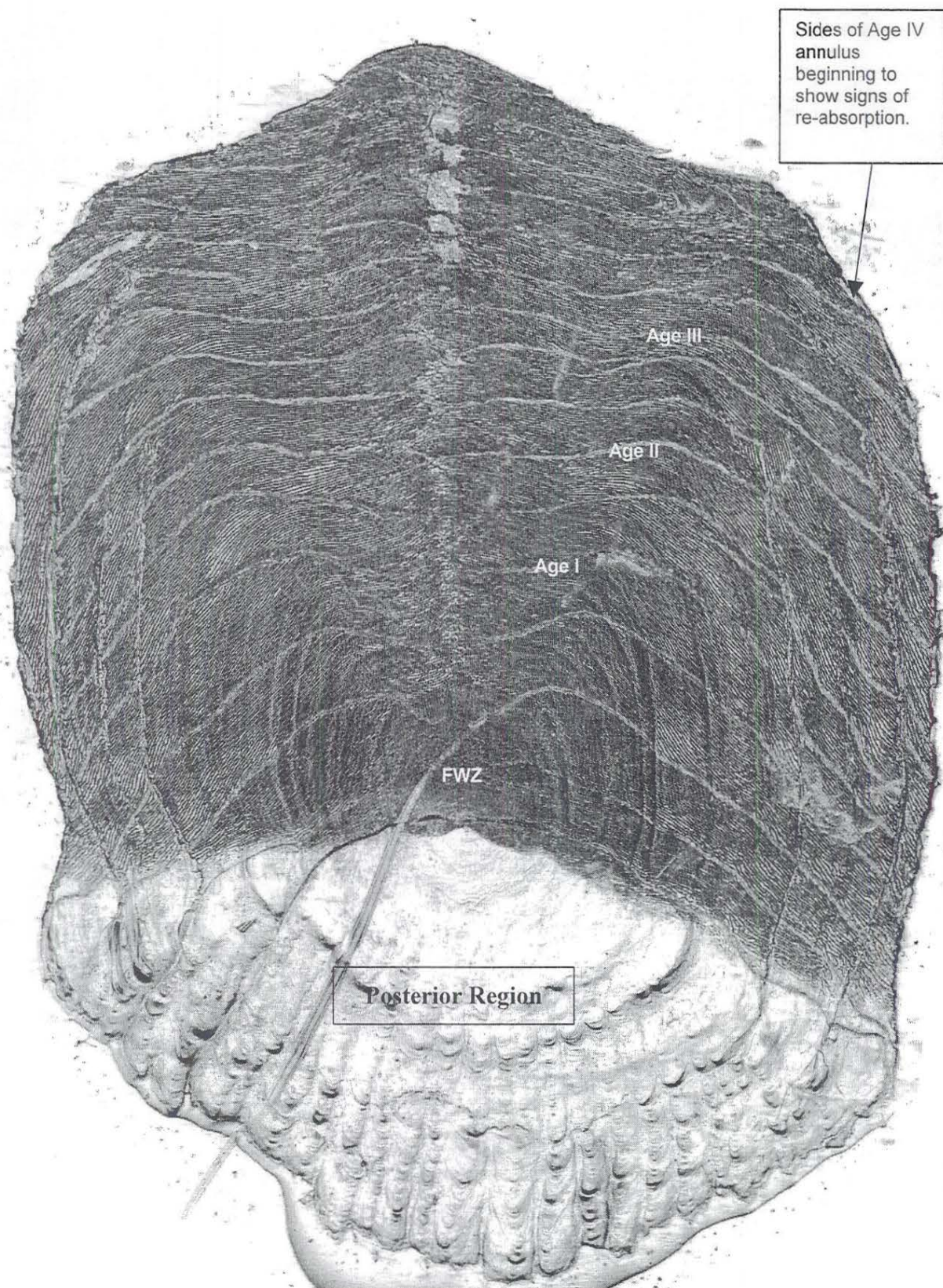


Figure 4a. Scale from a 4 year old male American shad (TL 448 mm) caught on May 11, 2001 in the Raubsville, Pennsylvania reach of the Delaware River depicting a significant re-absorption of sides of the anterior region, the side are beginning to encroach on the third annulus. The sides appear to exhibit greater re-absorption than does the crest of the anterior region. FWZ – Freshwater Zone Mark.

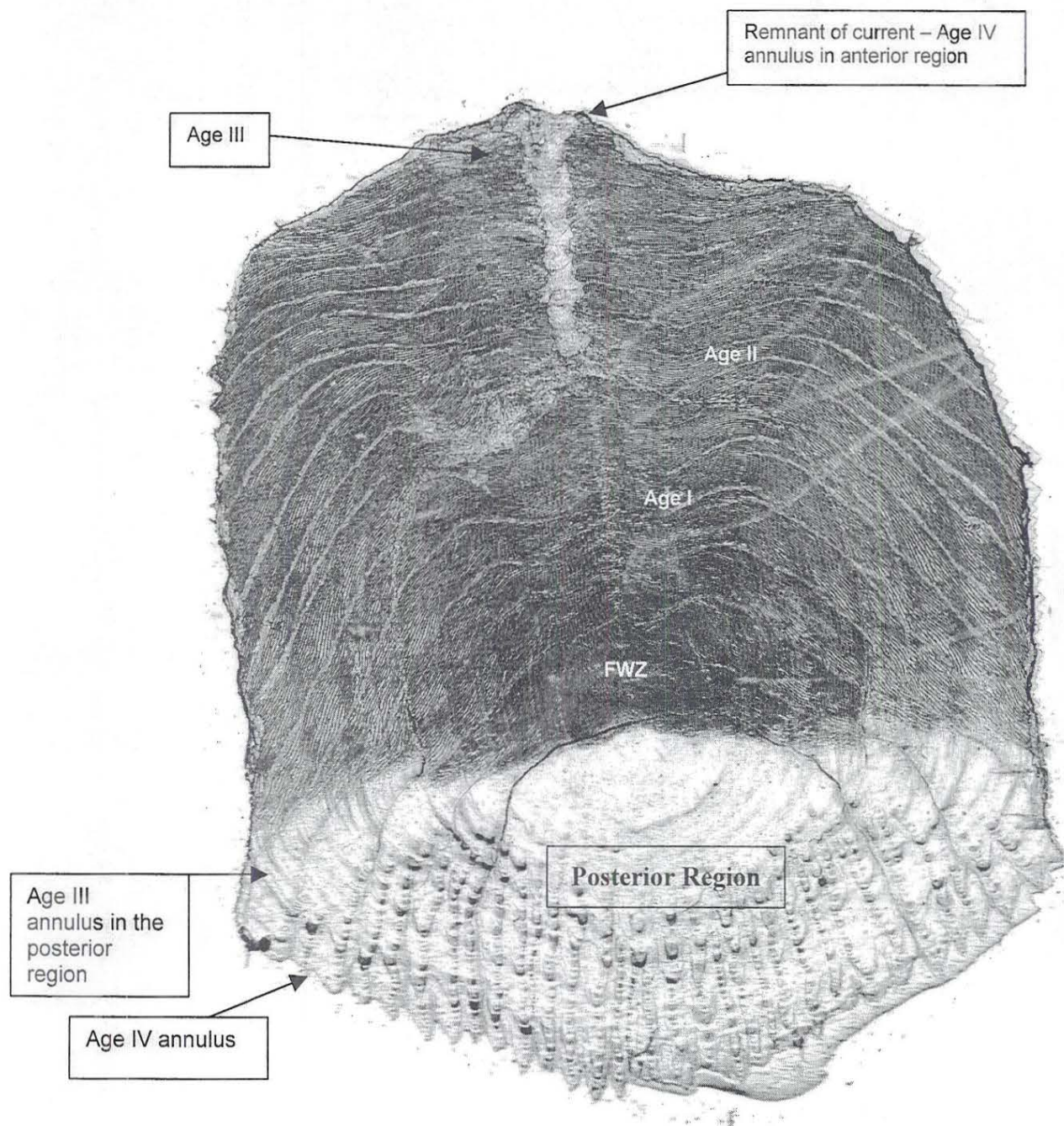


Figure 4b. Scale from a 4 year old male American shad (TL 483 mm) caught on May 24, 2001 in the Chain Dam tailrace of the Lehigh River depicting severe re-absorption back into the third annulus. The sides of the anterior region exhibit a greater amount of re-absorption than through its crest. FWZ – Freshwater Zone mark.

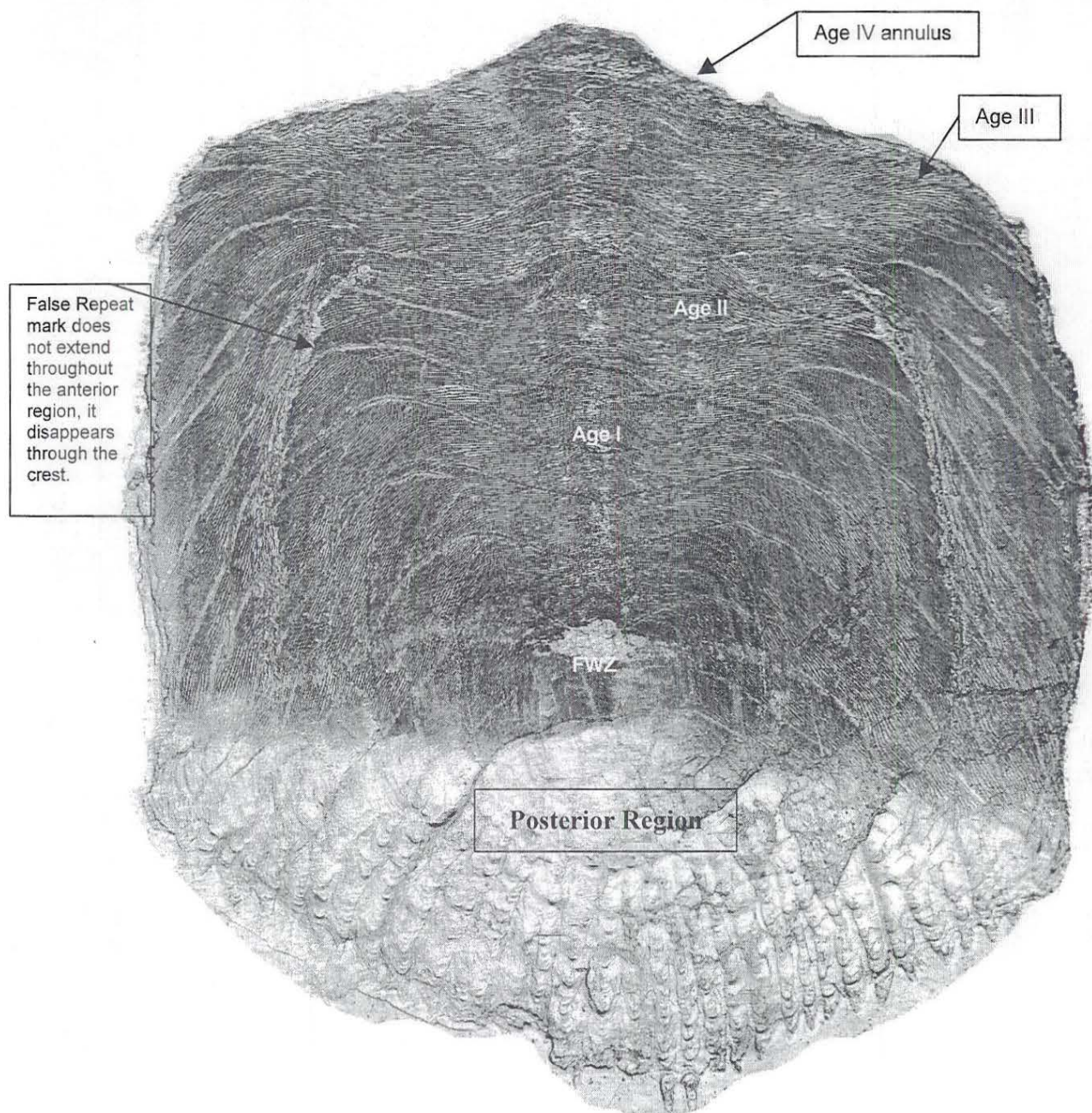


Figure 4c. Scale from a 4 year old male American shad (TL 516 mm) caught on May 24, 2001 in the Chain Dam tailrace of the Lehigh River depicting severe re-absorption back into the third annulus and false repeat spawning mark. FWZ – Freshwater Zone Mark.

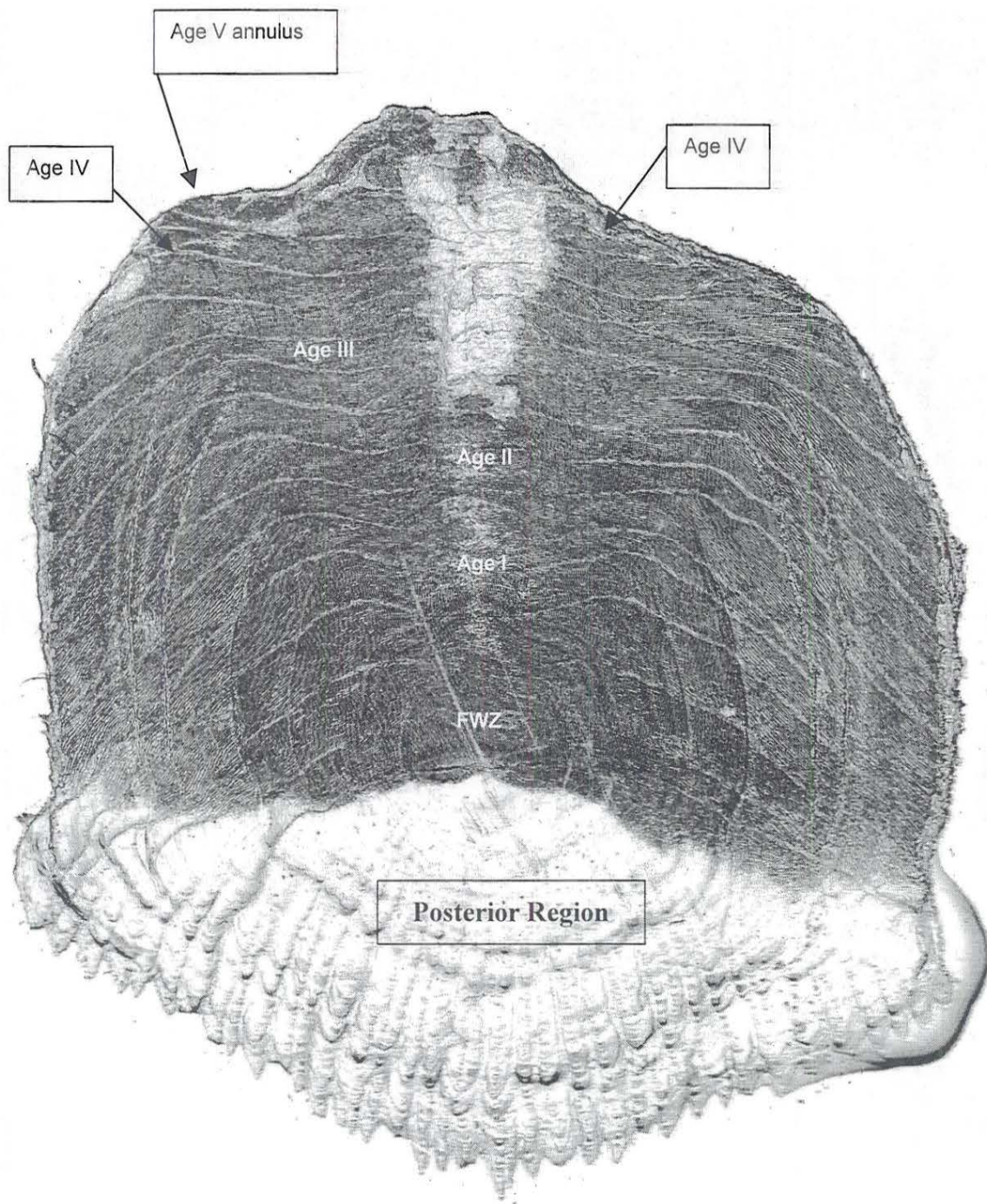


Figure 5. Scale from a 5 year old male American shad (TL 492 mm) caught on May 24, 2001 in the Chain Dam tailrace of the Lehigh River depicting severe re-adsorption back into the fourth annulus. FWZ - Freshwater Zone Mark.

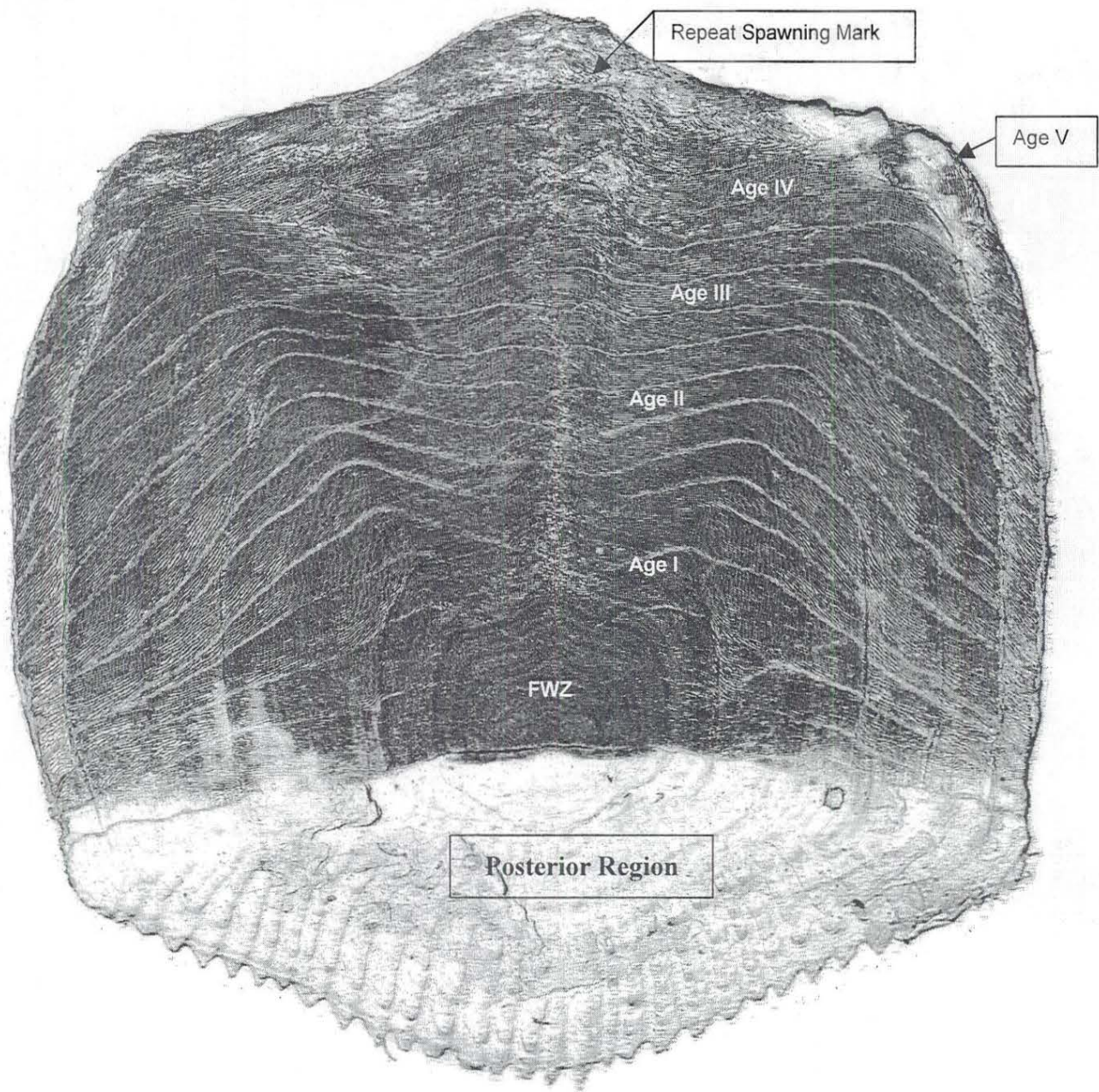


Figure 5a. Scale from a 5 year old male American shad (TL 432 mm) caught on June 21, 2001 in the first down river pool from the Northampton/Cementon Dam (RM 24.0) in the Lehigh River depicting one repeat spawning mark at Age IV to V transition area, current years annulus is almost completely re-absorbed. FWZ – Freshwater Zone mark.

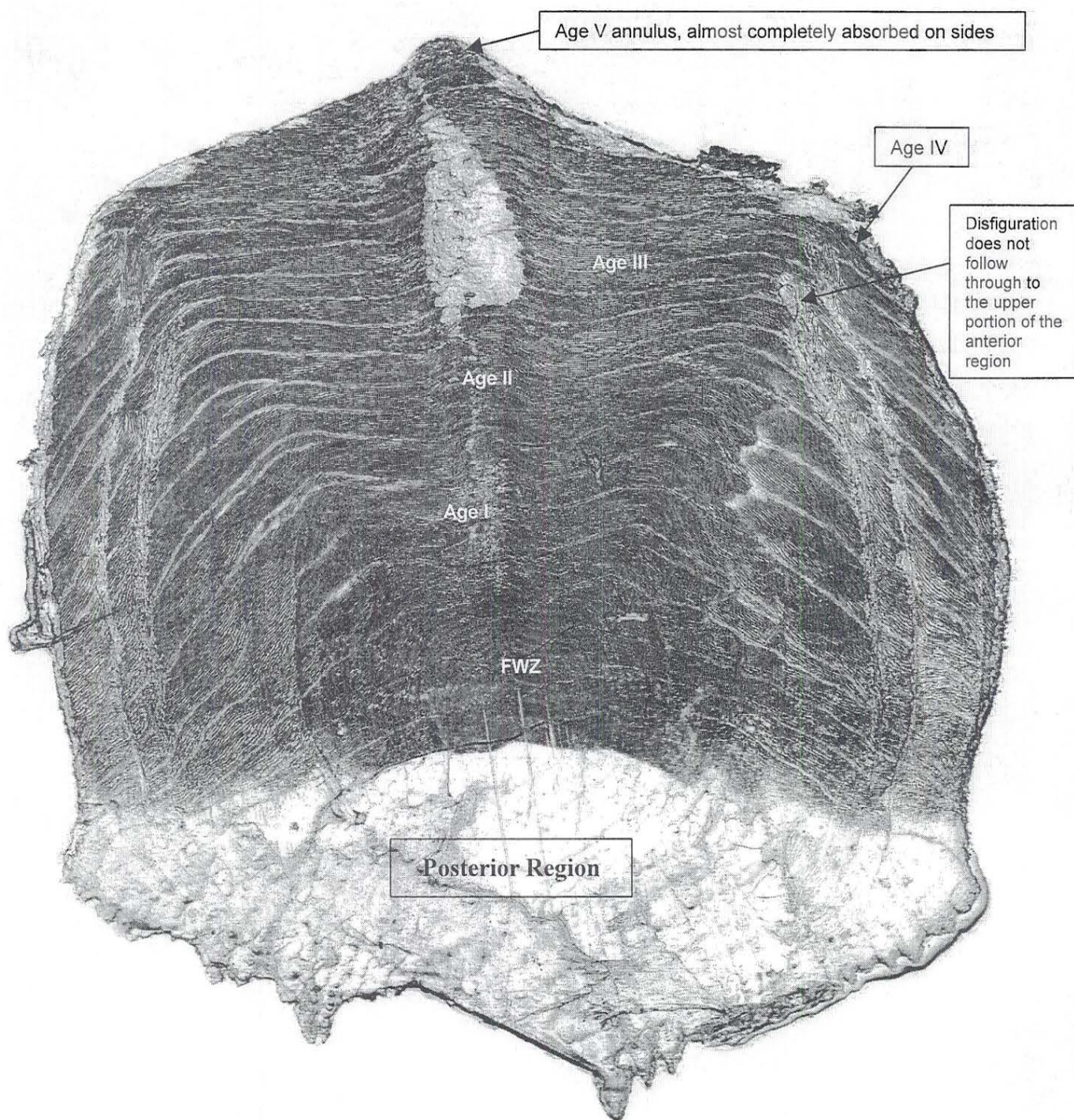


Figure 5b. Scale from a 5 year old female American shad (TL 575 mm) caught on May 24, 2001 in the Chain Dam tailrace of the Lehigh River depicting severe re-absorption of current annulus back, and something happening in the transition region from Age III to IV. FWZ – Freshwater Zone mark.

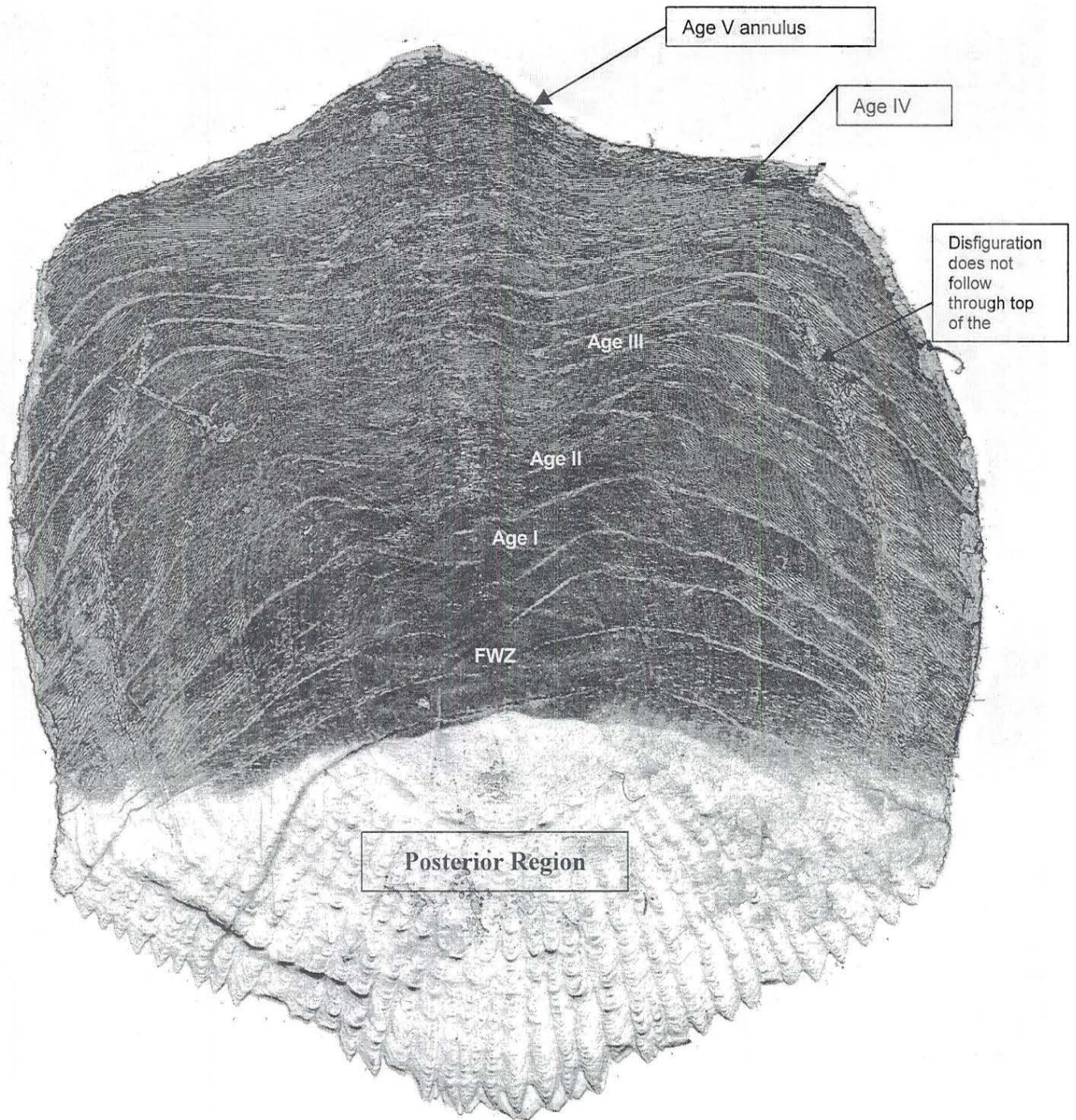


Figure 5c. Scale from a 5 year old male American shad (TL 501 mm) caught on May 24, 2001 in the Chain Dam tailrace of the Lehigh River depicting severe re-absorption of current annulus back, and severe disfiguration in the transition region from Age III to IV along the sides, but not through the crest of the anterior region. FWZ – Freshwater Zone Mark.

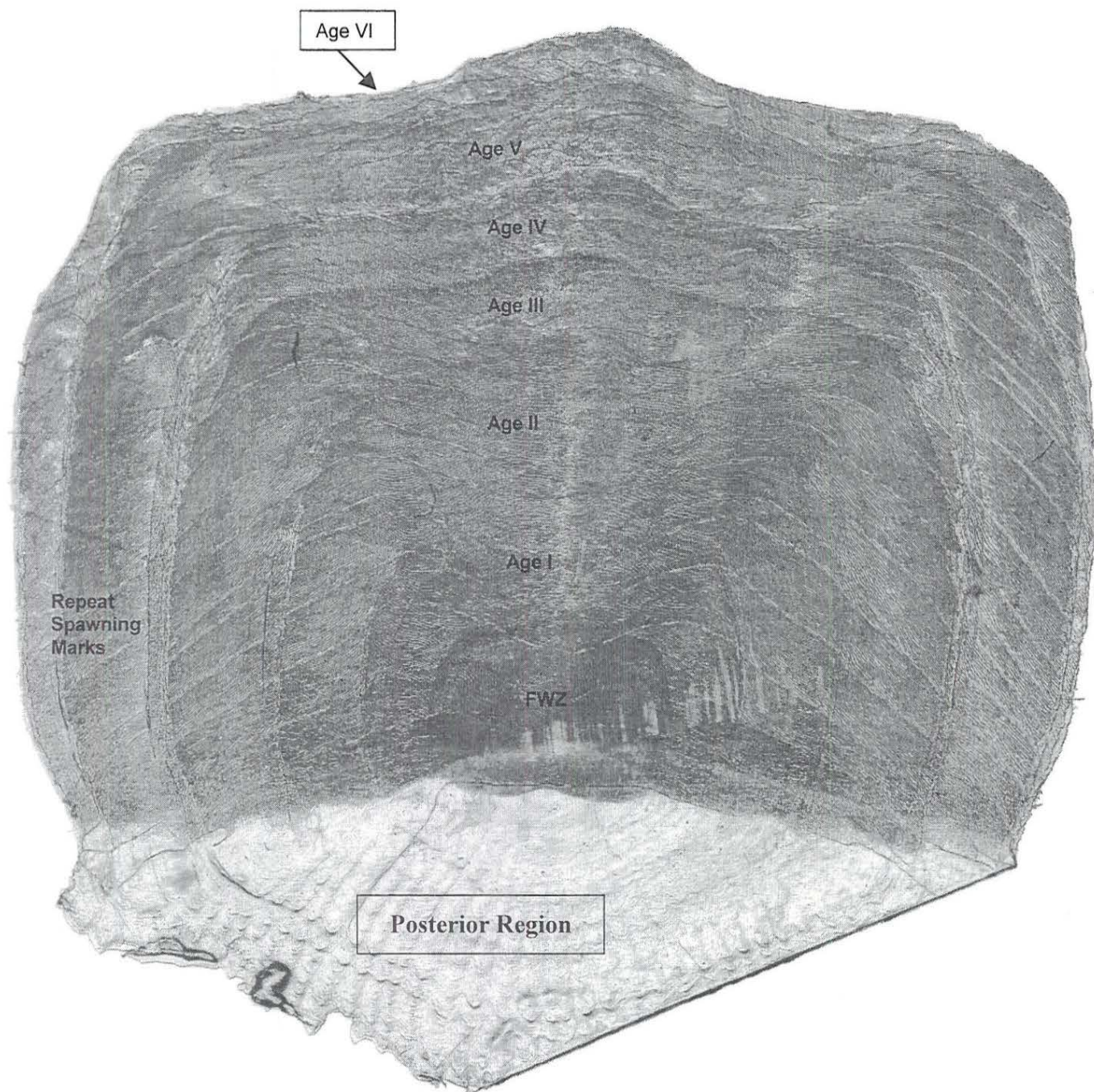


Figure 6. Scale from a 6 year old female American shad (TL 549 mm) caught on May 10, 2001 in the Delaware River at Smithfield Beach depicting 2 repeat marks, one in the transition region of Age III to IV (note severe erosion of Age 4 lateral area), and Age V to VI. This scale depicts a rare event of skipped spawning year (Age V). FWZ – Freshwater Zone Mark.

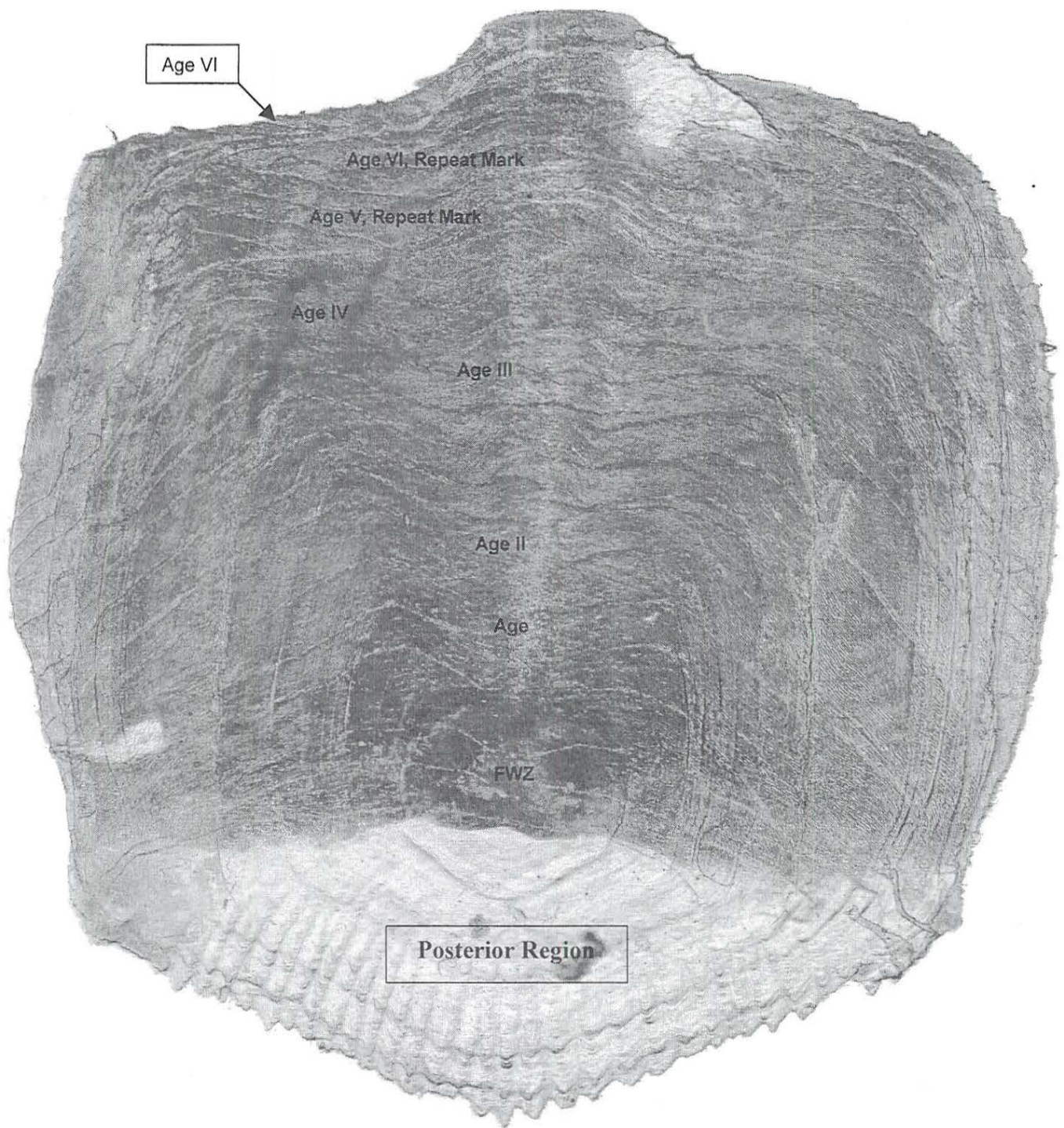


Figure 7. Scale from a 7 year old male American shad (TL 530 mm) caught on May 7, 2001 in the Delaware River at Smithfield Beach depicting 2 repeat marks. FWZ – Freshwater Zone Mark.

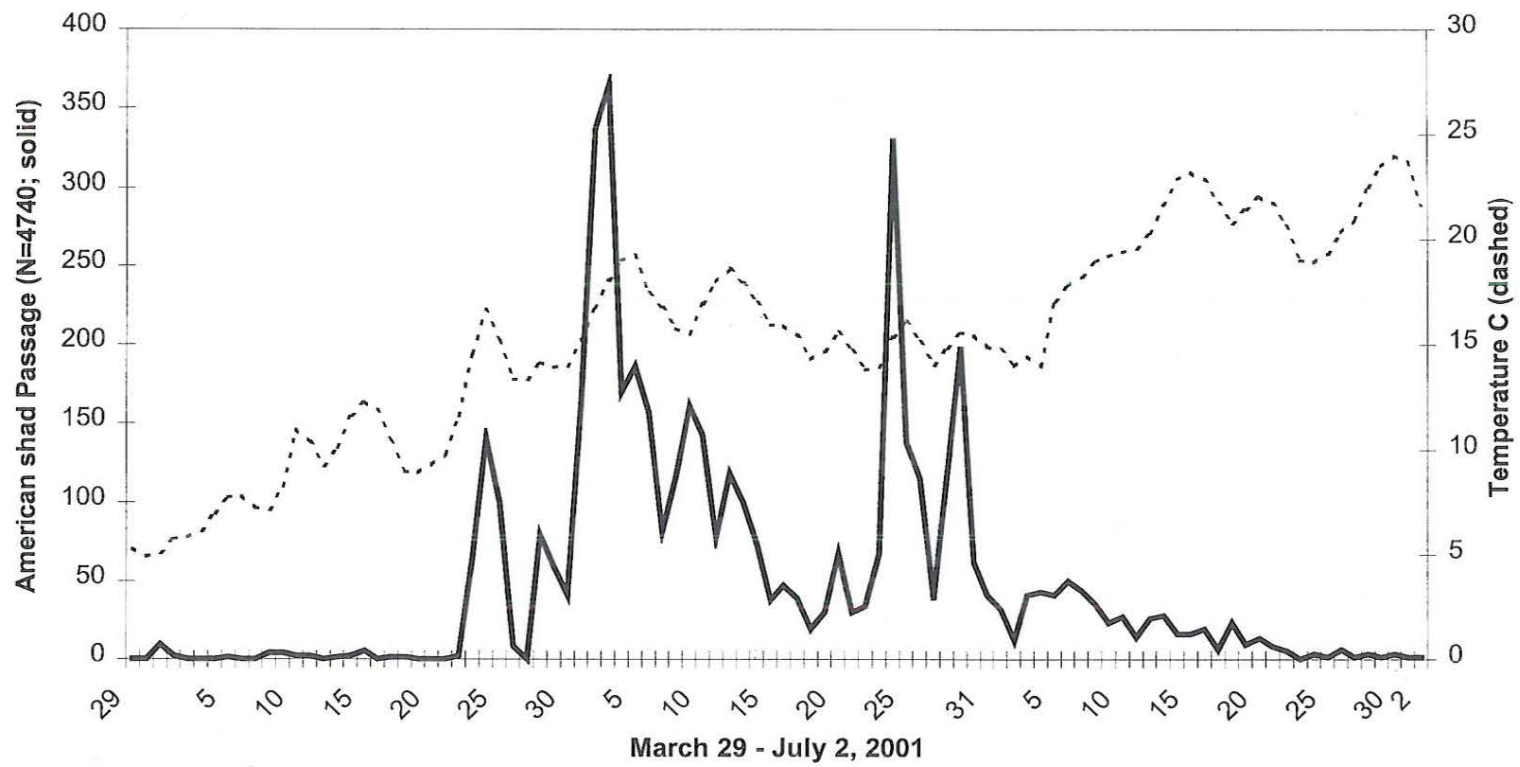


Figure 8. Plot of American shad passage at the Easton Dam fishway (RM 0.00) and Lehigh River mean daily water temperature.

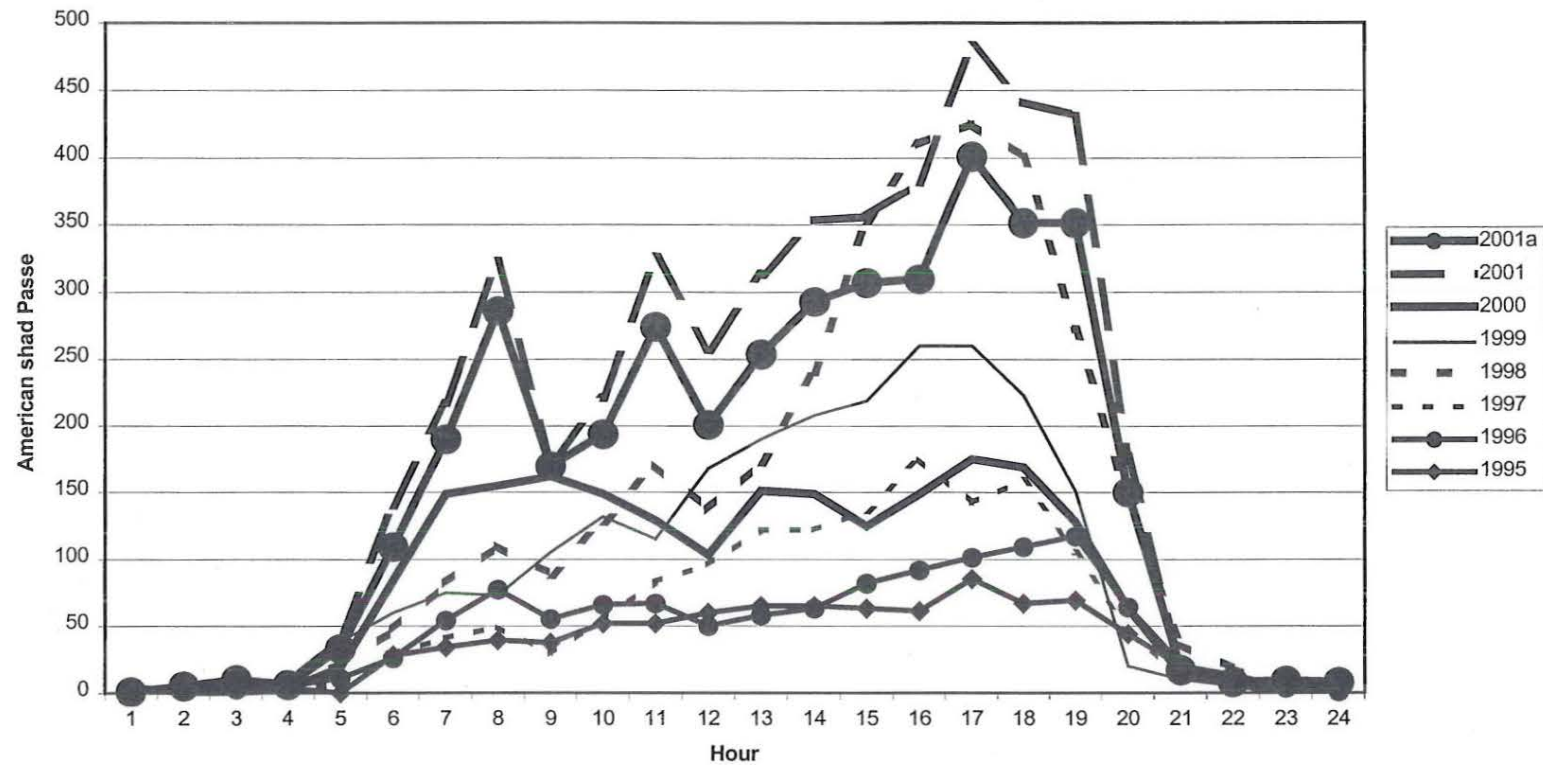


Figure 9. Passage by hour for all days combined at the Easton Dam fishway (RM 0.00) for 1995 (N=873), 1996 (N=1141), 1997 (N=1426), 1998 (N=3281), (N=2337), 2000 (N=2094), and 2001 (N=4966, 4740 less 41 shad with no time of passage) and 2001a (N=3938, 4740 less 41 shad with no time of passage and 1028 shad for periods where night passage was not recorded May 11-14, 14-16, 16-18, and 28-30).

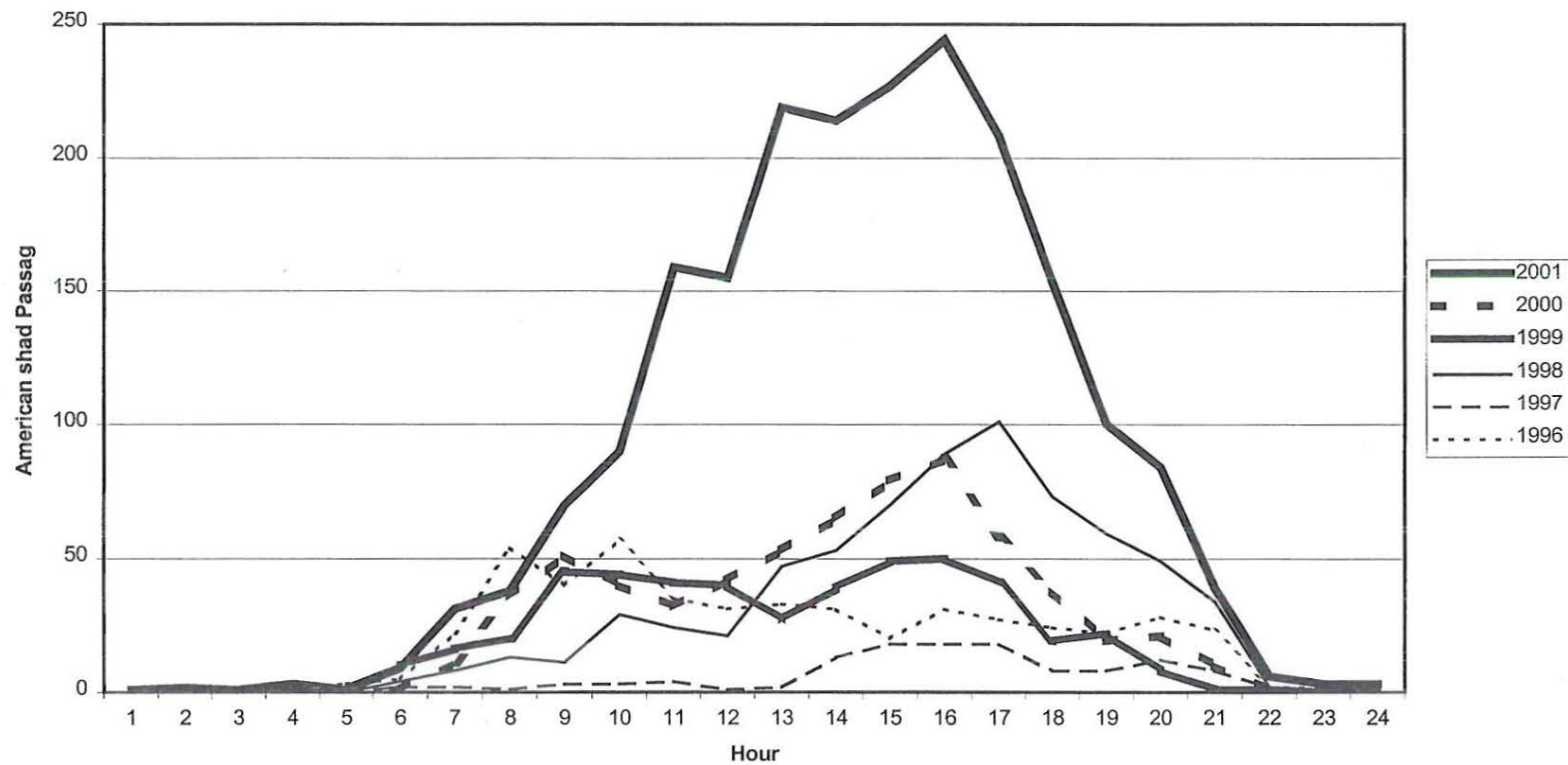


Figure 10. Passage by hour for all days combined at the Chain Dam fishway for 1996 (N=476), 1997 (N=126), 1998 (N=694), 1999 (N=479), 2000 (N=645) and 2001 (N=2057).

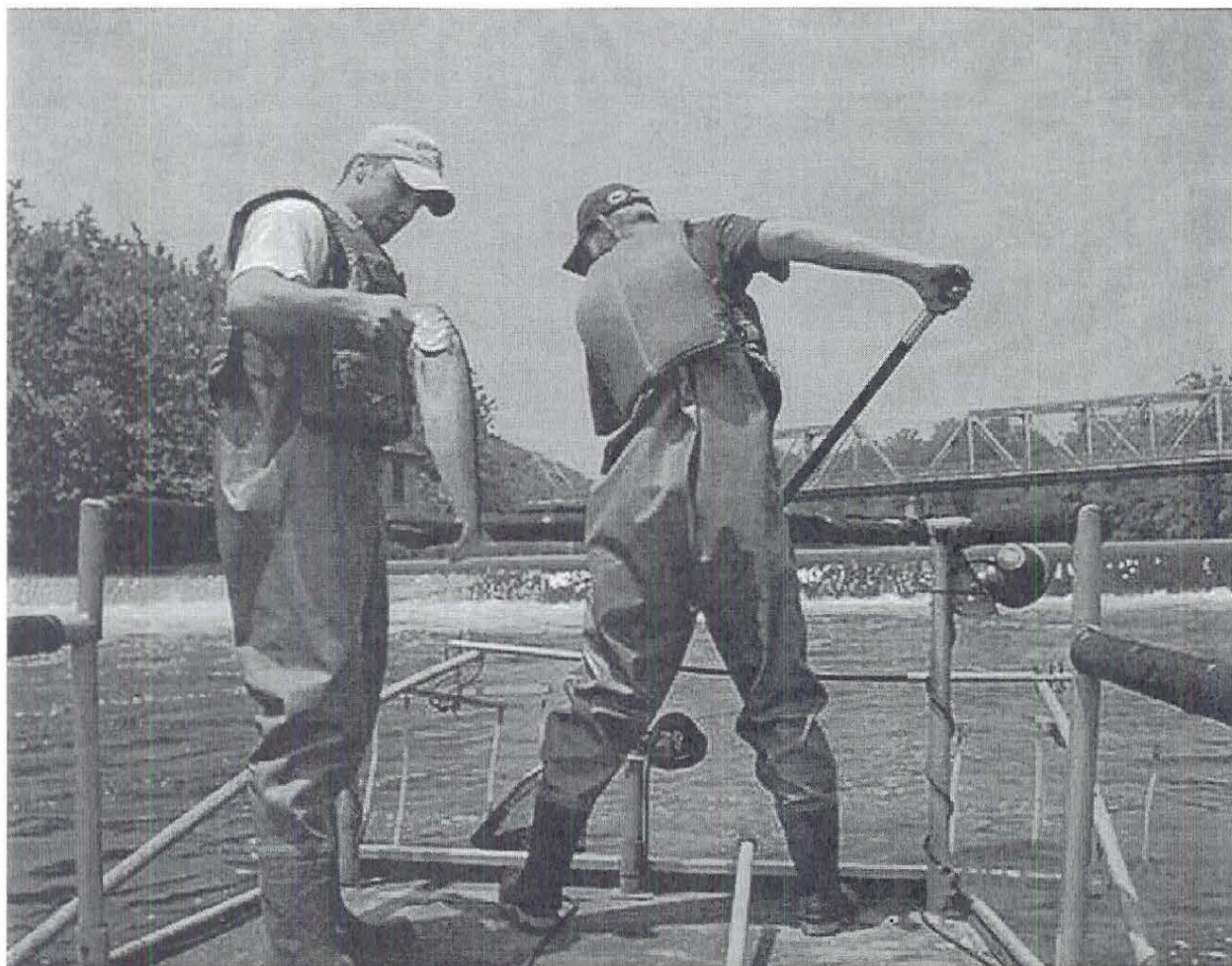


Figure 11. First adult American shad caught by the Pennsylvania Fish and Boat Commission down river from the Clementon/Northampton Dam (RM 24.0) in the Lehigh River on June 20, 2001.

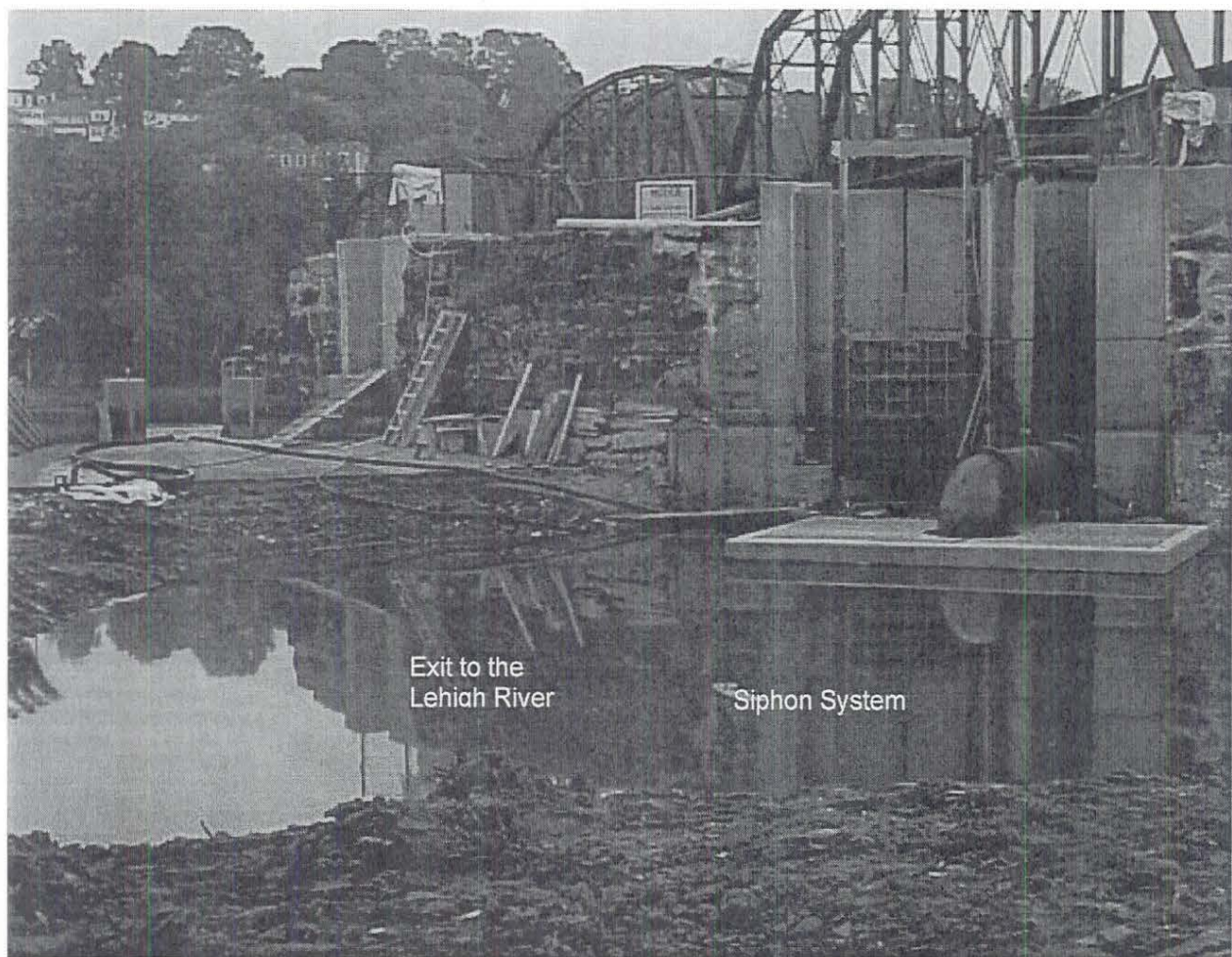


Figure 12. Easton Dam fishway's modified auxiliary flow system (October 2000).

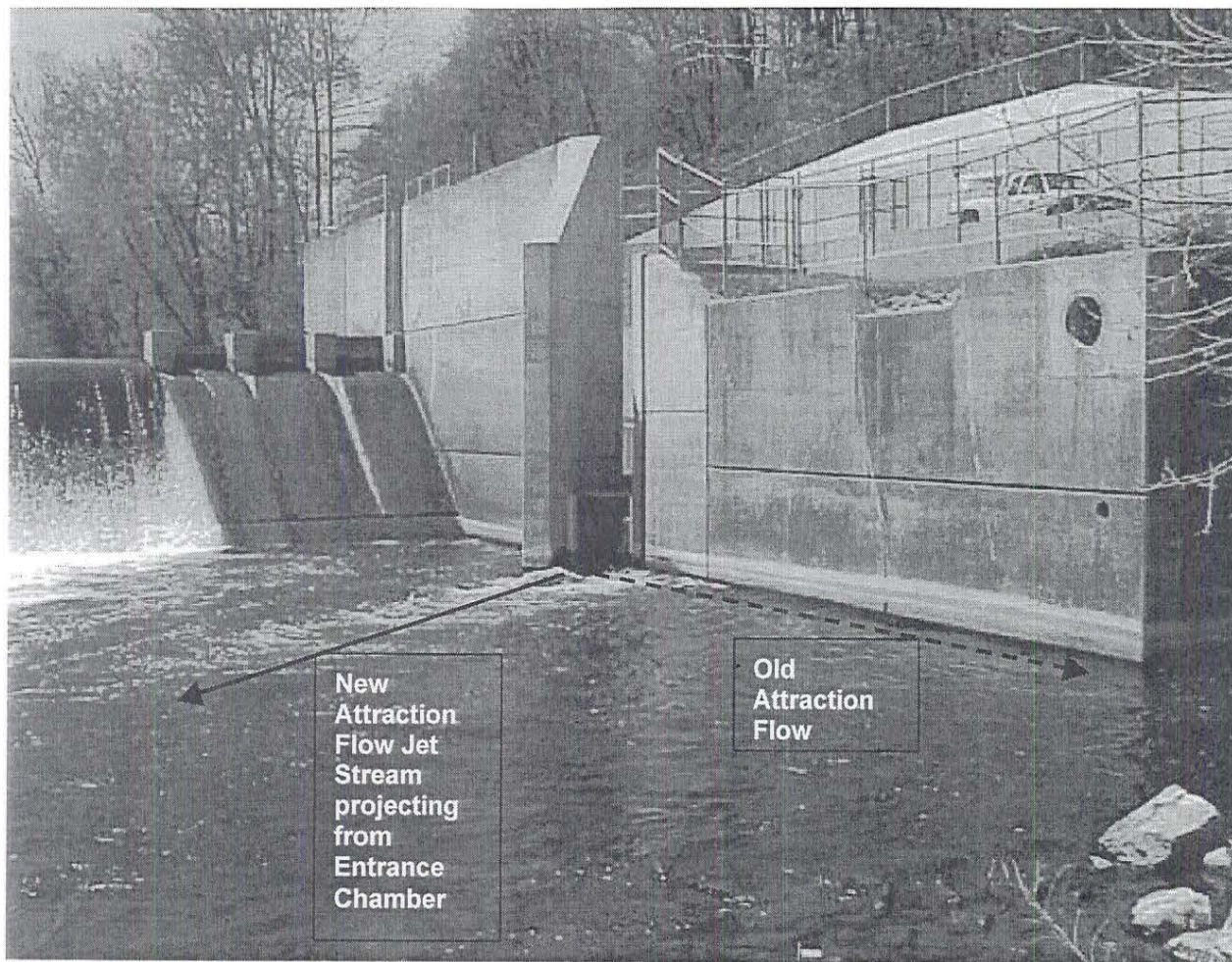


Figure 13. Chain Dam fishway's modified attraction flow jet (October 2000).

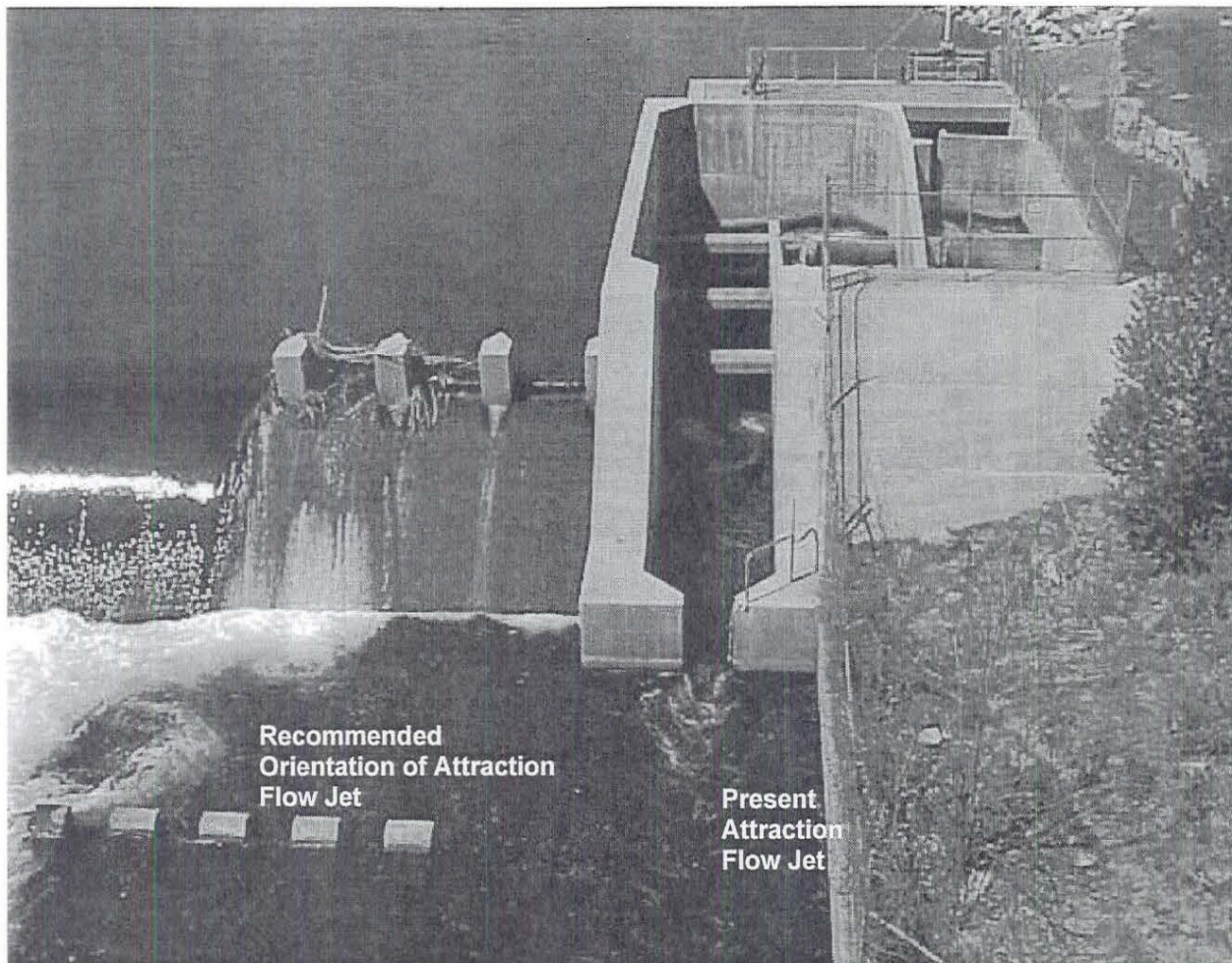


Figure 14. Hamilton Street recommended attraction flow jet (October 2000).