JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2008

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INTRODUCTION

The Pennsylvania Fish and Boat Commission has operated the Van Dyke Research Station for Anadromous Fishes since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River Basin. The objectives of the Van Dyke Station were to research culture techniques for American shad and to rear juveniles for release into the Juniata and Susquehanna Rivers. The program goal was to develop a stock of shad imprinted to the Susquehanna drainage, which will subsequently return to the river as spawning adults. With the completion of York Haven Dam fish passage facilities in 2000, upstream hydroelectric project owners were no longer responsible for funding the hatchery effort. Funding was provided by the Pennsylvania Fish and Boat Commission.

In 2003, a new effort in migratory fish restoration was undertaken. Adult hickory shad (*Alosa mediocris*) were collected and tank-spawned as part of the initial efforts to culture, release and restore runs of hickory shad to the Susquehanna and Delaware River basins.

As is previous years, production goals for American shad for 2008 were to stock 10-20 million American shad larvae. All Van Dyke hatchery-reared American and hickory shad larvae were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared shad from those produced by natural spawning of wild adults. All eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources.

EGG SHIPMENTS

Hickory shad

Adult pre-spawn hickory shad were collected from anglers or by electrofishing at the mouth of Deer Creek. A total of 9.8 million hickory shad eggs (31.1 L) were received in eight shipments from tank-spawning operations at Conowingo Dam (Table 1). Some 7.2 million (74%) of the hickory shad eggs were viable.

A test was conducted to compare tank-spawning with and without the use of hormone injections. Three replicates were performed (Table 2). Nearly twice as many eggs were produced from the untreated controls (6.6 million) than the hormone injected tests (3.2 million). Egg viability for the controls was 71% compared to 79% for the hormone-injected tests. This was, in part, due to the mortality of all eggs from shipment 8, trial 1. These eggs were the second batch to come off from trial 1 and were bagged at Conowingo at 7:00AM, but not put in incubation jars at Van Dyke until 7:30PM. This total mortality may have been due to poor eggs, too little oxygen added to the bag or the long time the eggs spent in the bag before being put in an incubation jar. Discounting this batch of eggs, the egg viability for the controls was greater than for the

hormone-injected fish for each of the three replicates. Two of the non-injected controls produced two batches of eggs, while each of the other trials produced only a single batch of eggs. Given the cost of the hormone implants ($12 per fish) and the success of tank-spawning without hormone injection (high egg production, high viability) we recommend future hickory shad tank-spawning be conducted without hormone implants.

American shad

A total of 20.1 million American shad eggs (441 L) were received in 40 shipments in 2008 (Table 1). This was the second highest quantity of eggs received since 2003 due to improved egg collection on the Delaware and Potomac Rivers (Tables 1 and 3, Figure 1). Overall American shad egg viability (which we define as the percentage which ultimately hatches) was 28%.

Twelve Potomac River egg shipments (8.5 million eggs) were received from April 10 to May 9, 2008. Overall viability was 41%. This is a slight increase in egg production over 2006 (7.5 million eggs).

Delaware River egg shipments were received from May 6 to June 2. A total of 17 shipments were received (5.9 million eggs) with a viability of 28%. This is above the average of 4.3 million eggs from 1999 to 2007, but well below the average of 10.5 million eggs from 1990 to 1998 (Table 4, Figure 1).

American shad eggs were also obtained from a tank-spawning effort at Conowingo Dam, operated by Normandeau Associates. Pre-spawn adult American shad were obtained from the West Fish Lift at Conowingo Dam. In most trials, shad were injected with hormones and allowed to spawn naturally. Two trials were experimental controls in

which shad were not injected with hormones. Both controls were unsuccessful at producing eggs. The tank-spawn array at Conowingo uses water pumped directly from the river and is subject to natural fluctuations in water temperature. Ability to control temperature in the tank (gradual warming to optimal temperature) is thought to be critical for successful tank-spawning without hormones (Jeff Evans, NC Wildlife Resource Commission, personal communication).

In hormone-injected trials, 5.7 million eggs, in 11 shipments, were delivered to the Van Dyke Hatchery, with a viability of 10%. By comparison, 10.3 and 6.8 million eggs were received from this source in 2006 and 2007, respectively. This has become a consistent source of eggs for the restoration program, but viability has been low, ranging from 9% to 33%.

No eggs were collected from the Hudson River in 2008 due to concerns over declines in the Hudson River stock. The loss of the Hudson River as an egg source is unfortunate because of its consistent production of high quality eggs. Egg production from the Potomac, Delaware and Susquehanna Rivers has been consistent over the last several years and it has become apparent that additional or expanded sources of eggs will be required to meet the goal of 10-15 million larvae stocked.

SURVIVAL

Survival of individual tanks followed patterns similar to those observed in the past in that the majority of the tanks experienced their highest mortality after nine days of age (Figure 2). Overall survival of American shad larvae was 71% compared to a range of 19% to 94% for the period 1984 through 2007. Tank C11 suffered complete mortality

when a red-spotted newt became lodged in the influent valve and cut-off flow to the tank. Tank E21 also suffered a high mortality incident when leaves lodged in the influent and reduced influent flow. Nine other tanks suffered high mortality when heating oil ran out over the Memorial Day weekend. High water in the Juniata River prevented scheduled stocking and resulted in an unusual number of tanks in use. This, combined with an extended period of cold weather, increased oil usage. Higher than normal mortalities occurred for a five day period, resulting in mortality of more than 500 thousand fry.

Over the last several years, we experienced poor survival of larvae in the hatchery and almost complete lack of hatchery juvenile production in the river, based on bio-monitoring collections. Our hypothesis was that low pH, aluminum toxicity and oxygen super-saturation worked together to weaken the fish and cause the mortalities (Hendricks 2007). To prevent mortality problems in the future, we recommended the following actions:

1. Install and utilize additional packed column de-gassers to reduce the need for oxygen injection.
2. Measure and record oxygen and nitrogen saturation on a daily basis.
3. Use the oxygen injection system only when needed and monitor oxygen saturation and larval condition when the system is in use.
4. Install and utilize a fluidized bed system, using limestone sand to buffer the Van Dyke source water, neutralize the pH and de-toxify dissolved aluminum.
5. Record pH, hardness and alkalinity on a regular basis to monitor fish culture water quality.

These recommendations were instituted in 2008, including the installation of a fluidized bed system (Figure 3). The system is crudely modeled after a system installed at the USFWS Warm Springs Regional Fisheries Center in Warm Springs, GA. We are indebted to Dr. Barnaby Watten of the USFWS for his assistance in developing this system. The fluidized bed system was installed at the head end of the warming pond. Gravity-fed spring pond water was directed into the bottom of two cone-bottom tanks partially filled with limestone sand. The velocity of the spring water fluidized the sand and the dissolution of the limestone sand raised the pH and hardness of the water. The limestone sand utilized was "High calcium glass sand #2" from Graymont Industries of Pleasant Gap, PA. It was purchased in 50 pound bags from Youngs Nutrition in Martinsburg, PA where it is sold as a feed additive to increase calcium content in milk from dairy cows. Mean particle size was between 300 and 400 microns. The limestone sand, as purchased, is very dusty and requires cleaning before use. This was accomplished by running the system to drain for two hours to clear the milky, high pH effluent or by cleaning small batches of sand in an 8 gallon bucket.

The actions taken in 2008 appeared to solve our mortality problems. Other than the incidents discussed above, no major mortalities occurred and our larvae looked larger and healthier than those stocked in recent years. In 2008, Van Dyke source water pH ranged from 5.9 to 7.1 with a mean of 6.5. Effluent from the fluidized bed system ranged from pH 7.1 to 11.0 with a mean of 8.7. Blending of source water and treated water was required to produce fish culture water in the desired range of pH 7 to 8. Blended fish culture water pH ranged from 6.8 to 9.1, with a mean of 7.4. Our improved skill in blending raw and treated water is apparent from Figure 4, where the drastic fluctuations in

pH which occurred in April were followed by much more consistent pH readings by June. The treatment system increased hardness from 10-20 ppm to 20-30 ppm.

LARVAL PRODUCTION

Hickory shad larvae (3.5 million) were stocked in the PA waters of Octoraro Creek below Octoraro Reservoir. Some 3.6 million hickory shad were also stocked in the Delaware River basin in Pennypack Creek (2.5 million) and Ridley Creek (1.1 million).

Production and stocking of American shad larvae, summarized in Tables 3, 4, 5 and 6, totaled 3.5 million. A total of 48 thousand was released in the Juniata River, 175 thousand in the Susquehanna River near Clemson Island, 1.7 million in the West Branch Susquehanna River, 172 thousand in the North Branch Susquehanna River in Pennsylvania, 76 thousand in Conodoguinet Creek, 46 thousand in West Conewago Creek, 125 thousand in Swatara Creek and 116 thousand in the Conestoga River. No shad larvae were provided to New York for stocking in the North Branch Susquehanna River or the Chemung River, due to the lack of certification that the larvae were VHS free. Large numbers of larvae were stocked in the West Branch because the Juniata River was high and turbid, but the West Branch was at normal levels and clear.

Although Delaware River egg collections increased over recent years, they were not sufficient to meet the goals for the Delaware River Basin. Larvae were stocked in the Lehigh River (697 thousand), the Schuylkill River (487thousand), and the Delaware River (158 thousand). Larvae stocked in the Delaware River were allocated to replenish the Delaware for the brood stock taken there.

Some 189 thousand fry were provided to the USFWS to be stocked in the Potomac River to replenish the Potomac for the brood stock taken there.

TETRACYCLINE MARKING

All American and hickory shad larvae stocked received marks produced by immersion in tetracycline (Table 7). All hickory shad larvae were marked with 512-ppm oxytetracycline hydrochloride for 4h duration and given a single mark on day 3. Immersion marks for American shad were administered by 4h bath treatments in 256-ppm.

All American shad larvae were marked according to stocking site and/or egg source, however the American shad marking scheme was complicated by mistakes, high water, and running out of heating oil. First, several mistakes were made in which tanks scheduled to be marked, were not marked on the day scheduled. Second, high water in the Juniata River delayed stocking for 1.5 million fry which were given an extra mark while they were waiting to be stocked. Third, tanks under culture during the heating oil incident were not marked in the cold water because it was feared the mark would not take. All marks were delayed during this period since otolith growth is proportional to metabolic rate and otolith increments formed during cold water would be expected to be very narrow. It was assumed that putting off marking for a few days would preserve the proper mark spacing.

Marks produced in 2008 are summarized in Table 7. Some 1.6 million larvae received quadruple marks, beginning at or after, day 15 and were stocked in the West Branch Susquehanna River. This sequence will not be repeated, thus, when these larvae

return as adults, they will be known age (see Table 8). An additional group of larvae (135 thousand) were marked on days 3,8,11,14,17 and also stocked in the West Branch. Because of the cold water associated with the heating oil incident, we are hoping that this mark will appear similar to a 3,6,9,12,15 tag. Some 83 thousand larvae were marked on day 3 and stocked in the Juniata or Susquehanna Rivers. Some 140 thousand larvae were marked on days 15,18 and 21 and stocked in the Juniata and Susquehanna Rivers. This is another sequence that will not be repeated, thus, when these larvae return as adults, they will also be known age. Larvae stocked in Conodoguinet Cr. received marks on days 3,6,12,15 (76 thousand larvae). Larvae stocked in Conestoga R. received marks on days 3,9,12,17 (116 thousand larvae). Larvae stocked in West Conewago Cr. received marks on days 3,9,12,15,18 (46 thousand larvae). Larvae stocked in Swatara Cr. received marks on days 3,6,11,17,20 (124 thousand larvae). Some 173 thousand larvae received marks on days 3,6,9,17 and were stocked in the North branch Susquehanna River. Larvae stocked in the Lehigh River received marks on days 9,12,15 (93 thousand), days 9,14,17 (54 thousand), or days 11,14,17 (550 thousand). Some 487 thousand larvae were marked on days 3,6,9,12 and stocked in the Schuylkill River. Some 158 thousand larvae were marked on days 3,6,12,15,18 and stocked in the Delaware River. Larvae stocked in the Potomac River as replenishment for brood taken (189 thousand) received marks on days 3 and 6.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways and examining otolith samples collected later. Otoliths were extracted and mounted in Permount on microscope slides. A thin section was produced by grinding the

otolith on both sides. Otolith sections were examined for marks with an epi-fluorescent microscope with a UV light source.

All fish examined exhibited marks, however observed marks did not necessarily conform to the marking protocol (Table 7). Digital photographs have been archived from representative samples of the marks detected for future reference. These will assist in identifying the origin of marks detected in out-migrating juveniles and returning adults from the 2008 cohort.

Only six hickory shad larvae survived raceway culture. Otoliths of five were successfully processed and all exhibited the intended single mark. Potomac River source fish, marked at days 3 and 6 and released in the Potomac River exhibited 100% mark retention and all marks were clearly 3,6 marks. Potomac River source fish, were scheduled to be marked at days 15,18,21 and released in the Juniata River. These fish were held in the hatchery due to high, muddy water in the Juniata River. While being held, they were given an extra mark on either days 24,25,26 or 27. After the marking sequence was finished, we realized that the West Branch Susquehanna River did not receive the rain that was received in the Juniata. Consequently, the West Branch was low and clear, and these fish were stocked there. A group of fish marked at either 15,18,21,26 or 15,18,21,27 was retained for tag retention studies. These exhibited 100% mark retention. Susquehanna and Potomac River source fish, marked on days 15,18,21 and stocked in the Juniata and middle Susquehanna Rivers exhibited 97% mark retention. One of the 30 fish analyzed appeared to have an extra tag at day 24. It is possible that this fish was transported from a tank or raceway with the 15,18,21,24 day tag.

Susquehanna River source fish, marked on days 3, 8,11,14,17, and released in the West Branch Susquehanna River exhibited 100% retention for the intended mark. Susquehanna or Delaware source fish marked at day 3 and stocked in the Juniata and middle Susquehanna Rivers were not held for mark retention. Susquehanna River source fish, marked on days 3, 6, 12, and 15, and released in Conodoguinet Creek exhibited 93% retention for the intended mark. Two of 27 (7%) had four marks, but the sequence appeared to be days 3, 11, 13 and 15. We have no explanation for this. Potomac River source fish, marked on days 3, 9, 12 and 17 and released in the Conestoga River exhibited 100% retention for the intended mark. Potomac River source fish, marked on days 3, 9, 12, 15 and 18, and released in West Conewago Creek exhibited 100% retention for the intended mark. Susquehanna River source fish, marked on days 3,6,11,17,20 and released in Swatara Creek exhibited 100% retention for the intended mark. Potomac River source fish, marked on days 3, 6, 9, and 17, and released in North Branch Susquehanna River (PA) exhibited 100% retention for the intended mark. Delaware River source fish, marked on days 9, 12, and 15, and released in the Lehigh River exhibited 100% retention for the intended mark. Delaware River source fish, marked on days 3, 6, 9, and 12, and released in the Schuylkill River exhibited 100% retention for the intended mark. Delaware River source fish, marked on days 3, 6, 12, 15 and 18, and released in the Delaware River exhibited 100% retention for the intended mark. Delaying the marking sequence by two days during the heating oil incident appeared to have the intended affect on the mark spacing. For example, marks on days 3,6,9 and 17 appeared similar to marks on days 3,6,9,15. Marking protocols for 2006 to 2010 are given in Table 8. The primary production mark for Potomac source larvae

stocked in the Juniata River or Susquehanna River near Montgomery Ferry will be changed every year to provide known age specimens for age verification.

SUMMARY

Eight shipments of hickory shad eggs (9.8 million eggs) were received at Van Dyke in 2008. Egg viability was 74% and 7.2 million hickory shad larvae were stocked in Octoraro Creek and in Delaware River tributaries, Pennypack Creek and Ridley Creek. Hickory shad brood that did not receive hormone injection produced more eggs than those with hormone injections. Viability of the eggs was similar, except for one questionable shipment, between hormone-injected brood and controls.

A total of 40 shipments of American shad eggs (20 million eggs) was received at Van Dyke in 2008. Total egg viability was 28% and survival of viable eggs to stocking was 71%, resulting in production of 4.0 million larvae. Larvae were stocked in the Juniata River (48 thousand), the Susquehanna River near Clemson Island (175 thousand), the West Branch Susquehanna River (1.7 million), the North Branch Susquehanna River in Pennsylvania (173 thousand), Conodoguinet Creek (76 thousand), West Conewago Creek (46 thousand), Conestoga river (116 thousand), and Swatara creek (124 thousand). Delaware river source larvae were stocked in the Lehigh River (697 thousand), the Schuylkill River (487 thousand) and the Delaware River (158 thousand).

Overall survival of larvae was 71%. Episodes of major mortality occurred in two tanks due to disruption of flow. Major mortality occurred in a number of tanks when our heating oil supply ran out. Mortalities thought to be due to oxygen super-saturation, low

pH and/or aluminum toxicity did not occur in 2008 with the installation of a fluidized bed system to increase pH and closer monitoring of the oxygen injection system.

All American and hickory shad larvae cultured at Van Dyke were marked by 4-hour immersion in oxytetracycline. Marks for American shad were assigned based on release site and/or egg source river. A number of unorthodox marks were produced because of errors in marking, extra marks given to fish cultured longer because of high river flows, and modification of the marking scheme associated with running out of heating oil. All mark retention specimens examined exhibited tetracycline marks. All but two groups exhibited the intended mark. A total of three specimens did not appear to have the intended mark. Digital photographs of representative specimens have been archived to aid in future mark evaluation. Hickory shad were marked at 512 ppm on day three. Mark retention for hickory shad was 100%, but only five specimens were processed.

RECOMMENDATIONS FOR 2009

1. Disinfect all egg shipments at 50 ppm free iodine.
2. Slow temper eggs collected at river temperatures below 55°F.
3. Routinely feed all larvae beginning at hatch.
4. Continue to hold egg jars on the incubation battery until eggs begin hatching (usually day 7), before transferring to the tanks. Transfer incubation jars to the tanks on day 7 without sunning. Sun the eggs on day 8 to force hatching.
5. Continue to siphon eggshells from the rearing tank within hours of egg hatch.
6. Continue to feed left over AP-100 only if freshly manufactured supplies run out.
7. Continue to hold Delaware River eggs until 8:00AM before processing.

8. Buy new foam bottom screens each year and specify “no-fire retardants” when ordering foam.
9. Modify the egg battery to accept 23 additional MSXXX jars (total 57).
10. Continue to collect American shad eggs from the Potomac River as an additional source of out-of-basin eggs.
11. Continue to develop a reference collection of scales and otoliths from known age American shad by marking according to year stocked (Table 8). Utilize uniquely marked larvae from the Potomac River egg source, stocked in the Juniata or Susquehanna Rivers.
12. Mark hickory shad at 512ppm OTC.
13. Continue using Pfizer Terramycin 343 (now FDA approved) for marking alosines.
14. Continue to utilize a fluidized bed system, using limestone sand to buffer the Van Dyke source water, neutralize the pH and reduce dissolved aluminum.
15. Continue to record pH, hardness and alkalinity on a regular basis to monitor fish culture water quality.
16. Continue to utilize additional packed column de-gassers to reduce the need for oxygen injection.
17. Continue to measure and record oxygen and nitrogen saturation on a daily basis. Use the oxygen injection system only when needed and monitor oxygen saturation and larval condition when the system is in use.
18. Mark all tanks of larvae beginning at 11:00AM, to ensure consistency in daily mark application.

19. Consider other options for hickory shad restoration, including direct stocking of eggs or stocking of pre-spawn adults, based on the absence of adult hickory shad in extensive collections conducted in 2008 by the Philadelphia Water Department.

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Figure 1.

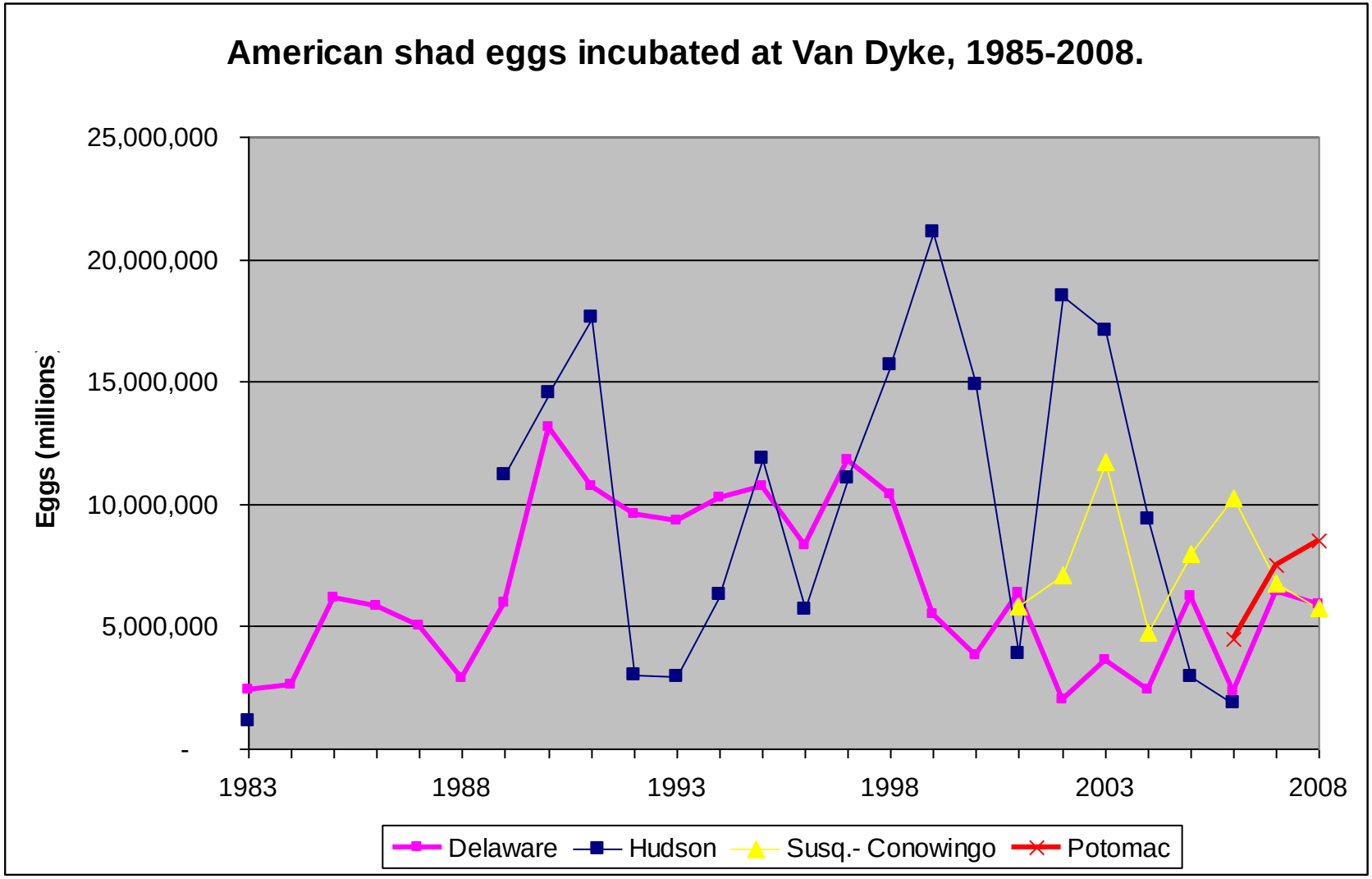
American shad eggs incubated at Van Dyke, 1985-2008.
Eggs (millions)
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
1983
1988
1993
1998
2003
2008
Delaware
Hudson
Susq.- Conowingo
Potomac

Figure 2.

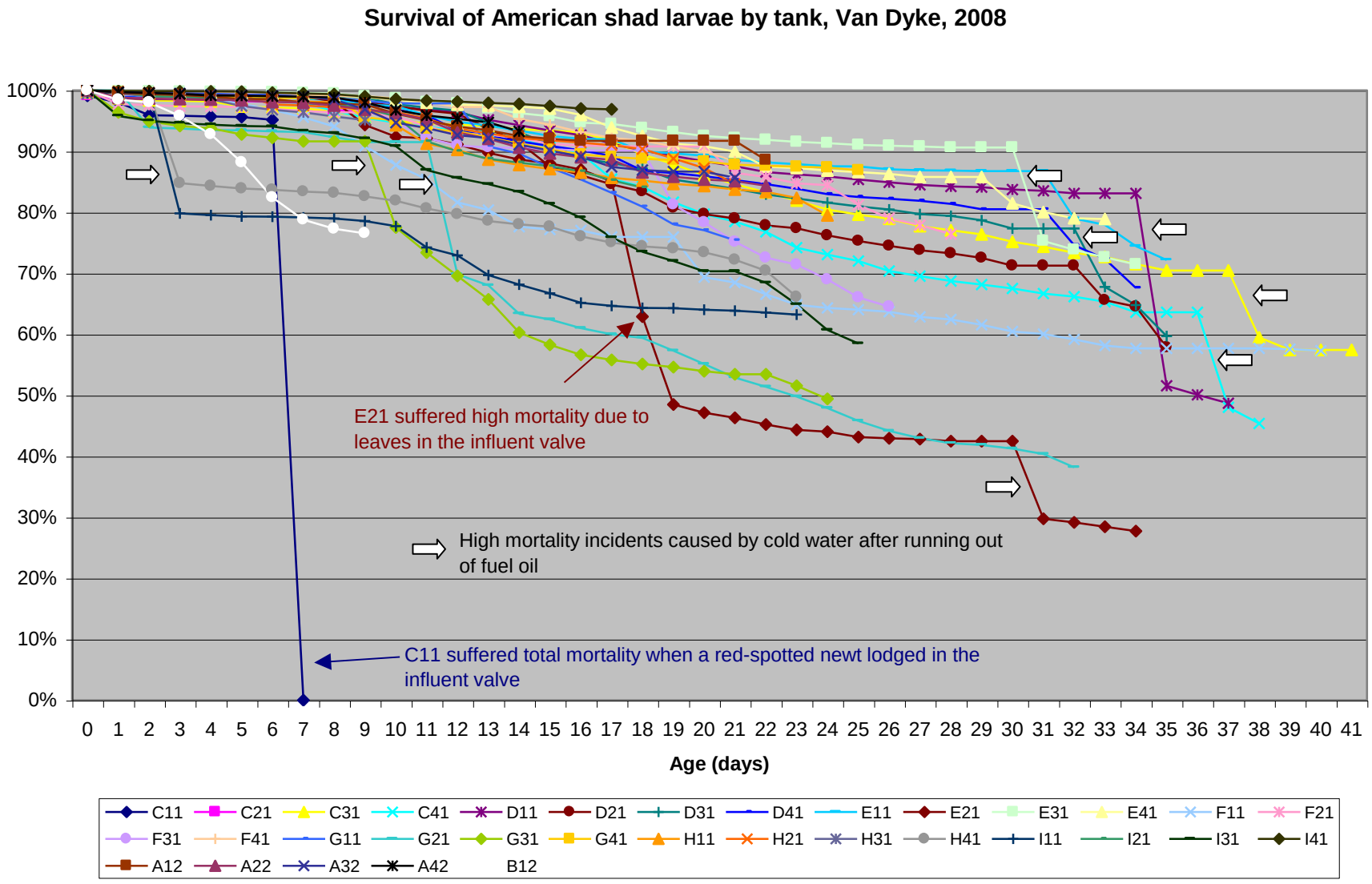
Survival of American shad larvae by tank, Van Dyke, 2008
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41
Age (days)
E21 suffered high mortality due to leaves in the influent valve
High mortality incidents caused by cold water after running out of fuel oil
C11 suffered total mortality when a red-spotted newt lodged in the influent valve
C11 C21 C31 C41 D11 D21 D31 D41 E11 E21 E31 E41 F11 F21
F31 F41 G11 G21 G31 G41 H11 H21 H31 H41 I11 I21 I31 I41
A12 A22 A32 A42 B12

Figure 3. Photograph of the fluidized bed system installed at the Van Dyke Hatchery.

Figure 4.

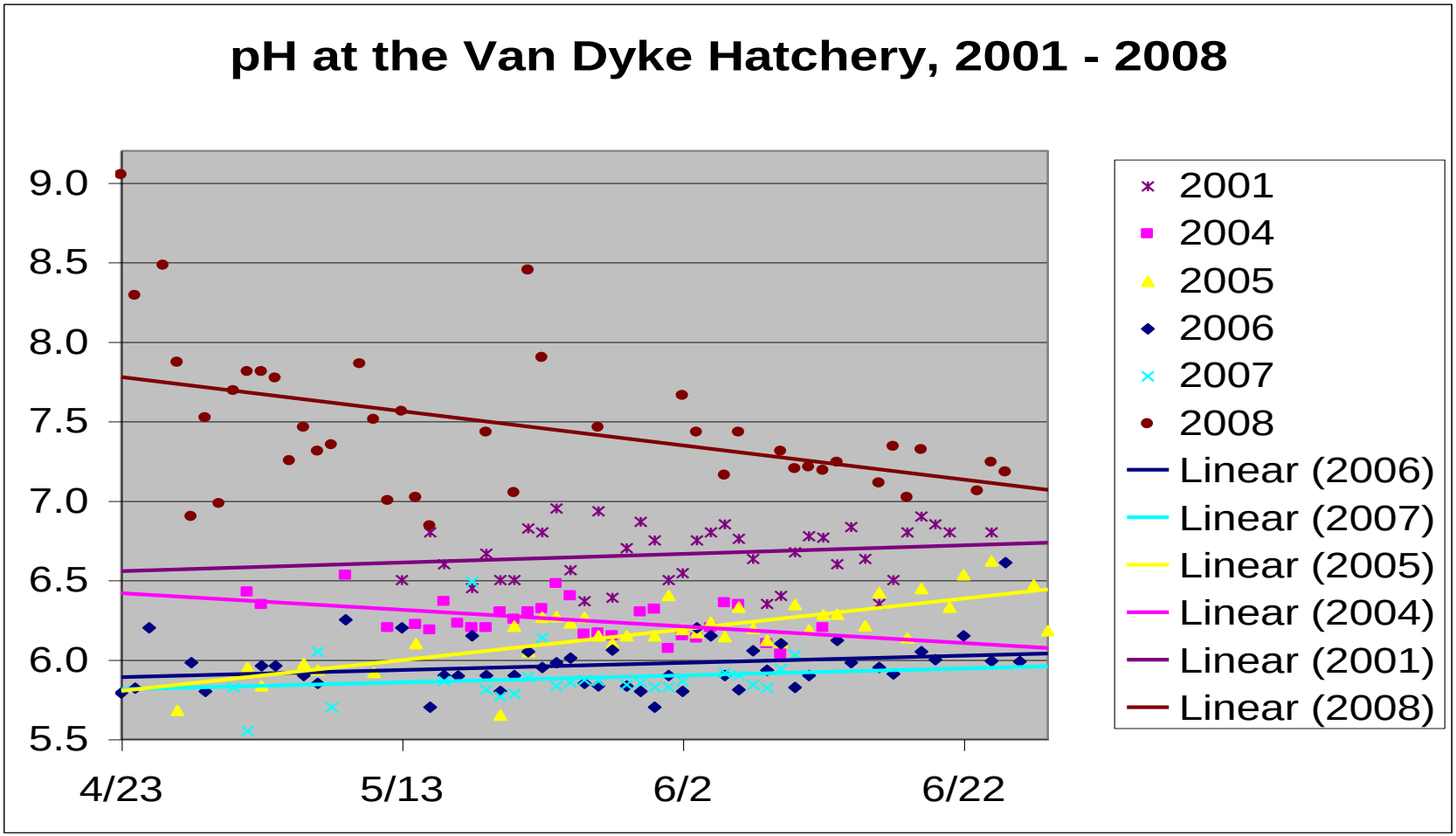
pH at the Van Dyke Hatchery, 2001 - 2008
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
4/23
5/13
6/2
6/22
2001
2004
2005
2006
2007
2008
Linear (2006)
Linear (2007)
Linear (2005)
Linear (2004)
Linear (2001)
Linear (2008)

Table 1. Egg shipments received at Van Dyke, 2008.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	American shad	Potomac	4/9/08	4/10/08	12.4	478,257	157,331	32.9%
2	American shad	Potomac	4/10/08	4/11/08	32.6	1,322,827	564,604	42.7%
3	American shad	Potomac	4/11/08	4/12/08	12.5	517,500	227,906	44.0%
4	Hickory shad	Susq.- Conowingo	4/13/08	4/14/08	6.3	1,831,311	1,516,517	82.8%
5	American shad	Potomac	4/14/08	4/15/08	5.7	224,678	102,649	45.7%
6	American Shad	Potomac	4/15/08	4/16/08	28.0	1,242,252	538,616	43.4%
7	American Shad	Potomac	4/16/08	4/17/08	26.1	1,135,472	433,380	38.2%
8	Hickory Shad	Susq.-Conowingo	4/17/08	4/17/08	4.4	1,267,020	0	0.0%
9	American shad	Potomac	4/17/08	4/18/08	30.7	1,457,350	612,352	42.0%
10	Hickory shad	Susq.-Conowingo	4/17/08	4/18/09	4.3	1,172,603	945,628	80.6%
11	American shad	Potomac	4/18/08	4/19/08	14.2	811,268	420,795	51.9%
12	Hickory Shad	Susq.-Conowingo	4/18/08	4/19/08	7.1	2,289,404	2,058,336	89.9%
13	Hickory shad	Susq.-Conowingo	4/19/08	4/20/08	0.8	325,945	296,859	91.1%
14	Hickory shad	Susq.-Conowingo	4/19/08	4/20/08	2.5	959,828	880,921	91.8%
15	Hickory Shad	Susq.-Conowingo	4/22/08	4/23/08	5.1	1,732,357	1,318,132	76.1%
16	Hickory Shad	Susq.-Conowingo	4/22/08	4/23/08	0.7	225,263	200,000	88.8%
17	American shad	Delaware River	4/27/08	4/28/08	2.5	86,883	26,121	30.1%
18	American shad	Potomac River	4/27/08	4/28/08	4.0	155,861	59,551	38.2%
19	American shad	Susq.- Conowingo	4/28/08	4/29/08	13.6	577,452	117,263	20.3%
20	American Shad	Potomac	4/4/08	4/5/08	9.5	370,171	130,768	35.3%
21	American Shad	Potomac	5/5/08	5/6/08	11.4	476,695	228,890	48.0%
22	American shad	Delaware	5/5/08	5/6/08	4.8	138,523	11,275	8.1%
23	American Shad	Delaware	5/6/08	5/7/08	6.6	226,949	92,481	40.7%
24	American shad	Delaware	5/7/08	5/8/08	2.5	87,807	15,387	17.5%
25	American Shad	Potomac	5/8/08	5/9/08	7.3	311,378	14,228	4.6%
26	American shad	Delaware	5/8/08	5/9/08	6.2	199,874	21,756	10.9%
27	American Shad	Susq.-Conowingo	5/8/08	5/9/08	6.5	546,891	20,116	3.7%
28	American Shad	Susq.- Conowingo	5/10/08	5/11/08	6.5	409,267	67,840	16.6%
29	American Shad	Susq.- Conowingo	5/10/08	5/11/08	5.8	378,043	54,800	14.5%
30	American shad	Delaware	5/11/08	5/12/09	4.6	153,182	44,499	29.1%
31	American shad	Delaware	5/12/08	5/13/09	3.0	90,542	9,920	11.0%
32	American Shad	Susq.- Conowingo	5/12/08	5/13/08	17.3	997,166	160,103	16.1%
33	American Shad	Delaware	5/13/08	1/0/00	1.3	43,758	21,823	49.9%
34	American Shad	Delaware	5/14/08	5/15/08	16.5	573,429	215,636	37.6%
35	American Shad	Susq.-Conowingo	5/14/08	5/15/08	4.8	334,875	3,028	0.9%
36	American Shad	Delaware	5/15/08	5/16/08	25.2	962,023	416,298	43.3%
37	American Shad	Susq.-Conowingo	5/18/08	5/19/08	12.2	818,940	18,141	2.2%
38	American Shad	Delaware	5/18/08	5/19/08	8.8	277,569	56,811	20.5%
39	American Shad	Delaware	5/20/08	5/21/08	4.2	153,838	35,450	23.0%
40	American Shad	Susq.-Conowingo	5/20/08	5/21/08	7.2	386,022	12,531	3.2%
41	American Shad	Susq.-Conowingo	5/20/08	5/21/08	9.6	558,375	44,631	8.0%
42	American shad	Delaware	5/26/08	5/27/08	14.4	737,168	379,368	51.5%
43	Amerian shad	Delaware	5/27/08	5/28/08	21.8	986,208	22,693	2.3%
44	American Shad	Susq. - Conowingo	5/27/08	5/28/08	13.6	689,748	28,363	4.1%
45	American Shad	Delaware	5/28/08	5/29/08	13.6	457,772	290,827	63.5%
46	American Shad	Delaware	5/29/08	5/30/08	8.1	501,192	0	0.0%
47	American shad	Delaware	6/1/08	6/2/08	4.1	190,934	10,397	5.4%
48	American shad	Susq.-Conowingo	6/2/08	6/3/08	1.3	52,687	0	0.0%
Totals			**No. of shipments**					
	American shad	**Potomac**	12		194.4	8,503,709	3,491,069	41.1%
		Delaware	17		148.2	5,867,652	1,670,744	28.5%
		Susq.- Conowingo	11		98.4	5,749,466	526,816	9.8%
		Grand total	**40**		**440.9**	**20,120,827**	**5,688,628**	**28.3%**
	Hickory shad	**Susq.- Conowingo**	**8**		**31.1**	**9,803,731**	**7,216,392**	**73.6%**

Table 2. Hickory shad tank spawning trials, 2008.

	Controls (no hormones)					Test (with hormone injection)				
Trial	**Shipment**	**Date**	**Eggs**	**Viable eggs**	**% viability**	**Shipment**	**Date**	**Eggs**	**Viable eggs**	**% viability**
1	4	4/14/08	1,831,311	1,516,517	83%	10	4/18/09	1,172,603	945,628	81%
1	8*	4/17/08	1,267,020	-	0%					
			3,098,331	1,516,517	49%					
2	12	4/19/08	2,289,404	2,058,336	90%	13	4/20/08	325,945	296,859	91%
2	14	4/20/08	959,828	880,921	92%					
			3,249,233	2,939,256	90%					
3	16	4/23/08	225,263	200,000	89%	15	4/23/08	1,732,357	1,318,132	76%
	Totals		**6,572,826**	**4,655,773**	**71%**			**3,230,905**	**2,560,619**	**79%**
						Grand Total		**9,803,731**	**7,216,392**	**74%**

*All eggs dead on arrival at Van Dyke. Eggs bagged at 7AM but not put in incubation jars until 7:30PM. May have been too long in bag, not enough DO, or bad eggs in the first place.

Table 3. Annual summary of American shad production, 1976-2008.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	No. of Fry stocked (exp.3)		No. of Fingerling stocked (exp.3)	Total stocked (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518		266	784	0.19	0.37
1977	145	6.4	46.7	2.9	969		35	1,003	0.16	0.34
1978	381	14.5	44.0	6.4	2,124		6	2,130	0.10	0.33
1979	164	6.4	41.4	2.6	629		34	664	0.10	0.25
1980	347	12.6	65.6	8.2	3,526		5	3,531	0.28	0.43
1981	286	11.6	44.9	5.2	2,030		24	2,053	0.18	0.39
1982	624	25.9	35.7	9.2	5,019		41	5,060	0.20	0.55
1983	938	34.5	55.6	19.2	4,048		98	4,146	0.12	0.22
1984	1157	41.1	45.2	18.6	11,996		30	12,026	-	0.73
1985	814	25.6	40.9	10.1	6,960		115	7,075	0.28	0.68
1986	1535	52.7	40.7	21.4	15,876		61	15,928	0.30	0.74
1987	974	33.0	40.7	15.8	10,274		81	10,355	0.31	0.66
1988	885	31.8	38.7	12.3	10,441		74	10,515	0.33	0.86
1989	1220	42.7	60.1	25.7	22,267		60	22,327	0.52	0.87
1990	896	28.6	56.7	16.2	12,034		253	12,287	0.43	0.76
1991	902	29.8	60.7	18.1	12,963		233	13,196	0.44	0.73
1992	532	18.5	68.3	12.6	4,645		34	4,679	0.25	0.37
1993	558	21.5	58.3	12.8	7,870		79	7,949	0.37	0.62
1994	551	21.2	45.9	9.7	7,720	*	140	7,860	0.31	0.68
1995	768	22.6	53.9	12.2	10,930	*	-	10,930	0.43	0.79
1996	460	14.4	62.7	9.0	8,466	*	-	8,466	0.59	0.94
1997	593	22.8	46.6	10.6	8,019		25	8,044	0.35	0.76
1998	628	27.7	57.4	15.9	11,757		2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412		-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535		-	10,535	0.56	0.87
2001	423	21.1	35.0	7.4	6,524		7	6,531	0.31	0.88
2002	943	35.6	38.8	13.8	2,589		-	2,589	0.07	0.19
2003	1005	33.0	49.4	16.3	12,742		-	12,742	0.39	0.78
2004	462	17.3	54.0	9.3	5,637		-	5,637	0.33	0.60
2005	372	17.1	36.6	6.0	5,208		1	5,209	0.30	0.87
2006	394	19.0	35.2	6.7	4,945		-	4,945	0.26	0.74
2007	404	20.7	27.7	5.8	2,509		-	2,509	0.12	0.43
2008	441	20.1	28.3	5.7	4,020		-	4,020	0.20	0.71
*Includes fry reared at Manning Hatchery.							**Total**	**251,895**		
				Total since 1985 (OTC marked)				**220,498**		

Table 4. American shad eggs used in Pennsylvania's shad restoration program, by egg source.

Year	Hudson Gill Net	Delaware Gill Net	Susquehanna Conowingo Tank Spawn	Susquehanna Lapidum Gill Net	Susquehanna Muddy Run Gill Net	Susquehanna Lamar Tank Spawn	Connecticut Gill Net	Pamunkey Gill Net	Mattaponi Gill Net	James Gill Net	Savannah Gill Net	Columbia Gill Net	Potomac Gill Net	Total
1971				8.42										8.42
1972				7.10										7.10
1973				4.74			4.30	8.45	6.48				34.64	58.61
1974							0.53	9.75	6.80	19.20		8.18	5.56	50.02
1975								1.88		7.15		18.42	5.70	33.15
1976		4.10										54.80		58.90
1977							0.35	4.40	0.57	3.42		8.90		17.64
1978								6.90		10.11		0.00		17.01
1979								3.17		4.99		0.00		8.16
1980								6.73		6.83		0.00		13.56
1981								4.58		1.26		5.78		11.62
1982								2.03		1.25		22.57		25.85
1983	1.17	2.40						5.49		5.91		19.51		34.48
1984		2.64						9.83		0.74		27.88		41.09
1985		6.16						5.28		2.05		12.06		25.55
1986		5.86						5.62		1.07		39.97		52.52
1987		5.01						4.35		0.11		23.53		33.00
1988		2.91						1.92		0.05		26.92		31.79
1989	11.18	5.96						1.91		0.53		23.10		42.68
1990	14.53	13.15				0.33		0.48			0.12			28.61
1991	17.66	10.75				0.30	1.10							29.80
1992	3.00	9.60					5.71			0.17				18.49
1993	2.97	9.30					7.45	1.78						21.50
1994	6.29	10.27					4.09	0.53	0.03					21.22
1995	11.85	10.75												22.61
1996	5.69	8.31				0.41								14.41
1997	11.08	11.76												22.84
1998	15.68	10.38				1.66								27.72
1999	21.10	5.49												26.59
2000	14.88	3.83												18.71
2001	3.92	6.35	5.81			5.05								21.13
2002	18.51	2.04	7.08			7.99								35.62
2003	17.12	3.61	11.72	0.56	0.02									33.04
2004	9.39	2.41	4.74	0.75										17.29
2005	2.92	6.21	8.00										0.00	17.14
2006	1.86	2.33	10.28										4.51	18.98
2007	0.00	6.46	6.77										7.49	20.72
2008		5.87	5.75										8.50	20.12
Total	188.95	159.26	37.35	21.57	0.02	15.74	23.53	85.08	13.88	64.84	0.12	291.62	45.90	947.86

Table 5. American and hickory shad stocking, 2008.

Date	Tank	Species	Number	Location	OTC mark (days)	Origin	Age	Size
4/23/08	A1 1	Hickory shad	1,492,467	Octoraro Cr.	3	Susquehanna	4	Fry
4/27/08	A2 1	Hickory shad	944,827	Pennypack/Ridley Cr.	3	Susquehanna	4	Fry
4/28/08	A3 1	Hickory shad	1,410,353	Octoraro Cr.	3	Susquehanna	4	Fry
4/28/08	A4 1	Hickory shad	642,473	Octoraro Cr.	3	Susquehanna	4	Fry
4/29/08	B1 1	Hickory shad	1,376,671	Pennypack/Ridley Cr.	3	Susquehanna	4	Fry
5/2/08	B2 1	Hickory shad	1,313,425	Pennypack/Ridley Cr.	3	Susquehanna	4	Fry
	C1 1	American shad	0		15,18,21	Potomac		
4/28/08	C2 1	American shad	188,739	Potomac R.	3,6	Potomac	9	Fry
5/28/08	C3 1	American shad	211,688	West Branch Suquehanna River	15,18,21,27	Potomac	39	Fry
5/28/08	C4 1	American shad	103,436	West Branch Suquehanna River	15,18,21,26	Potomac	38	Fry
5/29/08	D1 1	American shad	50,000	West Branch Suquehanna River	15,18,21,24	Potomac	38	Fry
5/29/08	D2 1	American shad	147,919	West Branch Suquehanna River	15,18,21,24	Potomac	36	Fry
5/29/08	D3 1	American shad	168,943	West Branch Suquehanna River	15,18,21,24	Potomac	36	Fry
5/29/08	D4 1	American shad	133,275	West Branch Suquehanna River	17,20,23,26	Potomac	35	Fry
5/30/08	E1 1	American shad	170,567	West Branch Suquehanna River	15,18,21,24	Potomac	35	Fry
5/30/08	E2 1	American shad	100,000	West Branch Suquehanna River	15,19,22,25	Potomac	34	Fry
5/30/08	E3 1	American shad	180,000	West Branch Suquehanna River	15,18,21,24	Potomac	34	Fry
5/30/08	E4 1	American shad	331,993	West Branch Suquehanna River	15,18,21,24	Potomac	33	Fry
6/16/08	F1 1	American shad	14,965	Lehigh R.	9,12,15	Delaware	40	Fry
6/3/08	F2 1	American shad	45,507	W. Conewago Cr.	3,9,12,15,18	Potomac	28	Fry
6/3/08	F3 1	American shad	75,699	Conodoguinet Cr.	3,6,12,15	Susquehanna	26	Fry
6/3/08	F4 1	American shad	115,529	Conestoga R.	3,9,12,17	Potomac	21	Fry
6/4/08	G1 1	American shad	172,581	N. Br. Susq. R.	3,6,9,17	Potomac	21	Fry
6/16/08	G2 1	American shad	53,832	Lehigh R.	9,14,17	Delaware	32	Fry
6/10/08	G3 1	American shad	7,030	Millerstown (Rt. 17 bridge)	15,18,21	Potomac	24	Fry
6/12/08	G4 1	American shad	124,031	Swatara Cr.	3,6,11,17,20	Susquehanna	25	Fry
6/16/08	H1 1	American shad	231,982	Lehigh R.	11,14,17	Delaware	24	Fry
6/11/08	H2 1	American shad	135,493	W. Br. Susq. R.	3,8,11,14,17	Susquehanna	21	Fry
6/6/08	H3 1	American shad	75,000	Clemson Island	3	Susquehanna	8	Fry
6/16/08	H4 1	American shad	133,868	Lehigh R.	11,14,17	Delaware	23	Fry
6/16/08	I1 1	American shad	184,580	Lehigh R.	11,14,17	Delaware	23	Fry
6/16/08	I2 1	American shad	77,558	Lehigh R.	9,12,15	Delaware	18	Fry
6/23/08	I3 1	American shad	33,433	Millerstown (Rt. 17 bridge)	15,18,21	Susquehanna	25	Fry
6/20/08	I4 1	American shad	367,618	Schuylkill R.	3,6,9,12	Delaware	17	Fry
6/20/08	A1 2	American shad	20,103	Schuylkill R.	3,6,9,12	Delaware	16	Fry
6/26/08	A2 2	American shad	100,000	Clemson I.	15,18,21	Susquehanna	22	Fry
6/27/08	A3 2	American shad	158,151	Delaware River, Smithfield Beach	3,6,12,15,18	Delaware	21	Fry
6/20/08	A4 2	American shad	99,053	Schuylkill R.	3,6,9,12	Delaware	14	Fry
6/20/08	B1 2	American shad	7,958	Millerstown (Rt. 17 bridge)	3	Delaware	7	Fry

* Red spotted Newt caught in valve overnight cut off flow to tank

Table 6. Summary of stocking of juvenile Alosines from the Van Dyke Hatchery, 2008.

	Site	Fry
American shad Releases	Millerstown (Rt. 17 Bridge)	48,421
	Clemson Island	175,000
	Conodoguinet Creek	75,699
	Conestoga River	115,529
	Swatara Creek	124,031
	West Conewago Creek	45,507
	North Branch Susquehanna River (PA)	172,581
	West Branch Susquehanna River	1,733,314
	Susquehanna River Basin Subtotal	2,490,081
	Delaware River	158,151
	Schuylkill River	486,774
	Lehigh River	696,785
	Potomac River	188,739
	Total American shad	**4,020,530**
Hickory shad releases	Octoraro Creek	3,545,292
	Susquehanna River Basin Subtotal	**3,545,292**
	Pennypack Creek	2,505,797
	Ridley Creek	1,129,126
	Delaware River Basin Subtotal	**3,634,923**
	Total Hickory shad	**7,180,215**

Table 7. Summary of marked Alosines stocked in Pennsylvania, 2008.

Number	Size	Immersion mark (days)	Stocking Location	Egg Source	Immersion mark	Immersion Mark Retention (%)	Feed Mark	Feed Mark Retention (%)	Fry Culture
American shad									
211,688	Fry	15,18,21,27	W. Br. Susq. R.	Potomac	256ppm OTC	100%	-	-	Van Dyke
103,436	Fry	15,18,21,26	W. Br. Susq. R.	Potomac	256ppm OTC	-	-	-	Van Dyke
100,000	Fry	15,19,22,25	W. Br. Susq. R.	Potomac	256ppm OTC	-	-	-	Van Dyke
133,275	Fry	17,20,23,26	W. Br. Susq. R.	Potomac	256ppm OTC	-	-	-	Van Dyke
1,049,422	Fry	15,18,21,24	W. Br. Susq. R.	Potomac	256ppm OTC	-	-	-	Van Dyke
1,597,821	Fry	Quadruple tag for known age study							
135,493	Fry	3,8,11,14,17	W. Br. Susq. R.	Susquehanna	256ppm OTC	100%	-	-	Van Dyke
82,958	Fry	3	Juniata/Susq. R.	Susq./Del.	256ppm OTC	-			
140,463	Fry	15,18,21	Juniata/Susq. R.	Susq./Pot.	256ppm OTC	97%*			
75,699	Fry	3,6,12,15	Conodoguinet Cr.	Susquehanna	256ppm OTC	93%**	-	-	Van Dyke
115,529	Fry	3,9,12,17	Conestoga R.	Potomac	256ppm OTC	100%			
45,507	Fry	3,9,12,15,18	W. Conewago Cr.	Potomac	256ppm OTC	100%	-	-	Van Dyke
124,031	Fry	3,6,11,17,20	Swatara Cr.	Susquehanna	256ppm OTC	100%			
172,581	Fry	3,6,9,17	N. Br. Susq. R.(PA)	Potomac	256ppm OTC	100%	-	-	Van Dyke
-	Fry	3,6,9,12,18	N. Br. Susq. R.(NY)		256ppm OTC	-			
-	Fry	3,15,18	Chemung R. (NY)		256ppm OTC	-			
92,523	Fry	9,12,15	Lehigh R.	Delaware	256ppm OTC	100%	-	-	Van Dyke
53,832	Fry	9,14,17	Lehigh R.	Delaware	256ppm OTC	-	-	-	Van Dyke
550,430	Fry	11,14,17	Lehigh R.	Delaware	256ppm OTC	-	-	-	Van Dyke
696,785	Fry	Triple tag							
486,774	Fry	3,6,9,12	Schuylkill R.	Delaware	256ppm OTC	100%	-	-	Van Dyke
158,151	Fry	3,6,12,15,18	Del. R. (Smithfield)	Delaware	256ppm OTC	100%	-	-	Van Dyke
188,739	Fry	3,6	Potomac R.	Potomac	256ppm OTC	100%	-	-	Van Dyke
Hickory shad									
3,545,292	Fry	3	Octoraro Cr.	Susquehanna	512ppm OTC	100%	-	-	Van Dyke
2,505,797	Fry	3	Ridley Cr.	Susquehanna	512ppm OTC	-	-	-	Van Dyke
1,129,126	Fry	3	Pennypack Cr.	Susquehanna	512ppm OTC	-	-	-	Van Dyke

* One of 30 appeared to have an extra tag at day 24

** Two of 27 appeared to be tagged at days 3,11,13,15

Table 8. Proposed marking plan for Alosines stocked in Pennsylvania, 2006-2010.

Size	Immersion mark (days)	Immersion mark	Stocking Location	Egg Source	Years
American shad					
Fry	18	256ppm OTC	Juniata/Susq. R.	Potomac	2006
Fry	15,18	256ppm OTC	Juniata/Susq. R.	Potomac	2007
Fry	15,18,21,24	256ppm OTC	Juniata/Susq. R.	Potomac	2008
Fry	3,9,12,15,18,21	256ppm OTC	Juniata/Susq. R.	Potomac	2009
Fry	3,6,12,15,18,21	256ppm OTC	Juniata/Susq. R.	Potomac	2010
Fry	3,6,9	256ppm OTC	Juniata/Susq. R.	Susquehanna	2006-2010
Fry	3,6,9,12,15	256ppm OTC	W. Br. Susq. R.	Potomac	2006-2010
Fry	3,6,12,15	256ppm OTC	Conodoguinet Cr.	Potomac	2006-2010
Fry	3,9,12,15	256ppm OTC	Conestoga R.	Potomac	2006-2010
Fry	3,9,12,15,18	256ppm OTC	W. Conewago Cr.	Potomac	2006-2010
Fry	3,6,9,15,18	256ppm OTC	Swatara Cr.	Potomac	2006-2010
Fry	3,6,9,15	256ppm OTC	N. Br. Susq. R.(PA)	Potomac	2006-2010
Fry	3,6,9,12,18	256ppm OTC	N. Br. Susq. R.(NY)	Potomac	2006-2010
Fry	3,15,18	256ppm OTC	Chemung R. (NY)	Potomac	2006-2010
Fry	9,12,15	256ppm OTC	Lehigh R.	Delaware	2006-2010
Fry	3,6,9,12	256ppm OTC	Schuylkill R.	Delaware	2006-2010
Fry	3,6,12,15,18	256ppm OTC	Del. R. (Smithfield)	Delaware	2006-2010
Fry	3,6	256ppm OTC	Potomac R.	Potomac	2006-2010
Hickory shad					
Fry	3	512ppm OTC	Conowingo Res. /Octoraro Cr.	Susquehanna	2006-2010
Fry	3	512ppm OTC	Delaware River	Susquehanna	2006-2010
Fry	3	512ppm OTC	Ridley Cr.	Susquehanna	2006-2010
Fry	3	512ppm OTC	Pennypack Cr.	Susquehanna	2006-2010