SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY SPRING 2016

November 2016

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Prepared for

SAFE HARBOR WATER POWER

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Executive Summary

Operation of the Safe Harbor Fish Lift began 22 April, 2016; one day after Holtwood passed 126 American shad into Lake Aldred. The average trough water temperature on 22 April was 63°F and the river flow was 29,000 cfs. A total of 97 American shad were passed on the initial day of operation. Operation at the Safe Harbor Fish Lift ended on June 10, 2016 due to the dwindling fish catch and warm water temperatures; indications that the migration run was ending. The 2016 fish passage season marks the twentieth season of volitional fish passage at the Safe Harbor Fish Lift.

The Safe Harbor Fish Lift passed 157,645 fish of 18 species and 1 hybrid upstream into Lake Clarke. Gizzard shad (144,315), American shad (4,242) and shorthead redhorse (3,067) dominated the catch, and comprised 96.2% of the total fish collected and passed. Gizzard shad (144,315) was the dominant species passed and comprised 91.5% of the catch.

A total of 4,242 American shad was passed during the 2016 season at Safe Harbor during 50 days of operation. The highest daily passage of American shad occurred on 25 April, when 331 American shad were captured and passed upstream. The highest passage hours for American shad during the entire season were observed between 0800 hours to 0859 hours (515), 1500 hours to 1559 hours (506), and 1400 hours to 1459 hours (505). These three hourly periods accounted for nearly 36% of the total season passage.

Fishway operations were conducted at water temperatures ranging from 57.1°F to 82.0°F and river flows of 17,800 to 55,800cfs. River flows were relatively stable during the entire fish passage season, resulting in no spillage or suspension of fish passage operations. Water temperature did not surpass 70° F until 27 May and ranged between 71.9° and 82° F for the remainder of the season.

On 37 of the 50 days of operation, water clarity was good (18-24 inches of visibility at the viewing window), allowing the viewing technicians to identify American shad with attached Maryland DNR floy tags. The number of floy tags observed at the Safe Harbor Fishway in 2016 was 2, (2 orange = 2016 effort).

Prior to the start of Safe Harbor fish lift operations in 2016, federal and state resource agency personnel stated their concern regarding the station's use of an air bubbler system to keep the fish trough exit clear of debris during fish passage operation. The resource agencies requested that the station evaluate fish passage when the air bubbler system is in use to determine if the bubbler system impedes fish movement through the fish trough. Safe Harbor indicated to FERC and the resource agencies that fish lift personnel would document deviations in fish behavior/passage if and when the air bubbler system was utilized.

During the 2016 fish passage season, we documented operation of the air bubbler system on 27 of the 50 days of operation. Daily observations of fish behavior/passage were made by the fish counting technicians. At no time during fish passage operations did the technicians observe fish "stacking up" at the trough exit area or large numbers of fish swimming downstream past the window after having passed the viewing window earlier in the day.

Future operations of the Safe Harbor Fish Lift will build on the past twenty years of experience.

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1.0 INTRODUCTION

On June 1, 1993 representatives of Safe Harbor Water Power Corporation (SHWPC), two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement committed Safe Harbor, Holtwood, and York Haven Hydroelectric projects to provide migratory fish passage at the three locations by spring 2000. A major element of this agreement was for SHWPC, the operator of the Safe Harbor Hydroelectric Project (Safe Harbor), to construct and place in operation an upstream fishway by April 1, 1997. The fishway that provides fish access into Lake Clarke was placed into service in April of 1997. The Brookfield Renewable Energy Group is now the sole owner/operator of the Safe Harbor Hydroelectric Station.

Objectives for 2016 operation were to (1) monitor passage of migratory and resident fishes through the fishway; (2) assess fishway effectiveness; and (3) assess any impacts of fish passage through the trough when the air bubbler system is in use during fish passage operations.

2.0 SAFE HARBOR OPERATION

2.1 Project Operation

Safe Harbor is situated on the Susquehanna River (river mile 31) in Lancaster and York counties, Pennsylvania. The project consists of a concrete gravity dam 4,869 ft long and 75 ft high, a powerhouse 1,011 ft long with 12 generating units with a combined generating capacity of 417.5 MW, and a reservoir of 7,360 surface acres. The net operating head is about 55 ft.

Safe Harbor is the third upstream dam on the Susquehanna River. The station was built in 1931 and originally consisted of seven generating units. Five units were added and operational in 1986, which increased the hydraulic capacity to 110,000 cfs. Each unit is capable of passing approximately 8,500 cfs. Natural river flows in excess of 110,000 cfs are spilled through three regulating and 28 crest gates. The five new mixed-flow turbines have seven fixed-runner blades, a diameter of 240 in, and runner speed of 76.6 rpm. The runner blades are somewhat spiraled and do not have bands at the top or bottom. Two of these new turbines are equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The seven old units are five-blade Kaplan type turbines. These units have horizontal, adjustable, propeller-shaped blades.

2.2 Fishway Design and Operation

2.2.1 Fishway Design

The fishway was sized to pass a design population of 2.5 million American shad and 5 million river herring. The design incorporated numerous criteria established by the USFWS and the resource agencies. Physical design parameters for the fishway are given in the 1997 summary report (Normandeau Associates, Inc. 1998).

The Safe Harbor fish lift has three entrances (gates A, B, and C). The lift has a fish handling system, which includes a mechanically operated crowder, picket screen, hopper, and hopper trough gate. Fishes captured in the lift are sluiced into the trough and pass into Lake Clarke. Attraction flow, in, through, and from the lift is supplied through a piping system controlled by motor operated valves, attraction water gates, attraction water pools, and two diffusers that are gravity fed from two intakes. Generally, water conveyance and attraction flow is controlled by regulating two motor operated valves and three attraction water gates, which control flow from and into the attraction water pools and the three entrance gates. Fish that enter the fishway entrances are attracted by water flow into the mechanically operated crowder chamber by regulating gate F. Once inside, fish are crowded over the hopper (capacity = 4,725 gallons), lifted, and sluiced into the trough. Fish swim upstream past a

counting facility, which includes a separate public viewing room and into the forebay approximately 150 ft upstream of the dam. The trough extends 40 ft into the forebay in order to sluice the fish past the skimmer wall.

Conceptual design guidelines for fishway operation included several entrance combinations. They are (1) entrance A, B, and C; (2) entrance B and C; (3) entrance A and C, and (4) entrance A, B, and C individually. Operation during the 2016 season utilized a combination of entrances A and C.

2.2.2 Fishway Operation

Safe Harbor fishway operation commences soon after passage of approximately 500 American shad via the Holtwood fishway. In 2016, operations commenced on 22 April, one day after Holtwood passed 126 American shad into Lake Aldred.

The Safe Harbor fishway began operation on 22 April, with operations ending on 10 June. Lift operations ended due to the dwindling fish catch and rising water temperatures; indications that the adult American shad migration season was ending.

Throughout the 2016 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

Daily operation of the Safe Harbor fishway was dependent on the American shad catch and managed in a flexible fashion. To minimize interruptions to fishway operation, Safe Harbor performed maintenance activities that included periodic cleaning of the exit channel, daily inspections, cleaning of picket screens, and other routine maintenance activities. On 15 May, Entrance Gate C was out of adjustment (unable to be lowered) for part of the day, but the issue was quickly resolved and did not occur throughout the remainder of the season. On 22 May, the crowder was out of service with repairs completed on 23 May, and aside from making an adjustment to the crowder on 28 May, no other mechanical issues occurred during the fish passage season.

2.3 Fish Counts

Fish lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biological technician. As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3 ft wide channel on the east side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are enumerated prior to exiting the fishway. Fish passage was controlled by the biological technician, who opened/closed a gate located downstream of the viewing window from a controller mounted inside the counting room. Each night, after operations ended for the day, fish were denied passage from the fishway by closing the gate downstream of the window.

A 1,500 watt halogen lamp mounted above the viewing window and three adjustable 500 watt underwater lights (two at mid-depth on either side of the window and one on the bottom) gave the biologist and/or technician a degree of control over lighting conditions at the window. Overhead and underwater light intensity was adjusted daily, based on the constantly changing ambient light conditions. In addition, a screen capable of adjusting the channel width at the counting window from 18 in to 36 in (and a range of intermediate widths) was adjusted as viewing conditions and fish passage dictated. For the entire 2016 season, the adjustable screen was set at 18 in.

At the end of each hour, fish passage data were recorded on a worksheet and entered into a Microsoft Excel spreadsheet on a personal computer. Data processing and reporting were PC based and accomplished by program scripts, or macros, created within Microsoft Excel software. After the technician verified the correctness of the raw data, a daily summary of fish passage was produced

and e-mailed to plant personnel. Each day's data were backed up on electronic media and stored off site. Daily reports and weekly summaries of fish passage were electronically distributed to members of the SHFPTAC and other cooperators.

3.0 RESULTS

3.1 Relative Abundance

The relative abundance of fishes collected and passed in 2016 by the Safe Harbor fishway is presented in Table 1. A total of 157,645 fish of 18 species and 1 hybrid passed upstream into Lake Clarke. Gizzard shad (144,315) was the dominant species passed and comprised 91.5% of the catch. Some 4,242 American shad were passed upstream through the fishway and comprised 2.6% of the catch. Other predominant fishes passed included shorthead redhorse (3,067), quillback (1,418), smallmouth bass (1,381), channel catfish (1,250), carp (1,035) and walleye (871). The highest fish passage day occurred on the initial day of operation (22 April), when 10,249 fish, (81% gizzard shad; 10% shorthead redhorse), were passed.

3.2 American Shad Passage

The Safe Harbor fishway passed 4,242 American shad in 2016 during 50 days of operation (Tables 1 and 2).This year's passage of American shad (4,242) is the highest number of American shad passed since 2010, but the eighth lowest in twenty years of operation (Table 3). Safe Harbor managed to pass 63.1% of the American shad passed at Holtwood Dam and nearly 30% of the American shad passed by Conowingo Dam, (Table 3). Peak shad passage occurred on 25 April, when 331 American shad were captured and passed during 10 hours of operation. American shad passage on 22 through 30 April, (1,444) accounted for 34% of the total season's passage.

American shad were passed at water temperatures of 57.1°F to 82.0°F and river flows of 17,800 to 55,800cfs (Table 2 and Figures 1and 2). River flows were relatively stable during the entire fish passage season, resulting in no spillage or suspension of fish passage operations. Water temperature did not surpass 70° F until 27 May and ranged between 71.9° and 82° F for the remainder of the season.

The number of American shad observed passing through the trough by hour is shown in Table 4. With the season's shad catch broken down based on hours of observation, passage rates were generally consistent from 0800 hrs to 1659 hrs. The highest passage hours for American shad during the entire season were observed between 0800 hrs to 0859 hrs (515), 1500 hrs to 1559 hrs (506), and 1400 hrs to 1459 hrs (505). These three hourly periods accounted for nearly 36% of the total season passage. The highest number of American shad passed in one hour (63) occurred between 0800 hrs and 0859 hrs on 24 May.

During the 2016 season, the Safe Harbor fishway passed two American shad with orange (2016) MD DNR floy tags that had been passed by downstream fish lift facilities.

3.3 Other Alosids

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2016.

3.4 Evaluation of Air Bubbler System

Prior to the start of Safe Harbor fish lift operations in 2016, federal and state resource agency personnel stated their concern regarding the station's use of an air bubbler system to keep the fish trough exit clear of debris during fish passage operation. The resource agencies requested that the station evaluate fish passage when the air bubbler system is in use to determine if the bubbler system

impedes fish movement through the fish trough. Safe Harbor indicated to FERC and the resource agencies that fish lift personnel would document deviations in fish behavior/passage if and when the air bubbler system was utilized.

During the 2016 fish passage season, we documented operation of the air bubbler system on 27 of the 50 days of operation. Daily observations of fish behavior/passage were made by the fish counting technicians. At no time during fish passage operations did the technicians observe fish "stacking up" at the trough exit area or large numbers of fish swimming downstream past the window after having passed the viewing window earlier in the day.

Since 1997 (initial year of operation at Safe Harbor), fish counting technicians have observed on a limited basis an initial unwillingness of fish to quickly swim past the viewing window. Upon inspection of the facility by station personnel, the cause has been a build-up of debris on the retractable screens at the viewing windows. Once the screens are cleaned of debris, fish passage returns to normal. It appears, based on these observations, that the air bubbler system located at the fish trough exit does prevent large amounts of debris from entering the fish trough when present at the trough exit, thus aiding in the maintenance of normal fish passage conditions for all fish species that enter and pass through the Safe Harbor fish lift.

4.0 SUMMARY

Aside from the two mechanical issues stated previously, the 2016 Safe Harbor fishway operating season was conducted with minimal disruptions to operations due to mechanical problems.

Although the 2016 Safe Harbor fish passage season was seventeen days longer than the 2015 season, resulting in 148 additional lifts and 155 more hours of viewing, overall fish passage numbers were basically half of those observed during 33 days of operation in 2015. The number of gizzard shad passed in 2016 (144,315) was only 47% of the total gizzard shad passed at Safe Harbor in 2015 (306,543). Although 346 more American shad were passed in 2016 than in 2015, the average number of shad per lift in 2016 (7.1) was less than the average observed in 2015 (8.6). Cooler water temperatures in May might have impacted overall fish passage to some degree this season, but caution must be exercised when comparing fish passage numbers between years due to variability of environmental conditions.

A total of 4,242 American shad were passed into Lake Clarke, or 63.1% of the American shad that were passed into Lake Aldred by the Holtwood fishway (Table 3). Ninety percent of the total American shad passed at Safe Harbor occurred prior to 28 May (Figure 2), two days after Holtwood passed 90% of their American shad season total. Future operations of the fishway will build on the past twenty years of experience.

5.0 RECOMMENDATIONS

1) Operate the fishway at Safe Harbor Dam per annual guideline developed and approved by the SHFPTAC. Fishway operation should adhere to the guideline; however, flexibility must remain with operating personnel to maximize fishway operation and performance.

6.0 LITERATURE CITED

Normandeau Associates, Inc. 1998. Summary of operation at the Safe Harbor Fish Passage Facility in 1997. Prepared for Safe Harbor Water Power Corporation, Conestoga, PA.

Normandeau Associates, Inc. 1999. Summary of operation at the Safe Harbor Fish Passage Facility in 1998. Prepared for Safe Harbor Water Power Corporation, Conestoga, PA.

TABLES AND FIGURES

Table 1

Number and disposition of fish passed daily by the Safe Harbor fishway in 2016.

Date	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1
Start Veiwing Time	7:45	8:00	7:30	7:30	8:00	8:00	7:30	9:30	8:00	7:30
End Viewing Time	16:15	16:30	16:15	17:30	17:20	17:05	17:15	17:10	17:10	17:10
Elapsed Viewing Time	8.5	8.5	8.8	10.0	9.3	9.1	9.8	7.7	9.2	9.7
Lifts Per Day	11	12	12	12	17	11	12	9	12	12
Water Temperature (F)	63	63	63	63	64.5	65.3	65.5	64.4	61.3	58.5
AMERICAN SHAD	97	230	123	331	186	130	128	107	112	43
GIZZARD SHAD	8,330	5,786	5,027	4,292	2,727	2,541	4,110	3,640	3,523	2,520
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	1	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	1
MUSKELLUNGE	0	1	0	0	0	1	0	0	0	0
CARP	0	3	12	8	14	3	4	1	7	3
QUILLBACK	251	92	35	43	52	83	155	4	2	1
S. REDHORSE	1,025	226	82	155	211	61	148	28	7	4
CHANNEL CATFISH	1	0	0	8	1	8	14	4	4	0
HYBRID STRIPED BASS	0	1	0	0	0	0	0	0	0	0
ROCK BASS	2	0	1	1	0	0	0	1	0	0
PUMPKINSEED	0	0	0	1	0	0	0	0	0	0
BLUEGILL	0	1	0	1	0	0	0	0	0	0
SMALLMOUTH BASS	504	356	51	41	43	29	13	8	3	0
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	1	0	0	0	0	0
WALLEYE	39	14	6	7	8	18	22	29	6	5
TOTALS	**10,249**	**6,710**	**5,337**	**4,888**	**3,243**	**2,875**	**4,594**	**3,822**	**3,664**	**2,577**

Table 1 (continued)

Date	5/2	5/3	5/4	5/5	5/6	5/7	5/8	5/9	5/10	5/11
Start Veiwing Time	7:30	8:00	8:00	7:30	9:00	7:30	8:00	7:30	8:00	7:20
End Viewing Time	17:35	17:15	17:10	17:15	17:10	17:15	17:10	17:40	17:15	17:25
Elapsed Viewing Time	10.1	9.3	9.2	9.8	8.2	9.8	9.2	10.2	9.3	10.1
Lifts Per Day	14	13	11	12	12	14	13	14	12	12
Water Temperature (F)	57.7	57.7	59	59.3	58	57.1	58	59	59.8	59.3
AMERICAN SHAD	55	117	128	88	103	37	9	64	16	25
GIZZARD SHAD	1,112	3,759	2,711	4,406	1,910	1,507	892	3,071	614	1,014
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	1	0
CARP	6	1	22	2	6	3	1	9	2	3
QUILLBACK	0	3	7	0	1	1	0	2	5	4
S. REDHORSE	3	6	151	65	0	5	12	73	40	23
CHANNEL CATFISH	0	0	3	46	2	6	6	8	10	3
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	1	0
ROCK BASS	0	0	0	0	0	0	0	0	0	1
PUMPKINSEED	0	0	0	0	0	0	0	0	0	0
BLUEGILL	0	0	0	1	0	0	0	0	0	0
SMALLMOUTH BASS	1	3	12	3	7	0	11	8	13	4
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	0	0	24	10	2	1	0	11	8	10
TOTALS	**1,177**	**3,889**	**3,058**	**4,621**	**2,031**	**1,560**	**931**	**3,246**	**710**	**1,087**

Table 1 (continued)

Date	5/12	5/13	5/14	5/15	5/16	5/17	5/18	5/19	5/20	5/21
Start Veiwing Time	8:00	8:45	8:00	7:20	8:00	7:30	7:40	8:00	9:20	7:30
End Viewing Time	17:30	17:15	17:00	17:15	17:10	17:10	17:05	17:05	17:00	16:50
Elapsed Viewing Time	9.5	8.5	9.0	9.9	9.2	9.7	9.4	9.1	7.7	9.3
Lifts Per Day	12	11	19	16	13	14	10	12	11	12
Water Temperature (F)	59.4	59.9	62.1	63	62	61	61	61	62.2	64.4
AMERICAN SHAD	39	61	149	115	105	124	74	69	142	138
GIZZARD SHAD	1,852	1,238	8,891	2,827	4,014	2,308	859	1,022	1,905	1,275
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
CARP	27	5	28	11	8	13	5	6	0	6
QUILLBACK	17	4	27	32	1	10	2	0	2	29
S. REDHORSE	80	90	124	38	0	2	0	7	16	114
CHANNEL CATFISH	11	11	15	61	5	11	5	2	2	8
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	1	0	0	0	0	0	1
PUMPKINSEED	0	0	0	0	0	0	0	0	0	0
BLUEGILL	0	0	0	0	0	0	1	0	0	0
SMALLMOUTH BASS	34	34	29	34	13	5	3	2	3	27
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	1
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	20	15	16	10	6	7	1	10	13	109
TOTALS	**2,080**	**1,458**	**9,279**	**3,129**	**4,152**	**2,480**	**950**	**1,118**	**2,083**	**1,708**

Table 1 (continued)

Date	5/22	5/23	5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31
Start Veiwing Time	7:45	8:00	7:40	8:00	7:45	8:00	7:45	8:00	7:40	8:00
End Viewing Time	17:15	17:15	17:20	17:15	17:15	17:15	17:15	17:15	17:05	17:00
Elapsed Viewing Time	9.5	9.3	9.7	9.3	9.5	9.3	9.5	9.3	9.4	9.0
Lifts Per Day	12	8	13	12	12	11	11	12	12	12
Water Temperature (F)	65.3	64.8	65.1	66	69	71.9	74.5	77.3	79	81
AMERICAN SHAD	55	68	264	143	112	70	48	23	52	51
GIZZARD SHAD	2,055	2,274	3,970	3,653	2,865	3,776	7,105	5,482	5,970	3,255
SEA LAMPREY	0	0	0	0	1	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	1
CARP	1	1	35	528	151	10	28	2	5	0
QUILLBACK	28	31	21	108	106	97	47	18	60	14
S. REDHORSE	42	8	16	35	44	42	29	25	14	10
CHANNEL CATFISH	23	8	13	20	87	75	53	65	74	64
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0
ROCK BASS	5	0	1	0	0	1	0	0	0	0
PUMPKINSEED	0	0	0	0	0	0	0	0	0	0
BLUEGILL	1	0	1	0	1	0	4	4	3	11
SMALLMOUTH BASS	13	5	8	8	7	1	14	11	6	3
LARGEMOUTH BASS	0	0	0	0	1	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	54	6	18	15	44	78	32	33	17	41
TOTALS	**2,277**	**2,401**	**4,347**	**4,510**	**3,419**	**4,150**	**7,360**	**5,663**	**6,201**	**3,450**

Table 1 (continued)

Date	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	**Season Total**
Start Veiwing Time	7:45	9:00	7:45	8:00	7:45	8:00	7:40	8:00	8:00	7:45	
End Viewing Time	17:15	17:00	16:10	16:30	16:15	17:00	17:00	16:30	15:30	15:00	
Elapsed Viewing Time	9.5	8.0	8.4	8.5	8.5	9.0	9.3	8.5	7.5	7.3	**455**
Lifts Per Day	12	9	10	9	9	13	13	12	9	10	**598**
Water Temperature (F)	82	81.6	81.3	80.6	79.8	79	79	77	75	73	
AMERICAN SHAD	45	12	17	29	30	37	26	6	2	7	**4,242**
GIZZARD SHAD	3,245	1,220	2,035	1,562	1,147	1,891	2,076	644	275	132	**144,315**
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0	**1**
BROWN TROUT	0	0	0	0	0	0	0	0	0	0	**1**
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	0	**1**
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0	**4**
CARP	27	5	17	1	0	1	2	2	0	0	**1,035**
QUILLBACK	16	0	3	0	1	0	1	2	0	0	**1,418**
S. REDHORSE	1	4	0	1	0	0	0	0	0	0	**3,067**
CHANNEL CATFISH	103	40	117	47	32	36	101	18	7	12	**1,250**
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0	**2**
ROCK BASS	0	0	0	0	0	0	0	0	0	0	**15**
PUMPKINSEED	0	0	0	0	0	0	0	0	0	0	**1**
BLUEGILL	5	1	0	0	0	0	3	0	0	0	**38**
SMALLMOUTH BASS	6	1	0	1	3	0	0	0	0	0	**1,381**
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0	**1**
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0	**1**
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0	**1**
WALLEYE	30	15	23	9	11	5	8	3	0	2	**871**
TOTALS	**3,478**	**1,298**	**2,212**	**1,650**	**1,224**	**1,970**	**2,217**	**675**	**284**	**153**	**157,645**

Table 2

Summary of daily average river flow as measured at USGS Gauge Marietta, water temperature, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Safe Harbor fish passage facility in 2016.

Date	River Flow[1] (mcfs)	Water Temp (°F)	Secchi (in)	Maximum # of Units Operating	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)	Daily No. of Am. Shad Passed
22-Apr	29,000	63	20	NA	A/C	500	171.0	226.3	97
23-Apr	27,700	63	14	NA	A/C	500	170.4	226.8	230
24-Apr	26,500	63	18	NA	A/C	500	170.7	226.4	123
25-Apr	25,300	63	20	NA	A/C	500	171.2	226.5	331
26-Apr	24,000	64.5	14	NA	A/C	500	170.0	226.6	186
27-Apr	23,000	65.3	12	NA	A/C	500	169.1	226.8	130
28-Apr	22,400	65.5	18	NA	A/C	500	170.0	226.8	128
29-Apr	22,600	64.4	10	NA	A/C	500	170.5	226.6	107
30-Apr	22,000	61.3	10	NA	A/C	500	169.4	226.6	112
1-May	22,100	58.5	18	NA	A/C	500	170.0	226.5	43
2-May	23,400	57.7	15	10	A/C	500	169.9	226.2	55
3-May	29,400	57.7	14	5	A/C	500	168.9	226.4	117
4-May	36,000	59	15	NA	A/C	500	170.8	226.6	128
5-May	49,600	59.3	10	10	A/C	500	172.3	225.4	88
6-May	53,100	58	14	11	A/C	500	173.1	226.5	103
7-May	55,800	57.1	18	11	A/C	500	172.1	226.3	37
8-May	53,300	58	20	11	A/C	500	172.6	226.1	9
9-May	50,700	59	18	12	A/C	500	172.6	226.7	64
10-May	47,500	59.8	20	NA	A/C	500	171.9	226.2	16
11-May	42,600	59.3	20	NA	A/C	500	170.6	226.8	25
12-May	38,200	59.4	20	NA	A/C	500	169.7	226.1	39
13-May	35,000	59.9	18	NA	A/C	500	170.7	225.9	61
14-May	33,000	62.1	20	NA	A/C	500	171.5	226.2	149
15-May	31,900	63	20	NA	A/C	500	170.8	226.2	115
16-May	31,600	62	20	7	A/C	500	171.8	226.4	105
17-May	31,500	61	18	11	A/C	500	172.1	226.4	124
18-May	31,000	61	20	NA	A/C	500	170.9	226.8	74
19-May	29,600	61	20	NA	A/C	500	170.1	226.7	69
20-May	27,400	62.2	20	NA	A/C	500	170.2	226.6	142
21-May	25,800	64.4	20	NA	A/C	500	169.2	226.4	138
22-May	25,600	65.3	20	NA	A/C	500	169.6	226.3	55
23-May	25,600	64.8	20	NA	A/C	500	169.9	226.4	68
24-May	30,100	65.1	20	NA	A/C	500	170.4	226.7	264
25-May	33,500	66	20	NA	A/C	500	170.2	226.4	143
26-May	32,500	69	24	NA	A/C	500	169.8	226.7	112
27-May	29,600	71.9	24	NA	A/C	500	170.2	225.7	70
28-May	27,100	74.5	24	NA	A/C	500	169.4	226.0	48
29-May	25,000	77.3	24	NA	A/C	500	169.4	226.2	23
30-May	23,700	79	24	NA	A/C	500	169.1	226.4	52
31-May	23,000	81	24	NA	A/C	500	170.5	226.8	51
1-Jun	20,800	82	18	NA	A/C	500	169.4	226.5	45
2-Jun	19,000	81.6	24	NA	A/C	500	169.3	226.1	12
3-Jun	17,900	81.3	16	NA	A/C	500	169.3	226.5	17
4-Jun	18,000	80.6	20	NA	A/C	500	169.1	226.5	29
5-Jun	17,800	79.8	18	NA	A/C	500	168.4	226.5	30
6-Jun	21,400	79	20	3	A/C	500	168.9	226.6	37
7-Jun	22,000	79	18	NA	A/C	500	169.1	226.6	26
8-Jun	24,500	77	14	7	A/C	500	169.7	226.6	6
9-Jun	23,800	75	14	NA	A/C	500	169.5	226.5	2
10-Jun	23,100	73	14	5	A/C	500	170.5	226.6	7

1 River flow measured at USGS Marietta Guage.

NA: information not available

Table 3

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2016.

	Conowingo East	Holtwood*		Safe Harbor		York Haven	
		Number	% of C.E.L.	Number	% of Holt.	Number	% of S.H.
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,687	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%
2004	109,360	3,428	3.1%	2,109	61.5%	219	10.4%
2005	68,926	34,189	49.6%	25,425	74.4%	1,772	7.0%
2006	56,899	35,968	63.2%	24,929	69.3%	1,913	7.7%
2007	25,464	10,338	40.6%	7,215	69.8%	192	2.7%
2008	19,914	2,795	14.0%	1,252	44.8%	21	1.7%
2009	29,272	10,896	37.2%	7,994	73.4%	402	5.0%
2010	37,757	16,472	43.63%	12,706	77.14%	907	7.14%
2011	20,571	21	0.1%	8	38.1%	0	0.0%
2012	22,143	4,238	19.1%	3,089	72.9%	224	7.3%
2013	12,733	2,503	19.7%	1,927	77.0%	202	10.5%
2014	10,425	2,589	24.8%	1,336	51.6%	8	0.6%
2015	8,341	5,286	63.3%	3,896	73.7%	43	1.1%
2016	**14,276**	**6,718**	**47.0%**	**4,242**	**63.1%**	**178**	**4.2%**

*Am. Shad passed at Holtwood from April 2 to June 8.

Table 4

Hourly summary of daily American shad passage at the Safe Harbor fish passage facility in 2016.

Date:	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
Observation Time-Start:	7:45	8:00	7:30	7:30	8:00	8:00	7:30	9:30	8:00	7:30	7:30	8:00
Observation Time-End:	16:15	16:30	16:15	17:30	17:20	17:05	17:15	17:10	17:10	17:10	17:35	17:15
Military Time (hrs)												
0600 to 0659												
0700 to 0759	1		2	2			2			6	2	
0800 to 0859	8	15	26	26	40	19	11		11	2	4	12
0900 to 0959	10	23	13	37	18	15	0	11	15	3	1	8
1000 to 1059	5	30	5	27	17	2	29	16	3	2	1	13
1100 to 1159	5	40	26	30	21	19	15	18	13	0	0	5
1200 to 1259	10	36	21	36	13	20	10	16	15	4	0	7
1300 to 1359	16	34	18	46	6	20	14	21	16	3	2	17
1400 to 1459	15	22	10	35	25	18	10	7	15	4	9	24
1500 to 1559	14	17	2	46	27	11	11	7	13	4	5	17
1600 to 1659	13	13	0	38	12	6	20	3	10	11	19	12
1700 to 1759				8	7		6	8	1	4	12	2
1800 to 1859												
1900 to 1959												
Total	**97**	**230**	**123**	**331**	**186**	**130**	**128**	**107**	**112**	**43**	**55**	**117**

Date:	5/4	5/5	5/6	5/7	5/8	5/9	5/10	5/11	5/12	5/13	5/14	5/15
Observation Time-Start:	8:00	7:30	9:00	7:30	8:00	7:30	8:00	7:20	8:00	8:45	8:00	7:20
Observation Time-End:	17:10	17:15	17:10	17:15	17:10	17:40	17:15	17:25	17:30	17:15	17:00	17:15
Military Time (hrs)												
0600 to 0659												
0700 to 0759		0		1		3		2				14
0800 to 0859	11	4		9	1	3	7	0	3	12	23	13
0900 to 0959	4	4	12	0	0	1	8	1	0	4	9	12
1000 to 1059	2	0	14	2	0	4	0	1	10	1	9	8
1100 to 1159	7	2	11	11	0	5	0	0	10	8	15	16
1200 to 1259	0	0	1	1	1	5	0	0	4	10	23	8
1300 to 1359	44	0	16	2	0	10	0	0	1	6	26	4
1400 to 1459	35	35	8	2	2	15	0	14	7	8	9	7
1500 to 1559	10	22	12	3	1	9	0	3	1	6	24	24
1600 to 1659	14	15	15	5	4	7	1	3	1	2	11	7
1700 to 1759	1	6	14	1	0	2	0	1	2	4		2
1800 to 1859												
1900 to 1959												
Total	**128**	**88**	**103**	**37**	**9**	**64**	**16**	**25**	**39**	**61**	**149**	**115**

Table 4
Continued.

Date:	5/16	5/17	5/18	5/19	5/20	5/21	5/22	5/23	5/24	5/25	5/26	5/27
Observation Time-Start:	8:00	7:30	7:40	8:00	9:20	7:30	7:45	8:00	7:40	8:00	7:45	8:00
Observation Time-End:	17:10	17:10	17:05	17:05	17:00	16:50	17:15	17:15	!7:20	17:15	17:15	17:15
Military Time (hrs)												
0600 to 0659												
0700 to 0759		1	4			17	2		4		9	
0800 to 0859	13	12	11	5		12	8	0	63	26	22	22
0900 to 0959	7	24	1	4	8	14	3	0	27	12	8	7
1000 to 1059	8	10	4	3	17	9	8	0	30	9	7	4
1100 to 1159	8	11	9	1	23	16	4	2	23	14	23	12
1200 to 1259	11	21	0	3	11	23	3	14	24	7	11	3
1300 to 1359	9	17	13	2	6	13	13	9	31	11	6	4
1400 to 1459	19	9	10	11	13	14	2	19	9	6	12	9
1500 to 1559	13	11	11	30	25	17	3	6	22	32	4	4
1600 to 1659	10	5	10	6	39	3	8	15	14	18	9	4
1700 to 1759	7	3	1	4			1	3	17	8	1	1
1800 to 1859												
1900 to 1959												
Total	**105**	**124**	**74**	**69**	**142**	**138**	**55**	**68**	**264**	**143**	**112**	**70**

Date:	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	***Season Total***
Observation Time-Start:	7:45	8:00	7:40	8:00	7:45	9:00	7:45	8:00	7:45	8:00	7:40	8:00	8:00	7:45	
Observation Time-End:	17:15	17:15	17:05	17:00	17:15	17:00	16:10	16:30	16:15	17:00	17:00	16:30	15:30	15:00	
Military Time (hrs)															
0600 to 0659															**0**
0700 to 0759	3		4		3		1		2		4			1	**90**
0800 to 0859	6	8	5	27	1		3	2	1	1	3	0	2	2	**515**
0900 to 0959	4	2	1	0	5	0	0	6	3	2	6	0	0	2	**355**
1000 to 1059	4	3	4	4	5	1	4	7	2	5	0	0	0	1	**350**
1100 to 1159	2	1	2	5	1	0	2	3	7	5	4	3	0	1	**459**
1200 to 1259	6	1	5	4	1	1	1	1	5	3	0	0	0	0	**400**
1300 to 1359	8	2	1	4	3	3	2	2	3	3	3	1	0	0	**491**
1400 to 1459	5	0	9	1	6	2	4	1	0	7	1	0	0	0	**505**
1500 to 1559	2	1	14	4	5	0	0	6	4	1	1	1	0		**506**
1600 to 1659	4	3	7	2	12	5	0	1	3	10	4	1			**435**
1700 to 1759	4	2			3										**136**
1800 to 1859															**0**
1900 to 1959															**0**
Total	**48**	**23**	**52**	**51**	**45**	**12**	**17**	**29**	**30**	**37**	**26**	**6**	**2**	**7**	**4,242**

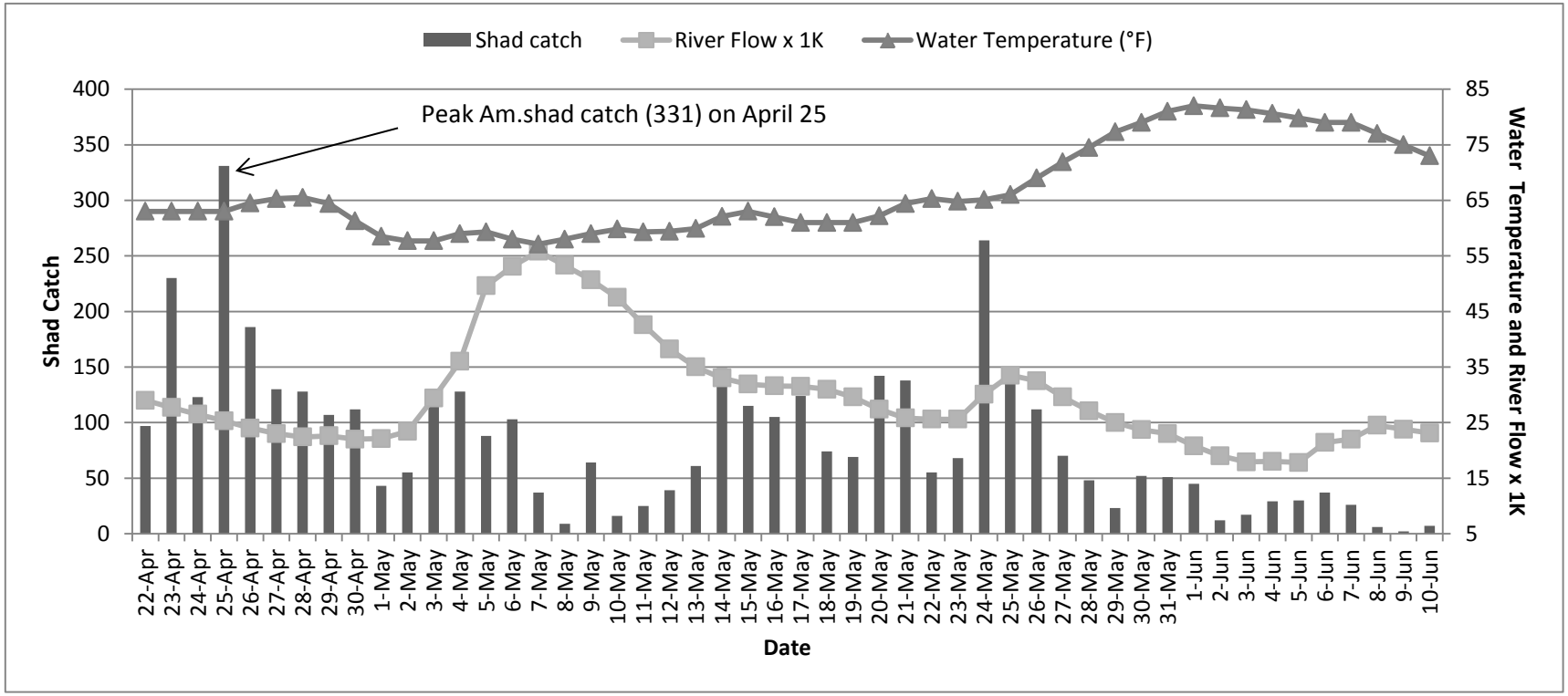

Figure 1

A plot of river flow (USGS Marietta Gauge) and water temperature (°F), in relation to the daily American shad catch at the Safe Harbor Fish Passage Facility, Spring 2016.

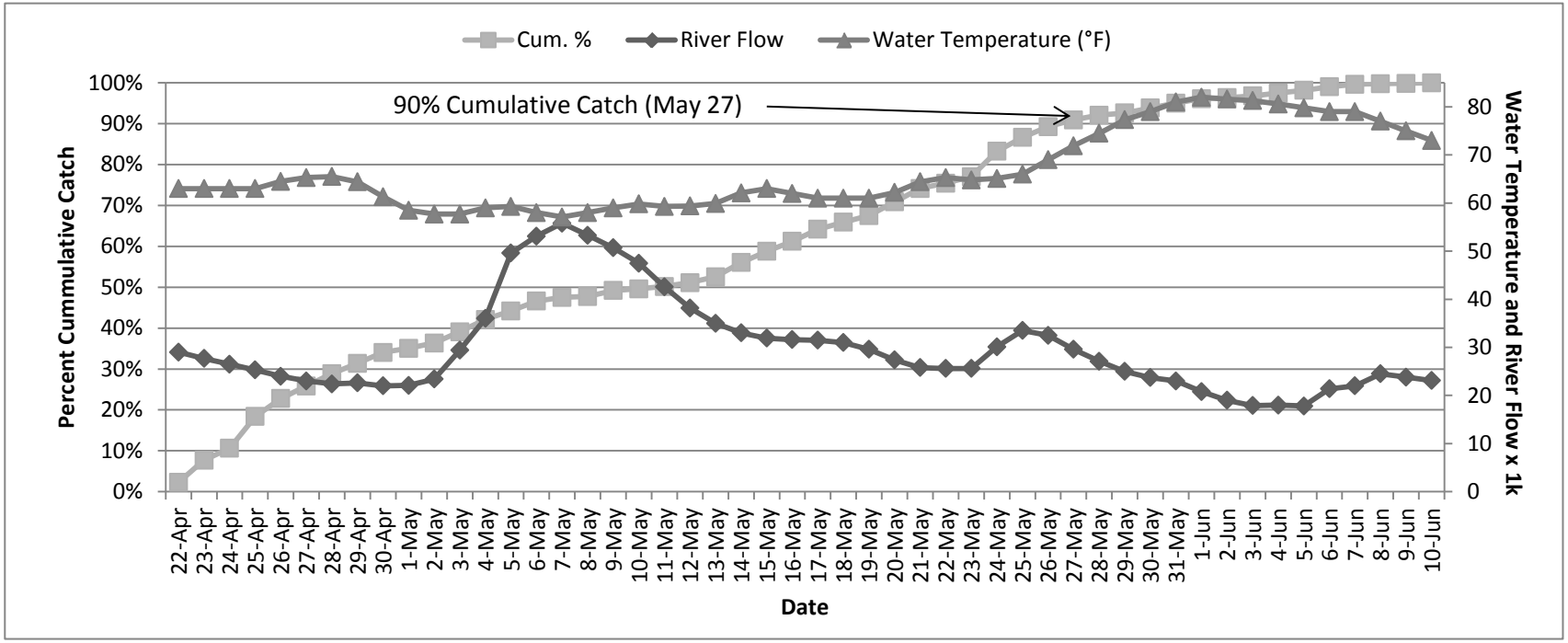

Figure 2

A plot of river flow (USGS Marietta Gauge) and water temperature (°F), in relation to the percent cumulative American shad catch at the Safe Harbor Fish Passage Facility, Spring 2016.