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November 26, 2014

VIA ELECTRONIC FILING
Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Re: TransCanada Hydro Northeast Inc.'s Study 22 – Interim Report on Juvenile shad Radio-tagging Trial; Response to Comments filed on Study 34;
Filed under: Project Nos. 1892-026, 1855-045, 1904-073 and 1904-074

Dear Secretary Bose:

TransCanada Hydro Northeast Inc. ("TransCanada") is the owner and licensee of the Wilder Hydroelectric Project (FERC No. 1892) (the "Wilder Project"), the Bellows Falls Hydroelectric Project (FERC No. 1855) (the "Bellows Falls Project"), and the Vernon Hydroelectric Project (FERC No. 1904) (the "Vernon Project"). The Wilder Project, the Bellows Falls Project and the Vernon Project are collectively referred to herein as the "TransCanada Projects." The current licenses for these projects each expire on April 30, 2018.

On October 13, 2013, TransCanada filed with the Commission its Revised Study Plan, as required by 18 C.F.R. 5.13(a). Study 22, Downstream Migration of Juvenile American Shad – Vernon proposed the use of radio telemetry involving attachment of radio-tags to juvenile shad greater than 110-mm in length. To evaluate the potential for tagging effects, a controlled experiment was to be conducted by holding groups of tagged and untagged juvenile shad in tanks and making formal observations on their relative behavior. The objective of this experiment is to evaluate whether the tagging process and tag itself affect the behavior of shad relative to untagged fish. If behavior of tagged fish is affected by tagging, the results of the field tests could be biased. This evaluation was conducted in Fall 2014 and involved hatchery-reared smolts as well as wild fish and included two different size radio-tags with two distinct attachment methods. A presentation of the results of this trial was presented at the FERC Technical Meeting on November 20, 2014. A report on the trial is included with this letter.

Vermont Agency of Natural Resources (VANR) and the US Fish and Wildlife Service (FWS) provided comments (on 7 October 2014, and 8 October 2014, respectively) on TransCanada's Proposed Study Plan 34 – Proposed Vernon Hydroacoustic Study. A review of the studies cited by FWS and VANR and their relevance to Study Plan 34 and to the Vernon Project is summarized in a memo prepared for TransCanada by Normandeau Associates. It is also included with this letter.

If there are any questions regarding the information provided in this filing or the process, please contact me at 603-498-2851 or by emailing john_ragonese@transcanada.com.

Sincerely,

John L. Ragonese
FERC License Manager

Attachments: Juvenile American Shad Radiotagging Assessment at Vernon Dam, 2014
Comments on studies cited by FWS and VANR

TransCanada Lower Connecticut River Relicensing

Summary Report: Juvenile American Shad Radio Tagging Assessment at Vernon Dam, 2014

Prepared for:
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Project No. 23301.042
November 2014

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1.0 Introduction

TransCanada's relicensing Study 22 - Downstream Migration of Juvenile American Shad at Vernon will be conducted during fall 2015. In preparation for that study, an evaluation of the effects of collection, transport, handling and tagging on mortality and behavior of juvenile American Shad was conducted during fall 2014, in accordance with the Revised Study Plan (RSP) for Study 22. Controlled experiments were conducted onsite at the Vernon Project using both hatchery-reared and wild caught juvenile shad held in tanks with circulating ambient river water. Hatchery-reared fish were supplied and delivered by U.S. Fish and Wildlife Service (FWS) from their North Attleboro Massachusetts Fish Hatchery. Wild fish were collected by boat electrofishing in the Vernon Pool of the Connecticut River. Sub-samples of hatchery-reared and wild juveniles were tagged with dummy tags of the same specifications as the radio tags proposed for the field study, but without working transmitters.

This work was conducted under a scientific collection permit issued by the New Hampshire Fish & Game Department (September 23, 2014, #F2014-106) and Fish Importation Permit issued by Vermont Fish and Wildlife Department (September 29, 2014, no permit number assigned).

1.1 Project Objectives

The objectives of the 2014 collection, transport, and handling mortality and behavior assessment at Vernon were to evaluate:

1. The mortality rate induced by transport of hatchery-reared fish from the FWS North Attleboro Fish Hatchery to the holding tanks at Vernon; and
2. Whether the tagging process and carrying the tag affect mortality and behavior relative to untagged fish.

Objectives specific to this preliminary summary report are based on an October 8, 2014 comment letter received from FWS in response to TransCanada's proposed "Vernon Hydroacoustic Study" (study plan no. 34). In that letter, FWS listed 10 reasons to be cautious about over-reliance on radio telemetry to meet Study 22's goal and objectives. Therefore, the objectives of this testing evaluation was to assist in determining whether a radio telemetry study would provide an appropriate assessment of Project effects on juvenile shad emigration, by addressing FWS' stated concerns:

1. the ability to produce/obtain a suitable number of juvenile shad for TransCanada and FirstLight's tagging studies in 2015 (i.e., > 110 mm);
2. successful transport and holding of fish at the study site;
3. application of tags;
4. mortality or other effects of tags and procedures, including tag loss/retention;
5. behavior of tagged fish;
6. losses and/or other impacts to study fish from handling at all steps in the process up to release;

7. timing of obtaining fish, tagging and releases (i.e., suitably sized fish may not be available until the mid to late part of the outmigration);
8. how will batch releases of radio-tagged fish occur relative to migrations of wild juveniles;
9. the unknown of when and where wild fish move as they out-migrate in the Lower Vernon Pool (i.e., the choice[s] of release site[s] may influence results); and
10. the unknown of when, where and how tagged juveniles are released compared to wild juvenile movements (locations) as they migrate downstream and encounter the various features of Vernon Power Station.

As applicable to this tagging evaluation, these items were addressed in Section 4 of this report.

2.0 Materials and Methods

2.1 Holding and Experimental Tank Deployment

Three circular tanks were installed directly above the Vernon fish ladder upstream exit area (Figure 2-1A). One tank, designated for holding and observation of hatchery-reared juveniles, was 7 ft. diameter by ~ 3 ft. deep (~700 gallons). Two tanks were 6 ft. diameter by ~2 ft. deep (~425 gallons) and were designated for holding wild-caught juveniles and for experimental units. Two submersible pumps, each powered by an independent electrical circuit were deployed, and each tank was supplied with circulating ambient river water from the Vernon forebay by each pump. Circulating flow rates were approximately 7-10 gallons per minute allowing complete turnover rates of 42 – 100 min. A mechanical air pump was installed to provide supplemental aeration of the 7-ft. diameter tank, and if necessary (depending on water quality), the smaller tanks. Additionally, compressed oxygen was bubbled into the 7-ft. diameter-holding tank to maintain suitable dissolved oxygen (DO) levels. For a minimum of two days after transfer of either wild or hatchery-reared fish, or other disruptive procedures (tagging) a low level of salinity was achieved by adding either crystal or block salt at least once daily and periodically as needed. All tanks were covered with mesh or light colored tarpaulins to reduce stress and prevent avian predation, and uncovered only during maintenance and observation periods.

2.1.1 Hatchery-Reared Fish Procurement

FWS spawned adult Connecticut River American Shad collected from the Holyoke Dam, Massachusetts, fish passage facilities during spring 2014. Spawning stock was transferred from Holyoke to the FWS' North Attleboro Fish Hatchery, North Attleboro, Massachusetts from May 21 through May 28, spawned from May 26 through May 31, and larvae hatched from June 2 through June 9, 2014 (Kevin Cheung, FWS, personal communication).

On October 7, 2014, FWS delivered approximately 2,000 juvenile shad to the Vernon site in two transport trucks. One truck had a round tank and the other had compartmentalized rectangular tanks. Each held approximately 5,000 juveniles, and approximately 1,000 juveniles from each was transferred. Transport tank water was 15°C, DO of 8.03 mg/l, and had salt added to 5 psu salinity. Upon arrival, the tanks were tempered to approach the experimental holding tank temperature by circulating ambient river water into the tanks for approximately 30 min. Holding tank water was 18°C, DO of 7.3 mg/l, and salinity of ~ 4 psu. FWS transferred fish to the holding tank by two methods. Fish from the rectangular transport tanks were transferred to an intermediate tank (~ 200 gallon capacity) using a discharge pipe, then netted to buckets in small batches and transferred to the 7-ft. holding tank. Fish from the circular transport tank were netted directly from the transport tank to buckets and transferred to the experimental holding tank (Figure 2-1B). After delivery and transfer, hatchery-reared fish were maintained and observed at least once per day, six days per week until October 31, 2014. Juveniles in the holding tank were fed commercial fishmeal *ad libitum* at least once per day, 6

A.

B.

days per week.

Figure 2-1. A. Holding and experimental tank layout. B. Intermediate transfer of hatchery-reared juveniles. (Photo credit: Ken Sprankle, FWS).

Juvenile growth rates during rearing at the hatchery during August and September were approximately 1 mm/d (data courtesy of Kevin Cheung, FWS). Upon delivery, mean total length was 103 mm (SD = 6.8, minimum = 89 mm, maximum = 115 mm, Figure 2-1). In subsequent length sampling, little to no additional growth was noted, and the mean length remained around 103 mm, though maximum lengths of 122 mm were observed (Figure 2-2).

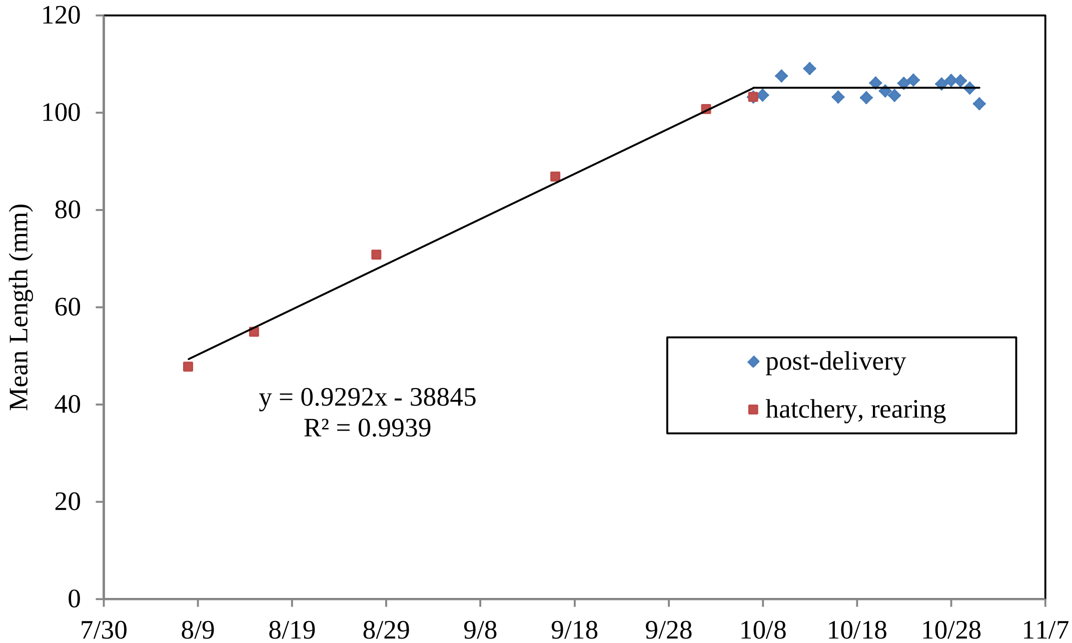

Figure 2-2. Mean total lengths from samples during rearing at the North Attleboro Fish Hatchery (courtesy of Kevin Cheung, FWS), August to early October, and for samples (where N was at least 5) collected after delivery and during tank trials at Vernon.

2.1.2 Wild Fish Collection

Between 2100 h and 2300 h on October 6, approximately 186 wild juvenile shad were collected from the Vernon forebay using standard boat electrofishing methods in five samples. Samples consisted of not more than 10 min. of peddle time, < 50 fish collected per sample, and minimal time from collection to transfer to a 6-ft. diameter holding tank (approximately 20 min.). To minimize stress, no length data were collected for wild fish until initiation of the tagging trials.

2.2 Tagging Trials

For tagging trials, two types of radio transmitter were used: Lotek model NTC-M-2 and model NTQ-1. Both tag types had unique attachment methods. For Model NTC-M-2 tags (5 mm wide x 3 mm high x 14 mm long, 0.43 g in air, estimated battery life 16 d at 2 s burst rate) an adaptation of the Hi-Z tag attachment method (Heisey et al. 1996) was used. The tag was affixed to a stainless tagging pin with monofilament (total weight of the transmitter and attachment materials =~ 0.8 g in air, Figure 2-3). Model NTQ-1 tags (5 mm wide x 3 mm high x 10 mm long, 0.25 g in air, 10 d at 2 s burst rate) were seized to a size 16 dry fly hook (total weight ~ 0.4 g in air, Figure 2-3).

The larger model NTC-M-2 tag was initially proposed because it had been used successfully in Susquehanna River studies. Connecticut River juveniles are smaller than Susquehanna River fish, however, which was the primary impetus to attempt to rear juveniles to a minimum tagging size in the hatchery. Upon initial trials, it was evident that both hatchery-reared and wild juveniles were not of sufficient size (ideally >120 mm for radio telemetry, minimum of 120 mm for turbine survival, Paul Heisey, Normandeau Associates). The more recently engineered Model NTQ-1 tag has not been used in large-scale field studies for juvenile alosine fish, however in pilot studies on Merrimac River alosines, which are similar in size to Connecticut River fish, that tag model and attachment method have been used successfully. A pilot study examining the effects of the NTQ-1 tag on juvenile Alewife (Normandeau 2012) determined that a minimum total length of 100 mm allowed juvenile Alewife to be able to swim upright and maintain position among untagged fish.

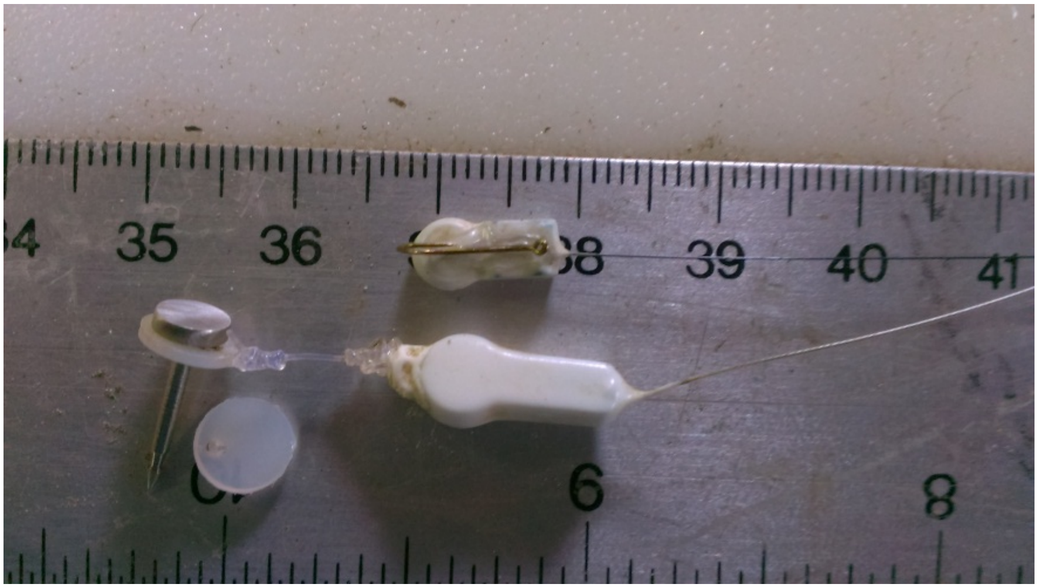

Figure 2-3. Transmitters used for tagging trials. Lotek model NTC M-2 transmitter with Hi-Z tag attachment used in Tagging Trial-1 (bottom); Lotek model NTQ-1 transmitter with No. 16 dry fly hook as used in Tagging Trial-2 and -3 (top).

2.2.1 Tagging Trial-1

Tagging Trial-1 was initiated on October 16, 2014. A 6-ft. diameter tank was stocked with approximately 175 untagged wild-caught juveniles and 50 untagged hatchery-reared juveniles to facilitate schooling behavior of tagged specimens. Tagging trials included 30 hatchery-reared and 10 wild-caught juvenile shad that were tagged with 'dummy' model NTC-M-2 transmitters (as described in Section 2.2 above). Since mean length of the hatchery-reared juveniles was < 110 mm, individual specimens were selected for tagging by bringing a number of fish to near the surface using a small seine net, then water brailing several fish to a tagging container filled with ambient water and salt to approximately 5 psu. Individuals that appeared to be > 110 mm were visually selected to eliminate additional stress imposed by physical measurement, held in water and tagged by inserting the tagging pin through the dorsal musculature just anterior to the dorsal fin origin (Figure 2-4).

Daily observation and water quality monitoring were conducted 6 days per week until October 30. Additionally, a submersible camera was deployed in the tank and set to record video to a digital video recorder from 0700 – 1900 h daily for a portion of the trial and a data sonde was deployed to collect continuous water quality data at 15-min. frequency for a portion of the trial (video and continuous water quality data have not yet been analyzed). Daily observations included mortality removal and quantification, instantaneous water quality measurement, and at least one 15-min. behavioral observation. Behavioral observation consisted of qualitative notes on general swimming direction and speed, relative swimming direction and speed of tagged and untagged fish, aberrant behavior, feeding, and response to startle.

Tank maintenance was performed at least once daily (6 d/wk.), including cleaning (minimized to reduce stress), flow adjustment as needed, addition of salt, and *ad libitum* feeding.

Figure 2-4. Tagging Trial-1, example of tagged juvenile American Shad using Lotek model NTC M-2 transmitter with Hi-Z tag attachment (top); and Lotek model NTQ-1 transmitter with No. 16 dry fly hook as used in Tagging Trial-2 and -3 (inset).

2.2.2 Tagging Trial-2

Tagging Trial-2 was initiated on October 21, 2014. A 6-ft. diameter tank was stocked with approximately 200 untagged hatchery-reared juveniles to facilitate schooling behavior of tagged specimens. Tagging trials included 22 hatchery-reared juveniles tagged (10 on October 21 and 12 on October 22) with model NTQ-1 tags (as described in Section 2.2 above). Juveniles were selected for tagging by bringing a number of fish to near the surface using a small seine net, then water brailing several fish to a tagging container filled with ambient water and soda water mixture (20:1 ratio) and salt to approximately 5 psu. Because of the smaller tag size, individuals were not culled for a specific size, but were visually selected for good condition: minimal scale loss, no evident fungal infection or fin rot, relatively large size (robust, no emaciation). Tagging specimens were held in water and tagged by inserting the hook into the dorsal musculature posterior to the dorsal fin. (Figure 2-4).

Daily and automated observation (digital video recording), water quality monitoring, and tank maintenance were as described for Tagging Trial-1 from October 22 through October 31, 2014.

2.2.3 Tagging Trial-3

Tagging Trial-3 was initiated on October 30, 2014. Approximately 217 untagged fish in apparently excellent health and exhibiting normal schooling and feeding behavior remained in the 6-ft. diameter tank used for Tagging Trial-1. Based on the initial stocking proportions of hatchery-reared and wild-caught juveniles in Tagging Trial-1, and initial observations of survival and behavior of wild-caught fish (see Section 3.2), it was assumed that the vast majority (but not more than 175 fish or 81% of the total) remaining were wild-caught. For tagging, 20 individuals were brought to near the surface using a dip-net and then water brailed to a tagging container filled with ambient water and soda water mixture (20:1 ratio) and salt to approximately 5 psu. Tag specifications and tagging methods were as described for Tagging Trial-2 except that tagged fish were returned to the same tank that they were selected from.

Daily and automated (digital video recording) observation, water quality monitoring, and tank maintenance, were as described for Tagging Trial-1, from October 31 through November 4, 2014.

3.0 Results

3.1 Hatchery-Reared Fish Delivery and Holding

On October 7, approximately 2,000 hatchery-reared juvenile American shad were transferred from FWS transport trucks to the 7-ft. holding tank. It was immediately evident that the fish density was too high, and oxygen consumption became problematic. As a result, approximately 500 fish were removed from the tank and released to the Connecticut River to reduce fish density and oxygen demand. Additionally, mechanical aeration was implemented, and on October 8, use of compressed oxygen was implemented to maintain water quality.

Mortality

- Estimated initial mortality on day-1 post-transfer (October 8) was low (0.9%).
- Daily mortality through day-8 (October 15) was < 1%, and cumulative mortality on day-8 was relatively low (N=35, 2.3%).
- On day-9 (October 16), the tank was disturbed to collect fish for tagging and stocking for Tagging Trial-1. Daily mortality rates remained <1% through day-12 (October 19). Cumulative mortality on day-12 was relatively low (N = 50, 3.5%).
- From day-13 – 18 (October 20 - 25), daily mortality rates increased to 1 – 2 %. On day-18, cumulative mortality was 180 (14.9%).
- A cold-front induced rain event occurred on October 23 (day-16), and between October 21 and October 25 water temperature fell 6°C from 17.2°C to 11.2°C. Significant mortality followed.
- Daily mortality on day-20 through day-24 (October 27 - 31) was 3 – 30%. Cumulative mortality by day-23 was near 100%. A small number (~20) remaining alive were released to the Connecticut River and the tank was drained.

Behavior

- Beginning at the time of stocking and continuing until approximately October 27 (day-20), hatchery-reared fish swam at an unexpectedly fast rate, estimated to be 1.5 – 2 ft/second, throughout most of the holding period.
- Oxygen consumption was very high and was not maintained at a near saturation level until water temperature began falling around October 20, and the density of fish was reduced.
- Active, vigorous feeding was observed beginning on day-2 (October 9). Vigorous feeding continued through day-20 (October 27). Relatively high velocity swimming continued until around day-20.
- From day-21 on, large mortalities occurred, swimming became more lethargic, and feeding was limited or absent.

Daily and cumulative mortality data are presented in Table 3-1. Instantaneous water quality observations are presented in Figure 3-1. Length data are presented in Figure 2-1 above.

Table 3-1. Daily and cumulative mortality (M) estimates for hatchery-reared juvenile American Shad transferred to Vernon Dam on October 7, 2014 (120 – 127 days-post-hatch). Day = days post-transfer.

Day	Date	Time	N mort.	M (%)	M cumulative (%)	N live	Note
0	10/7	1524	.			~1,500	stocked ~2000, but released ~500
1	10/8	740	13	0.9%	0.9%	1,487	
2	10/9	906	4	0.3%	1.1%	1,483	
3	10/10	830	5	0.3%	1.5%	1,478	
4	10/11	1801	1	0.1%	1.5%	1,477	
5	10/12	.		.	.		
6	10/13	805	7	0.5%	2.0%	1,470	
7	10/14	1410	3	0.2%	2.2%	1,467	
8	10/15	1125	2	0.1%	2.3%	1,465	
9	10/16	1000	3	0.2%	2.7%	1,462	stocked EXP1 with 30 tagged and ~50 untagged
10	10/17	855	2	0.1%	2.8%	1,380	
11	10/18	.		.			
12	10/19	700	10	0.7%	3.5%	1,370	
13	10/20	1230	24	1.6%	5.2%	1,346	
14	10/21	1435	22	1.5%	6.8%	1,114	stocked EXP2 with ~200 untagged and 10 tagged
15	10/22	1150	24	1.6%	9.9%	1,090	stocked EXP2 with 12 tagged
16	10/23	1050	30	2.0%	12.4%	1,060	rain event
17	10/24	1100	12	0.8%	13.4%	1,048	
18	10/25	745	18	1.2%	14.9%	1,030	turbid, cold
19	10/26	.		.			
20	10/27	940	46	3.1%	18.7%	984	
21	10/28	1230	150	10.0%	31.1%	834	
22	10/29	1140	257	17.1%	52.3%	577	
23	10/30	1330	456	30.4%	90.0%	121	
24	10/31	1215	140	9.3%	101.6%	-19	released ~20

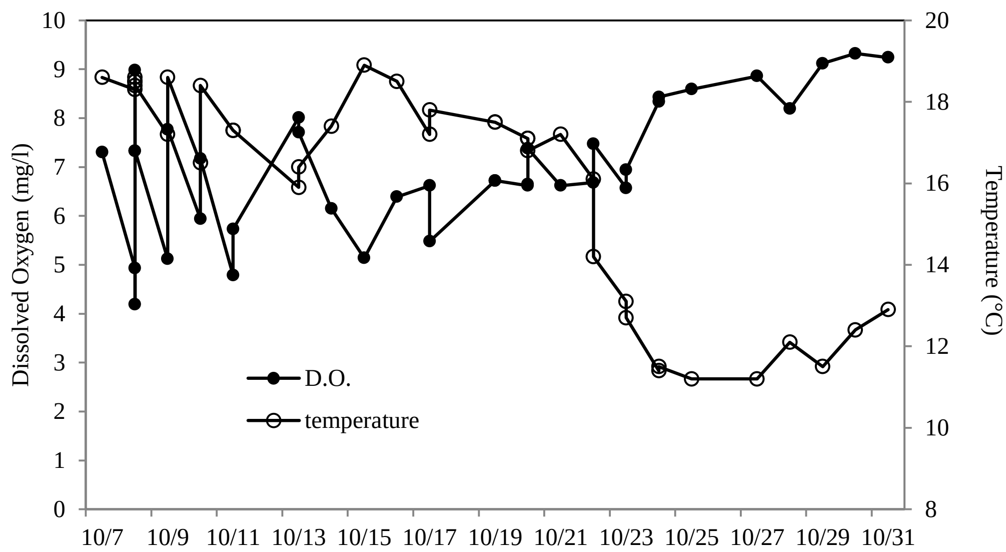

Figure 3-1. Instantaneous water quality measurements for 7 ft. diameter holding tank with hatchery-reared juvenile American Shad.

3.2 Wild-Caught Fish Holding

On October 6, approximately 186 wild-caught juvenile American Shad were stocked to a 6-ft. diameter-holding tank. Wild-caught fish were held for 10 d when they were transferred to Tagging Trial-1.

A subsample (N=26) of wild-caught juveniles measured on October 16, ranged from 81 – 111 mm, with a mean total length of 92.5 mm (SD = 7.9). Overall length subsamples, including tagged specimens and fish remaining at the termination of all experiments (fish remaining after Tagging Trial-3 were assumed to be wild-caught, but were mixed with a small number of surviving hatchery-reared fish) ranged from 81 – 124 mm with a mean total length of 99.7 mm (SD = 7.5).

<u>**Mortality**</u>

- Estimated initial mortality (day-1 post-collection) was zero (0%).
- On day-3, one mortality was recorded (0.5%).
- On day-10 post-collection (October 17) the tank was disturbed to collect fish for tagging and stocking for Tagging Trial-1.
- No additional mortalities were recorded through day-10 when fish from the holding tank were transferred to Tagging Trial-1 (cumulative mortality on day-10 = 0.5%).

<u>**Behavior**</u>

- By day-3 (October 10), active feeding was observed, and thereafter feeding was vigorous.
- Al fish were observed easily holding position or slowly circling (swimming < 1 ft/s) except when startled or feeding. When startled, response (stop, change direction,

accelerate, decelerate, regroup, resume former condition) occurred quickly and consistently. When feeding, swimming and active 'attacking' of food was consistently observed.

Daily and cumulative mortality data are presented in Table 3-2. Instantaneous water quality observations are presented in Figure 3-2. Length data are presented in Figure 3-3.

Table 3-2. Daily and cumulative mortality (M) estimates for ~186 wild-caught juvenile American Shad collected on October 6, 2014 and stocked to a 6-ft. diameter circular tank. Day = days post-collection.

Day	Date	Time	N mort.	M (%)	M cumulative (%)	N live	Note
0	10/6	2300	.			186	stocked 186 wild-caught
1	10/7	1020	0	0.0%	0.0%	186	
2	10/8	1257	0	0.0%	0.0%	186	
3	10/9	917	1	0.5%	0.5%	185	
4	10/10	859	0	0.0%	0.5%	185	
5	10/11	1805	0	0.0%	0.5%	185	
6	10/12	.		0.0%	.	185	
7	10/13	830	0	0.0%	0.5%	185	
8	10/14	1415	0	0.0%	0.5%	185	
9	10/15	1125	0	0.0%	0.5%	185	
10	10/16	1040	0	0.0%	0.5%	185	stocked remainder to EXP1

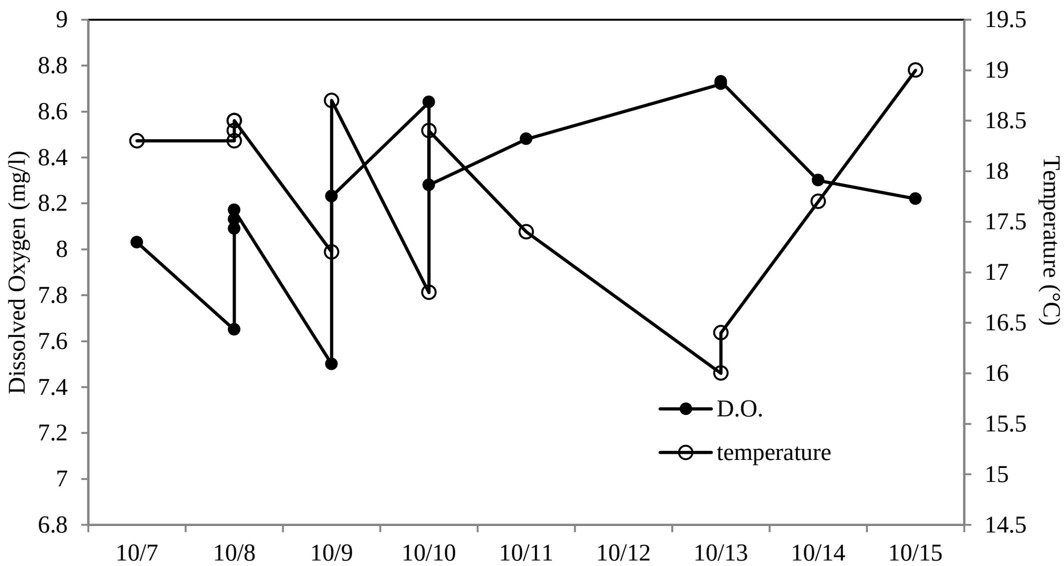

Figure 3-2. Instantaneous water quality measurements for 6 ft. diameter holding tank with wild-caught juvenile American Shad.

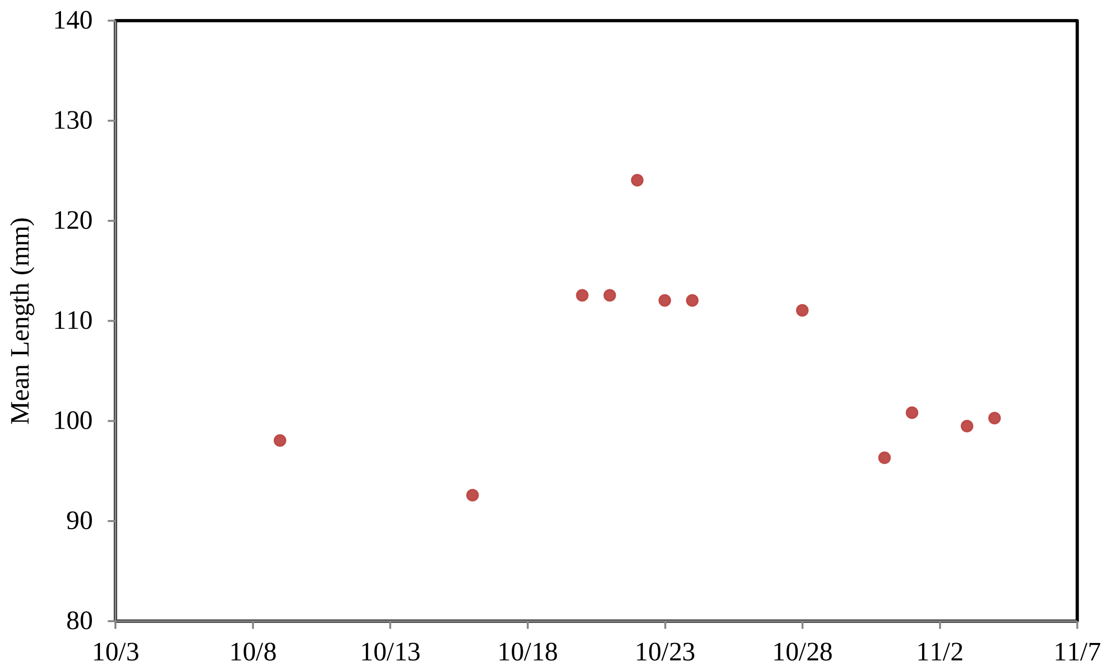

Figure 3-3. Mean total lengths of wild-caught juvenile American Shad collected throughout the study. Data collected after October 30 (from Tagging Trial-3) are for predominantly wild fish, but potentially mixed with hatchery-reared fish. Outliers are a function of small sample size on certain dates.

3.3 Tagging Trials

3.3.1 Tagging Trial-1

On October 16, 30 hatchery–reared and 10 wild-caught juveniles were tagged with model NTC-M-2 (larger) tags and stocked to a 6-ft. diameter experimental tank along with approximately 225 untagged juveniles (mostly wild-caught). Observations were conducted until October 30.

A subsample of total length data was collected from both hatchery-reared and wild-caught fish concurrent with the initiation of Tagging Trial-1 and is representative of the captive population, including the untagged school in experimental tanks (Table 3-3). Total length and weight data specific to tagged specimens were also collected after recovery (post mortem, Table 3-4).

Daily and cumulative mortality data are presented in Table 3-5. Instantaneous water quality observations are presented in Figure 3-4.

<u>**Mortality**</u>

- Estimated initial tagged fish mortality (day-1 post-tagging) was zero (0%).
- On day-3, four tagged hatchery-reared mortalities (13%) were recorded.
- On day-4, four tagged hatchery-reared and two tagged wild-caught mortalities were recorded for daily stock-specific mortality rates of 13% and 20%, respectively.
- On day-5, three tagged hatchery-reared and four tagged wild-caught tagged mortalities were recorded for daily stock-specific mortality rates of 10% and 40%, respectively.

- On day-6, three tagged hatchery-reared and one tagged wild-caught mortalities were recorded for daily stock-specific mortality rates of 10% each.
- On day-7, five tagged hatchery-reared and one tagged wild-caught tagged mortalities were recorded for daily stock-specific mortality rates of 17% and 10%, respectively.
    - Also on day-7 (October 23), a cold-front induced rain event occurred, and between October 21 and October 25 water temperature fell 6°C from 17.2°C to 11.2°C.
- On day-8, three tagged hatchery-reared mortalities were recorded (daily M = 10%). At that point, survival of tagged hatchery-reared juveniles was 27%, and survival of tagged wild-caught juveniles was 20%.
- By day-11, mortality was 100% for tagged hatchery-reared juveniles, and by day-12 mortality was 100% for tagged wild-caught juveniles.
    - Six decayed tagged mortalities that were recovered on or after day-11 from a standpipe enclosure were conservatively assumed to have died on or around day-9 when turbidity was too high to see in the tank.
    - A large mortality event of untagged hatchery-reared juveniles was simultaneously occurring in the 7-ft. diameter-holding tank.
- Through day-12, mortality of untagged (mostly wild-caught) juveniles was very low (3.6%, N=8).

Behavior

- Day-1 post-tagging:
    - ~6 tagged fish were observed listing (swimming on side); one of those was observed continuously barrel-rolling and swimming erratically relative to the school.
    - All fish (tagged and untagged), except the one noted above, were swimming clockwise with the current, ~1 – 1.5 ft/s. Tagged fish kept pace with school.
    - Tagged fish, except the 6 noted above, swam upright and normally.
    - Listing and rolling appeared to be due to the weight/drag of the tag and attachment materials.
    - When startled, tagged fish (except for ~3 listing) behaved similarly to untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior within 2 s).
    - Untagged fish were observed feeding at the water surface, but not aggressively. Tagged fish were not conclusively observed feeding.
    - Untagged wild-caught fish could not be discriminated from untagged hatchery-reared fish (behavior of all untagged fish was consistent).

- Day-3 post-tagging:
  - [4 tagged mortalities had been removed] ~8 tagged fish were observed listing (swimming on side). Most of those barrel-rolled 1-2 times per lap around the tank. When rolling, swim pattern and velocity were disrupted; but when righted fish accelerated to match the school. All other tagged fish matched school swimming.
  - When startled, tagged fish (except for ~8 listing) behaved similarly to untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior within 2 s). Tagged fish that were listing and rolling reacted erratically, many ramming the tank side.
  - Both untagged and tagged fish (but not the 8 listing fish) were observed feeding. Listing fish appeared to have difficulty maintaining buoyancy when attempting to rise to the surface.
  - No evidence of discrimination of untagged wild-caught and hatchery-reared fish was observed (behavior of all untagged fish was consistent).
- Day-4 post-tagging:
  - [4 tagged mortalities had been removed] 4 tagged fish were observed constantly barrel-rolling and 2 were clearly distressed. All other tagged fish were swimming upright and matched school swimming.
  - When startled, tagged fish (except for the 4 noted above) behaved similarly to untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior within 2 s).
  - Untagged fish were observed feeding vigorously at surface and in the water column; tagged fish were not observed rising for food, but may have been feeding in water column.
  - Flow direction was purposely reversed in the tank in an attempt to examine the relative swimming capability of tagged fish when swimming against the flow. The school continued to circle clockwise, but now against the current, maintaining relatively fast swimming speeds of ~1.5 ft./s.
- Day-6 post-tagging:
  - Relatively few tagged fish remained, but they all swam vertically. The swimming speed of untagged fish remained ~1.5 ft./s, but tagged fish were slightly slower overall.
  - When startled, the general response of tagged fish was the same as the untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior) except acceleration was less than for untagged fish.
  - Untagged fish were observed feeding vigorously at the surface and in the water column; tagged fish feeding could not be verified.

- Day-7 post-tagging:
  - o Few tagged fish remained, but they all swam vertically. The swimming speed of 2 (of 5 visible) tagged fish was slightly slower than the school which had a swim speed of ~1.0 ft/s.
  - o When startled, 3 tagged fish reacted similarly to the untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior), but 2 reacted more slowly or only stopped and did not change direction.

Table 3-3. Mean total lengths for subsamples of hatchery-reared and wild-caught juvenile American Shad at the start of Tagging Trial-1.

	Hatchery-Reared	Wild-Caught
N	50	26
Min	91	81
Max	120	111
Mean	103.8	92.5
SD	5.7	7.9

Table 3-4. Tagging Trial-1. Summary statistics for total length and weight of tagged hatchery-reared and wild-caught juvenile American Shad (measured post-mortem).

	Hatchery-Reared		Wild-Caught	
	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Min	106	10	108	10
Max	122	13	124	14
Mean	114.3	12.1	113.1	11.7
SD	4.7	1.2	4.4	1.3

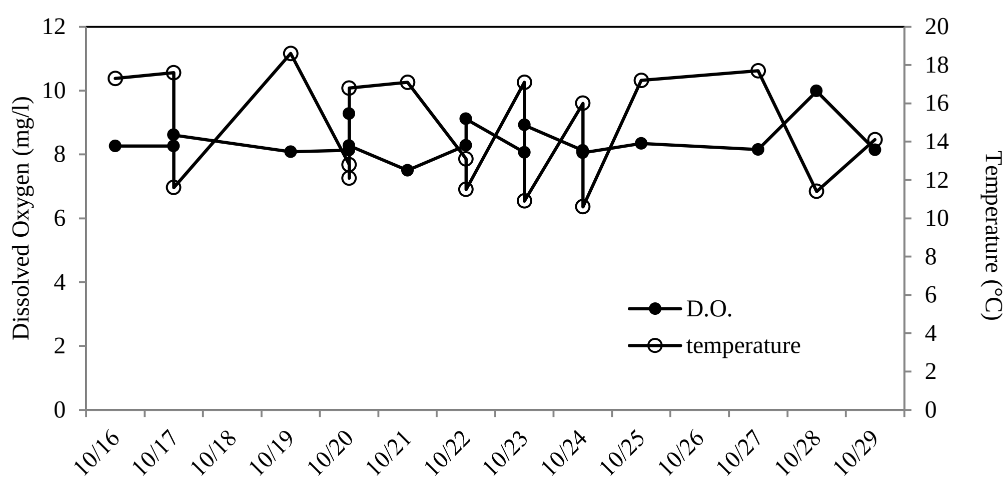

Figure 3-4. Instantaneous water quality measurements for Tagging Trial-1.

Table 3-5. Tagging Trial-1. Daily and cumulative mortality (M) estimates for 30 hatchery-reared and tagged, 10 wild-caught and tagged, and ~225 untagged (mixed stock) juvenile American Shad. Day = days post tagging.

			Mortalities (N)			M (%)			M_cumulative (%)			Live (N)		
			tagged		untagged	tagged		untagged	tagged		untagged	tagged		untagged
Day	Date	Time	hatchery	wild		hatchery	wild		hatchery	wild		hatchery	wild	
0	10/16[1]	1400										30	10	225
1	10/17	855	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	30	10	225
2	10/18	.	no observation			.	.	.	0.0%	0.0%	0.0%	30	10	225
3	10/19	700	4	0	0	13.3%	0.0%	0.0%	13.3%	0.0%	0.0%	26	10	225
4	10/20	1230	4	2	1	13.3%	20.0%	0.4%	26.7%	20.0%	0.4%	22	8	224
5	10/21	1435	3	4	0	10.0%	40.0%	0.0%	36.7%	60.0%	0.4%	19	4	224
6	10/22	1150	3	1	1	10.0%	10.0%	0.4%	46.7%	70.0%	0.9%	16	3	223
7	10/23[2]	1050	5	1	0	16.7%	10.0%	0.0%	63.3%	80.0%	0.9%	11	2	223
8	10/24	1100	3	0	1	10.0%	0.0%	0.4%	73.3%	80.0%	1.3%	8	2	222
9	10/25[3]	745	7	1	1	23.3%	10.0%	0.5%	96.7%	90.0%	1.8%	1	1	221
10	10/26	.	no observation			.	.	.	96.7%	90.0%	1.8%	1	1	221
11	10/27	940	1	0	3	3.3%	0.0%	1.4%	100.0%	90.0%	3.1%	0	1	218
12	10/28	1230	0	1	1	0.0%	10.0%	0.5%	100.0%	100.0%	3.6%	0	0	217
13	10/29	1140	0	0	0	0.0%	0.0%	0.0%	100.0%	100.0%	3.6%	0	0	217
14	10/30	1330	0	0	0	0.0%	0.0%	0.0%	100.0%	100.0%	3.6%	0	0	217

[1] stock 30 tagged hatchery, 10 tagged wild, 225 untagged

[2] rain event

[3] turbid, cold

3.3.1 Tagging Trial-2

On October 21, 10 hatchery–reared juveniles were tagged with the smaller Lotek model NTQ-1 tags affixed to a #16 dry fly hook and stocked to a 6-ft. diameter experimental tank along with approximately 200 untagged hatchery-reared juveniles. On October 22, 12 additional hatchery-reared juveniles were tagged and stocked to the experimental tank. Observations were conducted until October 31.

Total length and weight data were collected for tagged specimens after recovery (post mortem, Table 3-6). Daily and cumulative mortality data are presented in Table 3-7. Instantaneous water quality observations are presented in Figure 3-5.

Mortality

- Estimated initial mortality (day-1 post-tagging) was zero (0%).
- Also on day-3 (October 23), a cold-front induced rain event occurred, and between October 21 and October 25 water temperature fell 6°C from 17.2°C to 11.2°C.
- On day-6, 4 tagged juvenile mortalities were recorded (18%), there had been no previous tagged fish mortalities until day-6 (day-5 was not sampled). As of day-6, cumulative untagged mortalities totaled 7.5% (N = 15).
    - A large mortality event of untagged hatchery-reared juveniles was simultaneously occurring in the 7-ft. diameter-holding tank.
- On day-7, 3 tagged mortalities (14%) were recorded.
- On day-8, 9 tagged mortalities (41%) were recorded.
- On day-9, 5 tagged mortalities (23%) were recorded.
- On day-10, the final tagged fish was recorded as a mortality and the experiment was terminated. Untagged fish were either retained for length sampling or released to the Connecticut River (N=~40).
- Cumulative mortality of untagged fish was 20% on day-8, 43% on day-9, and 80% on day-10.
    - Mortalities of both tagged and untagged hatchery-reared fish appeared to be related to thermal stress.

Behavior

- Day-1 post-tagging (first group, October 22):
    - All fish were observed circling clockwise against light current and swimming ~ 1.5 ft/s.
    - All tagged fish were swimming vertically and normally with the school, matching pace. Tag attachment and position looked good.
    - When startled, tagged fish response was the same as untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior within ~2 s).
    - Both untagged and tagged fish were observed feeding.

- Day-2:
  - All fish were observed circling at swimming speed of ~ 1.0 ft/s (somewhat calmer behavior than the previous day).
  - All tagged fish were swimming vertically and normally with the school, matching pace. Tag attachment and position looked good.
  - When startled, tagged fish response was the same as untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior within ~2 s).
  - Both untagged and tagged fish were observed feeding actively,–darting and changing direction to attack prey.
  - Tagged fish were observed avoiding obstacles (salt block) similarly to the untagged fish (lateral and vertical avoidance).
- Day-3 (water was very turbid, creating limited observation):
  - When visible, all tagged fish appeared to be swimming vertical and normal, matching pace with the school.
  - Tagged fish were observed feeding.
- Day-4: no observation due to turbidity.
- Day-6:
  - One tagged fish was unable to keep up with the school, beginning to list, and appearing discolored. Most others appeared normal, swimming vertically and at pace with the school at ~1.5 ft./s.
  - Tag retention and position appeared good.
- Day-7:
  - All fish were observed circling clockwise. The tank was partially shaded and fish appeared reluctant to rise in water column.
  - A couple of tagged fish appeared weaker and swimming slightly slower than school. One was listing slightly. All others were swimming vertical and normally and keeping pace with the school. The entire school was observed swimming more slowly than the previous day (~1 ft./s). Tagged and untagged fish were swimming at ~ 5 tailbeats/s.
  - Tag attachments and orientation were good.
  - Tagged fish were observed feeding, but were reluctant to rise to surface.
  - When startled, 2 tagged fish appeared disoriented and one went moribund after startle. All other tagged fish response was the same as untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior).
- Day-8:
  - Only ~6 tagged fish were left following large mortality events that appeared to be related to thermal shock (note simultaneous mortality event in 7-ft. holding tank).

- o Remaining tagged fish were observed swimming vertical and normal, keeping pace with the school at ~1 ft/s.
- o Feeding was limited in untagged fish and was not confirmed in tagged fish.
- o Tag attachment and orientation appeared good.

Table 3-6. Tagging Trial-2. Summary statistics for total length and weight of tagged (assumed to be predominantly wild-caught) juvenile American Shad (measured post-mortem).

	Length (mm)	Weight (g)
N	22	22
Min	100	7
Max	120	13
Mean	108.5	9.6
SD	5.0	1.5

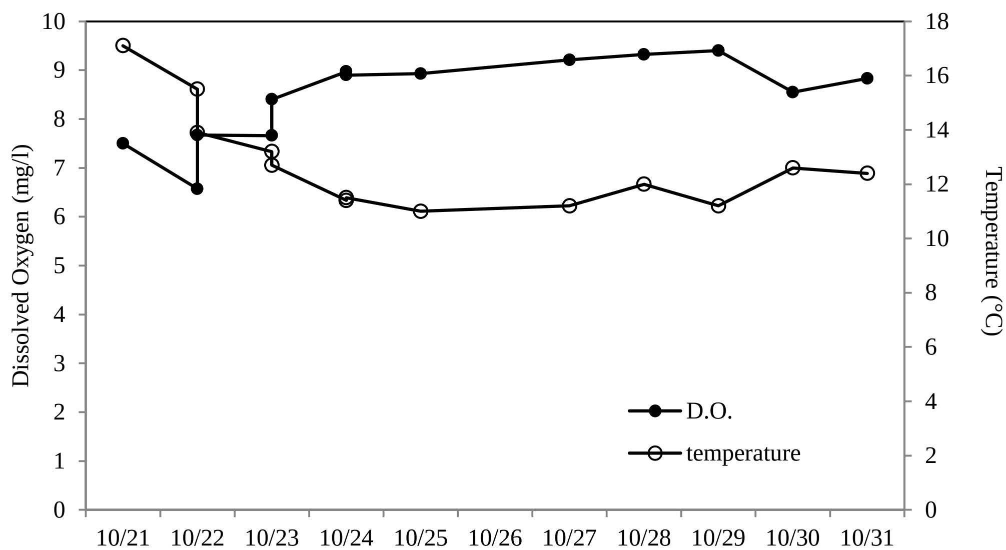

Figure 3-5. Instantaneous water quality measurements for Tagging Trial-2.

Table 3-7. Tagging Trial-2. Daily and cumulative mortality (M) estimates for 22 hatchery-reared and tagged and ~200 untagged hatchery-reared juvenile American Shad. Day = days post-tagging.

			Mortalities			M (%)			M_cumulative (%)			N_live		
Day	Date	Time	tagged	untagged	total	tagged	untagged	total	tagged	untagged	total	tagged	untagged	total
0	10/21[4]	1500										10	200	210
1	10/22[5]	1430	0	1	1	0.0%	0.5%	0.5%	0.0%	0.5%	0.5%	22	199	221
2	10/23[6]	1330	0	2	2	0.0%	1.0%	1.0%	0.0%	1.5%	1.4%	22	197	219
3	10/24	1100	0	1	1	0.0%	0.5%	0.5%	0.0%	2.0%	1.9%	22	196	218
4	10/25[7]	745	0	2	2	0.0%	1.0%	1.0%	0.0%	3.0%	2.9%	22	194	216
5	10/26	1435	no observation						0.0%	3.0%	2.9%	22	194	214
6	10/27	940	4	9	13	18.2%	4.5%	6.2%	18.2%	7.5%	9.0%	18	185	203
7	10/28	1230	3	3	6	13.6%	1.5%	2.9%	31.8%	9.0%	11.9%	15	182	197
8	10/29	1140	9	22	31	40.9%	11.0%	14.8%	72.7%	20.0%	26.7%	6	160	166
9	10/30	745	5	46	51	22.7%	23.0%	24.3%	95.5%	43.0%	51.0%	1	114	115
10	10/31	1215	1	73	74	4.5%	36.5%	35.2%	100.0%	79.5%	86.2%	0	41	41

[4] stock 10 hatchery tagged, 200 hatchery untagged

[5] stock 12 hatchery tagged

[6] rain event

[7] turbid, cold

3.3.1 Tagging Trial-3

On October 30, 19 of the approximately 217 fish remaining in the tank used for Tagging Trial-1 were tagged with the smaller Lotek model NTQ-1 tags affixed to a #16 dry fly hook and returned to the tank. Based on the starting proportions of hatchery-reared and wild-caught fish for Tagging Trial-1 (~78% wild-caught), and the behavior and apparent condition of wild-caught fish, it was assumed that the majority of remaining fish were of wild-caught origin. Of 19-tagged fish, one was noted to be in poor condition immediately upon release, but it could not be removed from the tank without perturbing the school so it remained in the tank until the next day. Therefore, the effective sample size used for mortality estimates was 18 tagged fish. Prior to tagging, fish were feeding vigorously and actively pursuing feed; however, a large mortality event was occurring in the 7-ft holding tank of untagged fish at this same time. In Tagging Trial-3, fish were returned to the same population from which they were netted and brailed, and three netting events were necessary to collect tagging specimens. This differs from Tagging Trials-1 and 2 where fish were collected from one tank and tagged before stocking to another tank. The additional stress of multiple perturbations (netting, handling, and tagging), along with the ongoing untagged fish mortalities must be considered in interpretation of Tagging Trial-3 results.

Total length and weight data were collected for tagged specimens after recovery (post mortem, Table 3-8).

Daily and cumulative mortality data are presented in Table 3-9. Instantaneous water quality observations are presented in Figure 3-6.

Mortality

- Estimated initial tagged fish mortality (day-1 post-tagging) was 11% (N=2).
    - Mortality events were likely related to thermal shock exacerbated by handling.
- On day-2, 1 tagged mortality (6%) and 9 untagged mortalities (4%) were recorded.
- On day-4, 13 tagged mortalities (72%) and 35 untagged mortalities (18%) were recorded.
- On day-5, cumulative tagged mortality was 100% and cumulative untagged mortality was 44% and the experiment was terminated. Untagged fish were either retained for length sampling or released to the Connecticut River (N=~68).
    - Mortalities of both tagged and untagged fish appeared to be related to thermal stress.

Behavior

- Day-1 post-tagging (October 31):
    - All fish were observed circling clockwise against a light current, 2 untagged fish were distressed.
    - All tagged fish were swimming vertically and normally with school, matching pace. Tag attachment and position looked good.

    - When startled, tagged fish response was the same as untagged fish (stop, change direction, accelerate, then regroup and resume previous behavior).
    - Untagged fish readily broke pattern and rose to feed, tagged fish were observed feeding in water column.
- Day-2:
    - One tagged fish was observed listing and one was observed swimming slower than school. The remainder were swimming vertical, normal, and at pace with school.
    - All fish were observed swimming more slowly, <1 ft/s and < 5 tailbeats/s.
    - Feeding was observed to be limited.
- Day-4:
    - All fish were observed circling clockwise against flow. Swim speed was < 1ft./s, ~5 tailbeats/s.
    - Only 2 tagged fish were left, but were among the most vigorous swimmers.
    - No feeding was evident.

Table 3-8. Tagging Trial-3. Summary statistics for length and weight of hatchery-reared juvenile American Shad (measured post-mortem).

	Length (mm)	Weight (g)
N	17	17
Min	85	5
Max	110	12
Mean	98.6	7.8
SD	5.2	1.4

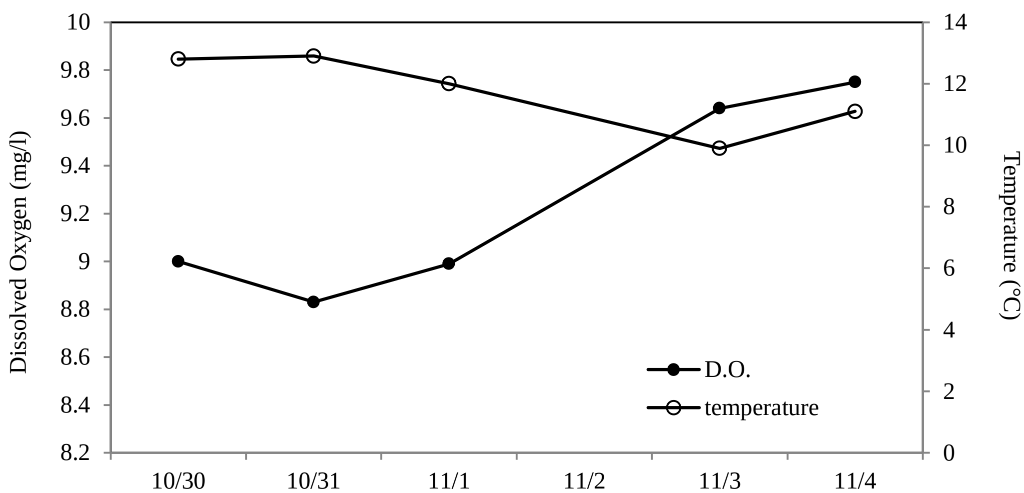

Figure 3-6. Instantaneous water quality measurements for Tagging Trial-3.

Table 3-9. Tagging Trial-3. Daily and cumulative mortality (M) estimates for 18 tagged and ~199 untagged juvenile American Shad. Fish were assumed to be ~78% wild-caught and 20% hatchery-reared.

			Mortalities			M (%)			M_cumulative (%)			N_live		
Day	Date	Time	tagged	untagged	total	tagged	untagged	total	tagged	untagged	total	tagged	untagged	total
0	10/30	1230										18	199	217
1	10/31	1215	2	1	3	11.1%	0.5%	1.4%	11.1%	0.5%	1.4%	16	198	214
2	11/1	825	1	9	10	5.6%	4.5%	4.5%	16.7%	5.0%	6.0%	15	189	204
3	11/2		no observation								6.0%	15	189	204
4	11/3	1044	13	35	48	72.2%	17.5%	22.4%	88.9%	22.5%	28.1%	2	154	156
5	11/4	1150	2	43	45	11.1%	21.5%	27.1%	100.0%	44.0%	48.8%	0	111	111

4.0 Discussion and Conclusions

4.1 Study Objectives

1. Evaluate the mortality rate induced by transport of hatchery reared fish from the FWS North Attleboro Fish Hatchery to distribution to the holding tanks at Vernon.

The initial (24-hr post-transfer) mortality rate was ~ 1%. Cumulative mortality of untagged hatchery-reared fish through October 24 (day-17 post-transfer) was 13%. This result supports the idea that transport and transfer mortality is acceptable for provision of hatchery-reared fish. It was assumed that large-scale mortality events in the holding tank and the experimental tanks after October 25 were induced by thermal shock. The assumption was corroborated by large-scale mortality events recorded in retained juveniles at the North Attleboro Hatchery at roughly the same time (Kevin Cheung, FWS, personal communication). However, this study demonstrated that:

- A lesser number of fish/lower density stocked to the holding tanks is desirable to maintain better water quality and reduce the potential for fungal infection. Fewer than 1,000 fish would likely be sufficient to provide hundreds for telemetry study purposes.
- Holding for long periods may result in large-scale mortalities at some point, likely instigated by thermal shock as ambient temperature rapidly decreases due to seasonal atmospheric events.
- It was observed that hatchery-reared fish behaved differently from wild-caught fish when segregated to individual tanks. The hatchery-reared fish swam at an unexpectedly fast rate from arrival until the period when high mortality rates were observed. When mixed, wild and hatchery-reared fish swam at the same rate and could not be discriminated.

2. Evaluate whether the tagging process and carrying the tag affect mortality and behavior relative to untagged fish.
   - Tagging trials included two tag sizes and attachment methodologies. The larger NTC-M-2 tag using the tagging pin (Hi-Z) method has been used successfully for juvenile American Shad telemetry in the Susquehanna River. That transmitter model has a longer history of use and a longer battery life, and given FWS attempts to rear fish to an appropriate size, was first proposed for use. Mortality and behavior assessments suggested that reasonable results might be achieved in a telemetry study over a short period (4 d survival was 80% in the tank trial) if sample size is adjusted accordingly, but given superior results with a smaller tag, the NTC-M-2 tag is not recommended.
   - The smaller NTQ-1 tag (10 d battery life) and hook attachment method had virtually no observable effects on behavior relative to untagged fish. In Tagging Trial-2, mortality of tagged fish was 0% through day 5, and we believe that the study was

confounded after that time by large-scale mortality that was related to effects other than tagging and handling. Tagging Trial-3 may have been entirely compromised by those outside factors, but results in that trial also demonstrated minimal impacts of this tag / attachment method on juvenile American Shad, at least for a period of time that is reasonable for a juvenile American Shad telemetry study.

- No tag ejection was noted in any of the tagging trials.

4.2 Preliminary Results Report Objectives

As discussed in Section 1.0, FWS suggested 10 reasons that radio tagging of juvenile American Shad may be problematic for achieving the goals and objectives of Study 22. The results from this tagging evaluation have largely addressed those concerns. The results of these trials indicate that using the smaller NTQ-1 tag (or even smaller tags if available) should provide meaningful and reliable data from radio tagged wild or hatchery-reared juvenile shad.

1. The ability to produce/obtain a suitable number of juvenile shad for tagging studies in 2015 (i.e., > 110 mm)
   - Results reported here clearly demonstrate that suitable numbers of juvenile shad can be reared in the hatchery for 2015 studies. In fact, after delivery of 2,000 juveniles to Vernon, FWS proceeded to release an additional 8,000, and we released ~500 (1/4) of fish that were delivered. In addition, sufficient numbers of wild fish were observed in the Vernon pool, and would likely be preferable to hatchery fish for Study 22.
2. Successful transport and holding of fish at the study site
   - Initial mortality and general mortality (until the previously discussed mortality events occurred) was relatively low. However, the results of this study suggest that holding fish for long periods at the site is disadvantageous. Cold fronts of increasing frequency characterize the peak juvenile shad emigration period - late September and October. Longer holding periods increase the risk of exposing captive fish to episodic temperature drops that, coupled with the stress of handling, may be detrimental. Those effects may be mitigated to some extent by insulating holding tanks to reduce thermal fluctuations due to air temperature. Additionally, Saprolegnia fungal infection was common in the 7-ft. diameter holding tank with a high density of hatchery-reared juveniles, and the risk of infection may be increased with holding time.
3. Application of tags
   - Results of this study suggest that the Hi-Z tag method, while effective for the Susquehanna River juvenile shad, which are significantly larger, should not be used for Connecticut River stock. The objective of providing sufficient fish >110 mm was met (with culling). Meanwhile, as discussed above, the advantages of longer battery life are negated by tag effects, arguing for the use of the smaller tag model. Use of the smaller tag also reduces the need to grow fish to larger size. The smaller tags can be used on fish 100 mm TL.
4. Mortality or other effects of tags and procedures, including tag loss/retention

- Discounting confounding mortality events, mortality resulting from the smaller NTQ-1 tag was very low. There appeared to be no tag retention problems for the observed periods with either tag/attachment method.

5. Behavior of tagged fish
   - The effect on behavior was pronounced in 20% or more of fish tagged with the larger tags at any given time. Effects on behavior of tagged fish with the smaller tags were negligible.
6. Losses and/or other impacts to study fish from handling at all steps in the process up to release
   - Assuming appropriate handling and holding times, and release within 24-hr after tagging, losses should be minimal. Wild-caught fish suffered <1% mortality over a 10-d hold period. Hatchery-reared fish suffered only ~ 3% mortality over a similar holding period. Longer holding periods may result in increased risk of large-scale mortality. This suggests that using wild-caught fish in smaller batches with shorter holding times would be most effective.
   - Additionally, although wild and hatchery-reared fish could not be discriminated when mixed, wild fish behaved better in holding. Swimming was more relaxed, feeding was more natural, and schooling behavior appeared more normal. In comparison, hatchery-reared fish circled continuously at a fast pace.
7. Timing of obtaining fish, tagging and releases (i.e., suitably sized fish may not be available until the mid to late part of the outmigration)
   - As noted above, the results presented here suggest that best results will be obtained using the smaller tag, which negates the necessity to rear fish to 110 mm for the radio telemetry study (however, for turbine survival studies, the minimum size fish needed is still 120 mm, preferably even larger). Both hatchery-reared and wild-caught fish were of suitable size for the smaller tag. Hatchery fish barely met the minimum size criteria for the larger tag (with culling). Using wild-caught fish would allow for matching collection and tagging to the true emigration period, as emigrating fish would be collected when available. In either wild or hatchery-reared fish, culling for larger individuals is recommended.
8. How will batch releases of radio-tagged fish occur relative to migrations of wild juveniles
   - Emigrating fish were evident in the Vernon forebay during this study until the rain/flow event, after which no wild fish were evident in the forebay. As discussed above, wild fish may be collected from the actively migrating population at or near the Vernon site allowing for batch releases of tagged fish that are in similar physiological condition.
9. The unknown of when and where wild fish move as they out-migrate in the Lower Vernon Pool (i.e., the choice[s] of release site[s] may influence results); and

- As discussed above, when wild fish out-migrate can be observed at and near Vernon dam. The use of wild fish captured in the vicinity of Vernon dam wild address the issue of "when" the fish migrate, because juveniles that have initiated migration will be collected. The issue of where wild fish move as they out-migrate can be addressed by releasing fish at several release sites across a release transect upstream from the dam to address the potential for release site bias.

10. The unknown of when, where and how tagged juveniles are released compared to wild juvenile movements (locations) as they migrate downstream and encounter the various features of Vernon Power Station.
    - The use of wild fish will eliminate concerns regarding whether hatchery-reared fish behave similarly to wild fish. Collection of wild fish during the outmigration period of late September/October will provide study specimens that are already motivated to migrate. Collection, tagging, and release can be done within a 24-hr period, minimizing holding time, stress, and delay, and allowing tagged specimens to rejoin their cohort. Tagging and release of those fish upstream of the dam should ensure timely return, so the 10 d battery life of the model NTQ-1 tag should be sufficient. In a pilot study conducted in 2013, 20 juvenile Alewife were tagged with NTQ-1 tags and released in the Merrimack River in New Hampshire. Fish that approached the Garvins Falls Project in that study had short residence times (< 3.3 hr., Normandeau 2013). Release at several points across a release transect will allow fish to approach the dam and encounter the station at different locations.

The 2015 tagging trials have demonstrated that wild fish will provide a superior level of fitness since longer holding periods are not necessary, and they would be known representative of the outmigrating population. The use of the smaller NTQ-1 tag is clearly preferable for Connecticut River studies, as tagging effects on behavior appeared to be minimal.

5.0 Literature Cited

Heisey, P.G., D. Mathur, and T. Rineer. 1996. A Reliable Tag-Recapture Method for Estimating Turbine Passage Survival: Application to Young-Of-Year American Shad (*Alosa sapidissima*). Canadian Journal of Fisheries and Aquatic Sciences 49: 1826-1834.

Normandeau (Normandeau Associates, Inc.). 2012. Juvenile clupeid radio tag attachment test – pilot study. Letter Report submitted to Public Service of New Hampshire. December 2012.

Normandeau (Normandeau Associates, Inc.). 2012. Garvins Falls Juvenile Clupeid Downstream Passage Telemetry Assessment. Letter Report submitted to Public Service of New Hampshire. December 2013.

Memorandum

14 October 2014

TO: John Ragonese, Jennifer Griffin

FROM: Dr. Christopher Gurshin, Maryalice Fischer

SUBJECT: Comments on studies cited by FWS and VANR 8-Oct Response [FWS] and 7-Oct Response [VANR] to Proposed Study Plan 34

Vermont Agency of Natural Resources (VANR)) and the US Fish and Wildlife Service (FWS) provided comments (on 7 October 2014, and 8 October 2014, respectively) on TransCanada's (TC's) Proposed Study Plan 34 – Proposed Vernon Hydroacoustic Study.

A review of the studies cited by FWS and VANR is provided in Table 1 and their relevancy to Study Plan 34 and to the Vernon Project is summarized by the following points:

a) Several inaccuracies persist in the citations provided by FWS and/or VANR that warrant clarification or correction.

- Anonymous (2013) cited by FWS in their 23 April 2014 letter and by VANR in their 7 Oct 2014 letter was also cited by FWS as Aquacoustics (2013), but is more precisely cited as a chapter in an anonymous report that was authored by Degan and Mueller (2013).
- The report on the hydroacoustic study of eels at Anson hydroelectric station was cited as Kleinschmidt (2006) when the correct citation is Kleinschmidt and Aquacoustics (2006).
- The Skalski et al. (1996) paper was inaccurately cited by FWS in their 23 April 2014 letter and by VANR in their 7 Oct 2014 letter with the year of 1998.

b) Six (35%) of the 17 studies have not been published in the peer-reviewed scientific literature.

c) Seven (41%) of the 17 studies used a single DIDSON or HA transducer (rather than multiple units as currently suggested by FWS, VANR and FERC

d) None of the studies demonstrates that deployment of fixed-location hydroacoustics could describe <u>all</u> of the stated (by FERC, FWS and VANR) objectives for hydroacoustics (timing, duration, relative magnitude, passage route selection, and forebay residency time/migratory delay)) for any migratory fish species, yet agencies and FERC have requested TC to do so for redundancy of collecting the same information using other methods for juvenile American Shad in Study Plan 22, and for American Eel, in Study Plans 19 and 20.

e) None of the studies used hydroacoustics to study passage or migration of American Shad. Only 2 unpublished cited studies (Nestler et al. 1999; Anonymous 2013) estimated fish passage of juvenile clupeids (Threadfin Shad and Blueback Herring). Concurrent hydroacoustic and fyke net sampling by Nestler et al. (1999) failed to produce a significant regression indicating highly variable hydroacoustic estimates of entrainment did not significantly correlate with the number captured by fyke nets.

f) Five (29%) of the studies used hydroacoustics to study fish passage or entrainment of American Eel or European Eel at a hydroelectric dam. One of these studies (Mueller et al. 2008) was not a field based study. Only one of the remaining 4 studies (Kleinschmidt and Aquacoustics 2006, unpublished) used more than 1 HA transducer or DIDSON; and in all cases, the study area consisted of a narrow, shallow channel within which HA monitoring occurred.

g) Eight (47%) of the studies used hydroacoustics to study fish passage or entrainment of salmonids at a hydroelectric dam.

h) Eleven (65%) of the studies demonstrated how hydroacoustics could assess timing, duration, and magnitude of fish passage or entrainment at a hydroelectric facility.

i) Thirteen (76%) of the studies demonstrated how hydroacoustics could assess relative magnitude of fish passage.

j) Seven (41%) of the studies demonstrated how hydroacoustics could estimate proportional passage route selection at a hydroelectric facility.

k) One (6%) of the studies estimated forebay residency time (migratory delay), but was done by radiotelemetry not by HA methods (Johnson et al. 2005). This study used both fixed-location hydroacoustics and radiotelemetry, but forebay residency time was only estimated by radiotelemetry. Their radiotelemetry results showed similar median residency times between tagged hatchery versus wild Steelhead (0.8 h vs. 0.6 h in 1997, 4.6 vs. 6.4 h in 1998, and 0.1 h vs. 0.1 h in 1999). This result supports, at least for juvenile Steelhead, the idea that hatchery fish could be surrogates for wild fish.

l) Proportional passage route selection determined concurrently by fixed-location hydroacoustics and radiotelemetry at Lower Granite Dam by Johnson et al. (2000) provided similar estimates of surface bypass collector efficiency (69% by hydroacoustics vs. 65% by radiotelemetry) and fish guidance efficiency (87% by hydroacoustics vs. 85% by radiotelemetry). This supports TC's claim that the behavior of tagged fish can be representative of the behavior of wild fish, and that a large comprehensive hydroacoustics study would only provide redundant passage route selection information at substantially high incremental cost.

m) While Kleinschmidt and Aquacoustics (2006) showed promising results for developing a hydroacoustic monitoring system that would determine and notify operators when out-migrating eels approached the Anson project (FERC No. 2365), Madison Paper Industries (MPI), in consultation with the Fish Passage Team (FWS, MDMR, NMFS, MDEP, MDIFW), decided to modify the existing facilities to facilitate eel passage during the FERC re-licensing process. After a 2007 PIT-tag study on downstream eel passage effectiveness at the Anson project was found inconclusive, MPI with approval from the Fish Passage Team conducted a more comprehensive study of eel passage using radiotelemetry, and not fixed-location hydroacoustics (Kleinschmidt 2013).

n) The successful use of DIDSON to detect and count migrating eels over short distances (<15 m) has been shown by Kleinschmidt and Aquacoustics (2006) for American Eel and by Bilotta et al. (2011) for European Eel. In the Bilotta study, targets were manually classified after reducing the data to eliminate backscatter without targets. The authors acknowledged that the intensive manual processing effort and expensive capital investment are problematic challenges to the widespread use of DIDSON for large monitoring programs, but they hoped that emerging analytical algorithms and automation procedures could reduce the labor effort. While the time series of DIDSON derived eel counts provided information to describe timing, duration and relative magnitude, it did not provide any information on migratory delay. Since their study was limited to a 12-m wide man-made channel, passage route selection was irrelevant. To apply this technology to Vernon, sampling at the two bypasses and 10 intake units requiring one DIDSON each, the capital expense for the sonars themselves alone would cost over $1 million, and by the Bilotta estimates, would take over 2,800 hours of labor to identify eels and probably closer to 5,000 hours to identify both eels and shad.

o) While multi-beam and split-beam hydroacoustics have been used to detect hundreds to thousands of out-migrating eels for estimating fish passage at small hydroelectric stations (Kleinschmidt and Aquacoustics 2006; McCarthy et al. 2008; Bilotta et al. 2011), Haro et al. (1999) was unable to show a significant correlation between bypass weir counts and acoustic counts when eel abundance was low. On the Connecticut River upstream of Vernon dam, the most recent five years (2009-2013) of available data collected for Vermont Yankee in ecological studies of the Connecticut River, in the vicinity of Vernon, suggests eel abundance above Vernon dam to be extremely low (Normandeau 2010, 2011, 2012, 2013, 2014). Only one American Eel was impinged at Vermont Yankee station during 2009-2013. During the same period, only one American Eel was caught immediately downstream of Vernon dam out of the 16 electrofishing samples collected each year, and no eels were caught upstream of Vernon dam out of the 24 electrofishing samples collected each year.

p) No studies have yet demonstrated the use of fixed-location hydroacoustics for long-term monitoring of eel passage and entrainment at large-scale hydroelectric facilities similar to applications for salmonids at large dams in the Columbia and Snake River basins. Based on results to date using hydroacoustics to monitor eels, the Electric Power Research Institute (EPRI) has awarded TransCanada's consultant, Normandeau Associates, with a contract to conduct an assessment of the existing hydroacoustic technologies <u>for their potential to study</u> downstream migrating American Eel approach and behavior at Iroquois Dam, the Beauharnois Power Canal and the Beauharnois Generating Station located on the St. Lawrence River. This is a pilot project designed to help determine if HA technologies are capable of documenting relative abundance and distribution of outmigrating eels as well as the behavior of eels during outmigration. Behaviors of interest include diurnal variation of downstream movement, favored locations in the St. Lawrence River channel or the water column during migration, vertical and/or horizontal movements, reaction to physical structures such as a nose pier or water control gate, and whether eels outmigrate in groups or aggregates.

FWS and VANR reported in their October 8, 2014 and October 7, 2014 (respectively) comments on TransCanada's (TC) Proposed Study Plan (PSP) that "…a search of FERC Online for the period 2000 – 2014 revealed that at least seven FERC projects have used (or have agreed to use) hydroacoustic technology". We reviewed the relevant documents available on the FERC e-library. The studies conducted at the 7 FERC projects cited by FWS and VANR are summarized in Table 2.

- Of the 7 FERC projects cited, only 4 actually used HA technologies for monitoring fish in a way that might be applicable to the Vernon project (e.g., split-beam arrays, DIDSON).
- Two other projects used other technologies identified as "hydroacoustics" (e.g., hydroacoustic tags or mobile hydroacoustic surveys), for reasons that are irrelevant to the agencies' study goals and objectives for the Vernon project.
- One study was conducted at a proposed tidal project site with fish passage concerns (and monitoring) that is not transferrable to the Vernon project.
- All of the 4 potentially applicable studies were for the purpose of post-license passage effectiveness monitoring, not for pre-licensing baseline studies.

Therefore, 4 applicable studies that "have used or have agreed to use" HA over the last 14 years does not support the contention that HA monitoring is a generally accepted practice.

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Table 1. Summary of studies cited by USFWS and VANR to support use of hydroacoustics to describe timing (*t*), duration (*D*), magnitude or abundance (*N*), passage route selection (PRS) and residency time or migratory delay (Δ*t*) for the out-migration of juvenile American Shad and adult silver-phase American Eel at Vernon.

Studies published in the peer-reviewed scientific literature are indicated by an asterisk (*).

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Anonymous 2013 (Same as Aquacoustics 2013; relevant chapter is the report by Degan and Mueller 2013)	Juvenile & adult Threadfin Shad, Blueback Herring	Multiple Simrad 333 kHz split beam EK60	Jocassee Pumped Storage Station (JPSS), S. Carolina	Used hydroacoustics to monitor at the JPSS intakes for estimating fish entrainment & entrainment-related mortality during pumping and generation. • Provided numbers entrained in each sampled intake and indirect length measurement. • Fish were assumed entrained based on trajectories approaching intake opening. • Results not presented by species or taxa.
Bilotta et al. 2011*	European Eel	One DIDSON (14 x 29 °)	River Huntspill channel, Somerset U.K.	• Study purpose was to evaluate the potential of DIDSON to quantify number and biomass of eel escapement. • 1 Jul through 30 Nov 2009 (153 days). • Upstream of sluice gate in narrow, 12-m wide river channel. • Sonar pointed perpendicular to flow. • Authors acknowledge this study provides no information on effects of the physical barriers on delaying eel migration. • Excessive labor (about 240 hours) to collect and analyze.

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Boswell et al. 2008*	Large Chinook Salmon, coastal and estuarine species	One DIDSON, at 3 different monitoring sites.	Based on data from Kenai River, Alaska Port Fourchon, LA Mobile River, AL	• This is a techniques paper documenting several analytical processing approaches in Echoview software. • Comparison of length, abundance, speed, and direction of travel based on 3 data sets on salmonids or estuarine fishes. • For two of the three data sets analyzed, the estimates of fish abundance derived from DIDSON analyses were not significantly different from the manual counts of DIDSON files.
Doehring et al. 2011*	5-6 cm juvenile *Galaxias*(a genus found in the tropics of the southern hemisphere)	One DIDSON at two different monitoring sites.	Two culverts, New Zealand	• Study purpose was to compare upstream migration counts between gated and un-gated culverts, and test suitability of DIDSON to monitor these small juvenile fish. • A 2-day study of continuous data collection using DIDSON in each of 2 shallow-water 5-m wide tidal floodgates/culverts. • Acoustic targets were visually identified as galaxiids on playback, counted and assigned direction as it exited the field of view (assumes no double counting). • Visual daytime observations verified small echoes as juvenile galaxiids. • The authors caution the readers to interpret their counts as relative abundance as species identification by DIDSON was challenging and affected by a number of conditions. • The authors concluded their DIDSON counts support migration was altered by the floodgate and related some tidal and diel patterns. • However, there was no method or test metrics to assess suitability of DIDSON for monitoring these fish (their 2nd objective). There were no quantitative ground-truthing or estimate of uncertainty by software user (only 1 person analyzed).

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Hamel et al 2008*	Rainbow Smelt	One HTI 200 kHz split-beam transducer	Lake Oahe Dam, S. Dakota	• Used a split-beam echosounder to compare smelt densities between control and strobe lights. • Strobe lights were shown to vertically displace smelt to approximately 6 m, which provides support that strobe lights could be used to reduce entrainment.
Haro et al. 1999	American Eeel	One Biosonics 420 kHz split-beam 6x12deg	Cabot Station, MA	• Study objectives included: (1) describe echo characteristics, (2) evaluate hydroacoustics to detect in-field eel movements, (3) model backscatter as a function of length, aspect, and acoustic frequency, and (4) provide recommendations for use of hydroacoustics for evaluating behavior and timing of eel movement. • A single 420 kHz split beam transducer 1 m depth & 6.5 m upstream of trash racks, pointed across forebay, parallel to racks and downward at angle of 5°. • "…the relationships between both daily and diel acoustic and video counts were low ($r^2 < 0.1$) and not statistically significant ($p < 0.05$)." • "discrimination of eel targets from those of other fishes remains problematic." • "On a nightly basis, the number of acoustic targets per unit time did not match counts at the bypass weir."

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Johnson et al. 1999	Yearling Steelhead Trout, Chinook, Coho Sockeye Salmon	Multiple Biosonics 420 kHz single beam transducers and a dual-head Simrad SM2000 multibeam sonar	Lower Granite Dam, USACE WA	• Study purpose was to measure performance of spill, intake screens, and prototype surface bypass structures. • Spring 1998 study period was dominated by juvenile salmonids. • 54 transducers sampled 4 SBC entrances, 9 of 15 turbine intake screens, 5 of 18 powerhouse pier noses and all 7 spill bays. • Multi-beam and split-beam transducers were used to explore milling behavior.
Johnson et al. 2000*	Yearling Steelhead Trout, Chinook, Coho Sockeye Salmon	Multiple Biosonics 420 kHz single beam transducers; 120 & 200 kHz split-beam	Lower Granite Dam, USACE WA	• Study purpose was to evaluate the surface bypass collector (SBC) and fish guidance efficiency of screens. • 29 single beam transducers were used to estimate total passage through SBC, powerhouse and spillway. • A 120 kHz & two 200 kHz split-beam transducers were used to estimate fish speed and direction on approach. • Fixed radiotelemetry of hatchery reared test fish were also used; sample sizes ranged from 168 wild Steelhead to 397 hatchery Chinook Salmon. • Concurrent radiotelemetry and hydroacoustics where both were available provided similar results (e.g., SBC entrance efficiency and fish guidance efficiency was respectively 69% and 87% for hydroacoustics and 65% and 85% for radiotelemetry).

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Johnson et al. 2005*	Yearling Steelhead Trout, Chinook, Coho Sockeye Salmon	Multiple 420 kHz single and split-beam transducers	Lower Granite Dam, USACE WA	• The surface bypass and collector (SBC) on the powerhouse of Lower Granite Dam was evaluated annually with biotelemetry and hydroacoustic techniques during the 5-year life span of the structure (1996–2000) to determine the entrance configuration that maximized passage efficiency and minimized forebay residence time. • Sample sizes were 400-800 yearling Chinook Salmon, 200-400 hatchery Steelhead, and 200-400 wild Stealhead. • Radiotelemetry was used to determine passage route and forebay residency time of tagged fish. • Tagged wild and hatchery Steelhead had similar forebay residency times each year from less than an hour to several hours (see Table 3 in Johnson et al.2005).
Johnson & Moursand 2000*	Juvenile salmonids	Two Simrad SM2000s	Bonneville Dam, USACE WA, OR	• This study describes a new technique to study fine-scale behavior in proximity to a dam structure. • Two Simrad SM2000 multibeam transducers were positioned at fixed location on barge upstream of the SBC in perpendicular orientation to track individual fish within the overlapping sampled volume overlapping. • No quantitative estimates of the sampling volume were provided, despite claiming it was “large”. • Although not specified in paper, this sonar operates at 200 kHz and has 128 receiving beams but are 20° x 1-2°, so the overlapping region would be presumably 20° x 20° consisting multiple beams spaced about 1 degree apart with target location precision of +/- 1-2°.

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Khan et al. 2009	Steelhead	Multiple Precision Acoustic Systems 420 kHz single & split- beam transducers, DIDSON	Dalles Dam, USACE WA, OR	• Study purpose was to characterize adult steelhead spatial and temporal distributions and passage rates at the sluiceway and turbines, and their movements in front of the sluiceway. • Study periods 1 Nov to 15 Dec 2008 & 1 Mar to 9 Apr 2009. • A total of 34 transducers (18 single-beam & 16 split-beam) to estimate passage and route selection. • DIDSON used to study fish movements at the sluiceway
Kleinschmidt & Aquacoustics 2006 (cited as Kleinschmidt 2006)	American Eel	DIDSON; 201 kHz Bisonics split-beam (6° and 4x8°); 120 kHz Simrad EK60 split-beam (7°)	Anson Hydroelectric Project, ME	• Study objectives were (1) to verify eels could be detected, (2) to optimize transducer sampling configuration, (3) to recommend deployment specifications for hydroacoustic monitoring of eels, (4) to develop processing methods to recognize and distinguish eels from non-target species from echograms and acoustic image patterns, and (5) to recommend turbine and waste-gate operation during eel outmigration. • Study period was 19 September through 4 October 2005 (16 days.) • One split-beam near surface and one near bottom both pointed horizontally perpendicular to flow; DIDSON aimed from near surface toward bottom and opposite bank. • Forebay of powerhouse is about 6 m deep and 32 m wide on the Kennebec River, which is much smaller than Vernon Dam and where eels are more abundant (study identified over 200 eels). • Surface deployed split-beam transducer systematically bias low estimates due to poor echo traces and more misclassification of debris (DIDSON was able to distinguish debris from eels more easily). • Study did recommend an automated eel-monitoring system could be developed using DIDSON and split-beam for determining timing, duration, and relative magnitude of outmigration.

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
McCarthy et al. 2008*	European Eel	One Simrad EY500 120 kHz split beam transducer	Ardnacrusha hydroelectric, Shannon River, Ireland	• Study purpose was to estimate the number and speed of eels traveling through a small (38 m wide) headrace canal. • A 4x10° 120 kHz split-beam transducer was aimed horizontally across headrace canal and sampled about 47 m^2 of the 297 m^2 cross section of the canal • Data were collected from 12 Aug through 12 Oct 2004. • This study lacked verification of eel echo classification necessary to assess validity of results (Fig 6 shows correlation between swim speed, flow and fish counts…could counts be debris influenced? Fig 6 shows fish speed < flow yet text says eel swimming speed > flow).
McKinstry et al. 2005*	Kokanee Rainbow Trout	Multiple 420 kHz Split beam transducer	Grand Coulee Dam, Bureau of Reclamation, WA	• The scope of this paper was presenting the statistical assessment of changes in behavior induced by strobe light treatments using acoustically tracked fish counts. • 5 down-looking split-beam transducers spaced in 4 m intervals from strobe light. • Fish tracks were not classified by taxa, and included other residential fish such as Walleye and Smallmouth Bass.
Mueller et al. 2008*	American Eel	Based on DIDSON	n/a	• Study purpose was "to explore the extent to which a computer-driven process can be used to classify sonar images." • Based on data collected during a feasibility study in the intake canal of a small hydroelectric station (Kleinschmidt 2006). • Results: neural network analysis misclassified 7% of eels as debris & 5% of debris as eels; discriminant function analysis misclassified 12% of eels as debris and 4% of debris as eels; K-nearest-neighbor analysis misclassified 17% of eels as debris & 12% debris as eels. • 5-12% misclassification.

Table 1. Continued

Citation (*)	Target Species	Technology	Site	Purpose and Comments
Nestler et al. 1999	Threadfin Shad Blueback Herring Centrarchids	Multiple Biosonics 420 kHz elliptical single-beam & circular dual-beam transducers	Richard B. Russell Dam, USACE GA, SC	• Chapter 6 study objectives were: (1) to determine if hydroacoustics could be used to monitor entrainment rates; (2) to measure entrainment through time, among intakes, and depths sampled; and (3) to determine if the number of operating units changed entrainment rates. • 2 transducers per turbine intake unit mounted on pivoting framework in front of each intake bay about 20-30° from vertica.l • Mostly tracked single fish echoes but during May when silt and dense juvenile threadfin shad were entrained, estimates were made by echo integration. • Hydroacoustic-derived entrainment was highest during September when Threadfin Shad were numerically dominant in net catches. During this time fish were more surface oriented than in other months. • Regression between concurrent hydroacoustic and net estimates of entrainment were not significant.
Skalski et al. 1996* (cited by FWS/VANR as Skalski et al. 1998)	Juvenile Steelhead, Chinook Salmon, Sockeye Salmon	Multiple Biosonics 420 kHz split beam	Wells Dam, Douglas County PUD, WA	• Study purpose was "to present statistical and logistical issues in designing a hydroacoustic study to estimate bypass efficiency". • Fixed-location hydroacoustics were used to estimate turbine bypass efficiency. • Spring (mid-Apr through mid-May) and summer (~2 weeks) during 3 years (1990-1992). • 25-29 transducers in turbine and spill intakes placed on bottom behind trash racks and faced upward. • Fyke net sampling described species composition of acoustic targets.

Table 2. Summary of FERC projects using HA technology.

FERC Project No.	Target Species	Technology	Site	Study Purpose/Comments
P-2145	Juvenile salmonids, adult Sockeye	Acoustic JSATs tags (w/ PIT and/or floy tags) with acoustic receiver networks.	Rocky Reach, (Chelan PUD) HCP 10-year report 2013.	• Juveniles – route selection, project survival. • Adults – upstream migration timing, escapement, fallback, etc. • "would like to replace expensive acoustic tagging with PIT tagging" (presentation 01/03/2014- Attachment B of report). • Pre- and post-license monitoring.
P-2365	Adult American Eel	2013 - One DIDSON 2005 study tested HA technologies.	Anson and Abenaki. Kennebec River ME. 2013, 2012, and 2005 studies.	• 2013 – "General eel migration patterns" based on single DIDSON in forebay, with radio telemetry. Note that MDMR (not the licensee) reviewed the DIDSON data. • 2005 – compared HA technologies and range/confidence of detections in small pilot project to determine if these technologies could be used in an automated eel detection system. Qualitative relative abundance. Fish throughout the water column and evenly dispersed across forebay/dam. • Post-license monitoring.
P-4678	Juvenile Blueback Herring	Mobile acoustic surveys and fixed HA.	Crescent, NY	• Evaluate the effectiveness of the acoustic deterrence system. • HA used to evaluate acoustic deterrence /guidance system (sound projection not an HA system) • Post-license monitoring.
P-6842	Coho, Steelhead smolts	Five HTI split beam, fixed aspect transducers	Wynoochee, WA. 2003 10-year HA report.	• Monitoring of "temporal distribution" to assess passage timing at discrete passage locations. • To optimize project's annual shutdown schedule. • Calculated "weighted fish indices" for counting/enumeration. • Post-license monitoring.

Table 2. Continued

FERC Project No.	Target Species	Technology	Site	Study Purpose/Comments
P-7481	Juvenile Blueback Herring	Nine transducers	New York State Dam. 1995 - 2013	• Annually determine when fish bypass needs to be opened with different flows (qualitative only, to optimize bypass flows). • No information on species vs. debris, etc. • Post-license operational monitoring.
P-11393	Juvenile Sockeye Salmon	No technology specified	Mahoney Lake, AK. 2002	• Annual population assessment using hydroacoustic survey to develop an indication of success of incubation (but not emergence timing), in conjunction with mid-water trawling for species and size/age specific data. • Post-license monitoring
P-12611	mixed estuarine and coastal marine species	Mobile: split-beam HA (BioSonics) 3 – 4 units. Fixed: 8 split beam arrays and "still experimental DIDSON".	Roosevelt Island Tidal Project, NY. 2006	• Pre-pilot license monitoring for tidal project. • Evaluation of fish movement around and through tidal turbines. • Mobile – distribution of fish population abundance, and migratory routes (limited monthly sampling). • Fixed – fish spatial distribution, abundance, location, swim direction, and velocity; characterize effects of turbines on individual fish and populations. • 2 arrays at far field up/downstream and 2 arrays immediately near field up/downstream. • Continuous 18-month monitoring.