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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

Duration: March 19, 2002 through September 30, 2002

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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 (PFBC), 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 PFBC began operating the Easton and Chain Dam fishways during the spring and monitoring fish passage. In addition, to satisfy Atlantic States Marine Fisheries Commission (ASMFC) stock characterization needs and our own urgent needs we 1) collected 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 (adult and young of the year American shad), and the annual egg take and collection of biological data from the Delaware River stock were included as part of the F-57-R, Fisheries Management Project, Sport Fish Restoration Act. In 1997, 1998, 1999, 2000 and 2001 these activities, excluding Lehigh River adult and young of the year monitoring, and the annual Delaware River egg take operation, were centered in project NA66FI0292, NA76FI0083, NA86FI0214, NA96FI0220, and NA06FI0191 *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 2002.

Objective:

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

Fish passage monitoring commenced on March 19 at the Easton Dam fishway and April 3 at the Chain Dam fishway and terminated at both dams on July 3, 2002 (Table 2). Recording time frames during this period are listed in Table 2. Major periods of lost monitoring (greater than 15 minutes) for each fishway are listed in Table 3. Lost time periods of less than 15 minutes on tape changing days and not coinciding with fishway maintenance (draining, cleaning, and refilling) were not included in 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 (Pre-Auxiliary Flow Modification - Easton: 1995-2000 and Chain: 1996-2000; Post-Auxiliary Flow Modification - Easton and Chain 2001-2002) 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). Pre-modification period refers to the time frame during which the fishways ability to attract American shad was impaired due to a continuous malfunctioning attraction flow system (reduced flow and extreme aeration in the entrance chamber). In addition for the Chain Dam fishway, the attraction flow emanating from the entrance was orientated parallel to the river flow and traversed along side the fishway and the riverbank. Post-modification period refers to the time frame after the corrections to the auxiliary flow systems were made in October 2000 (Easton - siphon, and Chain Dam - restrictor plate and reorientation of the entrance attraction flow stream approximately 45 degrees away from the river bank).

Lehigh River adult American shad collected by Fisheries Management Area 6 for origin analysis (stocked vs. wild) were taken during daytime electrofishing operations on June 6, 2002 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).

Average daily flow data for the Lehigh River was obtained from the USGS website for Pennsylvania streams, Glyndon Station No. 01454700.

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 3,314 adult American shad passed in 2002 (Table 4, Fig. 2). Monitoring commenced on March 19 with passage first recorded on April 10 and continued through July 1. Greatest movement occurred from May 6 through May 10 when at least 1,077 shad passed (Table 5). The highest daily passage of 320 shad occurred on May 8. A total of 3,285 video frames of shad passage were recorded; of these, single passages accounted for 99.15 percent (N=3257), dual passages 0.82 percent (N=27), and triple passage 0.03 percent on an individual

video frame (N=1, Table 6). During late April through early June, increases in mean daily river temperatures and decreases in river flow generally corresponded to periods of increased passage. Conversely decreases in mean daily river temperatures and increases of river flow corresponded to periods of decreased shad passage (Figs. 2-3).

There was no difference between the unadjusted and adjusted (less those days/recording periods where a significant block of monitoring time was lost) composite hourly passage from April 10 through July 1 (Table 7, Fig. 4). Passage was fairly evenly distributed during the morning (0700-0900; N=407) and late morning (1000-1200; N=510). Passage continued to increase in late afternoon (1300-1500; N=709) and into the early evening hours (1600-1900; N=1,327) with passage peaking at 1500 (N=283) and 1700 (N=373) hours, respectively. 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 8. Diurnal usage patterns varied daily and seasonally. Monthly usage summaries showed that the greatest movement of shad occurred from 1600-1900 hours in May (N=847) and in June (N=313). Passage was least evident from 0100-0500 and 2000-0000 hours.

Chain Dam Fishway (RM 3.0)

A minimum of 1,479 adult American shad passed in 2002 (Table 4). During late April through early June, periods of increased passage corresponded to increases in mean daily river temperatures and decreases in river flow. Conversely decreased shad passage (Figs. 5-6) corresponded to decreases in mean daily river temperatures and increases of river flow. The first shad passed on April 18 and passage continued through at least June 30 with monitoring ending on July 3, 2002 (Table 9). The greatest movements occurred on May 7 and May 8 (N=316), and from June 1 through June 5 (N=421). The highest daily passage occurred on May 8 (N=177), followed by May 7 (N=139), May 12 (N=110), June 2 (N=110) and June 3 and 4 (N=93 each). A total of 1,450 video frames were recorded during this period, of these, single passage accounted for 98.07 percent (N=1422) of the total (Table 6). Dual and triple passage rates accounted for 1.86 (N=27) and 0.07 percent (N=1) of each frame, respectively. From April 18 through June 30, 2002, the composite hourly passage was most evident from 0600 through 2000 hours, with the most active period ranging from 1400 through 1900 hours (N= 990) (Table 10, Fig. 7). Daily passage 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 11. Diurnal usage patterns varied daily. The greatest movement of shad in May occurred from 1600-1900 hours (N=476), followed by 1300-1500 (N=245), and 1000-1200 (N=160). Shad passage though the month of June was fairly uniform from 1000-1200 through 1600-1900. Least passage occurred during the 0100-0500 (N=3) and 2000-0000 (N=48) hour periods.

Cementon/Northampton Dam (RM 24.0)

No adult American shad were caught or seen in 49 minutes of electrofishing in the Northampton Dam tailrace area or in 42 minutes of electrofishing in the Hokendauqua pool (RM 23.6; 1 .0 km down river from the Northampton Dam) on June 20, 2002.

Adult Origin (Wild or Hatchery Fry)

A total of 100 adult American shad were collected for origin determination (wild vs. hatchery) via otolith analysis from the tailrace area of the Chain Dam on June 6, 2002. Otolith analysis of 99 shad (55 females, 44 males) was useful for origin determination. Hatchery reared shad accounted for 89 percent (N=84; 47 females, 41 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 12). Stocked male shad otoliths ages ranged from III to VI, with ages V (N=18) and VI (N=15) being the most abundant. Otolith ages for stocked origin females ranged from IV to IX, with ages V and VII being the most abundant (N=18 each). Hatchery shad were derived predominately from gametes from the PFBC's Smithfield Beach spawning operation, and perhaps also from the Hudson and Susquehanna River egg sources based on otoliths age and otoliths known age readings (Tables 13 and 14).

Wild adult shad accounted for 11 percent (N=11; 8 females, 3 males) of the total collected. Otolith ages of females of wild origin ranged from IV to VI with age V being the most abundant (N=6). The three male shad of wild origin otolith ages were IV, V, and VI (one each).

Adult Otolith Age Determination

Of the 100 adult American shad otoliths collected for origin determination, 97 were usable for age analysis (Table 11). The otoliths of three shad (2 female and 1 male) were not useable for age determination due to either being missing, crystallized, or ground out. Females were represented by ages IV through IX, with ages V (N=22) and VII (N=18) being the most abundant, followed by ages VI (N=8), IV (N=4), and VIII and IX (N=1 each). The mean total length for females ages IV through IX was 515, 544, 547, 569, 573, and 569 mm (Table 15). Males were represented by ages III through VI, with ages V (N=19) and VI (N=16) dominating the sample. The mean total length for males, ages III through VI were 406, 464, 490, and 505 mm. Furthermore, based on the OTC mark pattern 86 of the 97 shad were of known age (Age III: 1 male; IV: 2 females, 5 males; V: 13 females, 20 males; VI: 12 females, 14 males and age VII: 18 females, 1 male).

Adult Scale Age and Repeat Spawning Determination

Scale samples were collected on June 6, 2002, from 100 adult shad for age and repeat spawning analysis. Age and repeat spawning data was obtained from 98 of the 100 shad sampled. Scale samples from two female shad contained regenerated scales, thus were unreadable for aging purposes. Of the 100 examined, 56 were female and 44 were male (Table 16). Females were represented by ages IV through VII, with age V being the most abundant (N=29). Males were represented by ages III through VI, with age V being the most abundant (N=27). The mean total lengths for the respective ages of female and male shad are listed in Table 16.

All but two of the scale samples collected on June 6, 2002, exhibited signs of severe re-absorption. The lateral edges of the current years annulus were nearly absent and in some instances eroded back into the previous annulus near the base of the posterior region of the scale.

The minimal re-absorption seen on two samples 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 18.4 percent (N=18) of the 98 usable shad scales sampled. Seventeen of the 18 repeat spawning shad were of hatchery origin. The origin of one shad could not be determined. The repeat spawning rate by sex was 22.2 (12 of 54) female and 13.6 percent (6 of 44) for male shad (Table 17). All eighteen repeat spawning marks were single marks. Shad with regenerated scales were not included in the determination of the percentage of repeat spawning (N=2).

Comparison of Scale, Otolith Ages to Known Age

All American shad

The comparison of scale and otolith ages by sex from 95 shad (52 females, 43 males) indicates an agreement of 32 and 33 percent, with a combined rate of 33 percent (Table 18). Differences in ages by + 1 year were 35 percent for females and 51 percent for males; +2 years were 19 percent for females and 7 percent for males; +3 years was 4 percent for females; -1 year were 10 percent for females and 7 percent for males; and -2 years was 2 percent for males.

American shad with Known Ages

Seventy-nine (44 females; 35 males) of the 100 shad with known ages had corresponding scale age data (Table 19). The comparison of known ages with corresponding scale ages indicates an overall agreement of 37 percent (N=29). Known female ages ranged from IV (1998 year class) to VII (1995 year class) of which age VII was the dominant cohort (N=18). Of the 44 female shad 20 sets differed by -1 year (45.5%), -2 years (20.5%), and +1 (6.8 %). Twelve sets of otolith and scale ages agreed (27.3%). Male ages ranged from III (1998 year class) to VII (1995 year class), with most being age V (N=20). The agreement rate for male shad was 48.6 percent (N=17), followed by -1 and -2 year(s) difference rates of 34.3 (N=12) and 11.4 percent (N=4).

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

The read otolith ages of 84 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 79.8 percent (N=67), followed by aging differences of -1 year (9.5%, N=8), +1 year (8.3%, N=7), and +2 and -2 years (1.2 percent, N=1 each).

Sex Ratio

The sex ratio (56 female: 44 male) of the 100 adult shad collected on June 6, 2002, during 24.7 minutes of electrofishing (two fix anode arrays from a flatbottom boat) was 1.3:1.

Discussion:

American shad passage in 2002 was the second highest recorded ($N=3,314$) in the nine-year monitoring period (1994-2002) at the Easton Dam fishway (RM 0.0). The greatest passage was recorded in 2001 when at least 4,740 shad passed. Shad passage through the Easton Dam Fishway continues to fluctuate throughout the monitoring period (Snyder 2001). Passage counts in 2001 indicate that 1998's previous high of 3,293 was exceeded by 1,447 but only by 21 shad in 2002. These differences remained within the yearly fluctuation ranges recorded during the pre-auxiliary flow modification period (1995-2000; Snyder 2001). Thus, it was hard to assess the effectiveness of auxiliary flow modifications completed in 2000. What can be noted is that the Easton Dam Fishway required very little to no maintenance to maintain the proper attraction flow jet during the post-modification period. This is in stark contrast to the high daily maintenance required to place the attraction flow within the suitable range for at least part of the day during the pre-modification period. The 2002 shad run continued to support Snyder's (2000, 2001) premise that the 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. Additionally, fluctuations in passage during the pre-auxiliary flow modification period (1994-2000) were further compounded by the fishway's impaired ability to attract shad due to a malfunctioning attraction flow system (reduced 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 a siphon system. This modification provided a more consistent volume of water, eliminated air entrainment (during normal operation) and resulting aeration effects in the entrance chamber. Although passage in the post auxiliary flow modification period (2001-2002) was the highest recorded it continues to be affected by the variations noted above. Hydroacoustic monitoring in the Delaware River at Trenton, New Jersey in 2002 by Barnes-Williams Environmental Consultants for New Jersey Division of Fish and Game and the DRBC Fish and Wildlife Technical Committee conservatively estimated the 2002 run to be $399,200 \pm 2,000$ shad. Past Delaware River shad run estimates in 2001, 2000, 1999, 1998, and 1996 were $417,300 \pm 2,700$, $382,200 \pm 2,700$, $24,700 \pm 300$, $392,700 \pm 2,500$, and $524,300 \pm 2,800$. No monitoring occurred in 1997.

American shad passage through the Chain Dam fishway continues to be significantly higher during the post-modification period (2001-2002) than during the pre-modification period (1996-2000). Annual passage was more than double the highest pre-modification passage year recorded (1996, $N=694$) with passages of 2,057 in 2001 and 1,479 in 2002. In addition the recorded percent of passage, as compared to passage through the Easton Dam fishway, has remained the highest recorded with 44.6 percent in 2002 and 43.5 percent in 2001. Percent passage values were highly variable during the pre-modification period. Passage rates from 2000, 1999, 1998, 1997, and 1996 were 30.8 ($N=645$), 20.4 ($N=479$), 21.1 ($N=694$), 8.8 ($N=126$), and 43.4 percent ($N=496$).

Snyder (2001) reported that the auxiliary flow system of the Chain Dam fishway was still experiencing some problems. The restrictor plate installed in the auxiliary flow system to

eliminate aeration only does so when the auxiliary flow gate is at least three quarters of the way open, depending on river flow. Opening the gate to this level or above increases the rate of flow causing the formation of vortices at the head, which draw in debris, clog the grate and reduce flow over time. Reducing flow either by lowering the gate or through debris entrainment minimizes vortices at the head and accumulation of debris; however, reducing the flow reintroduces a significant aeration problem back into the entrance chamber. The debris situation was further compounded near the end of May and into June when an aquatic weed bed immediately up river was dislodged by spawning carp. This situation was not noted to occur in 2002, perhaps due to the constant high river flows and cooler temperatures. The attraction flow was maintained near the lower limit of the required 6 to 10 inch (152 to 250 mm) head difference exiting the entrance chamber throughout the run. There was no need in 2002 to install the up river debris boom suggested by Dick Quinn (personnel communication 2001). This may have been due to the high-sustained flows throughout much of the 2002 shad run.

The passage of American shad through both the Easton and Chain Dam fishways appear in part to be both temperature and river flow dependent based on passage for 2002 (high flow year) and 2001 (low flow year, flow comparison only) (Figs. 2-3, 5-6, and 8-9) (Snyder 2001). Passage during the period of April through early June generally increases during periods of increasing river temperatures and decreasing river flow. Conversely passage decreases during periods of decreasing river temperatures and increasing river flow. Both parameters demonstrate a correlation to passage, however, is unknown at which point either or both acting in concert are a factor. Movement of American shad through the fishways increases the average daily flow falls below 4,000 cfs.

Hourly usage at both fishways was similar during the pre- and post-modification periods, despite dramatic increases in passage in the post period, particularly for the Chain Dam Fishway. Usage patterns were similar to those previously reported by Snyder (2001), with most passage occurring from 0600 through 2000 hours (Tables 7-8, 10-11, 20 and 21; Figs. 4, 7). Shad were least active from 2100 to 0500 hours. Passage in all years at the Easton and Chain Dam fishways was variable, and shad were least active during the period of 0100-0500 hours. Monthly summaries for the Easton Dam fishway showed for May the 1600-1900 hour period was the most active in 1995 through 2002 and more variable during the month of June (Tables 8, 20 and 22). Since 1998 monthly summaries for the Chain Dam fishway showed that in May the 1300-1500 hour period was also a very active period (Tables 11, 21-22).

Snyder (2000) suggested that preferred usage times might change due to the modifications to the fishways if the previously reported operational problems were affecting passage. The 2002 and 2001 data shows that usage patterns were similar to that reported during the pre-modification period. The time period 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 reflected similar diurnal movement patterns 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 were 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 2002 was the fourth highest recorded at both the Easton (N=121) and Chain Dam (N=72) fishways (Table 4). These passages reflect a significant decline in use at both fishways from 1999's high of 1,263 and 958 gizzard shad, respectively and those of 2000 (Easton N=337; Chain (N=307) and 2001 (Easton N=392; Chain N=416). The high count of gizzard shad into the Lehigh River in 1999 was not mirrored in the catch data from the PFBC's American shad spawning operation in the Delaware River at Smithfield Beach (Snyder 1999)

Stock analysis continued 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 2002 showed 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, 91 (96 of 105 shad) in 2001, and 89 percent (89 of 99) in 2002. 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 (1998-2001) 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 numbers of wild shad present in the 1998, 1999, 2000, 2001 and 2002 runs, based on the percent of wild shad in the sample, were 66 (2% of 3,293), 165 (7% of 2,346), 188 (9% of 2,094), 427 (9% of 4,740) and 365 (11% of 3,314) (Table 23). 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 2005. 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 adult shad passing through the Chain Dam fishway that continued into 2002 as compared to the pre-modification period (1996-2000). The majority of spawning during the pre-modification period took place within the lower 3.0 miles of river, based on the low numbers of adults passed through the Chain Dam fishway and subsequent young-of-the-year (YOY) sampling. A preponderance of YOY sampled was 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 imprint. 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 fourth year in American shad restoration history that staff could reasonably distinguish the age class of adult shad based upon the presence of specific OTC marks for otolith ages III (1999; N=1), IV (1998; N=7), V (1997; N=33), VI (1996; N=19) and VII (1995; N=19) (Table 19). Known otolith ages and corresponding scale ages had an overall agreement rate of 36.7 percent in 79 samples. Individual age class agreement rates for ages III, IV, V, VI and VII were 100 (N=1), 71.4 (5 of 7), 57.6 (19 of 33), 15.8 (3 of 19) and 5.3 (N=1 of 19) percent, respectively. This was similar to the overall agreement rate of 28.7 percent in 2001 but was still a significant decrease in the overall agreement rate from 65.7 percent (50 of 76) in 2000 and 85.7 percent (42 of 49) in 1999.

The continuing decrease in agreement rates from 1999 to 2002 was concerning. All scale ages were determined following Cating's (1953) usage of transverse groove counts in relationship to annulus marks. Snyder (2001) noted that based on the tagging history supplied by the PFBC's Division of Research a portion of the 2001 OTC marked shad could be of different age classes since the same mark sequence was used during multiple years. Findings were similar in 2002 based on scale and known otolith age comparisons (Tables 13, 14 and 19). One male shad had a known otolith age of IV (1998; Day "3,9,12" tag) with a scale age of VI that corresponded to the same day tag used in the West Branch of the Susquehanna River in 1996 (561,000 fry). American shad with a known otolith age of V (1997; Day "5,9,13" tag) had no other alternate year class choices based on scale ages for which 14 of the 33 known aged shad differed by plus or minus one year. Known otolith age VI shad (1996; Day "3,6,9" tag) that had 16 of the 19 scale ages that differed by -1 and -2 years were feasible since this tag was also used in 1997 (486,000 fry, Juniata River; egg source Susquehanna River) for those with a scale age of V (12 of 19), and in 1998 (565,000 fry, Juniata River; egg source Hudson River) for those with a scale age of IV (4 of 19). Known age VII shad (1995; Day "5" tag) with corresponding scale ages that differed by -2 years were possible since this tag was also used in 1997 (2,801,000 fry Susquehanna River and 236,000 fry, Juniata River; egg source Hudson and Delaware Rivers) for those with a scale age of V (9 of 19). The remaining 9 of 19 shad with scale ages differences of minus one year could not be cross linked to another stocking water or year. Therefore, if these shad were removed from the estimate the agreement rate would increase from 36.7 (29 of 79) to 54.7 percent (29 of 53).

Known ages based on specific OTC tagging patterns may or may not reflect known age periods for a specific river. 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 to allow 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 reduction of agreement rates since 1999. This determination is based on the low number of shad with differing scale and otolith ages whose origins could be from different stocking years.

Snyder (2000) suggested that there is room for subjectivity in interpreting otolith ages as well as scales. The 2002 data continues to support this premise as the agreement rate between read

otolith ages and known ages was 79.8 percent. This is especially true, although perhaps only remotely possible of shad with similar tagging pattern stray from other waters.

The stocking program has established and continues to support a repeat spawning population in the Lehigh River. The 2002 run recorded the highest repeat spawning rate of 18.4 percent (18 of 98 shad). Repeat spawning rates have fluctuated since the first assessment in 1998. Prior repeat spawning rates were: 12.5 percent (13 of 96 shad) in 1998, 3.1 percent (3 of 96 shad) in 1999, 13.5 percent (13 of 96 shad) in 2000, and 3.8 percent (5 of 109) in 2001. The incidence of repeat spawning in the Delaware River at Smithfield Beach in 2002 was also the highest recorded (1996-2002) with a rate of 16.6 percent (63 of 380 shad) (Snyder 2002).

Snyder (2001) suggested that the rate of repeat spawning might be under estimated for the Lehigh and Delaware River shad populations. Repeat spawning rates for long-lived shad may be under estimated by the elimination of prior marks as depicted by the time series display reported in 2001. This also poses a problem for age determination, as complete annuli may be lost. The 2001 time series display of scale re-absorption clearly demonstrated the extent of re-absorption through time. The NYDEC Hudson River biologist continues to be amazed at the amount of re-absorption that takes place from scales collected in the Lehigh and Delaware rivers. Shad collected in the Hudson River freshwater tidal zone exhibit minimal scale re-absorption for similar time frames. As noted in 2001 and in 2002 some American shad during the later part of the run in both rivers exhibit signs of minimal re-absorption. These fresher scales may indicate that shad migrate throughout the spawning period and may move up river from the lower bay or even the ocean.

Furthermore, repeat spawners may be underestimated for another 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. Thus, a complete spawning mark may not be laid down. Perhaps only the sides of the scale may display scarring without disrupting the scale crest. Snyder (2001) indicated that another factor may be responsible for this anomaly. The intensity is not consistent within age classes, as some shad displayed strong visible marks and others only faint marks within the same region. Strong marks of this type may reflect repeat spawning by short-term shad.

The sex ratio of adult American shad in the Lehigh River (female: male) continues to remain fairly stable from 1997 through 2002. Sex ratios (female: male) 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), 2001 (1:1.6, N=100) and (1.3:1). Snyder (2001, 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.

A fourth low head dam, known as the Northampton Dam, at RM 24.0, has been determined to be a barrier to annual migrations of American shad (Snyder 2000). The USFWS has recommended and developed plans for notching the dam. In 2001 a total of nine adult American shad were caught immediately down river from the Northampton Dam. Their presence demonstrates that the Hamilton Street Dam fishway (RM 17.0) can and does pass American shad. However, no

adult American shad were caught down river of the Northampton Dam in 2002. Snyder (2001) noted that passage through the Hamilton Street Dam may be improved by reorienting the attraction flow jet to project out into the tailrace rather than along the shoreline, similar to the Chain Dam fishway modification of October 2000.

Snyder (2001) reported that the owner of the Northampton Dam, White Hall Cement Company, a subsidiary of LeFarge-North America, was pursuing the following options:

- 1) Changing operations 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 continues to investigate both options and remains receptive to providing passage, even though no adult shad were caught down river of the dam in 2002. Mr. Dave Dziubinski, Plant Manager, Whitehall Cement Plant, sent the following e-mail on October 11, 2002: "It is still the intention of the Whitehall Plant to bring this issue to closure as soon as is practical. Your inquiry of yesterday prompted me to bring our engineering group together for a project update. We are wrapping up the engineering study and cost plan for a new pumping system. We do not envision this taking too much longer and will endeavor to have it complete within the next couple of months. There is still the issue of possible permitting requirements that needs to be investigated. This effort has suffered a bit of a set back with the departure of Ed Werkheiser, the plants Environmental Manager. I have passed on this responsibility to our outside Environmental Consultant and he will begin to research this issue immediately. Unfortunately, this engineering work precludes us from moving forward, for the outcome of the study has a major influence on the course of action we would pursue in regards which of the fish passage options we would choose. I know I have not given you any new information, but I can assure you that we are working to resolve this by the end of the year so that we can plan, request funding for, and execute a project next year, (2003)..." Therefore, the earliest passage could occur would be in 2004.

Recommendations:

1. Continue time-lapsed video monitoring at both the Easton and the Chain Dam fishways in 2003.
2. Continue to pursue installing a debris deflector up river of the Chain Dam to prevent clogging of the auxiliary flow racks.
3. Continue to 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. 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, VI and VII year old shad based on PFBC OTC tagging) and scales for age and repeat spawning analysis.
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 2003.
6. Continue to pursue the cooperation of the private owner of the Northampton Dam to begin notching the dam for shad passage in 2003-4.
7. Evaluate the progress of restoration under existing passage regimes and make same projection of complete restoration or identify those bottlenecks that preclude restoration.

Objective:

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

These netting and spawning operations; although not covered nor funded as part of this project, merit detailing relative to the biological data taken. Gamete taking is part of the hatchery component of the restoration effort in the Lehigh and Schuylkill Rivers, tributaries to the Delaware River (1999-2001). From 1985 to 1988 inclusive, the gamete taking effort also provided part of the hatchery component of the restoration effort in the Susquehanna, Lehigh, and Schuylkill Rivers.

The spawning operation commenced on May 8 and concluded on June 5, 2002. River temperature at the start and end of the egg-taking event was 17°C (62.6°F) and 20.0°C (68.0°F). Only ten netting days occurred during this period as a result of sustained high flows and prolonged cold spells. High flows affected net performance throughout netting period. Indications of spawning activity (splashes) were low.

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 (Table 23). 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. Eleven nets were set on the first night (one net broke free after first check and drifted 1.5 miles down river) and 12 nets were fished each night thereafter. The number of nets set per mesh size (stretch, inch) each night is listed in Table 23. 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 were 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 otoliths 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 were sampled. In 2002 a total of 400 shad were caught from which scale and otolith samples were collected from 383 shad (239 females: 144 males).

As with adult shad from the Lehigh River, PFBC Division of Research staff interpreted otolith ages and identified chemical (OTC) marks. PFBC 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.

No American shad were collected in the Raubsville region (RM 176.6) of the Delaware River during this study.

Results:

Delaware River - Smithfield Beach (RM 218.0)

Ten nights of netting resulted in a catch of 400 adult American shad (248 females:152 males; Table 23). Nightly catches ranged from a low of 1 to a high of 86 shad. Sex ratio (female to male) was 1.6:1.0. 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. By-catch of non-targeted species was low and consisted of: gizzard shad *Dorosoma cepedianum* (N=5), striped bass *Morone saxatilis* (N=1), and white catfish *Ameiurus catus* (N=2) (Table 24). All non-targeted species were released alive except the sole male striped bass (617 mm TL, 2206 g).

This was the fourth year that American shad catches were enumerated by gillnet mesh size. Gillnet mesh data were collected from 400 adult shad caught from May 8 to June 5, 2002 (Tables 25-26). The greatest catch of female shad per net per mesh size was the 5.0 (N=119) inch mesh, followed by the 4.75 (N=34), 5.75 (N=22), 6.0 (N=21), 5.25 and 5.5 (N=20), and 4.5 (N=12) inch meshes. For male shad the greatest catch per mesh size was the 5.0 inch net (N=73), followed by the 4.5 (N=37), 4.75 (N=35), 5.25 and 5.75 (N=3), and 5.5 (N=1) inch mesh nets. No male shad were caught in the 6.0 inch mesh net.

Female adult shad comprised 62.0 (N=248) percent of the total catch of American shad (Tables 25-26). Mean total and fork lengths of female shad ranged from 435 to 615 mm and 385 to 549 mm, respectively with average weights ranging from 833 to 2880 g. Spawning readiness of those females caught were classified as follows: "Ripe" (51.6%; N=128), "Spent" (28.6%, N=71), Immature (10.9%, N=27) and Mature/Gravid (8.9%, N=22) (Table 29). Based on 222 of the 248 female shad caught the average respective ovarian weights for the above gonad states were 206.6 g (N=124, Ripe after being artificially spawned); 150.7 g (N=55, Spent), 305.4 g (N=26, Immature) and 443.7 g (N=17, Mature/Gravid) (Table 30).

Otolith analysis of 233 female shad sampled indicated the presence of six age classes (IV through IX), with age class VI being the most abundant (N=124), followed by age classes V (N=54), VII (N=34), VIII (N=10), IV (N=7) and IX (N=1) (Table 31). Otoliths from six females were not read due to being crystallized and or groundout during the preparation process. Of the 234 female shad sampled 98.3 (N=230) percent were wild and 1.7 (N=4) percent were PFBC hatchery shad. All four shad of stocked origin were identified to be of known age based on the OTC tagging pattern displayed by the otoliths. Two tagging patterns were present Day "5" (N=2)

and Day “3,6,9” (N=2). The Day “5” tag coincided to a known age of VII and was used to mark stocked fry in 1995 (Table 13). However this tagging pattern was used in 1994 and 1997 as well. Scale ages for the two female hatchery shad were V and IV. The female shad with a scale age of V was possible as the Day “5” tag was also used in 1997. Read otolith ages were VI and VII, and only age VII corresponded to a Day “5” tag year of 1995. Hatchery females bearing the Day “3,6,9” tag pattern were aged at IV by scales, and VI and VIII by otoliths. This tagging pattern was used in 1996 (Age 6), 1997 (Age 5), and 1998 (Age IV).

Male shad made up 38.0 percent (N=152) of the catch (Table 23). Mean total and fork lengths ranged from 422 to 585 mm and 375 to 520 mm (Table 27), respectively. Average weights ranged from 718 to 1804 g. Otolith analysis of 139 males indicated the presence of six age classes (III through VIII), with age classes V (N=58) and VI (N=51) being the most abundant, followed by age classes IV (N=14), VII (N=12), and III and VIII (N=2 each) (Table 32). Otoliths from four shad were unreadable due to crystallization or breakage. All 139 males sampled were of wild origin.

The otolith ages of seven known age shad (sexes combined) when compared with the read otolith ages had an agreement rate of 50.0 percent (2 of 4, one age VI (1996) and age VII (1995)). The read otolith age for two of four known aged shad differed by -1 year for the Day “5” tag and +2 years for the Day “3,6,9” tag. Scale ages had an agreement rate of 50.0 percent (2 of 4) with known otolith ages, while the remaining two with the Day “5” tag differed by -2 and -3 years. Scale and read otolith ages agreement rate was 25.0 percent (1 of 4), with ages differing for the Day “5” and “3,6,9” tags by -1 and -3 years, and +2 years, respectively.

Scale samples were collected from 382 adult American shad of which 380 were usable (236 females, 144 males) for age determination and repeat spawning analysis (Tables 33-34). Repeat spawning marks in female and male shad consisted of single, double (males only) and triple (females only) marks (Table 35). The combined (female and male) repeat spawning rate was 16.6 percent (N=63) with most being single repeats (95.2%, 60 of 63). Double and triple repeat marks comprised 3.2 (2 of 63) and 1.6 percent (1 of 63) of the repeat spawning shad, respectively. Scale analysis of 236 female shad yielded a repeat spawning rate of 16.9 percent (N=40). Repeat spawning occurred in age classes V (N=13), VI (N=23) and VII (N=4). Single repeat spawning marks occurred in ages V (N=13), VI (N=23) and VII (N=3). Triple marks occurred in age VII (N=1). Male shad had a repeat spawning rate of 16.0 percent (N=23) as determined from scales with single and dual marks. Single repeat spawning marks occurred in ages IV (N=1), V (N=12), and VI (N=8). Dual marks occurred in ages V and VI with one each.

The comparison of scale and read otolith ages by sex of 368 American shad (231 females and 137 males) indicated an agreement rate of 43.7 (N=101) and 44.5 (N=61) percent with an overall combined rate of 44.2 (N=162) percent (Table 36). Differences in ages between otolith and scale ages for female and male shad by one year were 46.3 (-1: 34.2%; +1: 12.1%) and 43.0 (-1: 29.9 %; +1: 13.1%) percent, respectively. The disparity between scale and otolith ages for both sexes ranged from -3 to +2 years.

Discussion:

This was the seventh year of collecting biological data from egg-taking operations at Smithfield Beach (RM 218.0). The low catch of American shad ($N=400$) was the direct result of climatic (fluctuating river temperatures) and environmental conditions (sustained high flows) and their associated effects on the shad run and netting operation. Passage through the both the Easton (RM 0.0) and Chain Dam (RM 3.0) in the Lehigh River, at tributary to the Delaware River (RM 183.6), appeared to be temperature and flow dependent (Snyder 2002). The passage of American shad through the fishways increased with increases in temperature and decreases in flow. Conversely, passage decreased with decreases in temperature and increases in river flow.

The 2002 spawning run of American shad had the highest occurrence of repeating spawners with an overall repetition rate of 16.6 percent (Tables 35 and 37). The incidence of repeat spawning during the seven-year monitoring period (1996-2002) has been highly variable. Snyder (2000) postulated that 1999's decline in the repeat spawning rate (4.4%) at Smithfield Beach shad and among shad migrating farther up river may have been related to 1999's severe drought conditions and its associated effects on an already physiologically stressed long river run shad. This decline may have carried over into the 2000 shad run (2.8%) and may also reflect the effects of the 1999 severe drought and prolonged high spring flows in 2000. Snyder (2000) noted that the long-term effects on the egg-taking operation at Smithfield Beach were unknown but would have had the greatest effect on those repeat spawning shad that had imprinted to the Smithfield Beach area. Thus, one would have expected a continual decline and/or the elimination of repeat spawning in this area.

The resurgence in the rate of repeat spawning from 2000 to 2002 (Table 37) tends to refute the perception that the egg-taking operation is seriously compromising American shad population component migrating through the Smithfield Beach pool. Physiological stresses during the 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 depicting scale re-absorption (Snyder 2001). Repeat spawning rates for long-term shad in freshwater may be underestimated due to severe re-absorption masking previous repeat marks. If a shad stays up river long enough, then based on the amount of re-absorption documented herein complete annuli and previous spawning mark may be lost. Furthermore, Snyder (2001) suggested that repeat spawning may be underestimated due to the discounting of incomplete, possibly repeat marks. The formation of incomplete spawning marks may occur as result of a short stay. 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.

The presence of PFBC stocked shad at Smithfield Beach normally occurs during high water years (1996, 1998 and 2000), and the 2002 run was no exception. Stocked shad were not present in low flow years 1997 and 1999 but did occur in the moderately normal flow year of 2001. The hypothesis postulated by Snyder (2001) that straying was related to normal to high spring flows continues to be supported by these findings.

Snyder (2001) stated that concern remains among state and federal agencies and anglers alike

that the spawning run of American shad in the Delaware River 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 declined from 1990 (15.9) through 1999 (2.6; Table 38). Snyder (2001, 2000) reported that the similarity in mean night catch rates of 2.8 in 2000 and 2001 might indicate that the decline of the run has leveled off. The slight increase in the mean night catch rate to 3.4 shad in 2002 may indicate that the shad run is beginning to rebound. However, 2002's catch may have underestimated the true status of the run as sustained high flows and fluctuating temperatures adversely affected netting effectiveness. Anchored net sets were stretched and barely holding. The decline in sex ratio (female: male) noted from 3.0:1 in 2001 to 1.6:1 in 2002 may have also reflected the adverse environmental conditions during the spawning operation and may not have been representative of the 2002 run. Sex ratios have been highly variable with values of 3.4:1 (1996), 3.6:1 (1997), 4.3:1 (1998), 8.4:1 (1999), 1.4:1 (2000) and 3.0:1 (2001), but the similarity in sex ratios between 2001 and 1996 may support the hydroacoustic estimates that show an increased run.

In 2002 American shad were not sampled in Raubsville area of the Delaware River. However, past sampling 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 samples were collected in April and early May and are 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 sex ratios in 2000 and 2002 reflect similar river and climatic conditions and perhaps lends further support to the assumption.

The 2002 Smithfield Beach shad catch frequency by sex and age determined through scale analysis ranged from ages IV through VII for females and III through VI for males (Table 39). The dominant age classes for female shad were V and VI with a catch frequency of 105 and 120. For male shad age V remained the most abundant age class. The age structure of the run from 1996 through 2002 continued to show that young sexually mature shad are the mainstay of the run.

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. 2001. NA06FI0191. 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.
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, octatetracycline) American shad fry stocked in the Lehigh River immediately up river of the Northampton Dam (RM 24.0) from 2002-1985.

Year	Number Stocked
2002	85,025
2001	675,625
2000	447,900
1999	501,000
1998	948,000
1997	1,247,000
1996	993,000
1995	1,044,000
1994	642,000
1993	790,000
1992	353,000
1991	793,000
1990	2,088,000
1989	833,000
1988	340,400
1987	491,000
1986	550,000
1985	600,000

Table 2. Video recording periods for the 2002 American shad spawning run at the Easton (RM 0.00: March -July 3) and Chain Dam (RM 3.00: April – July 3) fishways in the Lehigh River.

Recording Period	Hours	Recording Period	Hours
3/19-3/22	72	5/10-5/13	72
3/22-3/26	96	5/13-5/15	48
3/26-3/29	72	5/15-5/16	24
3/29-4/01	72	5/16-5/17	24
4/01-4/03	48	5/17-5/20	72
4/03-4/05	48	5/20-5/22	48
4/05-4/08	72	5/22-5/24	48
4/08-4/10	48	5/24-5/27	72
4/10-4/12	48	5/27-5/29	48
4/12-4/15	72	5/29-5/31	48
4/15-4/17	48	5/31-6/03	72
4/17-4/19	48	6/03-6/05	48
4/19-4/22	72	6/05-6/07	48
4/22-4/24	48	6/07-6/10	72
4/24-4/26	48	6/10-6/12	48
4/26-4/29	72	6/12-6/14	48
4/29-4/30	24	6/14-6/17	72
4/30-5/01	24	6/17-6/19	48
5/01-5/02	24	6/19-6/21	48
5/02-5/03	24	6/21-6/24	72
5/03-5/06	72	6/24-6/26	48
5/06-5/08	48	6/26-6/28	48
5/08-5/10	48	6/28-7/3	120

Table 3. Periods of lost monitoring and/or periods of reduced visibility at the Easton and Chain Dam fishways during the 2002 American shad run.

Easton Dam Fishway					
Recording Date	Duration Hours	Lost Recording Hours	Percentage Lost Hours	Explanation	
3/26	3/29	72	0.4	0.6	Fishway cleaning
4/01	4/03	48	1.1	2.3	Fishway cleaning
4/05	4/08	72	1.4	2.0	Fishway cleaning
4/10	4/12	48	2.6	5.3	Lights went out 15 min, cleaning 1.42 hrs
4/15	4/17	48	23.1	48.0	Turbid waters 20.14 hrs, lights out 3 hrs
4/19	4/22	72	0.5	0.6	Fishway cleaning
4/26	4/29	72	5.2	7.2	Cleaning 1.08 hrs, turbid water 4.09 hrs
4/29	4/30	24	24.0	100.0	24 hrs of very low visibility
5/13	5/15	48	48.0	100.0	Technical problems
5/17	5/20	72	71.4	99.0	Technical problems
5/27	5/29	48	48.0	100.0	Technical problems
6/19	6/21	48	0.6	1.2	Fishway cleaning
6/26	6/28	48	5.5	11.3	Lights off water very turbid
6/28	7/03	120	33.4	27.8	Lights went out/ batteries dead
Chain Dam Fishway					
4/05	4/08	72	5.4	7.5	Cleaning 32 min, lights out 5.06 hrs
4/08	4/10	48	2.1	5.1	Cleaning 1.13 hrs, lights out 1 hr
4/10	4/12	48	0.6	1.2	Lights out
4/12	4/15	72	1.2	1.6	Lights out
4/15	4/17	48	5.2	10.9	Lights out 40 min, cleaning and service 4.42 hrs
4/19	4/22	72	1.4	1.9	Cleaning 30 min, lights out 1.05 hrs
4/26	4/29	72	2.1	2.9	Cleaning 52 min, lights out 44 min, turbid water 32 min.
4/29	4/30	24	1.1	4.4	Fishway cleaning
5/01	5/02	24	0.4	1.7	Lights out
5/06	5/08	48	0.5	1.0	Fishway cleaning
5/10	5/13	72	0.5	0.7	Cleaning 19 min, lights out 30 min.
5/13	5/15	48	12.3	25.6	Turbid water
5/27	5/29	48	1.1	2.3	Fishway cleaning
6/03	6/05	48	12.3	2.2	Turbid water
6/28	7/03	120	69.4	57.9	Algae coated windows

Table 4. Fishes that have been observed (video taped) migrating through the Easton (RM 0.00; Pre-Auxiliary Flow Modification (Pre-AFM) 1994-2000; Post Auxiliary Flow Modification (Post-AFM) 2001-2002) and Chain (RM 3.00; Pre-AFM 1996-2000; Post-AFM 2001-2002) Dam fishways in the Lehigh River during the early spring and summer. 1994+ only American shad were counted.

Easton Dam Fishway									
Fish Species/Type	American Shad Spawning Run Year								
	Pre-AFM							Post-AFM	
	1994+	1995	1996	1997	1998	1999	2000	2001	2002
American shad	87	873	1141	1428	3293	2346	2094	4740	3314
Gizzard shad		51	23	15	45	1263	337	392	121
Striped bass		19	5	1	0	0	0	0	1
American eel		1	4	*	2*	4*	1*	*	12
Sea lamprey		6	27	38	22	181	253	894	490
Trout		109	43	79	193	111	231	267	309
Muskellunge		9	6	1	0	3	10	8	7
Chain pickerel		0	0	0	0	2	0	0	0
Walleye		3	2	0	1	1	0	1	2
Yellow perch		2	31	2	0	2	0	3	1
Bass		303	348	218	483	358	1149	377	584
Sunfish		368	289	130	210	140	1214	504	346
Crappie		0	2	2	0	0	0	0	0
Carp		338	1386	274	497	353	732	651	726
Quillback		0	0	0	11	9	17	21	22
Catfish		284	503	330	268	237	790	367	381
Minnows/Fallfish		0	4	11	63	221	67	279	109
Golden shiner		0	2	0	0	0	0	0	0
Sucker		1718	1607	435	209	2019	573	2292	1156
Total	87	4041	5423	2964	5297	7250	7468	10796	7581

Chain Dam Fishway							
Fish Species/Type	PreAFM					PostAFM	
	1996	1997	1998	1999	2000	2001	2002
American shad	496	126	694	479	645	2057	1479
Gizzard shad	39	11	15	958	307	416	72
Striped bass	2	0	0	0	0	0	0
American eel	34	*	32*	*	13*	*	80
Sea lamprey	7	2	1	165	58	570	1321
Trout	96	119	238	220	318	205	321
Muskellunge	1	1	0	1	4	0	2
Walleye	1	0	0	0	0	1	0
Yellow perch	90	10	5	19	75	59	2
Bass	557	389	823	765	1572	575	876
Sunfish	828	329	456	395	1409	1089	850
Crappie	0	6	0	0	0	0	0
Carp	1343	153	158	1201	137	193	244
Quillback				0	0	0	0
Catfish	545	427	279	215	592	318	210
Minnows/Fallfish	182	27	565	1079	1280	320	158
Golden shiner	6	0	2	0	0	0	0
Sucker	2899	852	326	2417	922	1143	621
Total	7126	2452	3594	7914	7332	6946	6236

* No attempts were made to count elvers.

Table 5. Daily and monthly passage of adult American shad in the Lehigh River through the Easton Dam Fishway (RM 3.00) in the Lehigh River during the Pre Auxiliary Flow Modification (Pre-AFM) 1995-2000, and Post Auxiliary Flow Modification periods (Post-AFM) 2001-2002.

Easton Dam Fishway								
Date	Pre-AFM						Post-AFM	
	1995	1996	1997	1998	1999	2000	2001	2002
3/31						1	9	
March						1	9	
4/01						.	2	
4/02						.	.	
4/03						1	.	
4/04						3	.	
4/05						.	1	
4/06				1		1	.	
4/07				.		2	.	
4/08				.		.	4	
4/09				.		.	4	
4/10				.		.	2	2
4/11				.		.	2	6
4/12				1		.	.	3
4/13				.		.	1	.
4/14			1	3		.	2	5
4/15			1	1	1	.	5	3
4/16			.	3	2	.	.	.
4/17			.	9	.	3	1	31
4/18			.	11	.	1	1	54
4/19			.	5	1	.	.	107
4/20	2		.	.	.	1	.	143
4/21	2		.	.	1	3	.	.
4/22	.		.	1	1	.	2	1
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	2
4/29	23	7	8	9	81	1	59	.
4/30	11	2	74	102	112	5	41	.
April	70	10	101	182	251	23	519	362
5/01	.	.	90	98	42	6	165	1
5/02	.	4	33	104	62	23	337	3
5/03	.	5	19	92	41	17	365	5
5/04	2	1	10	96	27	8	170	17
5/05	7	.	10	75	72	29	186	65
5/06	42	7	38	39	132	40	157	228
5/07	20	.	18	75	73	24	81	299
5/08	9	1	3	146	49	10	116	320
5/09	18	.	8	25	44	13	161	230
5/10	19	2	6	10	55	3	143	35
5/11	8	38	17	2	119	.	77	68
5/12	9	35	33	.	140	114	118	122
5/13	17	3	48	3	105	136	100	4
5/14	18	1	15	4	89	78	73	.
5/15	12	3	17	157	63	222	38	.
5/16	18	1	29	224	44	111	47	13
5/17	53	2	17	530	30	82	39	4
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	2002
5/20	11	162	32	125	82	.	67	4
5/21	16	122	28	86	162	3	30	3
5/22	22	47	50	21	67	5	34	8
5/23	10	28	31	5	19	2	67	27
5/24	26	1	31	4	14	4	331	137
5/25	30	23	73	5	6	3	138	91
5/26	8	21	56	26	29	3	115	55
5/27	13	9	74	26	92	.	39	20
5/28	20	2	57	15	100	15	116	.
5/29	6	3	18	58	37	80	199	32
5/30	47	8	6	101	22	79	62	3
5/31	31	1	7	58	41	38	41	38
May	525	734	883	2838	1941	1277	3661	1832
6/01	84	11	55	62	44	17	32	190
6/02	28	8	33	55	39	53	12	155
6/03	15	12	38	43	19	51	41	147
6/04	2	6	7	10	2	32	43	102
6/05	19	19	61	8	.	6	41	32
6/06	31	19	9	6	.	16	50	87
6/07	11	9	3	5	5	8	44	5
6/08	13	6	16	1	12	25	35	10
6/09	6	17	3	.	11	126	23	90
6/10	.	62	50	.	3	86	27	45
6/11	.	47	56	2	2	14	14	35
6/12	15	4	39	1	1	.	26	41
6/13	13	.	21	1	.	7	28	24
6/14	8	59	5	.	4	14	16	16
6/15	.	6	9	.	.	28	16	3
6/16	1	21	3	2	1	39	19	7
6/17	5	21	4	7	1	26	6	14
6/18	.	37	4	42	.	17	23	10
6/19	3	9	.	9	.	23	9	5
6/20	6	5	2	1	.	21	13	6
6/21	7	3	4	2	.	18	8	12
6/22	2	2	1	6	1	55	5	16
6/23	1	6	5	2	1	22	.	21
6/24	.	1	6	1	2	5	3	8
6/25	.	.	3	2	1	5	1	15
6/26	1	2	6	2	1	11	6	6
6/27	1	.	1	1	.	29	1	8
6/28	4	2	.	1	.	16	3	.
6/29	.	1	.	.	.	18	1	5
6/30	2	.	.	1	.	3	3	3
June	278	395	444	273	150	791	549	1118
7/01	.	1	.	.	.	.	1	2
7/02	.	.	.	.	.	.	1	.
7/03	.	.	.	.	.	1	.	.
7/04	.	.	.	.	1	.	.	.
7/05	.	.	.	.	3	1	.	.
7/06	.	.	.	.	.	.	.	.
...	.	.	.	.	.	.	.	.
7/11	.	1	.	.	.	.	.	.
July	0	2	0	0	4	2	2	2
Total	873	1141	1428	3293	2346	2094	4740	3314

Table 6. The number of video frames documenting passage events of American shad through the Easton (RM 0.0, 2002 - 1995) and Chain Dam (RM 3.0, 2002 - 1996) fishways in the Lehigh River.

Easton Dam Fishway											
Year	Total Number of Frames	Passage Event					Percent of Passage Event				
		Single	Dual	Tertiary	Quintet	Pentad	Single	Dual	Tertiary	Quintet	Pentad
2002	3285	3257	27	1	.	.	99.15	0.82	0.03	...	...
2001	4677	4615	61	1	.	.	98.68	1.30	0.02	...	...
2000	2080	2066	14	.	.	.	99.33	0.67	...	...	...
1999	2266	2191	70	5	.	.	96.69	3.09	0.22	...	...
1998	3244	3195	49	.	.	.	98.49	1.51	...	...	...
1997	1428	1428	.	.	.	.	100	...	...	...	...
1996	1131	1121	10	.	.	.	99.12	0.88	...	...	...
1995	873	873	.	.	.	.	100.00	...	...	...	...
Chain Dam Fishway											
2002	1450	1422	27	1	.	.	98.07	1.86	0.07	...	...
2001	2015	1979	32	3	.	1	98.21	1.59	0.15	...	0.05
2000	637	630	6	1	.	.	98.90	0.94	0.16	...	...
1999	458	437	21	.	.	.	95.41	4.59	...	...	...
1998	687	680	7	.	.	.	98.98	1.02	...	...	...
1997	126	126	.	.	.	.	100.00	...	...	...	...
1996	492	489	2	1	.	.	99.39	0.41	0.20	...	...

Table 7. Total hourly passage of adult American shad migrating through the Easton Dam fishway (RM 0.0; Pre-Auxiliary Flow Modification (Pre-AFM) 1995-2000; Post-Auxiliary Flow Modification (Post-AFM) 2001-2002) in the Lehigh River during the early spring and summer.

Easton Dam Fishway										
Hours	Pre-AFM						Post-AFM			
	1995	1996	1997	1998	1999	2000	2001*	2001 ^a	2002	2002 ^a
0000	4	1	2	12	9	4	8	8	1	1
0100	2	2	1	6	3	4	1	1	2	2
0200	2	5	1	2	4	1	5	5	3	3
0300	3	3	2	3	5	1	10	10	1	1
0400	4	4	3	8	11	3	6	6	3	3
0500	.	11	6	21	38	19	41	33	22	22
0600	28	26	29	47	60	84	140	109	64	64
0700	34	55	41	82	75	149	217	190	128	127
0800	39	81	49	110	73	155	323	286	139	137
0900	37	55	29	88	105	162	173	170	140	139
1000	52	65	55	128	132	149	221	194	187	187
1100	52	66	83	171	115	129	326	274	217	217
1200	60	49	96	137	168	103	257	201	206	204
1300	65	58	122	173	190	151	313	254	196	194
1400	65	61	123	240	208	149	353	293	230	230
1500	63	84	136	353	219	125	356	307	283	283
1600	61	91	175	410	260	149	382	310	316	316
1700	85	101	142	425	260	175	483	401	373	371
1800	67	109	158	401	223	169	441	351	310	309
1900	69	116	106	272	151	128	431	351	328	327
2000	44	65	45	145	20	63	178	150	140	139
2100	20	21	13	36	10	14	17	17	13	13
2200	13	8	5	18	5	6	8	8	10	10
2300	4	4	6	5	2	2	9	9	2	2
Total	873	1141	1428	3293	2346	2094	4699	3938	3314	3301

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

2001^a – less 41 shad, and days were a significant time block was not recorded

May 11-14, 14-16, 16-18, and 28-30, 2001.

2002^a – Less those days were a significant time block was not recorded.

Table 8.

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 the Post Auxiliary Flow Modification period 2001-2002.

Easton Dam Fishway												
Date	0100-0500		0600-0900		1000-1200		1300-1500		1600-1900		2000-0000	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
3/31	.	.	.	.	.	.	1	.	2	.	6	.
March Summary							1		2		6	
4/01	.	.	.	.	.	.	.	.	1	.	1	.
4/02	.	.	.	.	.	.	.	.	.	.	.	.
4/03	.	.	.	.	.	.	.	.	.	.	.	.
4/04	.	.	.	.	.	.	.	.	.	.	.	.
4/05	.	.	1	.	.	.	.	.	.	.	.	.
4/06	.	.	.	.	.	.	.	.	.	.	.	.
4/07	.	.	.	.	.	.	.	.	.	.	.	.
4/08	2	.	.	.	.	.	.	.	.	.	2	.
4/09	1	.	.	.	.	.	.	.	2	.	1	.
4/10	1	.	.	1	.	.	1	.	.	1	.	.
4/11	.	.	.	1	.	.	.	1	2	4	.	.
4/12	.	.	.	1	.	.	.	.	.	2	.	.
4/13	.	.	.	.	.	.	1	.	.	.	.	.
4/14	.	.	1	.	1	2	.	2	.	1	.	.
4/15	.	.	2	3	.	.	3	.	.	.	.	.
4/16	.	.	.	.	.	.	.	.	.	4	.	1
4/17	.	.	.	1	.	11	.	6	1	13	.	.
4/18	.	.	.	5	.	10	.	10	.	28	1	1
4/19	.	.	.	6	.	10	.	26	.	51	.	14
4/20	.	2	.	19	.	26	.	31	.	62	.	3
4/21	.	.	.	.	.	.	.	.	.	.	.	.
4/22	.	.	.	.	.	.	1	1	.	.	1	.
4/23	.	.	4	.	1	.	18	.	38	.	3	.
4/24	.	.	12	.	29	.	33	.	64	.	3	.
4/25	.	.	25	.	27	.	17	.	29	.	2	.
4/26	.	.	3	.	1	.	3	.	1	.	.	.
4/27	.	.	.	.	.	.	.	.	.	.	.	.
4/28	.	.	5	.	13	1	18	.	41	1	2	.
4/29	2	.	13	.	4	.	14	.	22	.	4	.
4/30	4	.	9	.	1	.	4	.	23	.	.	.
April Summary	10	2	75	37	77	60	113	77	224	167	20	19

Table 8. (Cont'd)

Easton Dam Fishway												
Date	0100-0500		0600-0900		1000-1200		1300-1500		1600-1900		2000-0000	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
5/01	1	.	10	.	14	.	28	.	104	1	8	.
5/02	1	.	47	.	46	1	88	2	139	.	16	.
5/03	3	.	82	.	55	.	74	1	130	4	21	.
5/04	2	.	69	1	14	.	21	4	58	12	6	.
5/05	2	.	23	3	46	10	37	15	70	36	8	1
5/06	.	.	36	3	23	9	29	47	56	156	13	13
5/07	.	.	20	20	6	55	21	86	27	121	7	17
5/08	4	.	21	21	21	47	19	70	44	162	7	20
5/09	2	.	26	38	12	58	29	54	76	77	16	3
5/10	3	1	25	2	25	3	34	12	53	17	3	.
5/11	4	1	5	4	7	6	14	15	45	38	2	4
5/12	2	.	10	7	28	22	23	43	54	48	1	2
5/13	.	1	11	3	16	.	27	.	43	.	3	.
5/14	.	.	5	.	11	.	17	.	35	.	5	.
5/15	1	.	3	.	8	.	17	.	9	.	.	.
5/16	.	.	10	.	7	1	8	.	20	12	2	.
5/17	.	.	6	3	7	1	12	.	12	.	2	.
5/18	.	.	4	.	4	.	1	.	7	.	3	.
5/19	.	.	3	.	1	.	6	.	15	.	5	.
5/20	1	.	8	3	9	.	16	3	26	.	7	.
5/21	2	.	3	3	2	1	4	.	14	2	5	.
5/22	.	.	10	.	4	.	9	1	11	5	.	2
5/23	.	.	7	2	10	.	15	6	31	10	4	5
5/24	6	.	62	13	68	10	85	27	98	58	12	20
5/25	3	4	44	13	14	9	40	17	35	39	2	5
5/26	1	.	12	7	40	55	26	13	33	19	3	3
5/27	.	1	1	18	8	.	9	.	18	.	3	1
5/28	1	.	11	.	20	.	28	.	51	.	5	.
5/29	.	.	36	.	50	20	51	9	54	3	8	.
5/30	2	.	7	.	12	1	17	1	21	1	3	.
5/31	.	.	9	1	10	2	6	9	15	26	1	.
May Summary	41	8	626	159	598	287	811	435	1404	847	181	96

Table 8. (Cont'd)

Easton Dam Fishway												
Date	0100-0500		0600-0900		1000-1200		1300-1500		1600-1900		2000-0000	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
6/01	.	.	9	21	8	47	8	35	7	69	.	18
6/02	.	2	4	40	.	47	2	17	6	42	.	7
6/03	.	1	7	19	9	19	16	39	9	63	.	6
6/04	.	1	7	35	17	27	10	16	7	20	2	3
6/05	.	1	11	15	9	.	12	.	9	15	.	1
6/06	.	3	14	28	9	26	8	15	16	14	3	1
6/07	2	.	10	.	9	.	7	3	15	1	1	1
6/08	3	.	5	3	14	2	2	.	8	4	3	1
6/09	.	4	8	19	5	21	7	15	3	28	.	3
6/10	1	1	13	13	6	14	3	6	.	10	4	1
6/11	.	1	2	13	7	9	2	3	.	8	.	1
6/12	.	2	.	7	.	8	.	13	.	8	.	3
6/13	.	2	.	6	9	6	2	7	5	3	.	.
6/14	.	.	11	2	5	4	.	5	.	5	.	.
6/15	.	.	6	1	2	1	5	1	3	.	.	.
6/16	.	.	11	.	3	1	3	.	1	5	1	1
6/17	.	.	4	4	1	.	.	3	.	6	1	1
6/18	.	.	6	1	6	3	4	1	7	5	.	.
6/19	1	.	3	3	4	.	.	1	1	1	.	.
6/20	1	.	8	5	1	.	1	.	2	.	.	1
6/21	2	.	2	1	2	3	2	5	.	3	.	.
6/22	1	1	4	6	.	3	.	5	.	.	.	1
6/23	.	1	.	9	.	6	.	2	.	3	.	.
6/24	.	1	.	4	1	2	1	1	1	.	.	.
6/25	.	.	.	6	.	6	1	2	.	.	.	1
6/26	1	.	2	3	.	3	1	.	1	.	1	.
6/27	.	.	.	6	.	2	.	.	.	.	1	.
6/28	.	.	3	.	.	.	.	.	.	.	.	.
6/29	.	.	.	2	.	2	.	1	.	.	1	.
6/30	1	.	2	1	.	1	.	1	.	.	.	.
June Summary	13	21	152	273	127	263	97	197	101	313	18	51
7/01	.	.	.	2	.	.	.	.	1	.	.	.
7/02	.	.	.	.	.	.	1	.	.	.	.	.
7/03	.	.	.	.	.	.	.	.	.	.	.	.
7/04	.	.	.	.	.	.	.	.	.	.	.	.
7/05	.	.	.	.	.	.	.	.	.	.	.	.
...	.	.	.	.	.	.	.	.	.	.	.	.
7/11	.	.	.	.	.	.	.	.	.	.	.	.
July Summary	0	0	0	2	0	0	1	0	1	0	0	0
Total Passage	64	31	853	471	802	610	1023	709	1732	1327	225	166

Table 9.

Daily passage of adult American shad through the Chain Dam Fishway (RM 3.00) in the Lehigh River during the Pre-Auxiliary Flow Modification (Pre-AFM) 1996-2000 and Post Auxiliary Flow Modification periods (Post-AFM) 2001-2002.

Chain Dam Fishway							
Date	Pre-AFM					Post-AFM	
	1996	1997	1998	1999	2000	2001	2002
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
4/19			1			.	13
4/20			1			.	14
4/21			.		1	.	.
4/22			.		.	.	1
4/23			1		.	.	.
4/24			.		.	3	.
4/25			2		.	3	.
4/26		2	.		.	1	.
4/27		.	1		.	3	.
4/28		.	.		.	8	2
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	1
5/05		.	9	.	2	101	6
5/06		.	15	.	6	36	25
5/07		.	34	1	2	9	139
5/08		.	4	1	11	8	177
5/09		.	9	1	.	13	19
5/10		1	3	29	1	21	5
5/11	1	.	2	6	10	86	3
5/12	2	3	.	76	11	10	110
5/13	.	.	1	26	11	40	4
5/14	.	1	.	40	27	19	4
5/15	.	.	1	23	26	8	
5/16	.	.	73	5	80	63	4
5/17	.	1	113	2	23	34	72
5/18	3	.	100	1	91	2	51
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	4
5/24	4	.	38	2	1	7	28
5/25	4	1	.	6	1	244	34
5/26	3	9	3	5	2	78	26

Table 9. (Cont'd)

Chain Dam Fishway							
Date	Pre-AFM					Post-AFM	
	1996	1997	1998	1999	2000	2001	2002
5/27	1	2	1	9	8	59	30
5/28	2	33	1	2	5	94	75
5/29	2	3	.	12	2	111	21
5/30	1	1	4	.	4	103	.
5/31	10	.	.	.	7	12	24
6/01	4	1	4	.	8	11	75
6/02	8	1	1	7	16	40	110
6/03	9	.	6	5	1	23	93
6/04	1	4	1	3	.	6	93
6/05	15	3	4	3	1	19	50
6/06	6	5	.	.	2	8	31
6/07	6	1	2	.	.	4	5
6/08	4	.	.	.	5	.	4
6/09	1	.	.	3	25	1	5
6/10	66	.	6	3	22	.	4
6/11	35	8	2	2	16	1	3
6/12	9	1	2	9	90	1	9
6/13	10	5	.	2	6	21	12
6/14	34	.	.	6	1	3	17
6/15	15	1	.	2	.	15	1
6/16	12	.	4	3	9	8	17
6/17	5	1	12	.	2	5	3
6/18	40	.	2	.	.	.	6
6/19	8	.	1	1	5	1	2
6/20	3	3	4	.	4	.	4
6/21	4	3	3	.	6	.	15
6/22	10	.	9	.	5	.	5
6/23	26	.	3	.	11	.	1
6/24	5	.	2	.	5	1	3
6/25	5	.	2	.	2	1	.
6/26	.	.	3	.	1	1	.
6/27	2	.	.	.	6	2	5
6/28	.	.	.	.	7	.	9
6/29	1	.	1	.	3	.	.
6/30	2	.	.	2	1	23	1
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	1479

Table 10. Total hourly passage of adult American shad migrating through the Chain Dam (RM 3.00), fishway in the Lehigh River during the Pre-Auxiliary Flow Modification (Pre-AFM; 1996-2000) and Post Auxiliary Flow Modification periods (Post-AFM; 2001-2002) during the early spring and summer.

Chain Dam Fishway							
Hours	Pre-AFM					Post-AFM	
	1996	1997	1998	1999	2000	2001	2002
0000	.	.	2	1	.	.	1
0100	2	.	1	2	.	.	1
0200	.	1	.	1	.	1	.
0300	2	2	1	1	1	3	1
0400	3	.	.	1	.	1	.
0500	5	2	4	10	1	9	1
0600	22	2	8	16	11	31	13
0700	54	1	13	20	36	38	36
0800	40	3	11	45	51	70	44
0900	57	3	29	44	40	90	46
1000	35	4	24	41	32	159	55
1100	31	1	21	40	42	155	78
1200	33	2	47	27	53	219	83
1300	31	13	53	39	65	214	81
1400	20	18	70	49	79	227	150
1500	31	18	89	50	87	244	182
1600	27	18	101	41	58	208	186
1700	24	8	73	19	38	153	178
1800	22	8	59	22	19	100	177
1900	28	12	49	8	21	84	117
2000	23	8	34	1	10	39	42
2100	2	2	2	1	1	6	3
2200	2	.	1	.	.	3	3
2300	2	.	2	.	.	3	1
Total	496	126	694	479	645	2057	1479

Table 11. Daily and monthly passages of adult American shad through the Chain Dam Fishway (RM 3.00) in the Lehigh River per the following six diurnal periods: 0100-0500; 0600-0900; 1000-1200; 1300 -1500; 1600-1900; 2000-0000 hours during the Post Auxiliary Flow Modification period (2001-2002).

Chain Dam Fishway												
Date	0100-0500		0600-0900		1000-1200		1300-1500		1600-1900		2000-2300	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
4/08	.	.	1	.	.	.	.	.	.	.	.	.
4/09	.	.	.	.	.	.	.	.	.	.	1	.
4/10	.	.	2	.	1	.	2	.	10	.	1	.
4/11	1	.	1	.	2	.	2	.	.	.	.	.
4/12	.	.	1	.	.	.	.	.	.	.	1	.
4/13	.	.	.	.	.	.	.	.	.	.	.	.
4/14	.	.	1	.	.	.	.	.	.	.	.	.
4/15	.	.	.	.	.	.	.	.	.	.	.	.
4/16	.	.	.	.	.	.	.	.	.	.	.	.
4/17	.	.	.	.	.	.	.	.	.	.	.	.
4/18	.	.	.	.	.	1	.	2	.	1	.	.
4/19	.	.	.	.	.	.	.	6	.	7	.	.
4/20	.	.	.	.	.	.	.	6	.	8	.	.
4/21	.	.	.	.	.	.	.	.	.	.	.	.
4/22	.	.	.	.	.	.	.	.	.	1	.	.
4/23	.	.	.	.	.	.	.	.	.	.	.	.
4/24	.	.	.	.	.	.	3	.	.	.	.	.
4/25	.	.	.	.	.	.	1	.	2	.	.	.
4/26	.	.	.	.	.	.	1	.	.	.	.	.
4/27	.	.	.	.	.	.	1	.	2	.	.	.
4/28	.	.	.	.	1	.	4	.	3	2	.	.
4/29	.	.	.	.	.	.	2	.	1	.	.	.
4/30	.	.	.	.	.	.	3	.	5	.	.	.
April Summary	1	0	6	0	4	1	19	14	23	19	5	0
5/01	.	.	1	.	9	.	16	.	22	.	.	.
5/02	1	.	14	.	15	.	64	.	58	.	2	.
5/03	1	.	16	.	81	.	76	.	22	.	.	.
5/04	.	.	33	.	21	.	57	1	26	.	2	.
5/05	1	.	22	.	55	.	18	1	4	3	1	2
5/06	.	.	2	.	14	.	12	4	8	19	.	2
5/07	.	.	.	6	1	4	.	37	8	89	.	3
5/08	.	.	.	3	4	13	1	53	3	94	.	14
5/09	.	1	.	1	9	2	2	5	2	9	.	1
5/10	.	.	2	.	4	.	6	2	4	3	5	.
5/11	1	.	10	.	23	.	39	3	11	.	2	.
5/12	.	.	2	2	2	.	2	7	2	95	2	6
5/13	.	.	4	.	17	1	8	2	9	1	2	.
5/14	.	.	4	.	5	1	7	1	3	2	.	.
5/15	.	.	1	.	2	.	3	.	2	.	.	.
5/16	1	.	3	.	13	.	20	2	24	2	2	.
5/17	2	.	5	.	10	1	5	29	9	41	3	1
5/18	1	.	1	1	.	7	.	31	.	12	.	.
5/19	.	.	.	.	1	.	2	.	1	.	.	.
5/20	.	.	11	.	33	.	29	.	19	.	1	.
5/21	.	.	.	.	.	.	.	.	.	.	.	.
5/22	.	.	.	.	.	.	1	.	3	.	.	.
5/23	.	.	.	.	.	.	.	1	5	3	.	.
5/24	.	.	1	.	2	1	1	9	3	18	.	.
5/25	.	.	2	1	79	3	109	6	53	24	1	.
5/26	.	.	7	.	14	2	19	12	32	11	6	1
5/27	.	.	.	5	2	4	20	8	36	10	1	3
5/28	.	.	5	24	7	9	43	21	35	21	4	.
5/29	1	.	18	4	8	2	29	3	46	11	9	1
5/30	1	.	14	.	42	.	25	.	20	.	1	.
5/31	1	.	1	4	3	5	5	7	2	8	.	.
May Summary	11	1	179	51	476	55	619	245	472	476	44	34

Table 11. (Cont'd)

Chain Dam Fishway												
Date	0100-0500		0600-0900		1000-1200		1300-1500		1600-1900		2000-2300	
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
6/01	.	.	2	10	4	11	3	13	2	40	.	1
6/02	.	1	3	18	12	36	15	15	10	36	.	4
6/03	.	1	2	2	6	24	8	39	7	26	.	1
6/04	.	.	1	15	.	39	3	23	2	14	.	2
6/05	.	.	2	7	4	15	9	12	4	16	.	.
6/06	.	.	5	12	2	14	.	2	1	3	.	.
6/07	.	.	.	2	2	2	2	1	.	.	.	.
6/08	.	.	.	.	.	1	.	1	.	2	.	.
6/09	.	.	.	.	1	.	.	2	.	3	.	.
6/10	.	.	.	1	.	.	.	2	.	1	.	.
6/11	.	.	.	.	.	2	.	1	1	.	.	.
6/12	.	.	1	.	.	3	.	5	.	.	.	1
6/13	1	.	8	3	4	.	2	6	5	2	1	1
6/14	.	.	2	2	1	.	.	5	.	10	.	.
6/15	.	.	.	.	10	.	.	.	5	1	.	.
6/16	.	.	.	2	4	6	1	4	2	1	1	4
6/17	.	.	2	2	1	.	.	1	1	.	1	.
6/18	.	.	.	.	.	.	.	5	.	1	.	.
6/19	.	.	1	.	.	.	.	.	.	2	.	.
6/20	.	.	.	.	.	1	.	2	.	1	.	.
6/21	.	.	.	6	.	3	.	5	.	1	.	.
6/22	.	.	.	2	.	1	.	2	.	.	.	.
6/23	.	.	.	.	.	1	.	.	.	.	.	.
6/24	.	.	.	.	.	.	1	3	.	.	.	.
6/25	.	.	.	.	.	.	1	.	.	.	.	.
6/26	.	.	.	.	.	.	.	.	1	.	.	.
6/27	.	.	1	2	1	.	.	3	.	.	.	.
6/28	.	.	.	1	.	1	.	.	.	7	.	.
6/29	.	.	.	.	.	.	.	.	.	.	.	.
6/30	1	.	10	1	1	.	3	.	7	.	1	.
June Summary	2	2	40	88	53	160	48	152	48	167	4	14
7/01	.	.	.	.	.	.	.	.	.	.	.	.
7/02	.	.	3	.	.	.	.	.	.	.	.	.
7/03	.	.	.	.	.	.	.	.	.	.	.	.
7/04	.	.	.	.	.	.	.	.	.	.	.	.
7/05	.	.	.	.	.	.	.	.	.	.	.	.
7/06	.	.	.	.	.	.	.	.	.	.	.	.
July Summary	0	0	3	0	0	0	0	0	0	0	0	0
Total Passage	14	3	228	139	533	216	686	411	543	662	53	48

Table 12. Otolith analysis for origin and age determination (hatchery vs. wild) from adult American shad by sex collected in the Lehigh River in 2002 (N = 100, 56 females: 44 males), 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 OTC (octatetracycline) treatment applied by the PFBC to stocked fry.

Otolith Age	Hatchery Origin							
	1999		2000		2001		2002	
	Female	Male	Female	Male	Female	Male	Female	Male
Unknown	0	3	0	0	0	0	1	1
3	0	2	0	1	0	0	0	1
4	6	44	1	4	1	15	1	6
5	16	6	23	50	5	23	18	18
6	13	4	9	1	31	19	7	15
7	1	0	1	0	2	0	18	0
8	0	0	0	1	0	0	1	0
9	0	0	0	0	0	0	1	0
Total	36	59	34	57	39	57	47	41
Wild Origin								
Unknown	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0
4	0	5	0	3	0	2	3	1
5	1	0	0	4	1	6	4	1
6	1	0	1	1	0	0	1	1
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
Total	2	6	1	8	1	8	8	3
Grand Total	38	65	35	65	40	65	56	44

Table 13. Daily tagging (OTC) pattern history of American shad stocked in the Lehigh River from 1993 to 2000 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
9	1993	3,13,17			790,000	-	Lehigh R.	Delaware R.
					2,499,000	44,000	Juniata R.	Delaware R.
8	1994	3,13,17			642,000	-	Lehigh R.	Delaware R.
					785,000	99,500	Juniata R.	Delaware R.
7	1995	5			1,044,000	-	Lehigh R.	Delaware R.
					8,339,000	-	Juniata R.	Hudson/Delaware R.
					731,000	-	Susquehanna R.	Hudson/Delaware R.
					5,05,000	-	James R.	Pamunkey R.
					1,175,000	-	Potomac R.	Potomac R.
			1997	5	236,000	-	Juniata R.	Hudson/Delaware R.
					2,801,000	-	Susquehanna R.	Hudson/Delaware R.
			1994	8	996,000	-	Juniata R.	Hudson R.
6	1996	3,6,9			993,000	-	Lehigh R.	Delaware R.
					43,000	-	Standing Ck.	Delaware R.
			1998	4	565,000	-	Juniata R.	Hudson R.
			1997	5	486,000	-	Juniata R.	Susquehanna R.
5	1997	5,9,13			1,247,000	-	Lehigh R.	Delaware R.
			1994	8	2,004,000	-	Juniata R.	Hudson R.
4	1998	3,9,12			948,000	-	Lehigh R.	Delaware R.
					321,000	-	W. Conewago Ck.	Hudson R.
			1996	6	561,000		W. Br. Susquehanna R.	Hudson/Delaware R.
3	1999	9,12,15			501,000		Lehigh R.	Delaware R.
			1998	4	305,000		Conodoquinet Cr.	Hudson R.
			1996	6	172,000		Conodoquinet Cr.	Delaware
2	2000	3,6,9,12,18			447,000		Lehigh R.	Delaware R.
			1999	3	219,000		W. Conewago Ck	Hudson

Table 14. Potential egg sources of adult hatchery shad caught at RM 3.00 (Chain Dam tailrace) in the Lehigh River on June 6, 2002 based on the daily OTC (octatetracycline) immersion-tagging pattern for read otolith ages and known otolith ages as determined by the PFBC's Division of Research. D= Delaware River, DH=Delaware and/or Hudson Rivers, H=Hudson River, and S=Susquehanna River.

Tagging Pattern	Otolith Age					Known Otolith Age		
	D	DH	H	S	Total	D	DH	Total
3,13,17	1	.	.	.	1	.	.	.
5	.	17	1	.	18	1	16	17
3,6,9	17	1	.	4	22	26	.	26
5,9,13	27	1	.	.	28	31	2	33
3,9,12	3	2	.	.	5	3	4	7
9,12,15	1	.	.	.	1	1	.	1
Total	49	21	1	4	75	62	22	84

Table 15. Summary of otolith age distribution of sample and mean total and fork lengths (mm) by age and sex for American shad caught at RM 3.00 (base of the Chain Dam tailrace) in the Lehigh River from 2002 through 1999. Fork lengths were only taken in 2000 and 1999.

Female									
Year	N	Otolith Age							
		2	3	4	5	6	7	8	9
2002	54	...	...	4	22	8	18	1	1
2001	40	...	...	1	6	31	2	...	...
2000	35	...	...	1	23	10	1	...	...
1999	38	...	...	6	17	14	1	...	...
Mean Total Length (mm) at Age									
2002	54	...	...	515	544	547	569	573	569
2001	40	...	...	513	499	551	558	...	...
2000	35	...	...	478	522	563	532	...	...
1999	35	...	...	479	517	535	459	...	...
Mean Fork Length (mm) at Age									
2002	...	...	...	...	...	...	...	...	...
2001	...	...	...	...	...	...	...	...	...
2000	35	...	...	424	463	497	474	...	...
1999	35	...	...	425	457	471	411	...	...
Male									
2002	43	...	1	7	19	16	...	...	...
2001	69	...	...	18	32	19	...	1	...
2000	65	...	1	7	54	2	...	...	...
1999		1	9	47	4				
Mean Total Length (mm) at Age									
2002	43	...	406	464	490	505	...	...	...
2001	69	...	...	456	479	507	...	497	...
2000	65	...	426	447	487	504	...	...	...
1999		383	440	452	466				
Mean Fork Length (mm) at Age									
2000	65	...	379	395	429	443	...	442	...
1999	61	341	388	398	410	...	...	...	...

Table 16. Summary scale age distribution of sample and mean total and fork lengths (mm) by age and sex for American shad caught at RM 3.00 (base of the Chain Dam tailrace) in the Lehigh River from 2002 through 1998. Fork lengths were only taken in 2000, 1999 and 1998.

Female									
Year	N	Scale Age							
		2	3	4	5	6	7	8	9
2002	54	...	...	9	29	15	1	...	...
2001	37	...	...	5	20	8	4	...	...
2000	33	...	...	1	19	12	1	...	...
1999	35	...	3	16	15	1	...	...	...
1998	22	...	...	6	16	1	...	...	...
Mean Total Length (mm)									
2002	54	...	...	510	551	570	569	...	...
2001	40	...	...	495	540	566	572	...	...
2000	35	...	...	478	525	540	574	...	...
1999	35	...	501	507	529	526	...	...	...
1998	23	...	...	513	532	539	...	...	...
Mean Fork Length (mm)									
2000	35	...	...	424	466	477	508	...	...
1999	35	...	446	447	467	460	...	...	...
1998	23	...	...	455	470	477	...	...	...
Male									
2002	44	...	1	15	27	1	...	...	...
2001	67	...	7	39	18	3	...	...	...
2000	63	...	1	11	41	10	...	...	...
1999	61	1	9	47	4	...	...	...	...
1998	24	...	8	14	2	...	...	...	...
Mean Total Length (mm)									
2002	44	...	406	469	507	452	...	...	...
2001	67	...	442	478	495	518	...	...	...
2000	63	...	430	454	486	493	...	...	...
1999	61	383	440	452	466	...	...	...	...
1998	24	...	441	466	466	...	...	...	...
Mean Fork Length (mm)									
2000	63	...	378	400	428	434	...	...	...
1999	61	341	388	398	410	...	...	...	...
1998	24	...	390	411	412	...	...	...	...

Table 17. Scale analysis for age and repeat spawning from 98 of the 100 (54 females; 44 males) adult American shad collected in the Lehigh River's Chain Dam tailrace on June 6, 2002.

Virgin shad		
Scale Age	Female	Male
Unageable	2	...
3	...	1
4	9	14
5	22	23
6	11	...
7	...	...
Total	44	38
Repeat Spawning		
	Female	Male
	1 Mark	1 Mark
Unageable	...	...
3	...	...
4	...	1
5	6	4
6	5	1
7	1	...
Total	12	6
Grand Total	56	44

Table 18. Comparison of scale and otolith ages for 95 (52 females, 43 males) of the 100 adult American shad caught at RM 3.00 (Chain Dam tailrace) in the Lehigh River on June 6, 2002.

Female Otolith Difference							Male Otolith Difference				
Scale Age	-2	-1	=	+1	+2	+3	-2	-1	=	+1	+2
3	.								1		
4	.		2	6		1			3	9	3
5	.	2	11	4	9	1		3	10	13	
6	.	3	4	8			1				
7	.				1						
Total	.	5	17	18	10	2	1	3	14	22	3
Percent Total	.	10	32	35	19	4	2	7	33	51	7
Grand Total	1	8	31	40	13	2					
Percent Grand Total	1	8	33	42	14	2					

Table 19. Comparison of known otolith ages with scale ages from 79 (44 females, and 35 males) of the 100 American shad caught at RM 3.00 (Chain Dam tailrace) in the Lehigh River on June 6, 2002.

Otolith Age	Female Scale Difference					Male Scale Difference				
	-2	-1	=	+1	+2	-2	-1	=	+1	+2
3	.	.	.	.	.	.	.	1	.	.
4	.	.	2	.	.	.	.	3	1	1
5	.	4	6	3	.	.	7	13	.	.
6	1	7	3	.	.	3	5	.	.	.
7	8	9	1	.	.	1	.	.	.	.
Total	9	20	12	3	.	4	12	17	1	1
Percent Total	20	46	27	7	.	11	34	49	3	3
Grand Total	13	32	29	4	1					
Grand Percent	16	41	37	5	1					

Table 20. 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 during the Pre Auxiliary Flow Modification period 1995-2000.

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

Table 20. (Cont'd)

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

Table 20. (Cont'd)

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

Table 20. (Cont'd)

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

Table 20. (Cont'd)

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

Table 20. (Cont'd)

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

Table 21. Daily and monthly passages of adult American shad through the Chain Dam Fishway (RM 3.00) in the Lehigh River per the following six diurnal periods: 0100-0500; 0600-0900; 1000-1200; 1300- 500; 1600-1900; 2000-0000 during the Pre Auxiliary Flow Monitoring period (1996 –2000).

Chain Dam Fishway															
Date	0100-0500					0600-0900					1000-1200				
	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
4/08															
4/09															
4/10															
4/11															
4/12															
4/13															
4/14															
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			.					.		.			.		
4/29			.					.		.			.		
4/30			.					.		.			.		
April Summary	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0
5/01			.					.		.			.		.
5/02			.					.		.			2	2	.
5/03			.					.		.			1	.	1
5/04			.				1	2		.			.	.	.
5/05			.				.	2		.			.	.	1
5/06			.				.	.		1			2	.	.
5/07			.				.	9		1			2	.	.
5/08			.	1	1		.	2		4			1	.	1
5/09			1	.	.		.	.		.			1	1	.
5/10			.	.	.		.	.	3	.			.	7	.
5/11			.	.	.		.	.	3	.			.	1	1
5/12			.	1	.		.	.	29	3	1		.	22	.
5/13			.	.	.		.	.	6	1			.	14	4
5/14			.	.	.		.	.	.	9			.	10	4
5/15			.	.	.		.	.	1	1			.	1	1
5/16			.	.	.		.	.	3	15			3	.	25
5/17		1	.	.	.		.	7		1			21	.	4
5/18		.	2	.	.	1	.	23	1	1			16	.	16
5/19	1	.	.	.	.	.	.	2	3	22	1		5	2	5
5/20	1	1	.	.	.	2	.	1	.	.	3		3	4	.
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	2		4	.	.
5/25	.	.	.	.	.	.	.	.	.	.	.		.	.	.
5/26	.	.	.	.	.	.	.	2	.	.	.	1	.	2	.
5/27	.	.	.	.	.	.	1	.	5	1	.	.	.	2	2
5/28	.	.	1	.	.	.	.	.	.	.	.	2	.	1	1
5/29	.	.	.	.	.	.	.	.	.	1	2	1	.	2	1
5/30	.	.	.	.	.	1	.	.	.	.	.	1	1	.	.
5/31	.	.	.	.	.	4	.	.	.	.	.	.	.	.	1
May Summary	6	3	5	10	1	25	4	58	106	62	24	5	70	91	68

Table 21. (Cont'd)

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

Table 21. (Cont'd)

Date	Chain Dam Fishway														
	1300-1500					1600-1900					2000-0000				
	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
4/08															
4/09															
4/10															
4/11															
4/12															
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								.					.		
4/25								.					.		
4/26		1					1	.					.		
4/27		.					.	1					.		
4/28		.					.	.					.		
4/29		.					1	1					.		
4/30		.					2	1					.		
April Summary		1					4	9					1		
5/01		.	.	1			.	2		.			.		
5/02		.	2	1			.	8	3	.			1		
5/03		.	1	2			.	7	2	.			.		
5/04		.	2	.			.	6	.	.			1		1
5/05		.	1	.	1		.	6	.	.			.		.
5/06		.	.	.	2		.	10	.	3			3		.
5/07		.	8	1	.		.	14	.	1			1		.
5/08		.	1	.	.		.	.	.	5			.		.
5/09		.	5	.	.		.	2	.	.			.		.
5/10		1	2	7	.		.	1	12	1			.		.
5/11		.	.	2	4	1	.	2	.	4			.		1
5/12		2	.	13	7	1	1	.	10	1			.	1	.
5/13		.	.	2	.	.	.	1	4	6			.	.	.
5/14		.	.	19	10	.	1	.	11	4			.	.	.
5/15		.	1	12	11	.	.	.	8	11			.	1	2
5/16		.	16	2	26	.	.	49	.	14			5	.	.
5/17		.	35	2	15	.	.	45	.	3			5	.	.
5/18	1	.	28	.	48	1	.	29	.	26			2	.	.
5/19	1	3	18	4	14	2	1	9	1	4	1	1	1	.	.
5/20	5	9	.	19	.	11	2	1	1	.	4	.	.	.	.
5/21	4	.	40	11	.	7	3	14	10	2	14	.	3	.	.
5/22	6	1	18	4	.	13	.	17	4	2	1	2	3	.	.
5/23	2	.	1	8	.	2	.	7	2	.	.	.	.	.	.
5/24	.	.	13	.	.	.	.	15	2	.	.	.	5	.	.
5/25	2	.	.	4	1	2	1	.	2	.	.	.	.	.	.
5/26	.	6	1	2	.	3	2	.	1	2	.	.	.	.	.
5/27	1	1	1	.	3	.	.	.	2	2	.	.	.	.	.
5/28	.	9	.	1	2	2	.	.	.	2	.	4	.	.	.
5/29	.	2	.	7	.	.	18	.	3	.	.	.	.	.	.
5/30	.	.	1	.	4	.	.	2	.	.	.	.	.	.	.
5/31	3	.	.	.	3	3	.	.	.	3	.	.	.	.	.
May Summary	25	34	195	124	151	48	29	247	78	96	20	7	30	2	4

Table 21. (Cont'd)

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

Table 22. 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
2002	April	2	37	60	77	167	19
	May	8	159	287	435	847	96
	June	21	273	263	197	313	51
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

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 22. (Cont'd)

Chain Dam Fishway							
Year	Month	Diurnal Period					
		0100-0500	0600-0900	1000-1200	1300-1500	1600-1900	2000-0000
2002	April	0	0	1	14	19	0
	May	1	51	55	245	476	34
	June	2	88	160	152	167	14
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
1996	April	.	1	1	2	6	.
	May	15	142	87	116	307	67
	June	10	74	93	83	104	31

Table 23. Summary of origin determination (hatchery vs. wild) and annual run composition of American shad, sexes combined, based on samples collected in the Lehigh River from 1999 to 2002. Easton Fishway (RM 0.00) opened in 1994, thus the first year expected to contain returning river bred American shad is in 1998.

Year	Total N	N		Percentage		Easton Passage (N)	Estimated Composition of Run	
		Hatchery	Wild	Hatchery	Wild		Hatchery	Wild
2002	99	88	11	89	11	3314	2929	365
2001	105	96	9	91	9	4740	4313	427
2000	100	91	9	91	9	2094	1906	188
1999	102	95	7	92	8	2346	2158	188
1998	53	52	1	98	2	3293	3227	66
1997	54	51	3	94	6	1428	1341	87
1996	39	36	3	92	8	1141	1050	91
1995	33	24	9	73	27	873	637	236

Table 25. Average total and fork length (mm), and weight (g) by sex by constant gillnet mesh size (stretch inches) for 248 female adult American shad caught in the Delaware River at Smithfield Beach (RM 218.0 from May through June 5, 2002 in 11 nights of netting).

May 8-9, 2002													
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	...	...	...	...	...	...	...	...	...	...	...	...	...
4.75	3	567.3	5.9	563	574	493.0	22.3	469	513	2006.3	294.2	1735	2319
5.0	12	564.3	25.5	523	606	499.3	23.1	468	538	1940.1	263.7	1566	2253
5.25	7	575.7	17.4	550	594	509.4	18.3	488	532	1877.7	325.5	1427	2280
5.5	11	570.5	17.4	549	600	504.1	15.7	481	529	2021.2	487.9	1510	2584
5.75	9	577.8	20.1	540	601	512.4	17.0	482	535	2015.6	138.3	1817	2183
6.0	9	579.0	19.5	552	603	509.7	16.4	485	529	2151.2	223.9	1926	2561
May 12, 2002													
4.5	...	...	...	...	...	...	...	...	...	...	...	...	...
4.75	1	550.0	N/A	550	550	495.0	N/A	495	495	1842.0	N/A	1842	1842
5.0	5	562.4	34.4	510	600	497.2	25.9	459	523	1646.2	142.3	1421	1794
5.25	...	...	...	...	...	...	...	...	...	...	...	...	...
5.5	2	569.5	14.8	559	580	501.5	12.0	493	510	2374.5	495.7	2024	2725
5.75	6	573.8	26.3	540	605	514.0	24.2	480	542	2066.3	322.9	1761	2681
6.0	5	570.6	34.8	515	610	509.2	30.5	464	549	2231.6	207.9	1879	2424
May 29 - 30, 2002													
4.5	...	...	...	...	...	...	...	...	...	...	...	...	...
4.75	...	...	...	...	...	...	...	...	...	...	...	...	...
5.0	2	554.0	19.8	540	568	492.5	20.5	478	507	1500.5	276.5	1305	1696
5.25	2	566.5	17.7	554	579	494.5	13.4	485	504	1562.5	361.3	1307	1818
5.5	...	...	...	...	...	...	...	...	...	...	...	...	...
5.75	...	...	...	...	...	...	...	...	...	...	...	...	...
6.0	...	...	...	...	...	...	...	...	...	...	...	...	...
June 2 - 5, 2002													
4.5	12	528.6	34.6	435	561	466.3	30.3	385	495	1167.9	255.0	833	1683
4.75	30	556.7	19.6	520	596	492.4	16.3	460	520	1291.3	181.5	1013	1456
5.0	100	557.5	19.7	515	610	494.7	16.6	461	535	1378.3	197.9	1015	2007
5.25	11	562.5	20.1	535	589	501.7	19.9	479	532	1488.1	155.3	1251	1689
5.5	7	575.4	14.1	554	600	510.9	13.9	487	533	1782.0	235.6	1505	2165
5.75	7	572.7	17.9	543	604	507.9	18.7	484	544	1848.4	266.4	1568	2299
6.0	7	581.6	25.1	548	615	517.1	23.7	485	548	1964.1	313.2	1570	2415
Summary													
4.5	12	528.6	34.6	435	561	466.3	30.3	385	495	1167.9	255.0	833	1683
4.75	34	557.4	18.8	520	596	492.5	16.2	460	520	1370.6	288.8	952	2319
5.0	119	558.3	20.9	510	610	495.2	17.4	459	538	1448.2	266.7	1015	2253
5.25	20	567.5	19.1	535	594	503.7	18.6	479	532	1631.9	296.3	1251	2280
5.5	20	572.2	15.5	549	600	506.2	14.5	481	533	1972.8	433.0	1387	2880
5.75	22	575.1	20.6	540	605	511.4	18.9	480	544	1976.3	246.6	1568	2681
6.0	21	577.9	24.5	515	615	512.1	21.8	464	549	2108.0	246.6	1570	2561

Table 26. Summary of mean total and fork length (mm), and weight (g) by constant gillnet mesh size (stretch inches) for adult female American shad caught in the Delaware River at Smithfield Beach (RM 218.0) for 2002 (N=248), 2001 (N=687), 2000 (N=316, (306)), and 1999 (N=636). () indicated number of shad used in weight assessment. Note: 5.75 inch mesh net not used in 1999 or 2000.

Mesh Size (inches)	N	2002				2001				2000				1999			
		Total Length (mm)				Fork Length (mm)				Weight (g)							
		Mean	Std. Dev.	Min	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
4.5	12	528.6	34.6	435	561	466.3	30.3	385	495	1167.9	255.0	833	1683				
4.75	34	557.4	18.8	520	596	492.5	16.2	460	520	1370.6	288.8	952	2319				
5.0	119	558.3	20.9	510	610	495.2	17.4	459	538	1448.2	266.7	1015	2253				
5.25	20	567.6	19.1	535	594	503.7	18.6	479	532	1631.9	296.3	1251	2280				
5.5	20	572.2	15.5	549	600	506.2	14.5	481	533	1972.8	433.0	1387	2880				
5.75	22	575.1	20.6	540	605	511.4	18.9	480	544	1976.3	246.6	1568	2681				
6.0	21	577.9	24.5	515	615	512.1	21.8	464	549	2108.0	264.6	1570	2561				
2001																	
4.5	93	535.6	21.5	492	600	475.1	18.8	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	308	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				
2000																	
4.5	48 (45)	543.7	29.6	463	608	486.4	28.4	435	585	1455.0	372.7	819	2606				
4.75	20 (18)	556.0	19.2	512	587	493.5	17.4	460	525	1617.8	343.0	1093	2150				
5.0	99 (96)	550.0	25.8	497	607	489.0	22.9	441	546	1640.4	364.2	985	2548				
5.25	51 (50)	551.3	21.7	499	592	491.3	19.0	448	530	1650.8	286.1	1193	2508				
5.5	69 (69)	553.6	27.8	457	613	493.2	21.4	445	545	1848.2	291.7	1159	2685				
5.75	...	...	...	...	...	...	...	...	...	...	...	...	...				
6.0	29 (28)	558.9	21.8	510	601	495.8	20.6	454	534	2026.1	290.5	1545	2779				
1999																	
4.5	63	523.5	18.0	480	563	461.4	16.7	422	498	1249.1	254.6	800	2150				
4.75	73	536.2	21.1	455	577	472.6	18.9	407	507	1534.9	318.6	1000	2550				
5.0	373	533.8	18.6	478	595	471.4	16.3	423	525	1434.7	215.8	750	2200				
5.25	90	541.9	19.7	501	606	478.6	17.0	448	532	1595.7	210.0	1175	2050				
5.5	30	548.6	25.0	490	614	485.0	21.8	435	531	1749.7	222.7	1350	2209				
6.0	7	527.0	11.3	519	535	469.5	17.7	457	482	1315.0	233.3	1150	1480				

Table 27. Average total and fork length (mm), and weight (g) by sex by constant gillnet mesh size (stretch inches) for 152 adult male American shad caught in the Delaware River at Smithfield Beach (RM 218.0 from May 8 through June 5, 2002 in 10 nights of netting.

May 8 – 9, 2002													
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	8	488.5	31.7	422	515	433.4	26.5	377	456	1111.5	177.0	735	1269
4.75	10	496.0	39.7	423	545	438.7	33.4	375	483	1120.5	236.2	718	1553
5.0	37	514.7	21.5	461	550	453.3	18.6	406	485	1340.1	190.0	996	1804
5.25	1	529.0	N/A	529	529	465.0	N/A	465	465	1505.5	N/A	1505	1505
5.5	1	532.0	N/A	532	532	471.0	N/A	471	471	1406.0	N/A	1406	1406
5.75	1	529.0	N/A	529	529	465.0	N/A	465	465	1623.0	N/A	1623	1623
6.0	...	...	...	...	...	...	...	...	...	...	...	...	...
May 12, 2002													
4.5	3	508.7	15.2	495	525	457.0	17.1	441	475	1296.0	162.4	1120	1440
4.75	2	502.0	25.5	484	520	442.0	18.4	429	455	1125.0	60.8	1082	1168
5.0	12	508.0	15.9	490	549	451.2	14.5	440	490	1171.3	128.8	1051	1461
5.25	1	520.0	N/A	520	520	461.0	N/A	461	461	1263.0	N/A	1263	1263
5.5	...	...	...	...	...	...	...	...	...	...	...	...	...
5.75	...	...	...	...	...	...	...	...	...	...	...	...	...
6.0	...	...	...	...	...	...	...	...	...	...	...	...	...
May 29 - 30, 2002													
4.5	2	490.0	0	490	490	435.0	0	435	435	926.5	37.5	900	953
4.75	...	...	...	...	...	...	...	...	...	...	...	...	...
5.0	2	541.5	26.2	523	560	479.5	20.5	465	494	1534.5	149.2	1429	1640
5.25	...	...	...	...	...	...	...	...	...	...	...	...	...
5.5	...	...	...	...	...	...	...	...	...	...	...	...	...
5.75	1	479.0	N/A	479	479	421.0	N/A	421	421	1002.0	N/A	1002	1002
6.0	...	...	...	...	...	...	...	...	...	...	...	...	...
June 2 - 5, 2002													
4.5	24	504.8	19.5	468	535	447.5	16.8	416	476	1017.3	119.9	742	1283
4.75	23	513.4	27.9	440	571	453.7	22.7	392	494	1128.9	134.7	864	1396
5.0	22	527.6	22.3	478	585	467.4	19.9	425	520	1267.7	155.2	905	1544
5.25	1	565.0	N/A	565	565	506.0	N/A	506	506	1417.0	N/A	1417	1417
5.5	...	...	...	...	...	...	...	...	...	...	...	...	...
5.75	1	544	N/A	544	544	486.0	N/A	486	486	1367.0	N/A	1367	1367
6.0	...	...	...	...	...	...	...	...	...	...	...	...	...
Summary													
4.5	37	500.8	22.5	422	535	444.6	19.6	377	476	1055.2	155.6	735	1440
4.75	35	507.7	31.7	423	571	448.7	26.2	375	494	1126.3	163.2	718	1553
5.0	73	518.2	22.2	461	585	457.9	19.6	406	520	1295.9	182.6	905	1804
5.25	3	538.0	23.8	520	565	477.3	24.9	461	506	1395.0	122.5	1263	1505
5.5	1	532.0	N/A	532	532	471.0	N/A	471	471	1406.0	N/A	1406	1406
5.75	3	517.3	34.0	479	544	457.3	33.2	421	486	1330.7	312.1	1002	1623

Table 28. Summary of mean total and fork length (mm), and weight (g) by constant gillnet mesh size (stretch inches) for adult male American shad caught in the Delaware River at Smithfield Beach (RM 218.0 for 2002 (N=152), 2001 (N=238), 2000 (N=225; (217)), and 1999 (N=76). () indicates number of shad used in weight assessment. Note: 5.75 inch mesh net not set in 1999 or 2000.

2002													
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	37	500.8	22.5	422	535	444.6	19.6	377	476	1055.2	155.6	735	1440
4.75	35	507.8	31.7	423	571	448.7	26.2	375	494	1126.3	163.2	718	1553
5.0	73	518.2	22.2	461	585	457.9	19.7	406	520	1295.9	182.6	905	1804
5.25	3	538.0	23.8	520	565	477.3	24.9	461	506	1395.0	122.5	1263	1505
5.5	1	532.0	...	...	...	471.0	...	...	...	1406.0	...	...	...
5.75	3	517.3	34.0	479	544	457.3	33.2	421	486	1330.7	312.1	1002	1623
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
2001													
4.5	141	490.6	19.9	428	535	435.9	17.2	381	472	981.2	120.6	698	1418
4.75	48	496.6	22.9	447	556	440.8	20.0	408	494	1031.0	142.9	636	1509
5.0	41	512.3	19.5	475	562	453.1	17.7	405	490	1171.3	123.0	920	1467
5.25	6	511.2	33.7	462	544	457.0	26.7	425	485	1155.7	266.4	866	1581
5.5	2	494.5	26.2	476	513	442.0	28.3	422	462	875.5	391.0	599	1152
5.75	0	...	...	...	...	...	...	...	...	...	...	...	...
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
2000													
4.5	154 (147)	482.7	24.4	415	560	429.2	21.6	375	510	1011.4	170.3	680	2037
4.75	5 (4)	521.0	17.0	491	530	462.4	12.9	440	473	1295.3	119.8	1159	1451
5.0	41 (41)	497.4	18.7	461	537	441.1	16.4	410	474	1165.9	177.8	887	1981
5.25	17 (17)	504.8	31.5	460	580	449.8	27.1	408	511	1254.0	290.6	788	1886
5.5	8 (8)	510.1	39.1	435	563	451.9	36.0	380	495	1383.1	322.2	791	1769
6.0	0	...	...	...	...	...	...	...	...	...	...	...	...
1999													
4.5	31	487.6	21.5	455	540	432.5	24.3	401	515	966.1	124.8	750	1400
4.75	20	499.7	15.3	459	530	440.2	15.4	400	470	1113.4	167.5	717	1450
5.0	20	495.7	23.2	442	520	440.0	21.7	390	476	1126.8	150.0	850	1500
5.25	3	508.3	21.4	495	533	448.7	12.5	440	463	1116.7	76.4	1050	1200
5.5	1	454.0	...	...	...	405	...	...	...	800.0	...	...	...
6.0	1	469	...	...	...	420	...	...	...	600.0	...	...	...

Table 29. Summary of 248 male American shad by gonad state caught by floating gillnets of various mesh sizes in 8 nights of netting from May 8-9; 12; 30; June 2-5, 2002 in the Delaware River at Smithfield Beach (RM 218.0) Gonad State categories are Immature, Mature/Gravid, Ripe and Spent.

Date	Immature	Mature/Gravid	Ripe	Spent	Total
5/8	13	10	16	1	40
5/9	4	4	3	...	11
5/12	4	3	12	...	19
5/30	...	...	...	4	4
6/2	1	1	21	14	37
6/3	1	...	15	10	26
6/4	3	4	30	31	68
6/5	1	...	31	11	43
Total	27	22	128	71	248
Percent	10.9	8.9	51.6	28.6	

Table 30. Average ovarian weight by the gonad state of 222 female American shad caught by constant mesh gillnets set in the Delaware River at Smithfield Beach (RM 218.0, N=248) from May 8 through June 5, 2002. Ripe female ovarian weights are after artificial stripping has occurred.

Gonad State	Number Sampled	Mean Weight	Std. Dev.	Minimum Weight (g)	Maximum Weight (g)
Immature	26	305.4	66.3	181	414
Mature/Gravid	17	443.7	126.5	144	740
Ripe	124	206.6	80.5	52	429
Spent	55	150.7	53.9	75	299

Table 31. Summary of otolith age distribution, and mean total and fork lengths (mm) and weight (g) by age for **female** American shad caught during the annual spawning operation conducted in Delaware River at Smithfield Beach (RM 218.0) from 2002 through 1997.

Otolith Age Distribution								
	Age							
	N	3	4	5	6	7	8	9
2002	233	.	7	57	124	34	10	1
2001	549	1	77	270	166	28	7	.
2000	194	.	5	57	81	45	6	.
1999	146	1	33	64	46	2	.	.
1998	132	.	7	69	36	11	9.	.
1997	42	.	10	12	13	7	.	.
Mean Total Length (mm) at Age								
2002	233	.	530	552	564	568	568	569
2001	549	542	532	541	559	570	558	.
2000	194	.	519	535	553	567	576	.
1999	146	498	524	536	541	483	.	.
1998	132	.	510	527	555	568	564	.
1997	42	.	489	517	567	576	.	.
Mean Fork Length at Age								
2002	233	.	471	490	500	502	501	502
2001	549	478	473	480	494	505	493	.
2000	194	.	457	485	548	503	515	.
1999	146	441	463	473	476	425	.	.
1998	132	.	450	465	491	500	497	.
1997	42	.	440	462	505	510	.	.
Mean Weight (g) at Age								
2002	233	.	1284	1486	1602	1606	1539	1689
2001	549	1177	1328	1399	1498	1505	1469	.
2000	194	.	1564	1545	1719	1766	1972	.
1999	146	1250.	1463	1502	1554	1225	.	.
1998	132	.	1451	1447	1658	1698	1787	.
1997	42	.	1262	1463	1852	2154	.	.

Table 32. Summary otolith age distribution, and mean total and fork lengths (mm) and weight (g) at age for **male** American shad caught during the annual spawning operation conducted in Delaware River at Smithfield Beach (RM 218.0) from 2002 through 1997.

Otolith Age Distribution							
	Age						
	N	3	4	5	6	7	8
2002	139	2	14	58	51	12	2
2001	194	3	64	95	28	4	.
2000	143	4	37	65	33	3	1
1999	59	.	22	30	7	.	.
1998	78	1	18	45	10	4	.
1997	32	3	13	10	5	1	.
Mean Total Length (mm) at Age							
2002	139	423	503	510	519	514	535
2001	194	484	489	498	511	504	.
2000	143	452	475	490	513	539	580
1999	59	.	480	497	507	.	.
1998	78	513	488	491	508	511	.
1997	32	428	458	500	527	544	.
Mean Fork Length (mm) at Age							
2002	139	376	445	451	460	455	471
2001	194	430	434	441	452	450	.
2000	143	402	423	435	455	477	511
1999	59	.	428	439	446	.	.
1998	78	468	429	433	450	453	.
1997	32	386	413	454	474	505	.
Mean Weight (g) at Age							
2002	139	727	1145	1159	1238	1265	1511
2001	194	994	979	1030	1095	1107	.
2000	143	816	960	1081	1214	1327	1495
1999	59	.	961	1096	1139	.	.
1998	78	1323	1066	1093	1168	1173	.
1997	32	739	948	1250	1438	1495	.

Table 33. Summary of scale age distribution, mean total and fork lengths (mm) and weight (g) by age for female American shad caught during the annual spawning operation conducted in Delaware River at Smithfield Beach (RM 218.0) from 1997 through 2002.

Scale Age Distribution						
Year	N	Age				
		3	4	5	6	7
2002	236		3	105	120	8
2001	545		58	293	182	12
2000	189		25	72	84	8
1999	147		9	77	58	3
1998	148	1	26	95	24	2
1997	60		17	19	21	3
Mean Total Length (mm) at Age						
2002	236		502	554	567	591
2001	545		519	542	563	580
2000	189		535	544	561	571
1999	147		507	525	548	581
1998	148	562	513	539	560	564
1997	60		488	523	578	593
Mean Fork Length (mm) at Age						
2002	236		445	491	503	522
2001	545		460	481	499	516
2000	189		477	548	504	507
1999	147		448	464	483	513
1998	148	492	452	476	494	500
1997	60		438	470	518	507
Mean Weight (g) at Age						
2002	237		1417	1492	1615	1895
2001	545		1205	1382	1539	1745
2000	180		1639	1668	1737	1694
1999	147		1284	1428	1620	1675
1998	148	1992	1389	1535	1685	2041
1997	60		1225	1542	2021	2086

Table 34. Summary of scale age distribution, mean total and fork lengths (mm) and weight (g) by age for male American shad caught during the annual spawning operation conducted in Delaware River at Smithfield Beach (RM 218.0) from 2002 through 1997.

Scale Age Distribution						
Year	N	Age				
		3	4	5	6	7
2002	144	1	15	92	36	.
2001	193	3	77	104	8	1
2000	136	...	26	87	22	1
1999	57	...	9	34	14	.
1998	86	1	32	45	8	.
1997	40	5	14	14	7	.
Mean Total Length (mm) at Age						
2002	144	423	492	509	531	.
2001	193	456	486	503	528	530
2000	136	...	473	493	510	520
1999	57	...	474	495	498	.
1998	86	462	490	494	509	.
1997	40	437	457	507	533	.
Mean Fork Length at Age						
2002	144	375	436	451	468	.
2001	193	404	431	446	468	478
2000	136	...	421	438	452	460
1999	57	...	417	440	440	.
1998	86	407	433	436	452	.
1997	40	395	412	460	483	.
Mean Weight (g) at Age						
2002	144	718	1075	1186	1284	.
2001	193	860	979	1047	1209	1192
2000	128	...	1008	1093	1153	1184.
1999	57	...	863	1107	1086	.
1998	86	1120	1089	1119	1156	.
1997	40	816	958	1239	1464	.

Table 35. Scale age and repeat spawning by sex for 380 American shad (236 females and 144 males) netted in the Delaware River at Smithfield Beach (RM 218.0) during May 8-9; 12-13, 29-30, and June 2-5, 2002.

May 8 - 9								
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	2	.	.	.	6	1	.	.
5	13	6	.	.	30	4	.	.
6	15	2	.	.	5	5	.	.
7	1	1	.	1	.	.	.	.
Total	31	9	0	1	42	10	0	0
May 12 - 13								
3	.	.	.	.	.	.	.	.
4	.	.	.	.	1	.	.	.
5	5	3	.	.	9	4	.	.
6	4	5	.	.	1	2	.	.
7	1	1	.	.	.	.	.	.
Total	10	9	0	.	11	6	0	0
May 29 - 30								
3	.	.	.	.	.	.	.	.
4	.	.	.	.	2	.	.	.
5	1	.	.	.	1	1	.	.
6	2	1	.	.	.	1	.	.
7	.	.	.	.	.	.	.	.
Total	3	1	0	.	3	2	0	0
June 2 - 5								
3	.	.	.	.	.	.	.	.
4	1	.	.	.	5	.	.	.
5	73	4	.	.	39	3	1	.
6	76	15	.	.	21	.	1	.
7	2	1	.	.	.	.	.	.
Total	152	20	0	.	65	3	2	0
Summary								
3	.	.	.	.	1	.	.	.
4	3	.	.	.	14	1	.	.
5	92	13	.	.	79	12	1	.
6	97	23	.	.	27	8	1	.
7	4	3	.	1	.	.	.	.
Grand Total	196	39	0	1	121	21	2	0
%	83.1	16.5	.	0.4	84.0	14.6	1.4	.
Sexes Combined								
Total	317	60	2	1				
%	83.4	15.8	0.5	0.3				

Table 36. Comparison of otolith and scale ages of 368 adult American shad (231 females and 137 males) caught in the Delaware River at Smithfield Beach (RM 218.0) on May 8-9, 12-13, 28-30, and June 2-5, 2002.

Female Scale Age Difference							
Otolith Age	-3	-2	-1	=	+1	+2	Total
3	.	.	.	.	.	.	.
4	.	.	.	1	5	1	7
5	.	.	1	34	19	1	55
6	.	.	54	66	4	.	124
7	1	11	22	.	.	.	34
8	1	7	2	.	.	.	10
9	1	.	.	.	.	.	1
Total	3	18	79	101	28	2	231
%	1.3	7.8	34.2	43.7	12.1	0.9	
Male Scale Age Difference							
3	.	.	.	1	.	1	2
4	.	.	.	6	4	4	14
5	.	.	5	39	14	.	58
6	.	.	34	15	.	.	49
7	.	10	2	.	.	.	12
8	1	1	.	.	.	.	2
Total	1	11	41	61	18	5	137
%	0.7	8.0	29.9	44.5	13.1	3.6	
Combined Scale Age Difference							
Total	4	29	120	162	46	7	368
%	1.1	7.9	32.6	44.2	12.5	1.9	

Table 37. Summary of repeat spawning occurrence of American shad (sexes combined) caught in anchored constant mesh monofilament gillnets during the PFBC's annual spawning operations at Smithfield Beach (RM 218.0) in the Delaware River from 1996-2002.

Year	Number			Percent	
	Virgin	Repeat	Total	Virgin	Repeat
2002	317	63	380	83.4	16.6
2001	335	43	378	94.6	5.8
2000	316	9	325	97.2	2.8
1999	195	9	204	95.6	4.4
1998	210	24	234	89.7	10.3
1997	90	10	100	90.0	10.0
1996	88	11	99	88.9	11.1

Table 38. Catch rate statistics for adult American shad, mean catch per night, for the PFBC's Delaware River spawn-take at Smithfield Beach (RM 218.0) from 1990 through 2002 SE=Standard Error.

Catch Rate Statistics		
Year	Mean Catch per Night	SE
2002	3.4	0.9
2001	2.8	0.4
2000	2.8	0.6
1999	2.6	0.3
1998	5.0	0.9
1997	3.7	0.5
1996	3.7	1.8
1995	5.8	0.7
1994	4.9	0.8
1993	5.0	0.8
1992	13.0	1.7
1991	9.7	1.7
1990	15.9	2.2

Table 39. Catch frequency by scale age for female and male shad caught during the egg-taking operations in the Delaware River at Smithfield Beach area (RM 218.0) from 1996-2002.

Females						
Year	Age					Total
	3	4	5	6	7	
2002	0	3	105	120	8	236
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						
2002	1	15	92	36	0	144
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

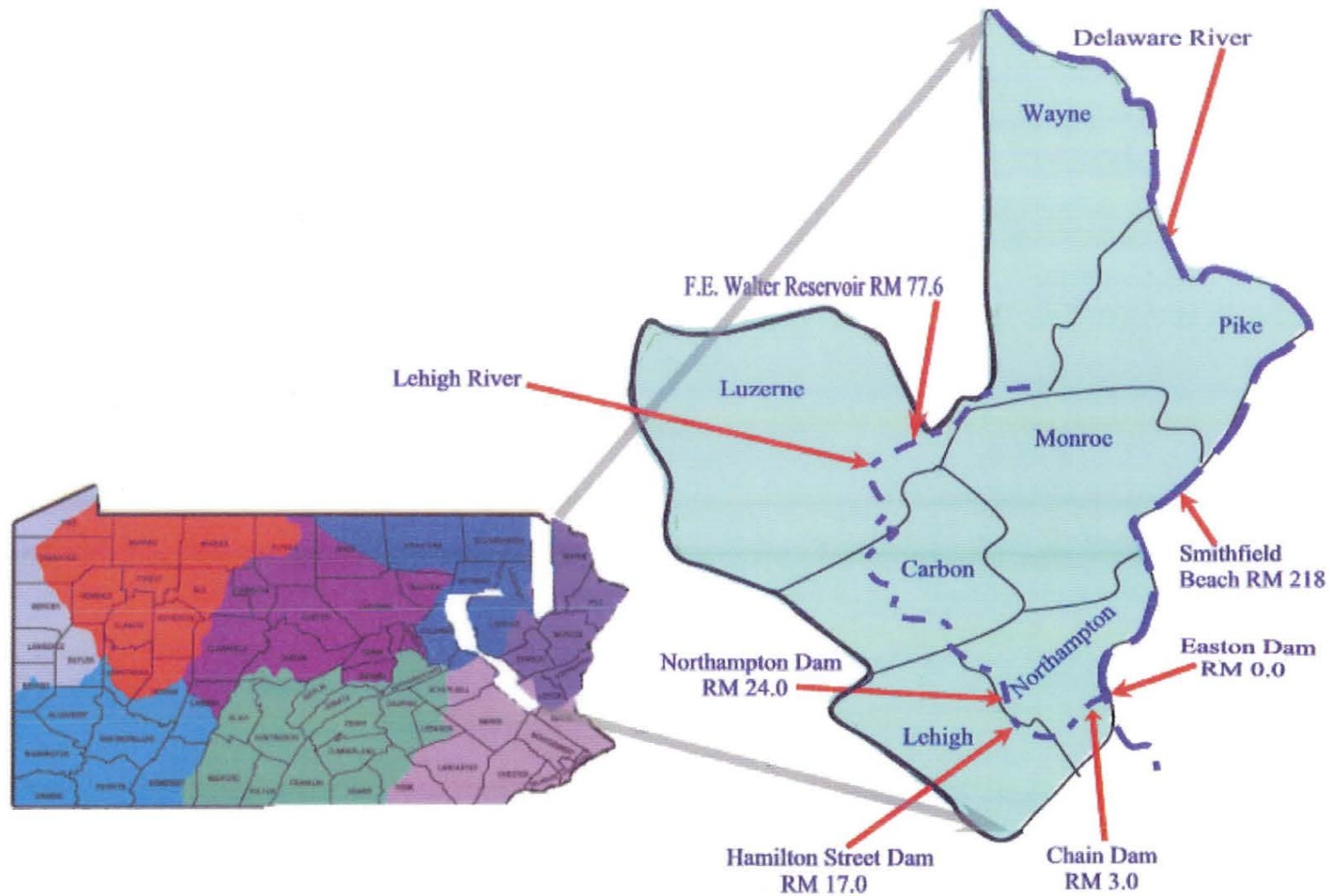


Figure 1. Location of the lowhead dams in the Lehigh River: Easton (RM 0.0; fishway w/public and private observation windows), Chain (RM 3.0; fishway w/private observation window), Hamilton Street (RM 17.0; fishway w/no observation window), and Northampton/Cementon Dam (RM 24.0; no passage facility) (Map not to scale).

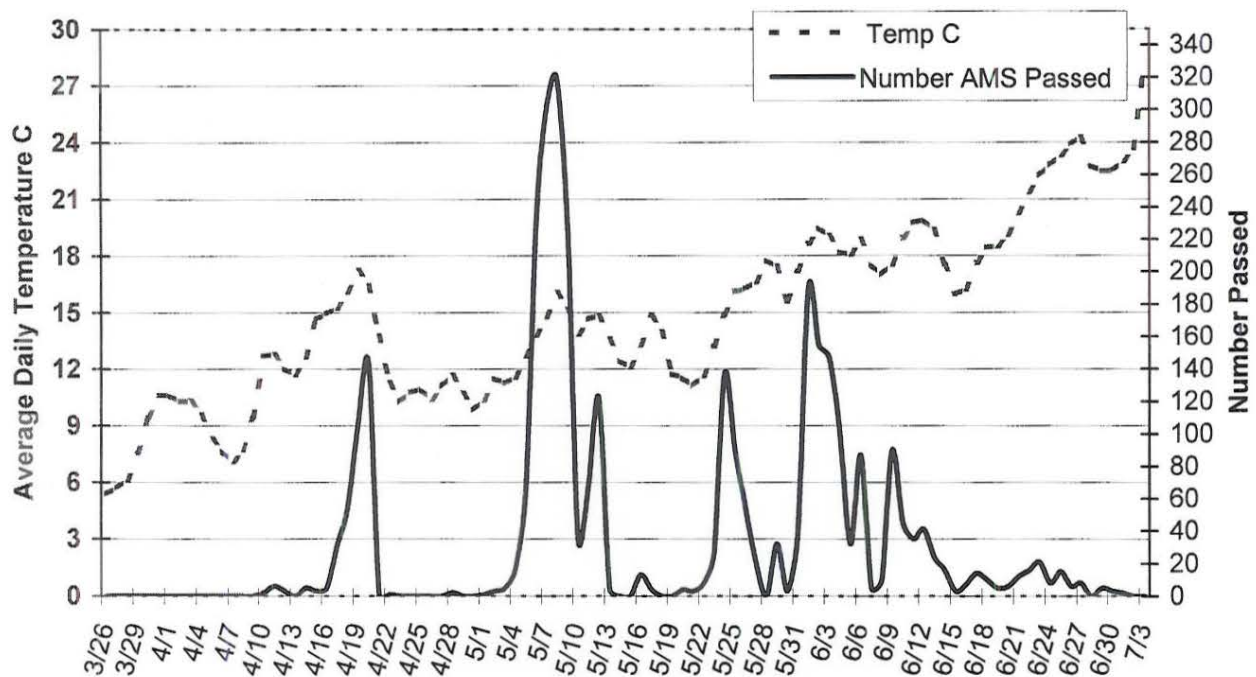


Figure 2. Plot of daily passage of American shad at the Easton Dam fishway (RM 0.00) and Lehigh River average daily water temperature ($^{\circ}\text{C}$) from March 26 through July 3, 2002.

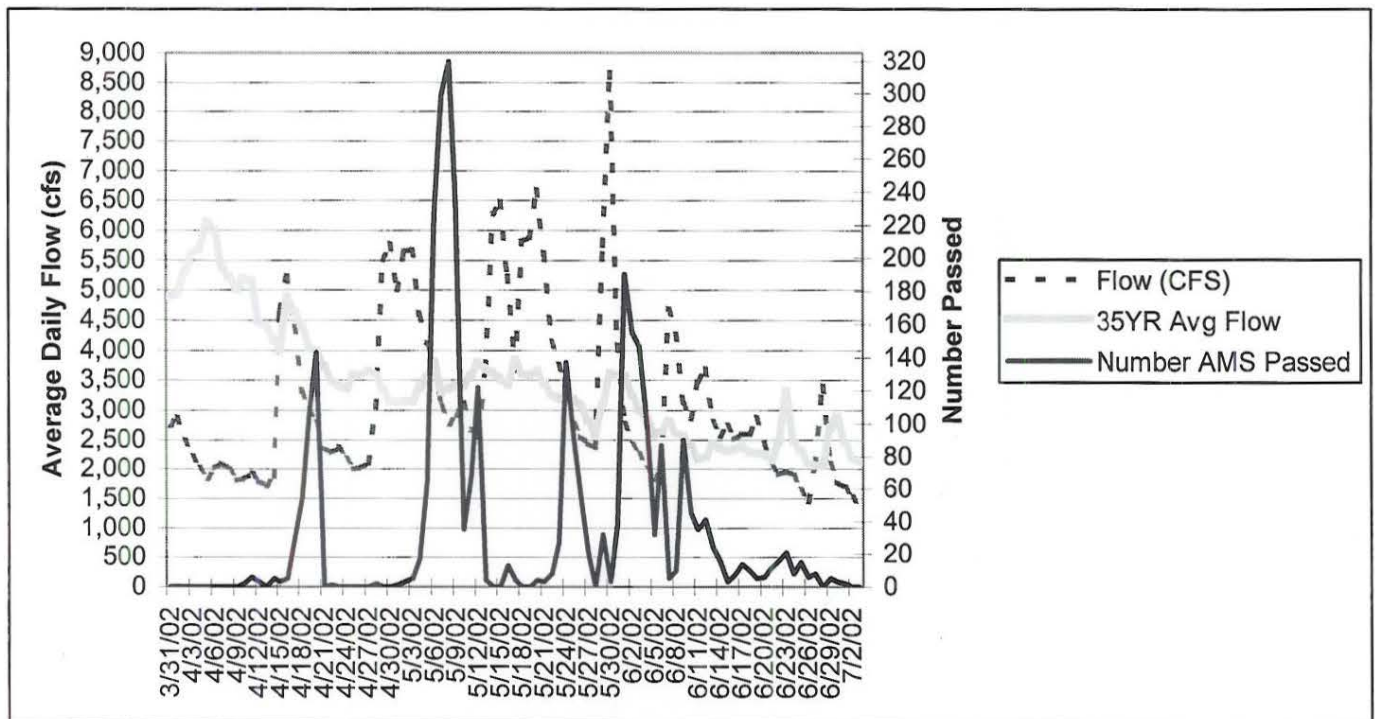


Figure 3. Plot of daily passage of American shad passage at the Easton Dam fishway (RM 0.00) and Lehigh River average daily flow (cfs) from March 31 through July 3, 2002.

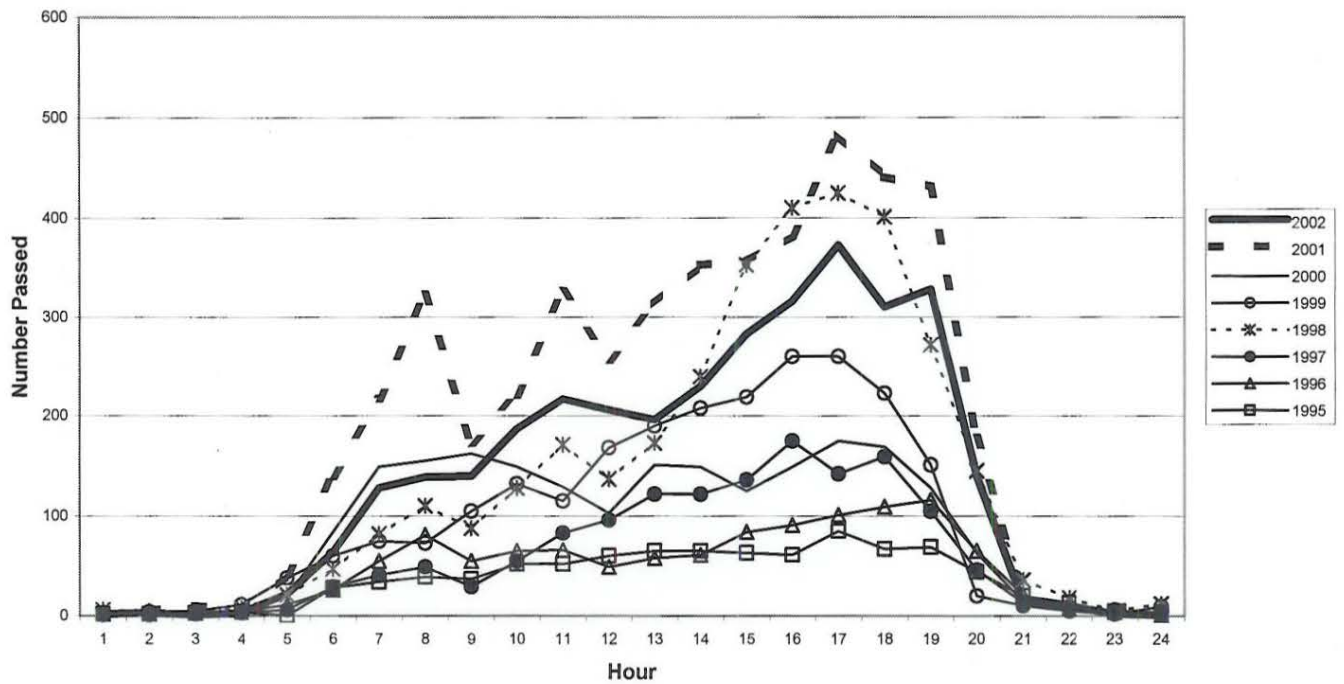


Figure 4. Plot of American shad by hour for all days combined at the Easton Dam fishway (RM 0.00) in the Lehigh River for 1995 (N=873), 1996 (N=1,141), 1997 (N=1,426), 1998 (N=3,281), 1999 (N=2,337), (N=2,094), 2001 (N=4,699; 4,740 less 41 shad with no time of passage), and 2002 (N=3,314).

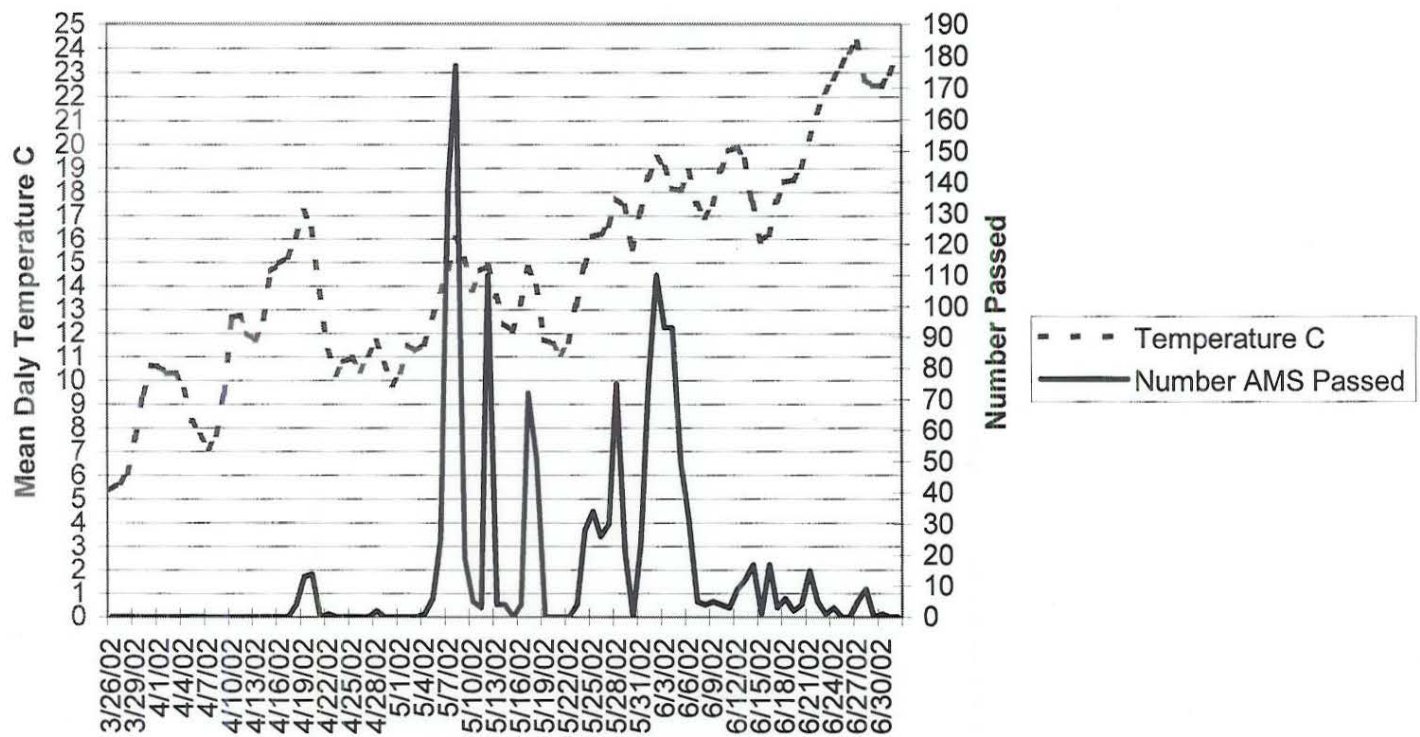


Figure 5. Plot of daily passage of American shad at the Chain Dam fishway (RM 3.00) and Lehigh River average daily water temperature ($^{\circ}\text{C}$) from March 26 through July 3, 2002.

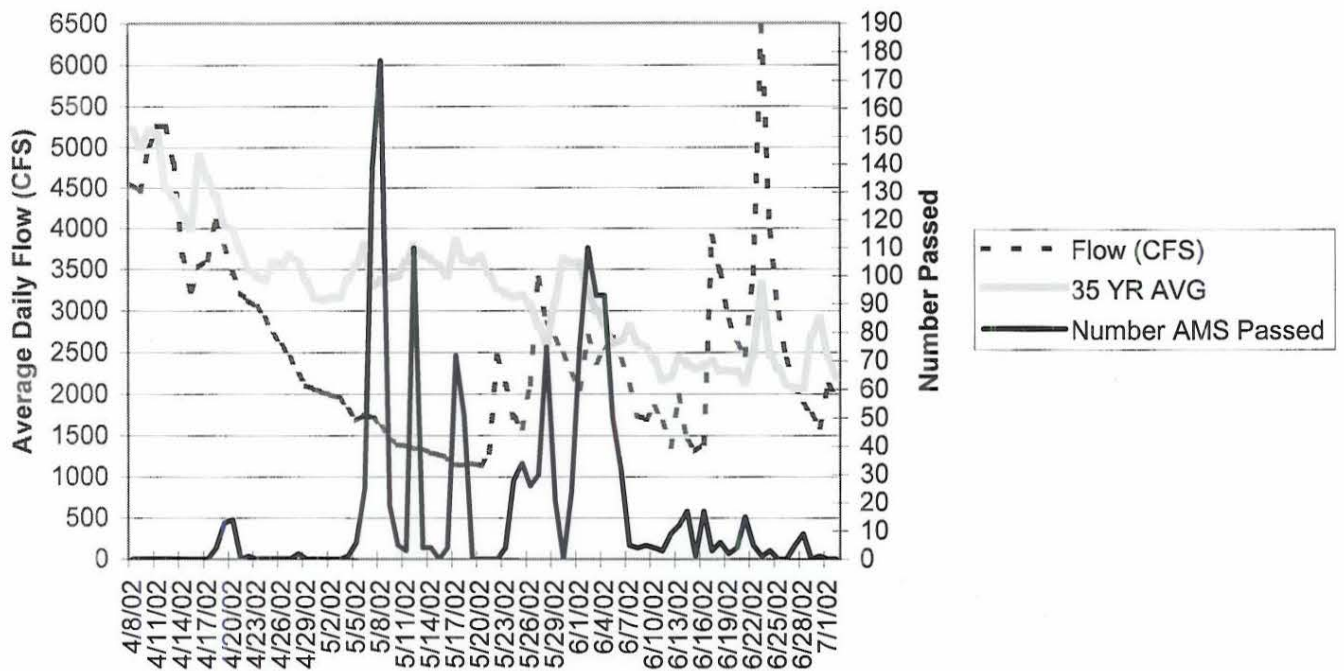


Figure 6. Plot of American shad passage at the Chain Dam fishway (RM 3.00) and Lehigh River average daily flow (cfs) from April 8 through July 3, 2002.

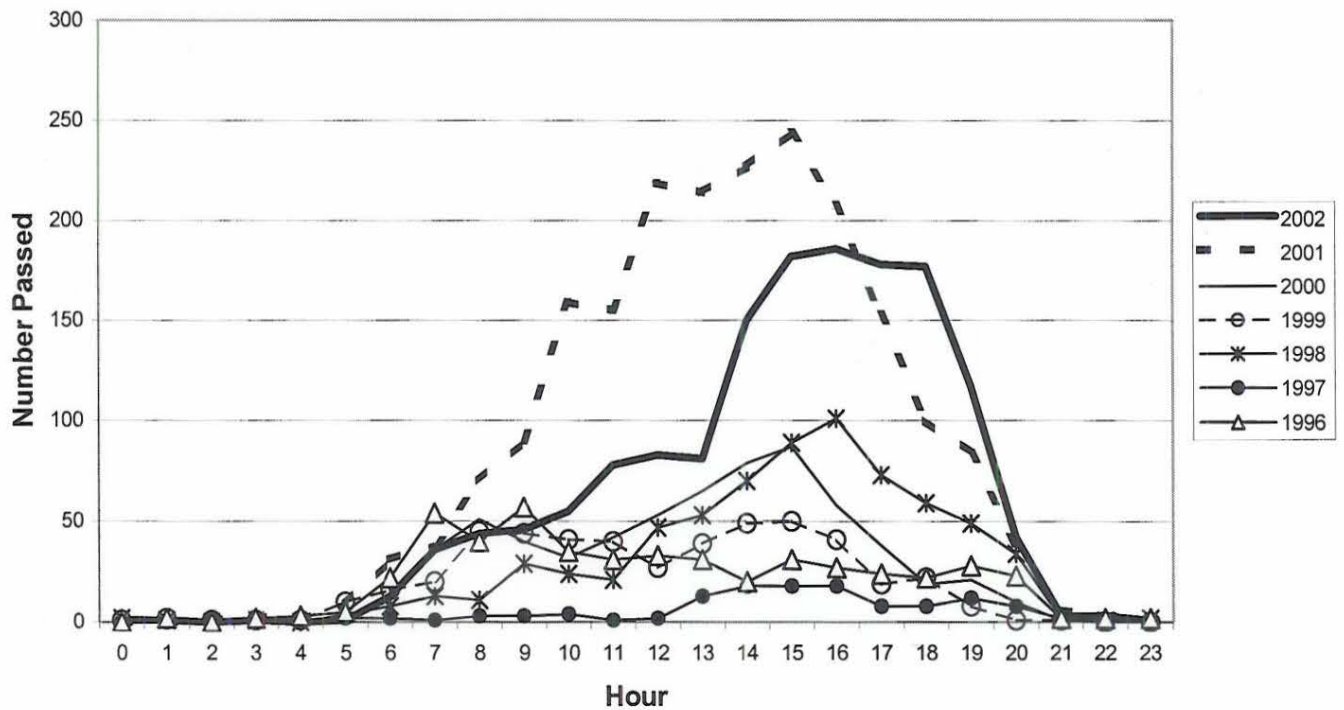


Figure 7 Plot of American shad passage by hour for all days combined at the Chain Dam fishway (RM 3.0) for 1996 (N=476), 1997 (N=126), 1998 (N=694), 1999 (N=479), 2000 (N=645), 2001 (N=2,057), and 2002 (N=1,479).

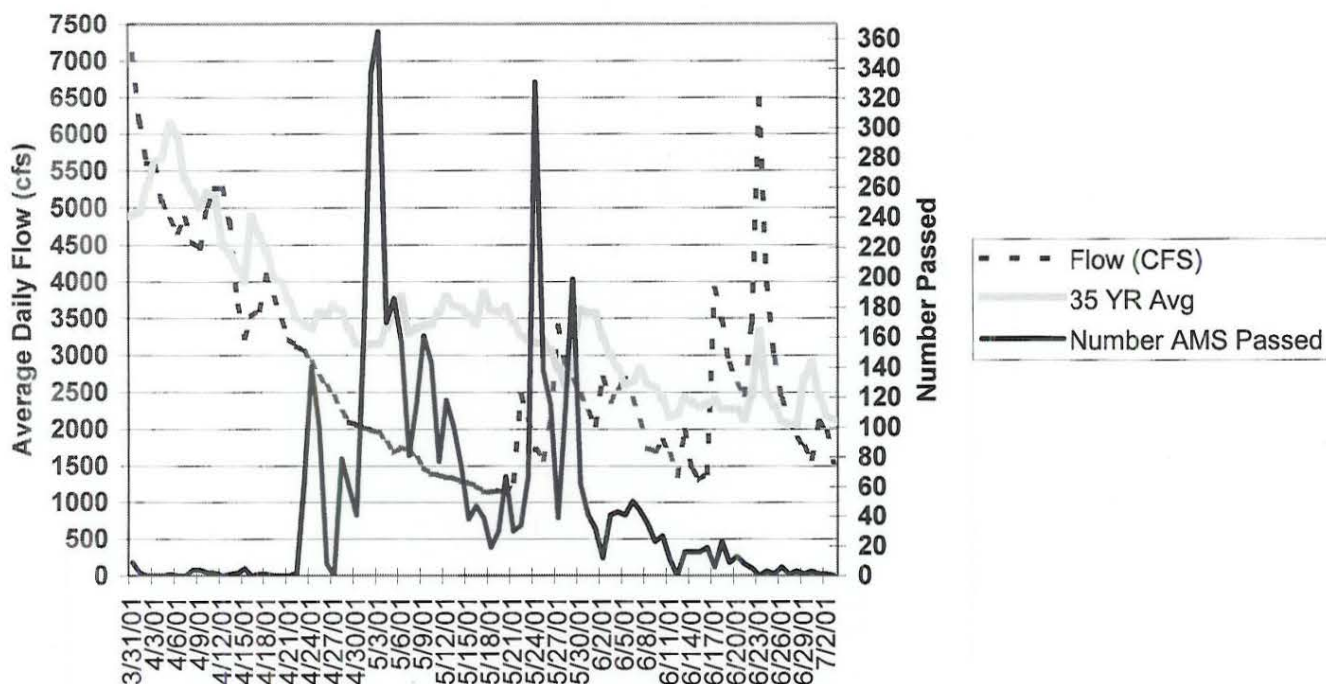


Figure 8. Plot of American shad passage at the Easton Dam fishway (RM 0.00) and Lehigh River average daily flow (cfs) from March 31 through July 3, 2001

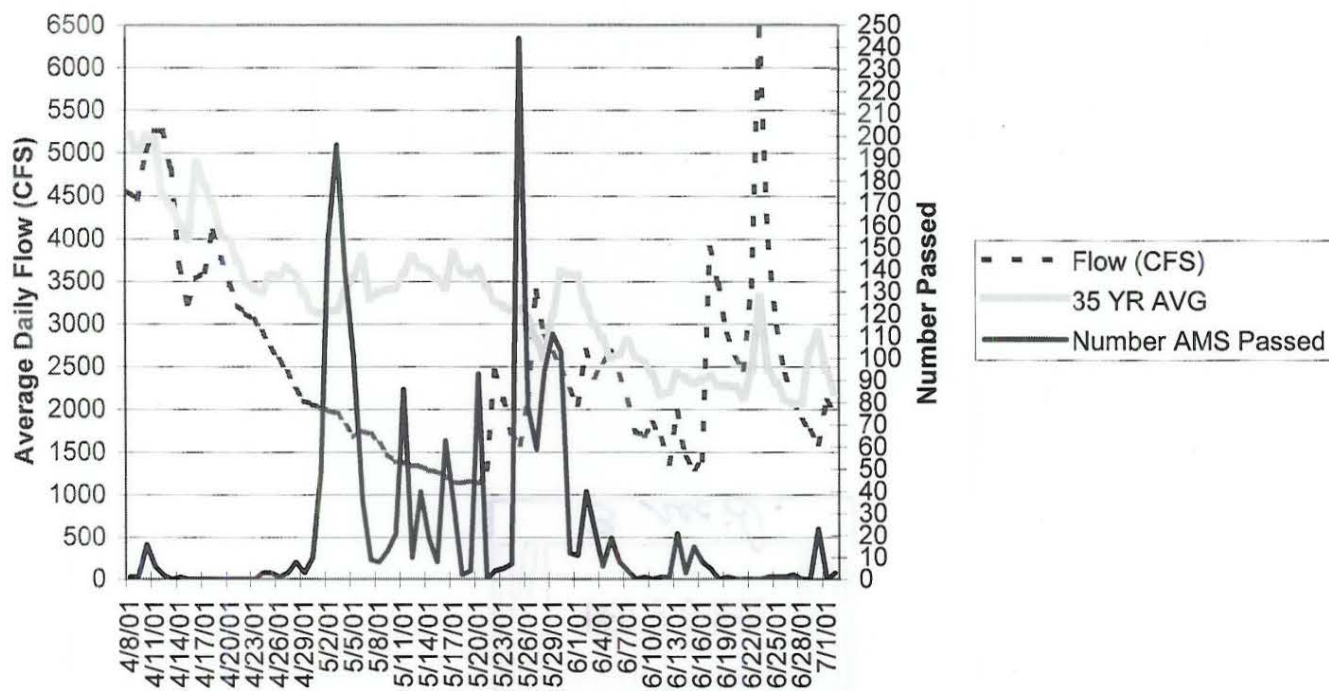


Figure 9. Plot of American shad passage at the Chain Dam fishway (RM 3.00) and Lehigh River average daily flow (cfs) from March 31 through July 3, 2001.