FirstLight Power Resources

Turners Falls Hydroelectric Project (FERC No. 1889)
Northfield Mountain Pumped Storage Project (FERC No. 2485)
March 2016 Study Report Meeting

March 16, 2017

Report Filings

- 5 reports filed
  - 2 reports filed on 12/28/2016
    - 2nd Year Odonates
    - 2nd Year Ichthyoplankton
  - 3 reports filed on 03/1/2017
    - Downstream Eel
    - Ultrasound Array
    - Operations Model

Relicensing Process - Next Steps

Study Report Meeting (Stakeholders and FirstLight)
- March 16, 2017

Study Report Meeting Summary Filed (FirstLight)
- March 31, 2017

Disagreements/Modifications to Study/Propose New Study (Stakeholders)
- May 1, 2017 (technically April 30, 2017, but falls on a Sunday)

File Responses to Disagreements (Stakeholders and FirstLight)
- May 30, 2017

FERC Issues Determination
- June 29, 2017

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Study Recap

FERC Filing Date	No. of Studies	Study Name Abbreviations
09/15/2014	2	Full River Reconnaissance, Rec Inventory
12/31/2014	2	Archaeological- Phase 1A only, Historic Structures
09/14/2015	9	Hydraulic Model Study, Aquatic Habitat Mapping, Tributary Access, Canal Drawdown, NFM Land Management, Whitewater, Day/Overnight Rec Facilities, Rec Study of NFM, Traditional Cultural Properties.
03/01/2016	13	Water Quality, US Passage Eel, Shad Spawning, CFD Modeling, River2D model of NFM tailrace, Odonates, Fish Assemblage, Cabot Emergency Gates, Ichthyoplankton, Terrestrial Wildlife & Botanical, RTE, Rec Use/User Survey, Land Use Inventory
10/14/2016	10	Erosion Causation, Sediment Monitoring, IFIM Study, US & DS Adult Shad, DS Juvenile Shad (Interim), Entrainment, Littoral Zone, Sea Lamprey Spawning, Mussels, Project Ops impact on Rec
12/28/2016		Supplemental Ichthyoplankton (Year 2), Supplemental Odonate Work (Year 2)
03/01/2017	3	DS Eel (2-year study), Ultrasound Array, Operations Model
Total	39	

Agenda

Time	Study Name
9:00-9:30 am	Introductions, Meeting Objectives, Schedule
9:30-10:15 am	Study No. 3.3.10 Assess Operational Impacts on Emergence of State Listed Odonates (2nd year)
10:15-10:30 am	15 minute break
10:30-11:15 am	Study No. 3.3.20 Ichthyoplankton Entrainment Assessment at the Northfield Mountain Pumped Storage Project (2nd year)
11:15-Noon	Study No. 3.3.19 Evaluate the Use of an Ultrasound Array to Facilitate Upstream Movement to Turners Falls Dam by avoiding Cabot Station Tailrace
Noon-1:00 pm	Lunch- on your own
1:00-2:00 pm	Study No. 3.3.5 Evaluate Downstream Passage of American Eel (2-Year Study)
2:00-2:30 pm	Discuss Process for Developing HSI Curves for Sea Lamprey (as required in FERC's February 17, 2017 Study Plan Determination Letter
2:30-3:00 pm	Study No. 3.8.1 Operations Model Report

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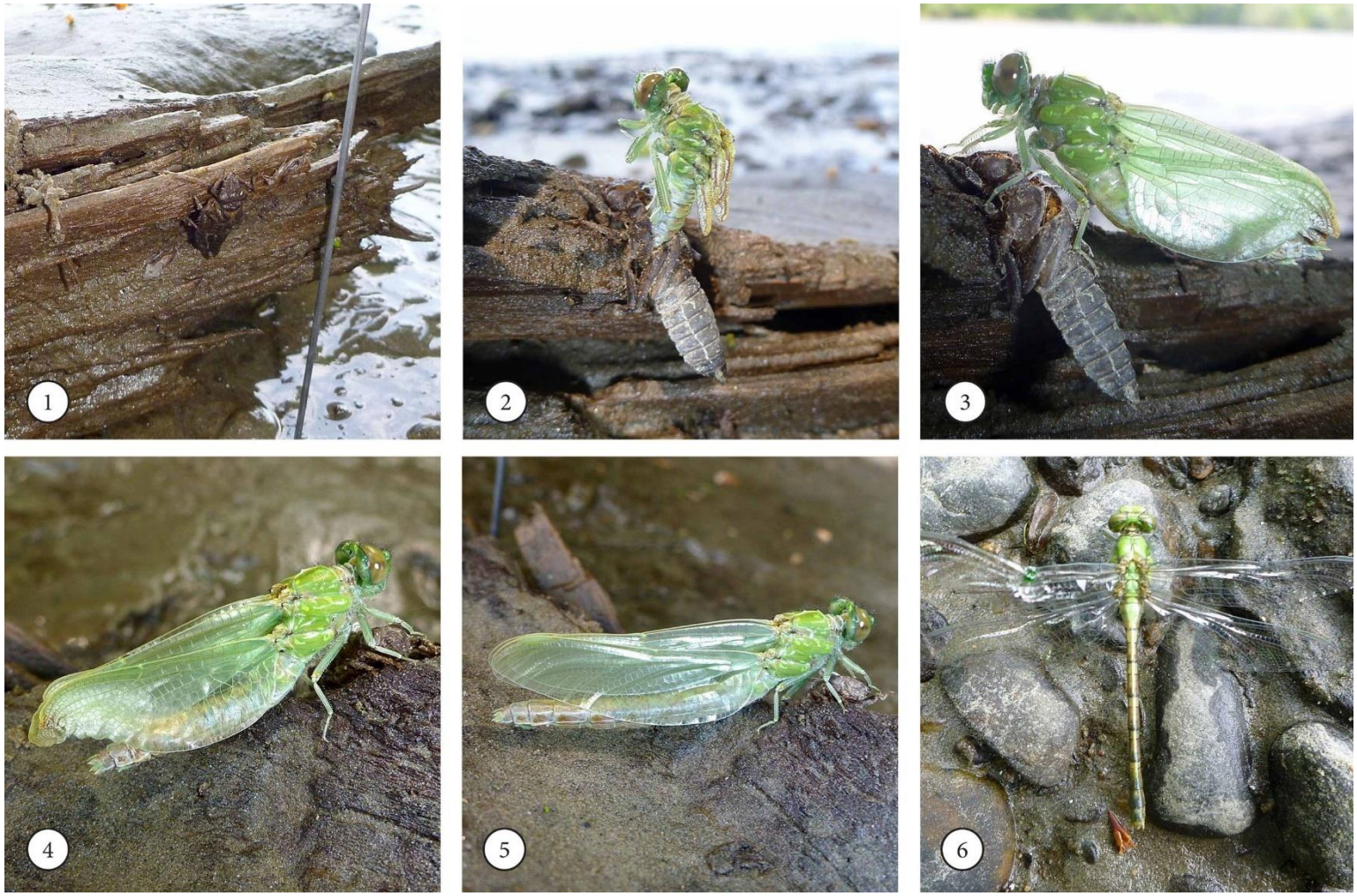
3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River



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3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Study Objectives

- Conduct field surveys and synthesize existing data to characterize the odonate community and species emergence and eclosure behavior in the Project area.
- Assess the effects of Project operations, especially water surface elevation changes, on the emergence, eclosure, and habitat of state-listed odonate species and the odonate community.

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Phase 1 (2014)

- Qualitative surveys: species composition, habitat, and emergence behavior
- Phase 1 report filed with Updated Study Report (Sept. 2015)

Phase 2 (2015)

- Quantitative surveys: species composition, emergence and eclosure behavior, and habitat
- Related water surface elevation data to emergence behavior to assess potential operational impacts

Phase 3 (2016)

- Supplemental fieldwork: emergence and eclosure behavior for state-listed species, especially eclosure speed
- Modified the operational effects analysis based on additional eclosure speed data, computation of critical protective rates, and hydraulic model outputs

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Phase 2 Methods (2015)

- Quantitative sampling at 6 transects/site (5 sites); biweekly sampling from May to September
- For every exuvia/teneral: recorded vertical crawl height, horizontal crawl distance, substrate, and other basic information (time, date, etc.)
- Specimens were collected, individually labeled, and identified to species
- Emergence speed was recorded when possible
- Dataloggers recorded WSEL and water temperature at 15-minute intervals

Phase 3 Methods (2016)

- Qualitative sampling at 8 sites (late May to mid-July); recorded emergence/eclosure speed, vertical and horizontal crawl distances
- Computed **Critical Protective Rates** (CPRs) for species and species groups [critical height percentiles divided by eclosure duration (2.0 hrs)]
- CPRs compared to the 95th percentiles of the **Maximum Hourly Rate of Change** (MHR-95%) at sites in the impoundment, downstream from the dam, and bypass reach
- Operational effects analysis based on behavior (climbing height and eclosure time) and rate of water level changes.

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Critical Height Percentiles

- Computed based on quantiles (i.e., percentiles) of 5, 10, 20, 30, and 50% from the field-collected climbing height data.
- These are critical heights (units = ft) protective of 95, 90, 80, 70, and 50% of the population.

Critical Protective Rates (CPR)

- CPR = critical height percentiles divided by eclosure duration [2.0 hrs]
- units = ft/hr; computed for 50%, 70%, 80%, 90% and 95%

Maximum Hourly Rate of Change (MHR)

- Positive MHR for water levels from 4am to 5pm, May 15 to August 15
- Impoundment: from hydraulic model, 2000-2015; Downstream: from hydraulic model, 2008-2015; Bypass reach: from water level loggers, 2014-2015

Risk Assessment

- Compare CPRs to MHR-95% at sites in the impoundment, downstream from the dam, and bypass reach
- Analysis is therefore based on behavior (climbing height and eclosure time) and rate of water level changes

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

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Species List and Sample Sizes (2015-2016)

Species	Abbreviation	2015 Phase 2 Survey Site					2016	Total
		1	2	3	4	5		
Basiaeschna Janata	BaJa	0	0	0	0	2		2
Boyeria vinosa	BoVi	58	3	11	6	0		78
Cordulegaster maculate	CoMa	0	0	0	1	0		1
Dromogomphus spinosus	DrSp	3	10	1	2	2	3	21
Epitheca princeps	EpPr	0	0	0	1	101		102
Gomphus abbreviates	GoAb	2	4	0	14	0		20
Gomphus vastus	GoVa	70	129	2	18	0	130	348
Hagenius brevistylus	HaBr	2	1	1	0	0		4
Libellula sp.	Lisp	0	0	0	0	6		6
Libellulinae (unidentified)	Li	0	0	0	0	12		12
Macromia illinoiensis	MaIl	3	2	6	2	1		14
Neurocordulia yamaskanensis	NeYa	3	8	4	6	2		23
Ophiogomphus rupinsulensis	OpRu	5	20	0	0	0		25
Perithemis tenera	PeTe	0	0	0	0	27		27
Stylurus amnicola	StAm	3	1	5	0	0	4	13
Stylurus spiniceps	StSp	23	25	9	5	0	21	83
		172	**203**	**39**	**55**	**153**	**158**	**779**

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

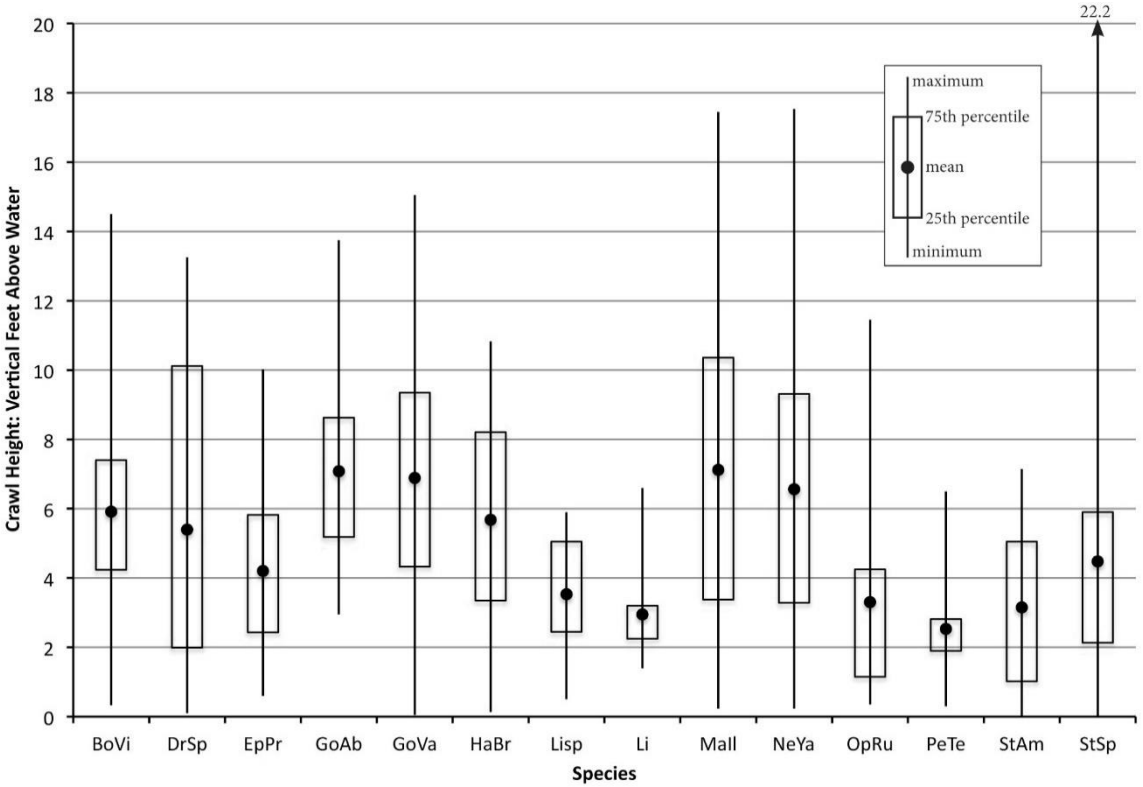
Crawl Height

Median height of 5.5 ft from the water surface

Shorter heights for more lentic species

Among riverine species: shortest for:

- *S. amnicola* (2.2 ft)
- *S. spiniceps* (3.4 ft)
- *O. rupinsulensis* (3.5 ft)



3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

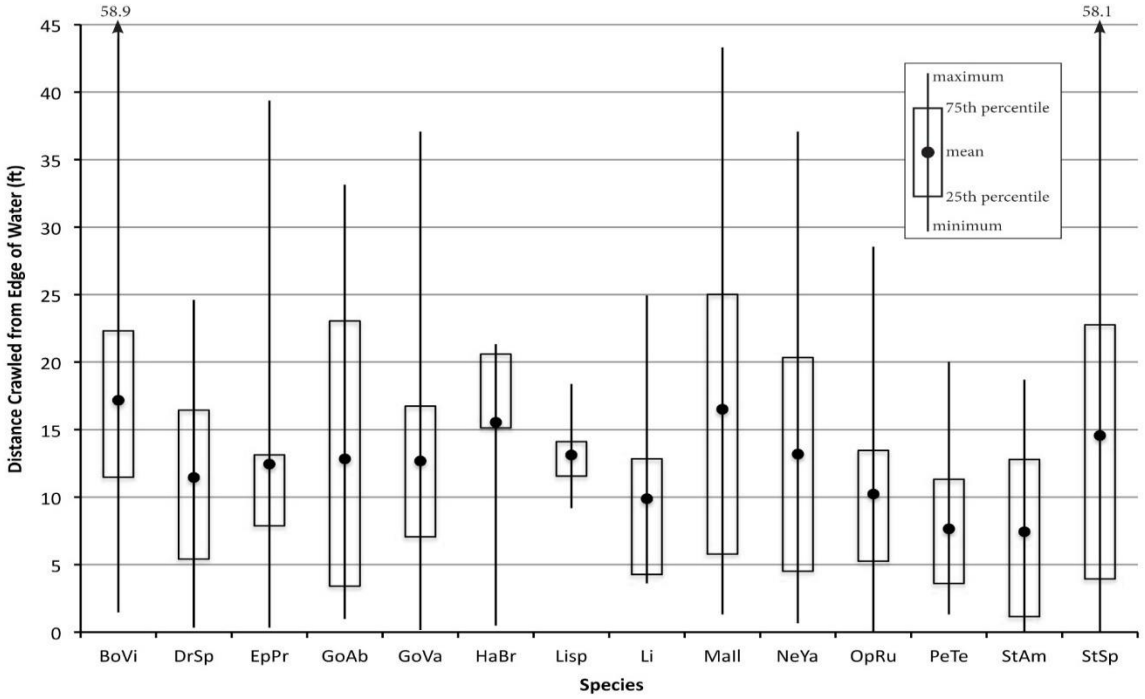
Crawl Distance

Median distance of 12.5 ft from the water's edge

Shorter distances for more lentic species

Among riverine species: shortest for:

- *S. amnicola* (4.1 ft)
- *O. rupinsulensis* (8.5 ft)



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3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Eclosure Speed Statistics

Species/Statistic	Eclosure Period Start-Free	Free-Flight	Start-Flight
Boyeria vinosa			
Sample Size	1	1	1
Min Time	0:30	0:54	1:24
Max Time	0:30	0:54	1:24
Average Time	0:30	0:54	1:24
Dromogomphus spinosus			
Sample Size	6	6	6
Min Time	0:10	0:21	0:41
Max Time	0:30	1:28	1:58
Average Time	0:22	0:47	1:10
Gomphus abbreviatus			
Sample Size	1	1	1
Min Time	0:30	0:46	1:16
Max Time	0:30	0:46	1:16
Average Time	0:30	0:46	1:16
Gomphus vastus			
Sample Size	130	122	122
Min Time	0:08	0:14	0:28
Max Time	0:30	1:34	1:45
Average Time	0:17	0:43	1:00
Libellulidae			
Sample Size	3	2	2
Min Time	0:30	0:25	0:55
Max Time	0:30	1:36	2:06
Average Time	0:30	1:00	1:30
Stylurus amnicola			
Sample Size	7	6	6
Min Time	0:09	0:15	0:29
Max Time	0:30	0:30	1:00
Average Time	0:21	0:24	0:43

Species/Statistic	Eclosure Period Start-Free	Free-Flight	Start-Flight
Stylurus spiniceps			
Sample Size	25	25	25
Min Time	0:07	0:16	0:24
Max Time	0:30	0:55	1:25
Average Time	0:13	0:28	0:41
Ophiogomphus rupinsulensis			
Sample Size	7	7	7
Min Time	0:30	0:07	0:37
Max Time	0:30	0:52	1:22
Average Time	0:30	0:20	0:50
Gomphus Group			
Sample Size	137	129	129
Min Time	0:08	0:14	0:28
Max Time	0:30	1:34	1:58
Average Time	0:17	0:43	1:01
Stylurus Group			
Sample Size	32	31	31
Min Time	0:07	0:15	0:24
Max Time	0:30	0:55	1:25
Average Time	0:14	0:27	0:42
All Species			
Sample Size	180	170	170
Min Time	0:07	0:07	0:24
Max Time	0:30	1:36	2:06
Average Time	0:18	0:39	0:58

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3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Critical Height Percentiles and Critical Protective Rates

		Critical Height Percentiles (ft)					Critical Protective Rates (CPR)				
Species	**n**	**5%**	**10%**	**20%**	**30%**	**50%**	**95%**	**90%**	**80%**	**70%**	**50%**
B. vinosa	78	1.51	2.26	3.96	4.53	5.47	0.75	1.13	1.98	2.26	2.73
D. spinosus	21	0.13	0.15	1.84	2.50	2.83	0.06	0.08	0.92	1.25	1.42
E. princeps	102	0.93	1.46	2.12	2.60	4.00	0.47	0.73	1.06	1.30	2.00
G. abbreviatus	20	3.35	3.51	5.05	5.22	7.08	1.67	1.76	2.52	2.61	3.54
G. vastus	348	1.81	3.07	4.42	5.59	7.34	0.91	1.53	2.21	2.79	3.67
M. illinoiensis	14	0.75	1.60	3.14	3.67	6.98	0.38	0.80	1.57	1.83	3.49
N. yamaskenensis	23	1.12	1.71	2.69	4.03	5.63	0.56	0.86	1.34	2.02	2.82
O. rupinsulensis	25	0.43	0.79	1.11	1.31	3.45	0.22	0.40	0.56	0.65	1.73
S. amnicola	13	0.15	0.27	0.37	0.75	2.17	0.07	0.13	0.18	0.37	1.08
S. spiniceps	83	0.09	0.18	1.01	2.24	3.35	0.04	0.09	0.51	1.12	1.68
Aeshnidae	80	1.52	2.30	3.99	4.58	5.51	0.76	1.15	1.99	2.29	2.76
Gomphus	389	1.69	2.81	4.15	5.26	7.23	0.85	1.41	2.07	2.63	3.62
Libellulidae	45	1.00	1.44	1.78	1.94	2.50	0.50	0.72	0.89	0.97	1.25
Stylurus	100	0.08	0.17	0.67	2.14	3.29	0.04	0.08	0.34	1.07	1.65
Stylurus: 1.5-hr Critical Time											
S. amnicola	13	0.15	0.27	0.37	0.75	2.17	0.10	0.18	0.24	0.50	1.44
S. spiniceps	83	0.09	0.18	1.01	2.24	3.35	0.06	0.12	0.67	1.49	2.23
Stylurus	100	0.08	0.17	0.67	2.14	3.29	0.05	0.11	0.45	1.43	2.19

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Risk Assessment: Comparing CPRs to MHR-95%

(shading means CPR < MHR-95%)

			Maximum Hourly Rate of Change (ft/hr): 95th Percentile (MHR-95%)												
			Downstream from the Dam					Bypass Reach		Turners Falls Impoundment					
			Station (Downstream to Upstream)					Rock Dam		HEC-RAS Transect (Downstream to Upstream)					
	Critical Protective Rate		109.52	113.17	115.07	116.64	118.51	Below	Above	2895	14877	25845	31191	48441	56235	70507
Species/Group	Percentile	Value	0.45	0.62	0.65	0.85	1.25	2.54	3.02	0.89	0.81	0.74	0.72	0.66	0.65	0.66
G. abbreviatus	CPR-95%	1.67														
	CPR-90%	1.76														
	CPR-80%	2.52														
	CPR-70%	2.61														
	CPR-50%	3.54														
G. vastus	CPR-95%	0.91														
	CPR-90%	1.53														
	CPR-80%	2.21														
	CPR-70%	2.79														
	CPR-50%	3.67														
Gomphus Group	CPR-95%	0.85														
	CPR-90%	1.41														
	CPR-80%	2.07														
	CPR-70%	2.63														
	CPR-50%	3.62														

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Stylurus Group	CPR-95%	0.04														
	CPR-90%	0.08														
	CPR-80%	0.34														
	CPR-70%	1.07														
	CPR-50%	1.65														
N. yamaskenensis	CPR-95%	0.56														
	CPR-90%	0.86														
	CPR-80%	1.34														
	CPR-70%	2.02														
	CPR-50%	2.82														

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Risk Assessment: Comparing CPRs to MHR-95%

(shading means CPR < MHR-95%)

			Maximum Hourly Rate of Change (ft/hr): 95th Percentile (MHR-95%)												
			Downstream from the Dam					Bypass Reach		Turners Falls Impoundment					
			Station (Downstream to Upstream)					Rock Dam		HEC-RAS Transect (Downstream to Upstream)					
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O. rupinsulensis	CPR-95%	0.22														
	CPR-90%	0.40														
	CPR-80%	0.56														
	CPR-70%	0.65														
	CPR-50%	1.73														
M. illinoiensis	CPR-95%	0.38														
	CPR-90%	0.80														
	CPR-80%	1.57														
	CPR-70%	1.83														
	CPR-50%	3.49														

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Risk Assessment: Comparing CPRs to MHR-95%

(shading means CPR < MHR-95%)

			Maximum Hourly Rate of Change (ft/hr): 95th Percentile (MHR-95%)												
			Downstream from the Dam					Bypass Reach		Turners Falls Impoundment					
			Station (Downstream to Upstream)					Rock Dam		HEC-RAS Transect (Downstream to Upstream)					
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E. princeps	CPR-95%	0.47														
	CPR-90%	0.73														
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	CPR-80%	1.99														
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Libellulidae Group	CPR-95%	0.50														
	CPR-90%	0.72														
	CPR-80%	0.89														
	CPR-70%	0.97														
	CPR-50%	1.25														

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Additional Risk in Impoundment: Boat Wakes (0.23 correction factor)

Species/Group	Critical Protective Rate Percentile	Value	MHR-95% HEC-RAS Transect (Downstream to Upstream) 14877	25845	31191	48441	56235	70507
			1.04	0.97	0.95	0.89	0.88	0.89
G. abbreviatus	CPR-95%	1.67						
	CPR-90%	1.76						
	CPR-80%	2.52						
	CPR-70%	2.61						
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G. vastus	CPR-95%	0.91						
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	CPR-70%	2.63						
	CPR-50%	3.62						
S. amnicola	CPR-95%	0.07						
	CPR-90%	0.13						
	CPR-80%	0.18						
	CPR-70%	0.37						
	CPR-50%	1.08						
Stylurus Group	CPR-95%	0.04						
	CPR-90%	0.08						
	CPR-80%	0.34						
	CPR-70%	1.07						
	CPR-50%	1.65						
N. yamaskenensis	CPR-95%	0.56						
	CPR-90%	0.86						
	CPR-80%	1.34						
	CPR-70%	2.02						
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D. spinosus	CPR-95%	0.06						
	CPR-90%	0.08						
	CPR-80%	0.92						
	CPR-70%	1.25						
	CPR-50%	1.42						
O. rupinsulensis	CPR-95%	0.22						
	CPR-90%	0.40						
	CPR-80%	0.56						
	CPR-70%	0.65						
	CPR-50%	1.73						
M. illinoiensis	CPR-95%	0.38						
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E. princeps	CPR-95%	0.47						
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Libellulidae Group	CPR-95%	0.50						
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	CPR-80%	0.89						
	CPR-70%	0.97						
	CPR-50%	1.25						

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

Stylurus: 2-hr versus 1.5-hr Critical Time

			Maximum Hourly Rate of Change (ft/hr): 95th Percentile (MHR-95%)												
			Downstream from the Dam Station (Downstream to Upstream)					Bypass Reach Rock Dam		Turners Falls Impoundment HEC-RAS Transect (Downstream to Upstream)					
	Critical Protective Rate		109.52	113.17	115.07	116.64	118.51	Below	Above	2895	14877	25845	31191	48441	56235	70507
Species/Group	Percentile	Value	0.45	0.62	0.65	0.85	1.25	2.54	3.02	0.89	0.81	0.74	0.72	0.66	0.65	0.66
S. amnicola	CPR-95%	0.07														
(2 hr critical time)	CPR-90%	0.13														
	CPR-80%	0.18														
	CPR-70%	0.37														
	CPR-50%	1.08														
Stylurus Group	CPR-95%	0.04														
(2 hr critical time)	CPR-90%	0.08														
	CPR-80%	0.34														
	CPR-70%	1.07														
	CPR-50%	1.65														
S. amnicola	CPR-95%	0.10														
(1.5 hr critical time)	CPR-90%	0.18														
	CPR-80%	0.24														
	CPR-70%	0.50														
	CPR-50%	1.44														
Stylurus Group	CPR-95%	0.05														
(1.5 hr critical time)	CPR-90%	0.11														
	CPR-80%	0.45														
	CPR-70%	1.43														
	CPR-50%	2.19														

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

RISK ASSESSMENT

Turners Falls Impoundment (TFI)

- The maximum hourly rates of change in the TFI appear to pose little threat to the Gomphus Group, except slight effects (MHR-95% > CPR-90%) for *D. spinosus*.
- Potential effects of hourly rates of change in the TFI are greatest for *S. amnicola*, *S. spiniceps*, and *O. rupinsulensis*.
- MHR-95% is typically only greater than CPR-90% or CPR-95% for *N. yamaskanensis*, *M. illinoiensis*, *E. princeps*, *B. vinosa*, and the Libellulidae that were documented in Barton Cove.
- The boat wake correction factor of 0.23 ft resulted in slightly higher risk for all species and species groups.

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

RISK ASSESSMENT

Downstream from Cabot Station

- Effects of Project operations on WSEL and rates of change diminish with increasing distance downstream from Cabot Station.
- Potential effects are highest for those species that eclose closer to the water, notably *S. amnicola*, the Stylurus Group, *O. rupinsulensis*, and *D. spinosus*.
- At Third Island, approximately 5 miles downstream from Cabot Station, and at the Route 116 Bridge, approximately 10 miles downstream from Cabot Station, maximum hourly rates of change do not appear to have a strong effect any of the Gomphus Group, and only slight effects on *M. illinoiensis* and *N. yamaskanensis*.

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

RISK ASSESSMENT

Bypass Reach

- Water level fluctuations resulting from Project operations appear to affect odonate emergence in areas of the Connecticut River closest to Cabot Station and in the bypass reach.

- Potential effects are highest within the bypass reach (upstream and downstream from Rock Dam), where MHR-95% exceeds the CPR-70% for the Gomphus Group, and CPR-50% for species such as *S. amnicola*, *S. spiniceps*, and *O. rupinsulensis*.

- However, flow manipulation in 2014 and 2015 for relicensing studies caused a higher frequency and magnitude of water surface elevation changes than would have been observed under more typical spring and summer conditions.

3.3.10-Assess Operational Impacts on Emergence and Eclosure of State-Listed Odonates in the Connecticut River

RISK ASSESSMENT

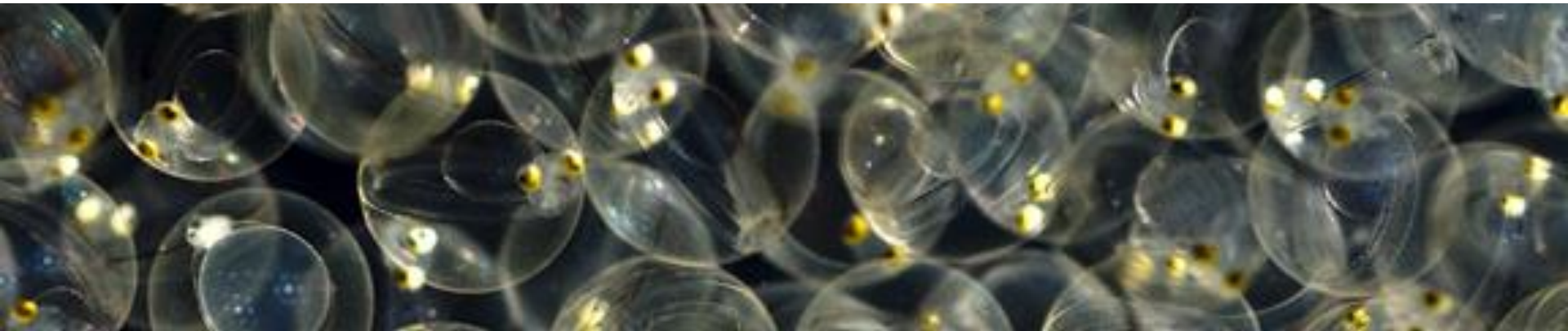
Timing of Peak Flows

- Analysis focused on MHR-95% for the period from 4am to 5pm, May 15 to August 15. Peak odonate activity from pre-dawn through early afternoon.
- At Cabot Station, operations typically release flows early-mid afternoon. MHR-95% statistics that include the late afternoon time period may be overly conservative for odonates whose peak activity is in the morning.
- Similar daily trends in the TFI, influenced by Northfield Mountain and Vernon.

3.3.20-Ichthyoplankton Study (2nd Year)

Study Objectives

- Calculate the number of American shad eggs and larvae entrained at the Northfield Mountain Project;
- Estimate the loss of adult and juvenile shad equivalents based on shad egg and larvae entrainment at the Northfield Mountain Project;
- Determine the temporal distribution of entrainment;
- Detect if there is a relationship between river flow and entrainment density.



3.3.20-Ichthyoplankton Study (2nd Year)

Entrainment Sampling
Sampling system consisted of PVC and rubber piping, a digital flowmeter, a1,000-liter plastic tank, and a 0.333 mm mesh plankton net. 50m^3 (13,250 gallons) of intake water at a rate of 3 and 3½ gal/sec was filtered for each sample. Approximately 1 hour to collect each sample.

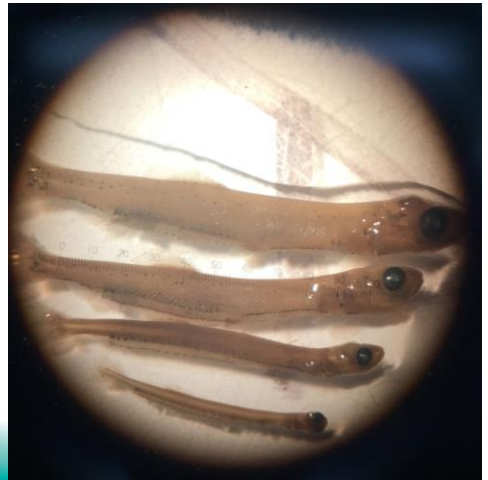
Offshore Sampling
Samples were collected in the intake/tailrace channel with a weighted 60-cm diameter paired bongo nets with 0.333 mm mesh deployed from a boat. Nets were towed obliquely until at least 100 m^3 of river water were sampled. General Oceanics flowmeters were suspended in the center of each net to measure the volume of river water filtered during each tow.

Sample Processing
Samples were sorted by biologists trained in ichthyoplankton identification with the aid of a dissecting microscope. American shad larvae and eggs were removed from the samples, identified and enumerated. A QC program designed to ensure that the Average Outgoing Quality Limit for sorting and identification is greater than 90% was followed.

3.3.20-Ichthyoplankton Study (2nd Year)

Findings

- 47 entrainment samples and 33 verification samples were collected from May 11 to July 29, 2016.
- The entrainment sample densities are the sample count divided by the sample volume.
- Eggs were first observed in the June 2 collections and were present through July 8. Egg density peaked June 8 when a density of 15.3 eggs per 100 m^3 was observed.
- Larvae were first observed in May 25 collections and were present through July 8. Larval density peaked June 2 when the density of 11.5 larvae per 100 m^3 was observed.
- Offshore sampling was conducted adjacent to Northfield Mountain intake on evenings corresponding with entrainment sampling. Three tows were collected each week.
- Overall shad egg and larval densities collected at the intake were lower than those collected in the entrainment samples.
- There was no temporal distribution of eggs or larvae entrained.
- No trend detected between river flow and entrainment density.



3.3.20-Ichthyoplankton Study (2nd Year)

Findings

- When extrapolated by the volume of water pumped during the spawning season over 9 million shad eggs and 5 million shad larvae were estimated to be entrained at the Northfield Mountain Project in 2016. In 2015, just over 3 million eggs and 500,000 larvae were entrained.

- Based on the entrainment estimate the number of equivalent juvenile and adult American shad lost to entrainment was estimated to be 2,093 juveniles or 578 adult American shad in 2016 compared to 2015 when 696 equivalent juvenile shad or equivalent 94 adults were lost to entrainment.

- American shad spawning strategy includes broadcasting large numbers of eggs which experience high natural mortality. Female American shad spawn between 150,000-500,000 eggs, with fecundity increasing with age, length, and weight. Only about 1 out of every 100,000 eggs survives to become a spawning adult.

- The higher shad ichthyoplankton densities in 2016 did not seem to effect year class strength as it coincided with the highest juvenile index recorded in 38 years. These juvenile indices have been positively correlated with recruitment levels of adult female shad returning 4-6 years later.

3.3.19-Ultrasound Array Study

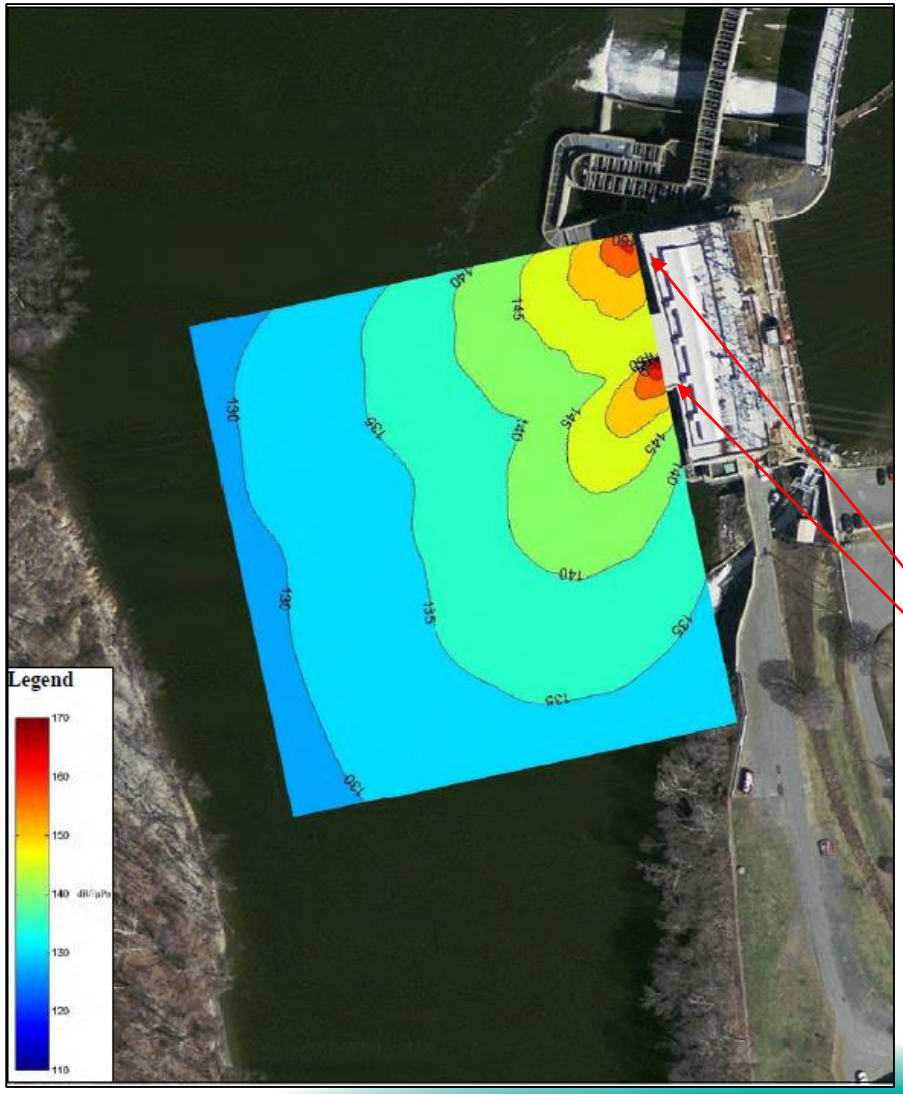
Study Objectives:

- Establish a high frequency sound (ultrasound) array across the entire Cabot Tailrace and determine the effect of the ensonified field on upstream migrating shad moving past Cabot Station
- Goal – Determine if an ultrasound barrier could be used to repel adult shad from the Cabot Station Tailrace and guide them to into the bypass reach to the Spillway Ladder.

Methods (overview):

1) Install ultrasound array in Cabot Tailrace
2) Monitor shad in the Cabot Ladder Entrance via DIDSON camera
3) Monitor tagged fish via radio telemetry

3.3.19-Ultrasound Array Study



Ultrasound Installation:

- Alden Lab and Scientific Solutions, Inc
- System included a power amplifier, underwater sound projectors (transducers), and a PC-based signal generator
- Signal – random noise signal band-limited to 122-128 kHz
- Pulse duration of 0.5 seconds

3.3.19-Ultrasound Array Study

Ultrasound and Flow Schedule:

- System was turned on at 7 am each activation day
- Proposed test flows in the Bypass Reach:
  - 4,400 cfs
  - 2,500 cfs
  - 1,500 cfs
  - 1,000 cfs
- The duration of ultrasound operation and test flows were: 2 days on 1 day off, per flow scenario. This test scheme was developed in consultation with stakeholders.
  - Meant to investigate how shad would respond to the signal over time (i.e. would acclimation occur).

May

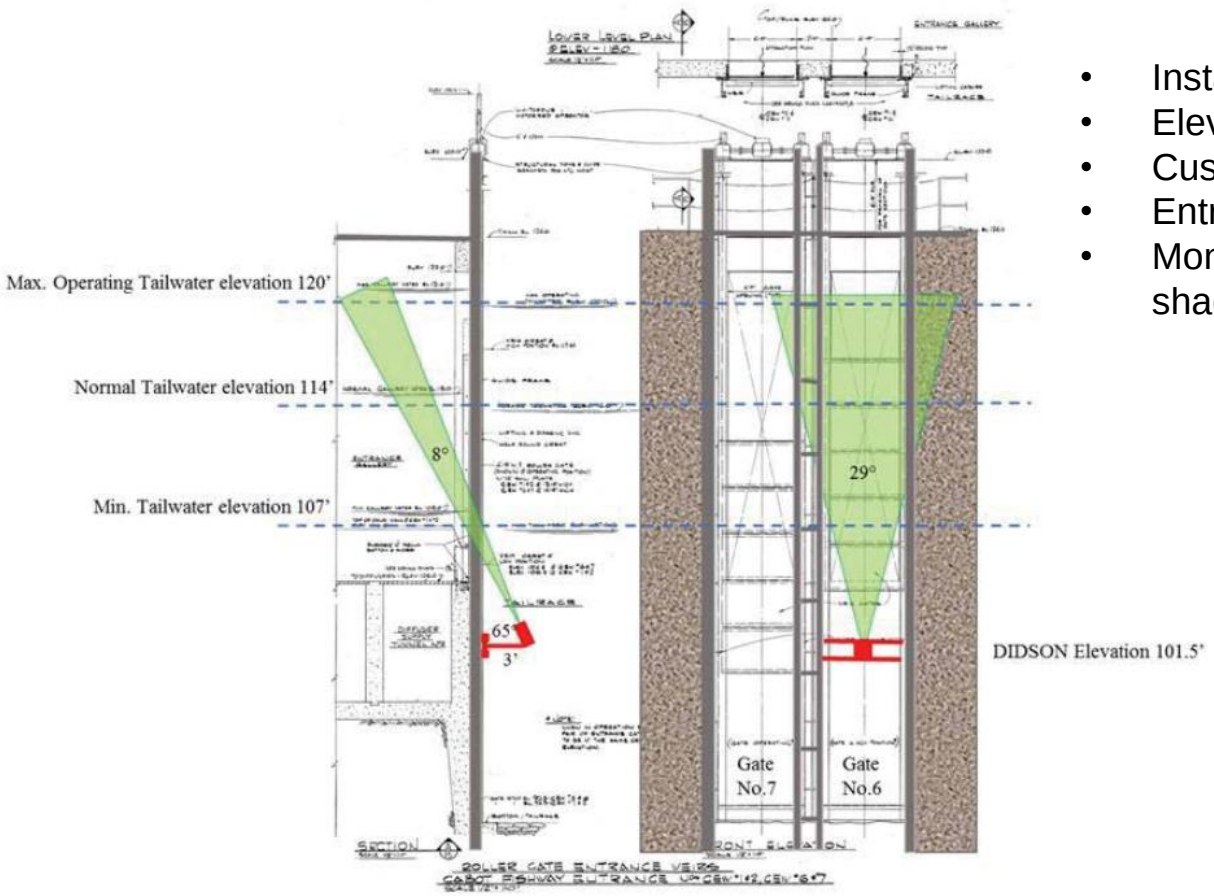
Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

June

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	
26	27	28	29	30		

	2,500 cfs (array on)
	4,400 cfs (array on)
	2,500 cfs (array off)
	4,400 cfs (array off)
	1,500 cfs (array on)
	1,000 cfs (array off)
	1,000 cfs (array on)
	1,500 cfs (array off)

3.3.19-Ultrasound Array Study



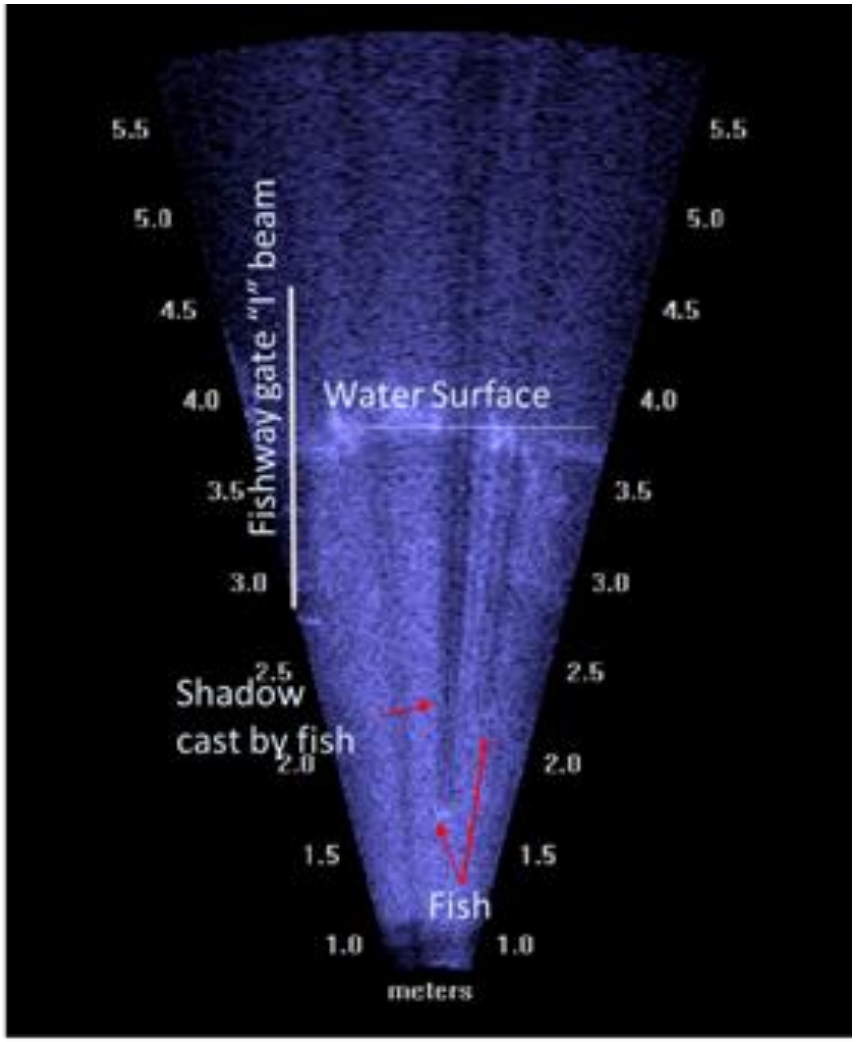
DIDSON Camera Installation:

- Installed at Cabot fishway entrance gate
- Elevation of 101.5 ft
- Custom bracket
- Entrance No. 6
- Monitor presence/absence of untagged shad

3.3.19-Ultrasound Array Study

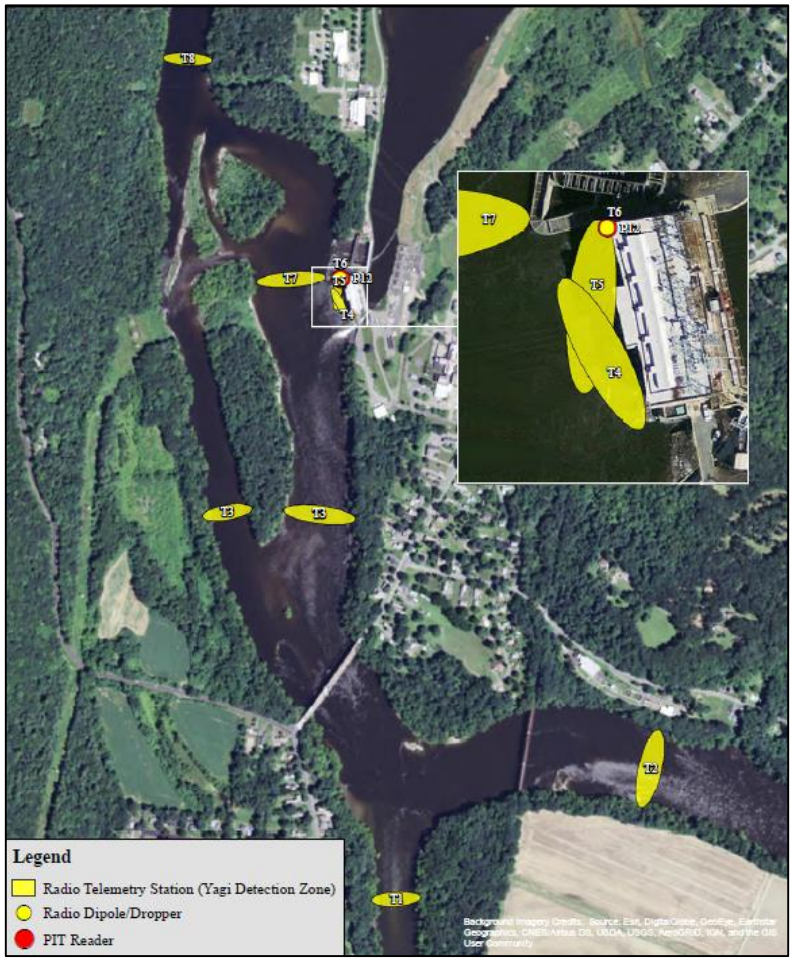
DIDSON Camera:

- Data collected using Sound Metric Corporation DIDSON operated at high resolution (1.8 MHz)
- Files written to an external hard drive
- Subsampling of the dataset included review of the first 15 minutes of every hour between sunrise and sunset
- Shad identified by the acoustic shadow cast as they move through beam
- QA/QC – files randomly selected to be re-sampled and targets recounted



3.3.19-Ultrasound Array Study

Fixed Telemetry Monitoring Stations: 12 Radio stations, 2 PIT stations



3.3.19-Ultrasound Array Study

Shad Tagging:

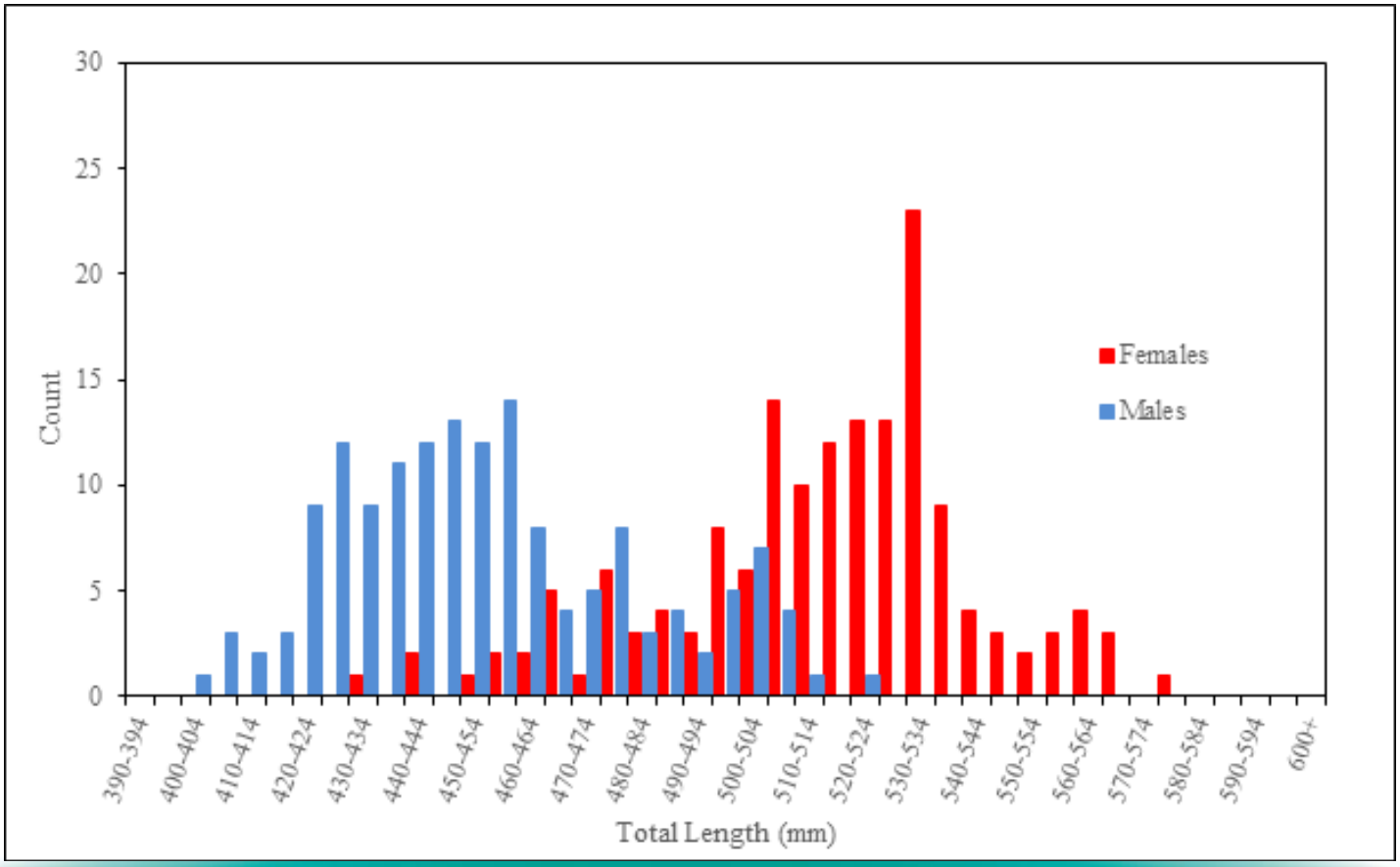
- Fish collected at Holyoke Dam fish lift trapping facility
- Esophageal implantation of radio tags and insertion of PIT tags anterior of anal vent
- Two release sites:
  - Holyoke impoundment fish lift exit flume
  - Downstream of Holyoke at Jones Ferry (part of NAI study)

Date of Collection/Release	Collection Location	Study Team	Release Location	Number of Double Tagged Shad
5/4/2016	Holyoke	KA	Upstream Holyoke	30
5/9/2016	Holyoke	NAI	Downstream Holyoke	24
5/10/2016	Holyoke	KA	Upstream Holyoke	30
5/11/2016	Holyoke	NAI	Downstream Holyoke	24
5/13/2016	Holyoke	NAI	Downstream Holyoke	24
5/17/2016	Holyoke	KA/NAI	Upstream/Downstream Holyoke	30/23
5/18/2016	Holyoke	NAI	Downstream Holyoke	25
5/20/2016	Holyoke	NAI	Downstream Holyoke	24
5/24/2016	Holyoke	KA/NAI	Upstream/Downstream Holyoke	28/25
5/27/2016	Holyoke	NAI	Downstream Holyoke	24
			TOTAL	**311**

3.3.19-Ultrasound Array Study

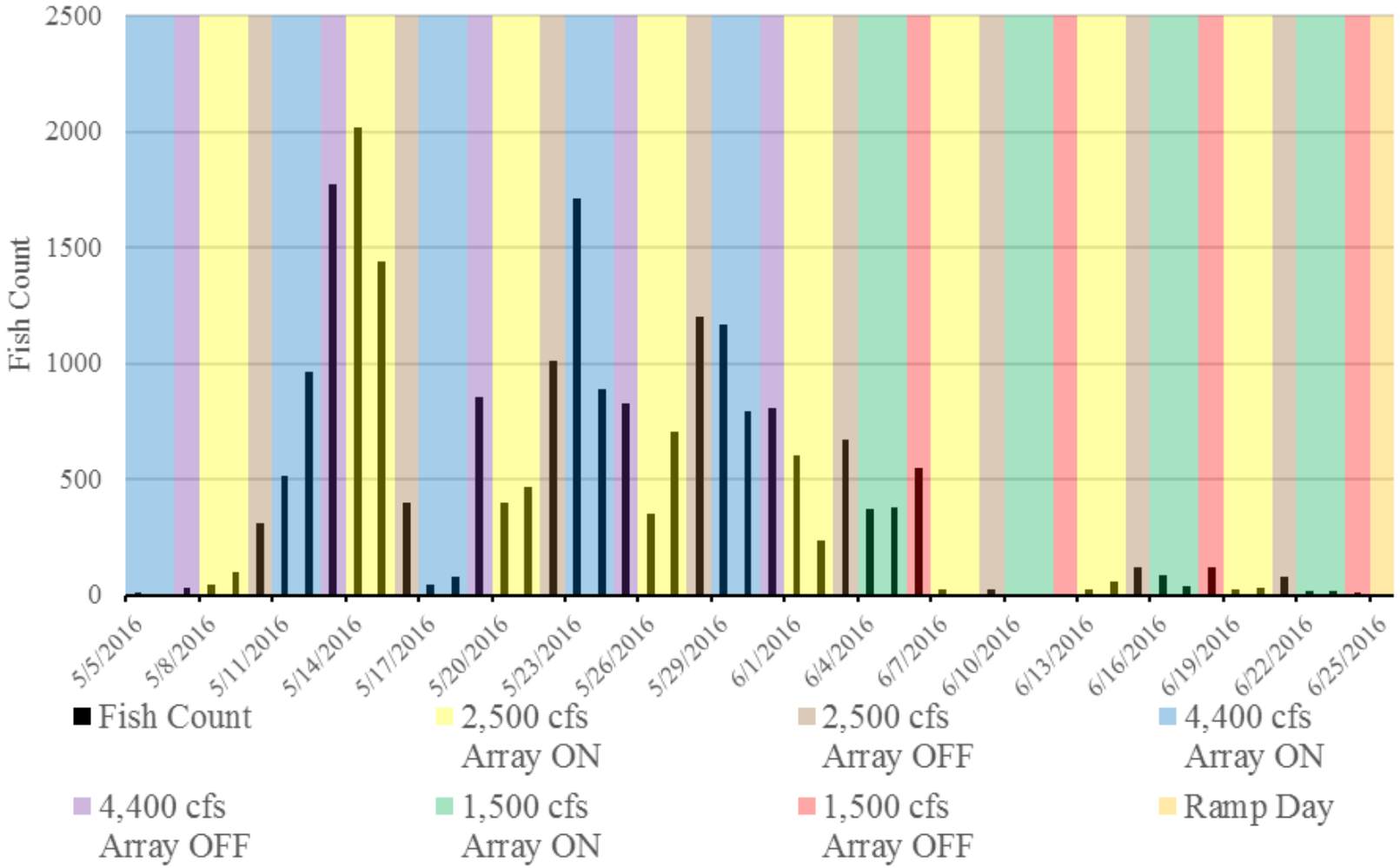
Results:

- Length frequency of 311 shad tagged for this study
- 153 males tagged (49%), mean total length = 454 mm
- 158 females tagged (51%), mean total length = 515 mm



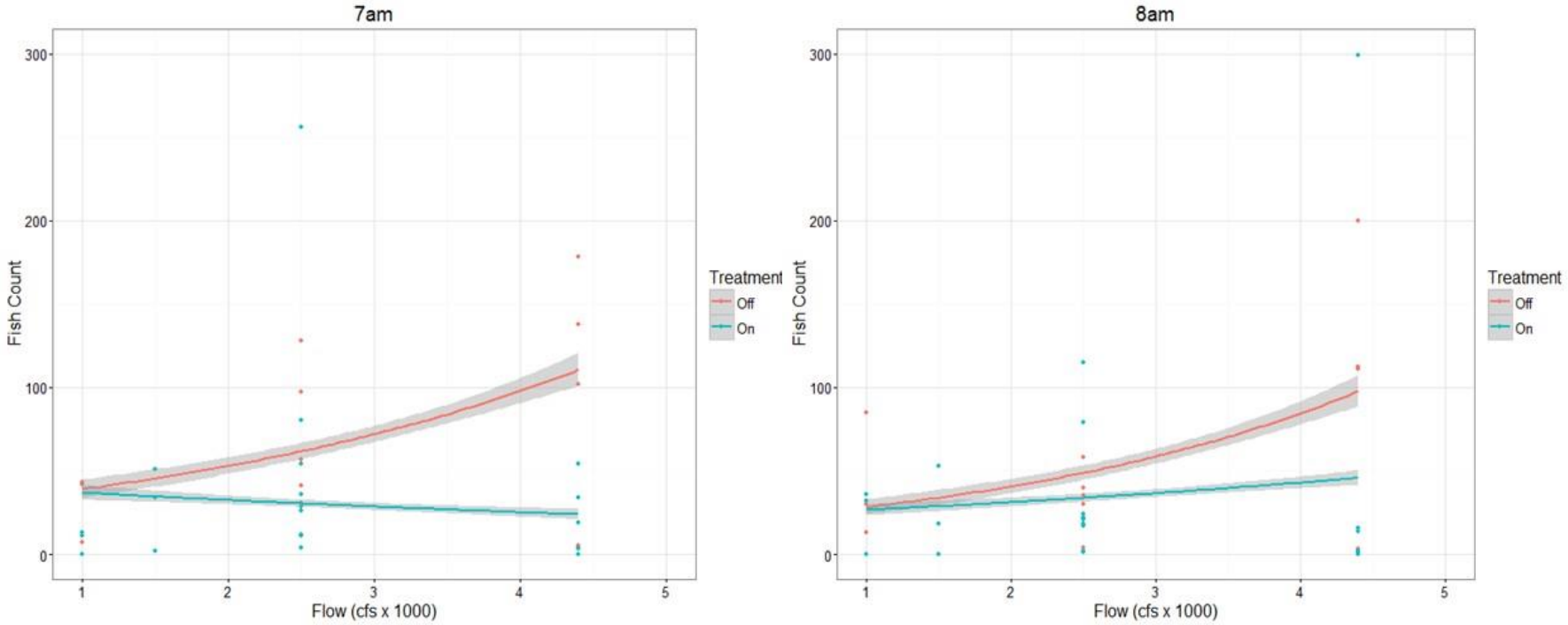
3.3.19-Ultrasound Array Study

DIDSON Results: Overall Raw Count Data



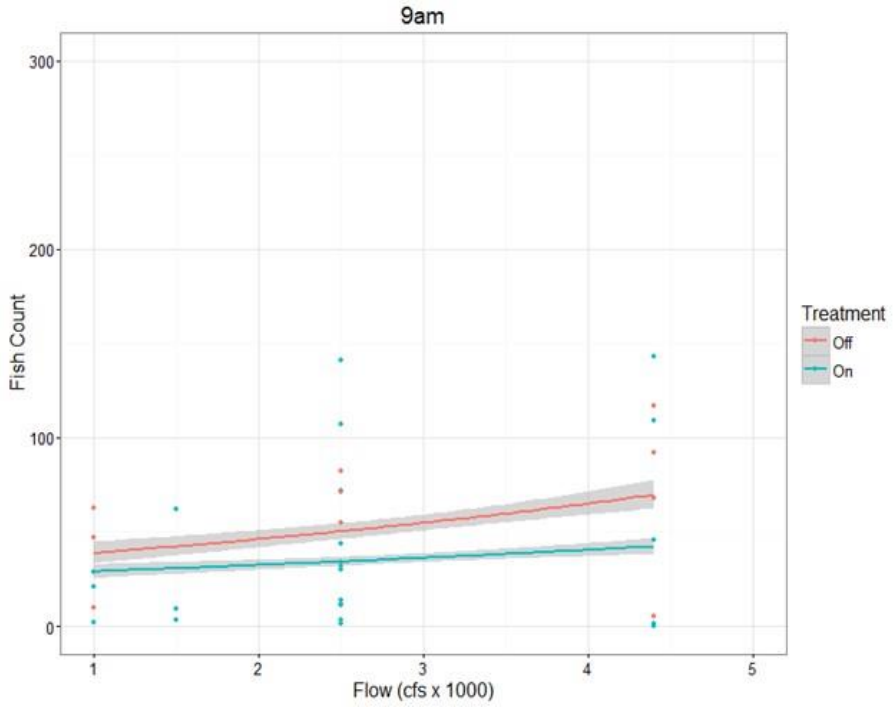
3.3.19-Ultrasound Array Study

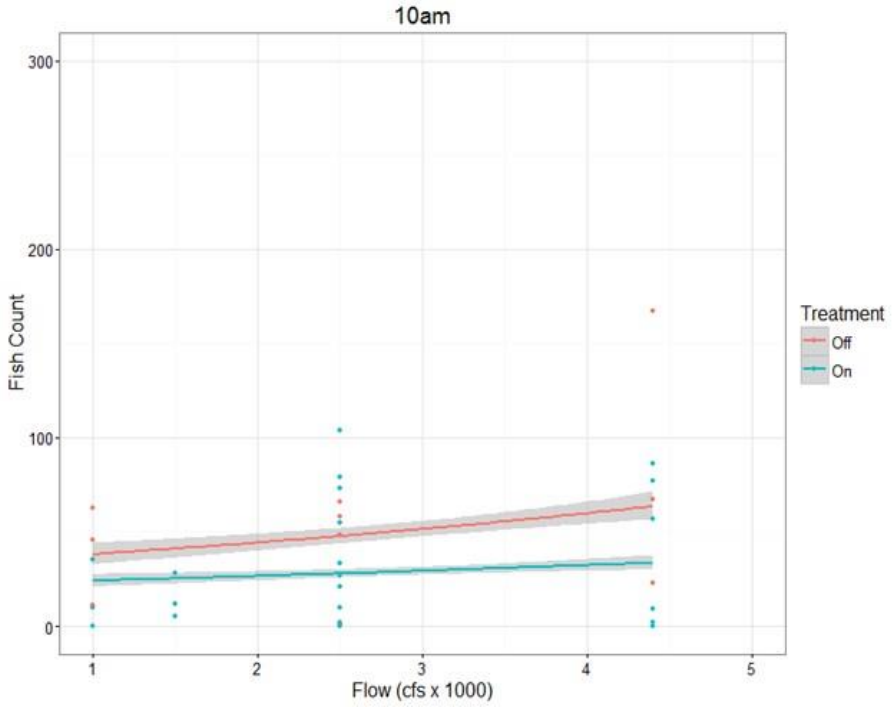
Hourly Analysis:



Hour	Coefficients	Estimate	Std. Error	Z value	P value
7:00 am	Intercept	3.36	0.10	35.31	<0.001
	Flow	0.31	0.03	11.28	<0.001
	Treatment On	0.38	0.13	2.89	0.004
	Flow:Treatment On	-0.43	0.04	-10.5	<0.001
8:00 am	Intercept	2.98	0.11	27.33	<0.001
	Flow	0.37	0.03	12.00	<0.001
	Treatment On	0.14	0.14	1.02	0.31
	Flow:Treatment On	-0.21	0.04	-5.01	0.001

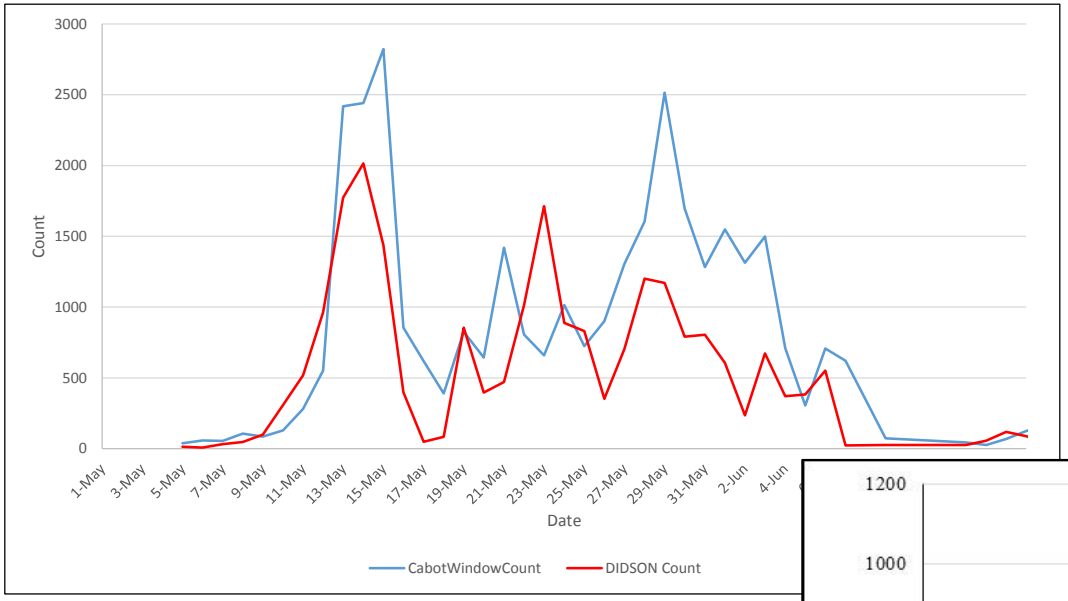
3.3.19-Ultrasound Array Study



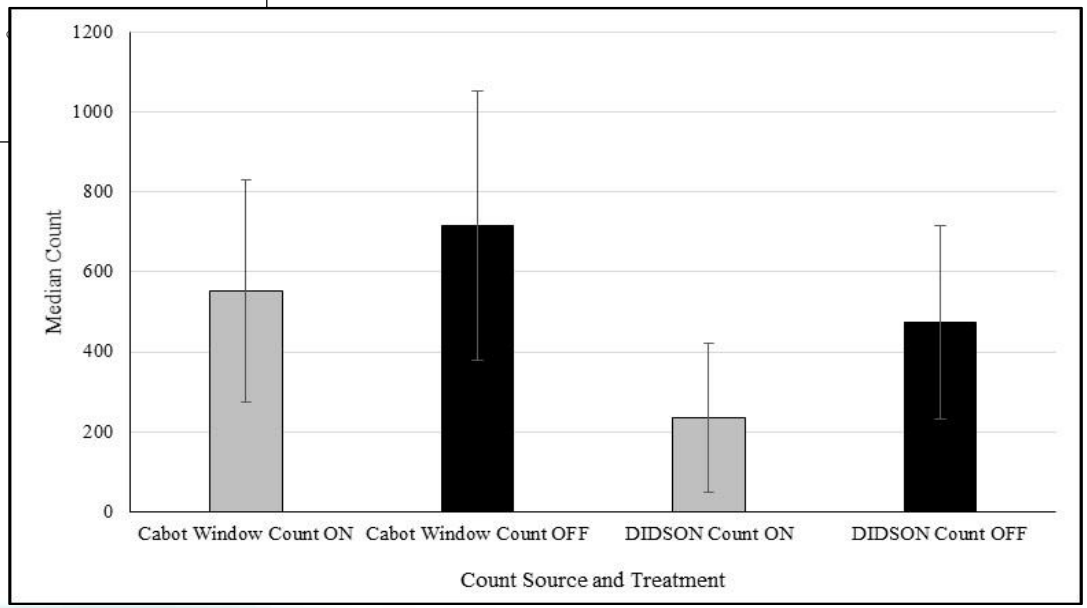


Hour	Coefficients	Estimate	Std. Error	Z value	P value
9:00 am	Intercept	3.47	0.10	34.51	<0.001
	Flow	0.17	0.03	5.66	<0.001
	Treatment On	-0.23	0.13	-1.70	0.09
	Flow:Treatment On	-0.06	0.04	-1.51	0.13
10:00 am	Intercept	3.49	0.10	33.94	<0.001
	Flow	0.15	0.03	4.80	<0.001
	Treatment On	-0.41	0.14	-2.86	0.004
	Flow:Treatment On	-0.05	0.04	-1.21	0.23

3.3.19-Ultrasound Array Study



- Comparison of Cabot Ladder Viewing Window counts and the DIDSON camera counts



- Median Daily Shad Counts (+/- Std Error) from May 5 to June 16, 2016
- Cabot viewing window and DIDSON camera under Array on/off conditions
- Mann-Whitney U test, there were no significant differences (Cabot window on/off p= 0.86), (DIDSON on/off p= 0.26)

3.3.19-Ultrasound Array Study

Telemetry Analysis:

- 33 out of 118 fish released upstream of Holyoke made it to the Telemetry Network
- 25 out of 193 fish released downstream of Holyoke made it to the Telemetry Network
- In total, 58 fish (18.6% of all releases) reached the Telemetry Network
- 39 fish entered the vicinity of the Ultrasound Array
- 29 of those fish moved upstream once detected in array (motivated by Bypass Flow, $p < 0.001$, HR = 1.46) and not Array being on or off ($p = 0.58$, HR = 0.83)

Conclusions:

- No significant difference between counts at the Cabot Fish Ladder when the system was on or off (Cabot viewing window and DIDSON counts)
- There was a significant difference between on and off DIDSON counts within the first 2 hours of the system being activated
- After 2 hours of the system being activated, there is no longer any difference and fish seem to have no problem swimming within or through the array

FirstLight Power Resources

3.3.19-Ultrasound Array Study

2017 Proposed Study

- Since there was a significant difference between on and off DIDSON counts within the first 2 hours of the system being activated during the 2016 study we plan to investigate using the Ultrasound array at different intervals less than 2 hours in 2017.
- The study is planned for 4 weeks during peak American shad passage (May-early June).
- On/Off schedule will be determined adaptively based on real time review of the DIDSON data in an attempt to minimize acclimation to ultrasound
- During the study bypass flows of 2,500 and 4,000 cfs will be provided.
- Ultrasound array and DIDSON camera will be set up similar to last year.
- Sound Metrics will investigate equipment upgrades designed to increase the sound pressure levels of the deterrent signal.

3.3.5-Downstream Passage of American Eel (2-Year Study)

Study Objectives:

- Characterize the general migratory timing and presence of silver-phase American Eel migrating past the Turners Falls and Northfield Mountain Projects relative to environmental factors and operations

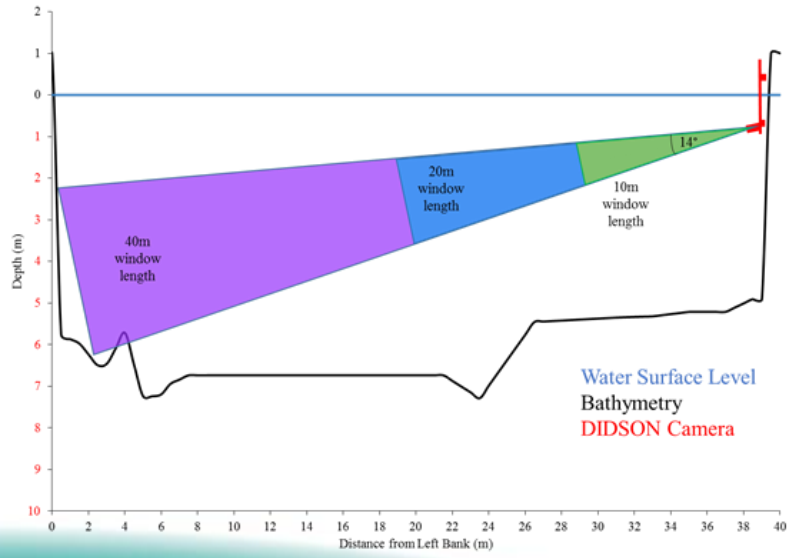
- Quantify movement rates and proportion of eel passing downstream via various passage routes at the Turners Falls and Northfield Mountain Projects as well as evaluate the proportion of eel entrained

- Evaluate survival of eel passed at the available routes of passage at the Turners Falls Project

3.3.5-Downstream Passage of American Eel (2-Year Study)

Migratory Timing:

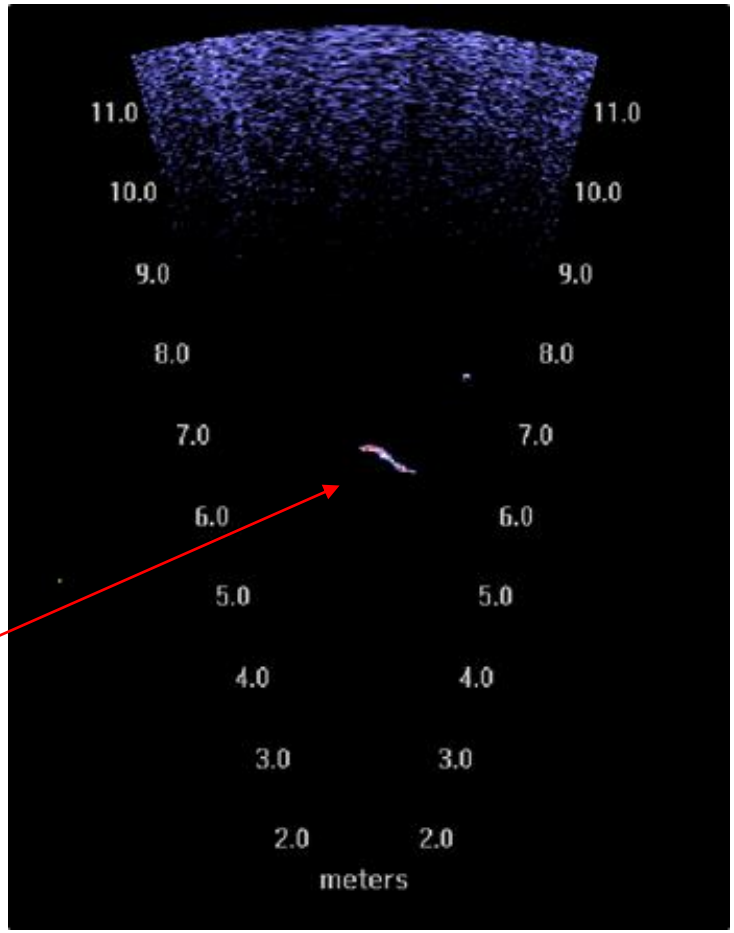
- Assessed using DIDSON camera
- Mounted to the west canal wall
- Data collection between August 1, and November 15, 2015 and 2016
- 3 ft depth, 3° upstream, 12° downward



3.3.5-Downstream Passage of American Eel (2-Year Study)

Data Analysis:

- Data processed using DIDSON v5.26.06 software by Sound Metrics Corp
- Data filtered to remove frames that did not contain targets of defined size
  - Convolved Samples Over Threshold (CSOT)
- Reduced file size and time of manual review
- Files reviewed from 1700 to 0500

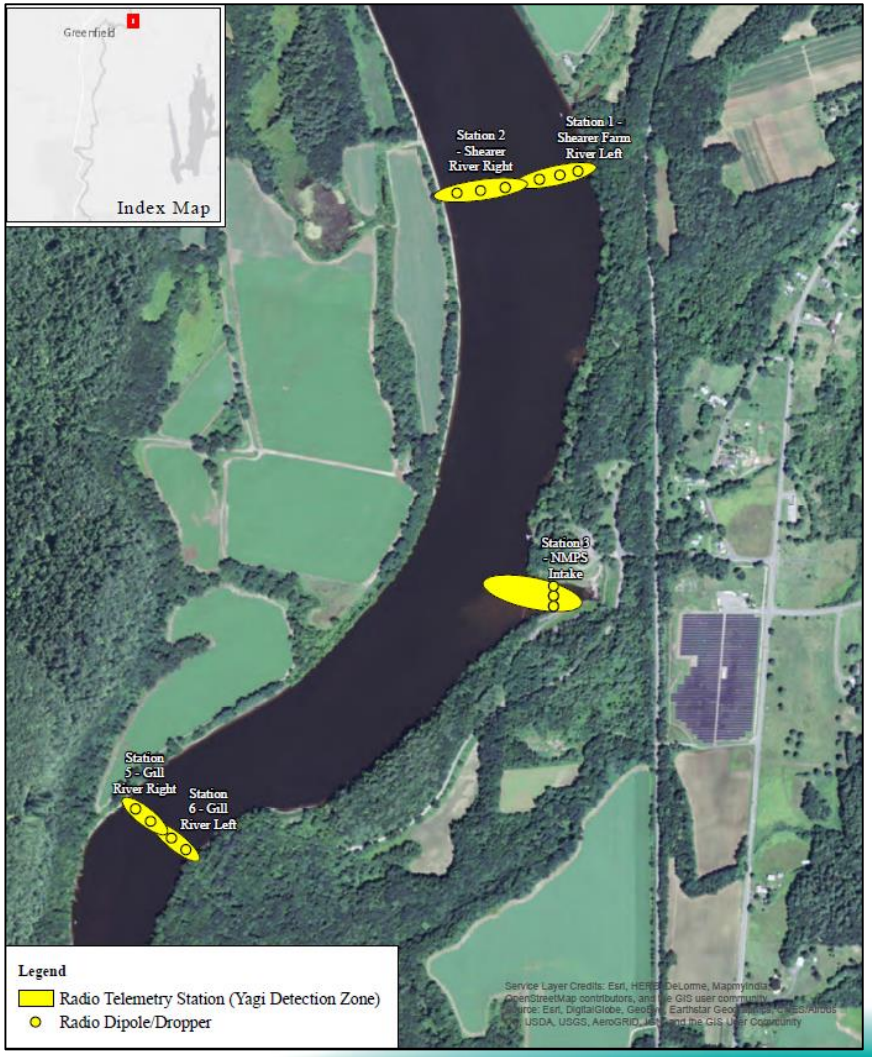


Example Eel target

- Length of 0.77m recorded in High Frequency mode

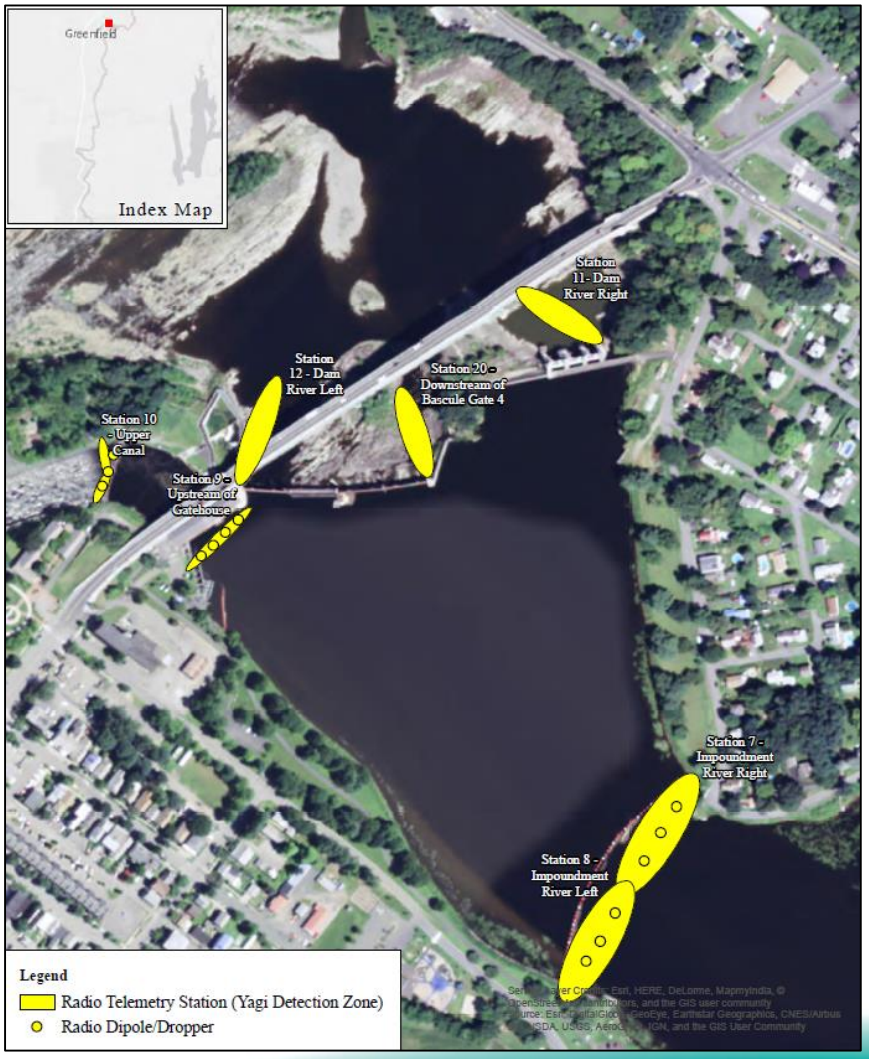
3.3.5-Downstream Passage of American Eel (2-Year Study)

Telemetry Stations: Upstream to Downstream



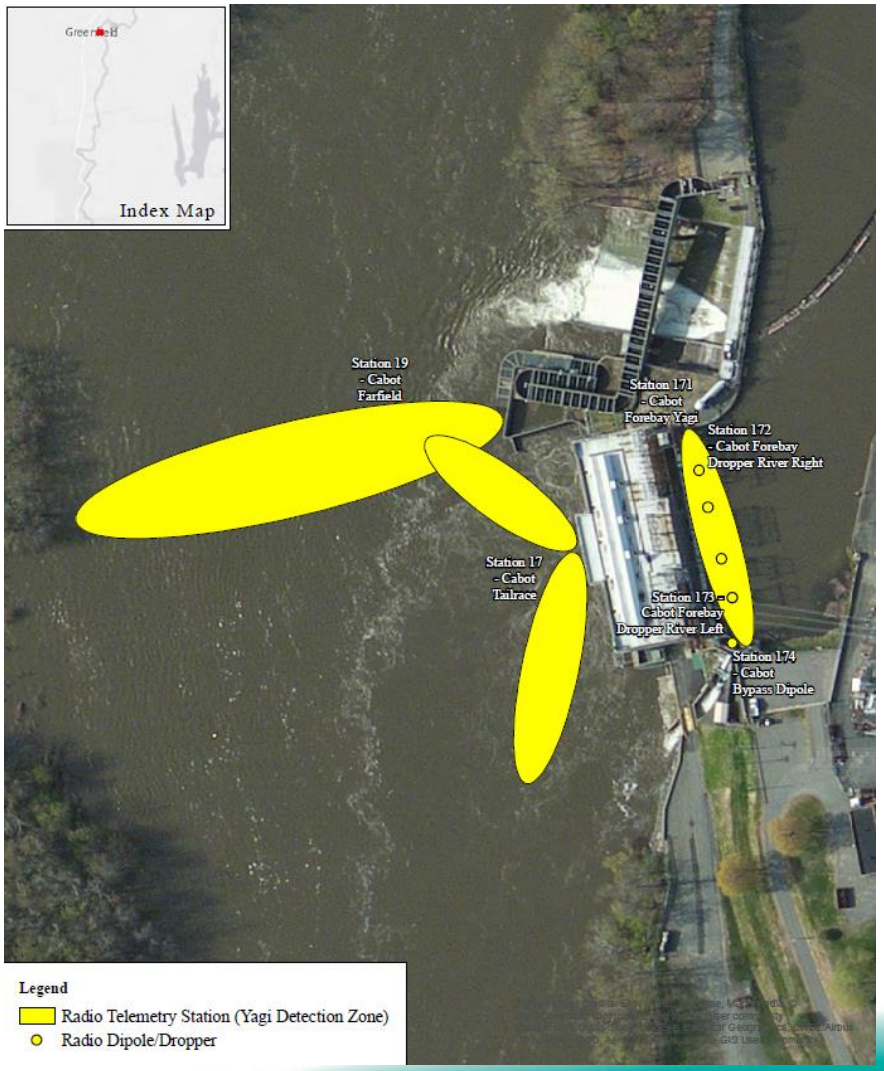
3.3.5-Downstream Passage of American Eel (2-Year Study)

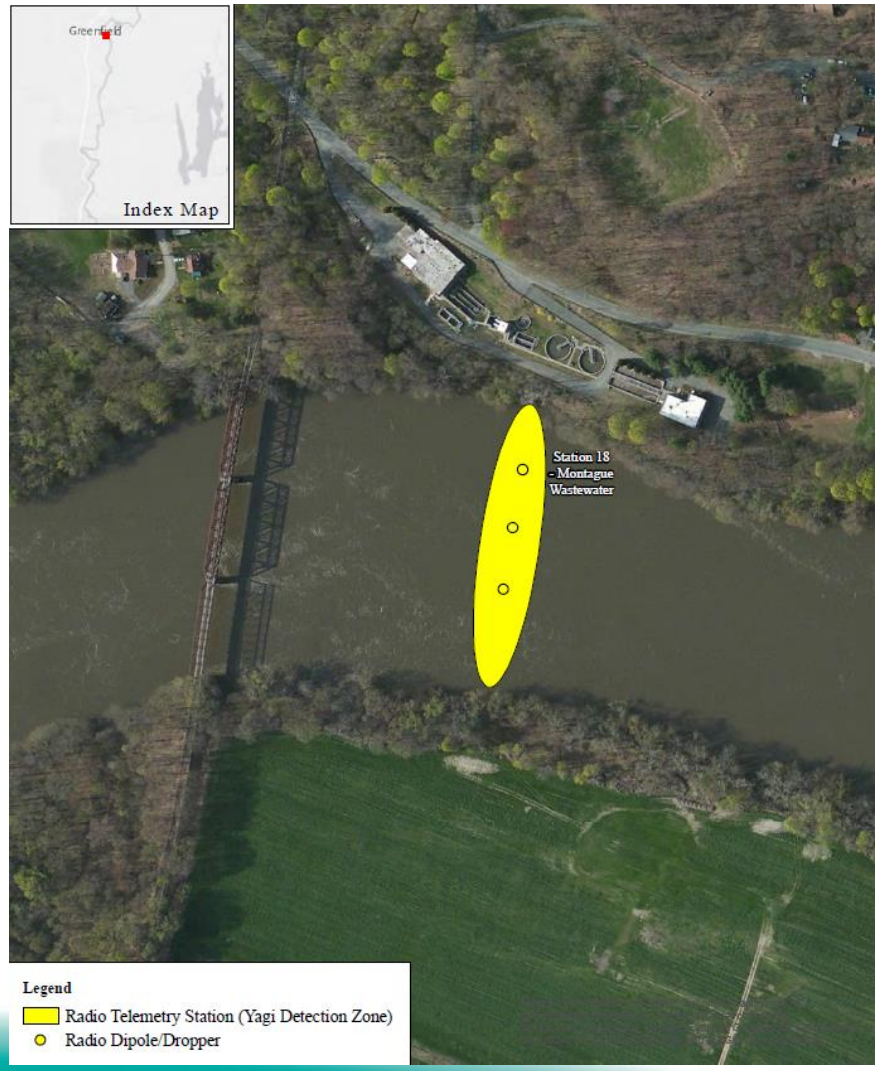
Telemetry Stations: Upstream to Downstream



3.3.5-Downstream Passage of American Eel (2-Year Study)

Telemetry Stations





3.3.5-Downstream Passage of American Eel (2-Year Study)

Eel Transport and Holding:

- Eels flown from Canada to Mass
- Held in three 1,000 gallon tanks
- Flow through ambient water from TFI
- Covered with 1/8 inch mesh to prevent escapement

3.3.5-Downstream Passage of American Eel (2-Year Study)

Eel Tagging:

- Tagged a total of 132 eel (2015)
- TX-PSC-I-80-M Pisces Transmitters (10x28mm)
- Two frequencies: 149.740 and 149.760
- An additional 165 Eel tagged by TransCanada

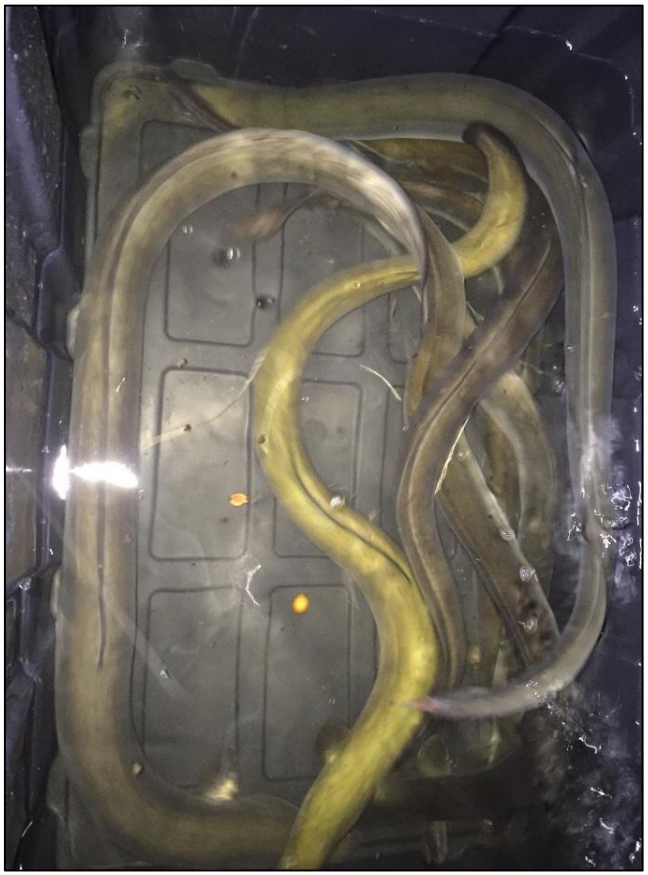
- Tags surgically implanted and sutured
- Eels anesthetized and allowed to recover for 6 to 8 hrs post tagging

3.3.5-Downstream Passage of American Eel (2-Year Study)

Eel Releases:

- Released over six days in the evenings between October 26 and November 4, 2015
- FirstLight Eels released at two sites:
  1) ~5 km upstream of NMPS Intake (n = 72)
  2) ~3 km upstream of Turners Falls Dam (n = 60)

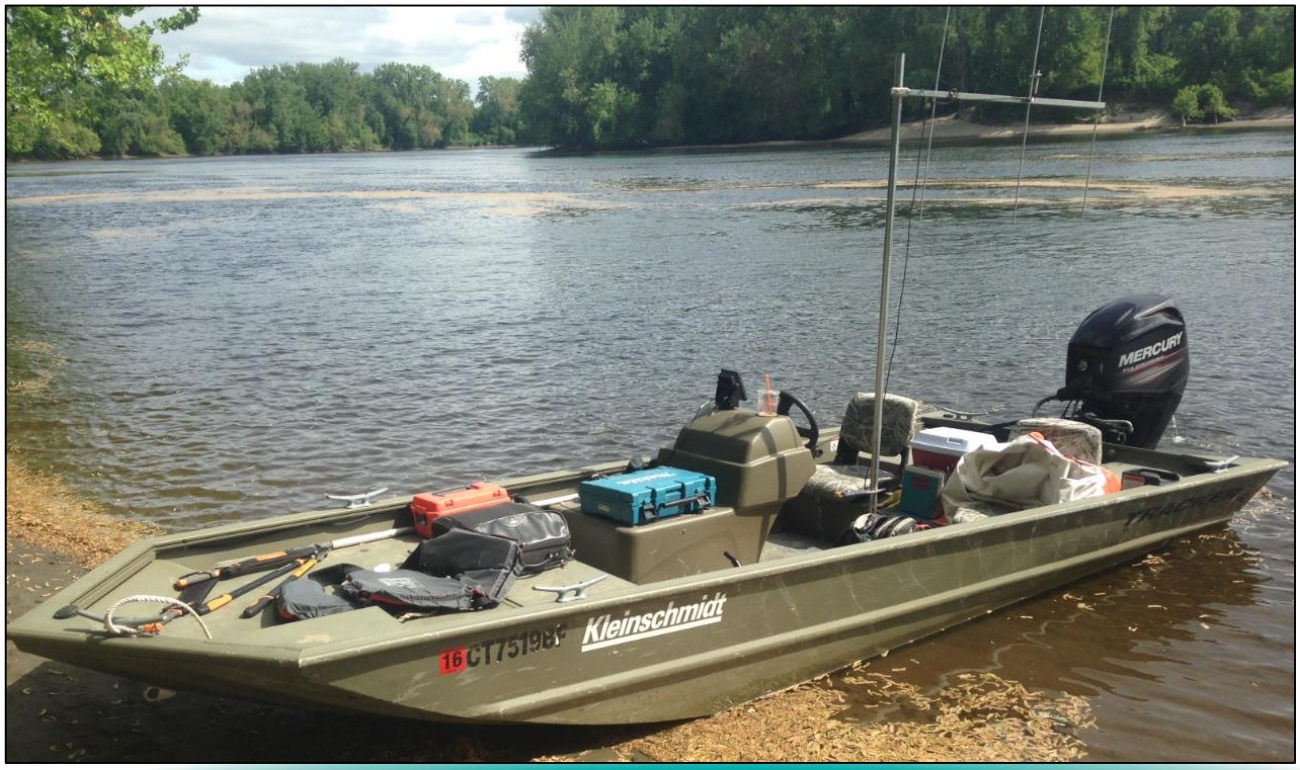
- TransCanada Eels released at four sites:
  1) Bellows Falls Impoundment (n = 48)
  2) Bellows Falls Canal (n = 17)
  3) Wilder Impoundment (n = 50)
  4) Vernon Impoundment (n = 50)



3.3.5-Downstream Passage of American Eel (2-Year Study)

Mobile Tracking:

- Eleven tracking events occurred between October 27 and November 19, 2015
- Performed twice weekly
- 5 km upstream of NMPS Intake to 5 km downstream of Cabot Station (excluded the TF bypass reach and power canal)



3.3.5-Downstream Passage of American Eel (2-Year Study)

Results

- DIDSON
- Overall Probability of Movement through Project
- Entrainment at NMPS
- Route Selection at Turners Falls Dam
- Escapement from Power Canal
- Turbine Survival (Hi-Z Tag)

3.3.5-Downstream Passage of American Eel (2-Year Study)

DIDSON

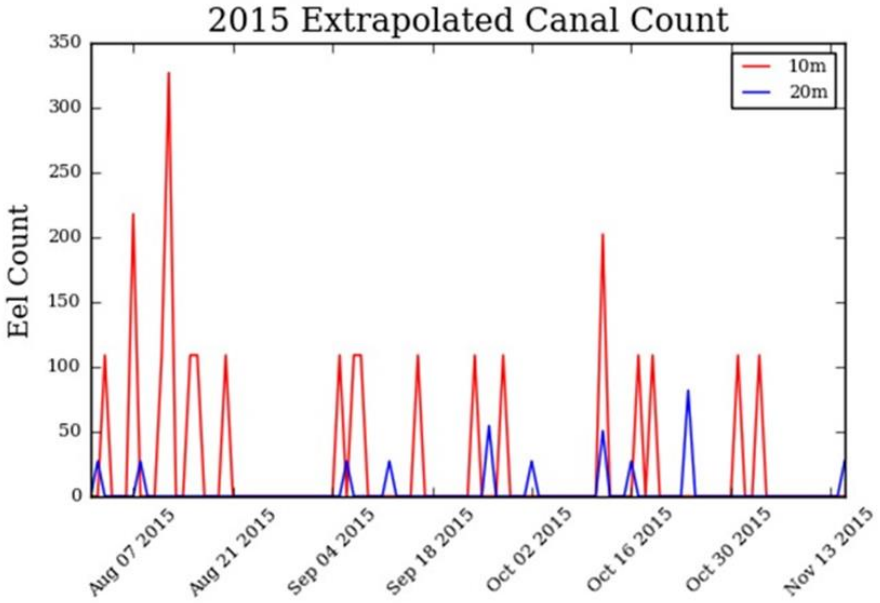
DIDSON Count Analysis

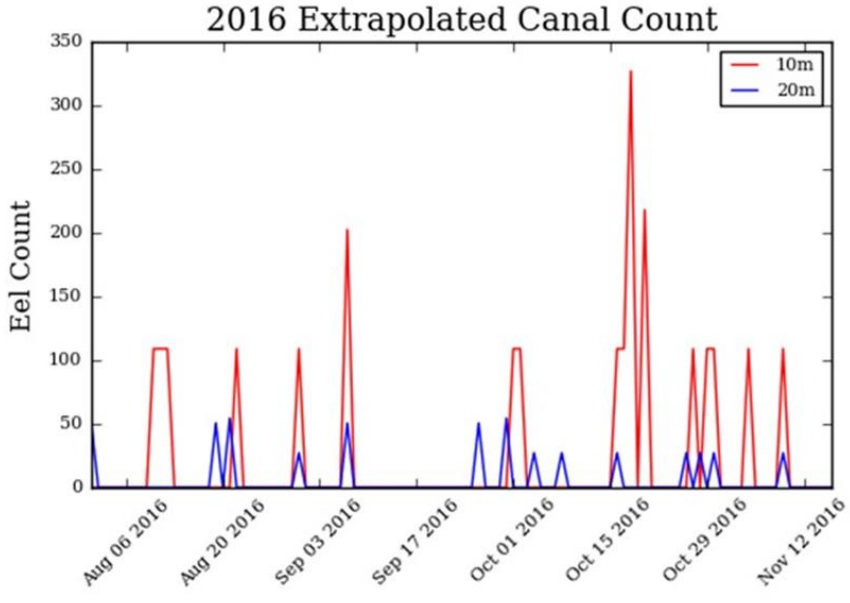
- With exception of annual canal drawdown, analyzed DIDSON camera data between 1700-0500 every day
  - 37,460 min. (2015)
  - 32,920 min. (2016)
- In total, 41 eels identified at 10 m range, 29 eels at 20 m range
- Raw counts were sparse
- Eel observed moving through canal between early August and mid-November during both years
  - 2015 – largest counts appeared in August
  - 2016 – largest counts mid-October

Extrapolated Counts by DIDSON range setting and year

Year	10 m	20 m
2015	2,382	378
2016	2,273	529

3.3.5-Downstream Passage of American Eel (2-Year Study)





3.3.5-Downstream Passage of American Eel (2-Year Study)

Overall probability of movement through project (CJS)

- 1) Impoundment recapture location consisted receivers of Shearer Farms (T1, T2), NMPS Intake (T3) , Gill Bank (T5, T6), the TFI Boat Barrier (T7, T8), and the Gatehouse (T9)
- 2) Project recapture location consisted of all receivers within the Bypass Reach (T20, T11, T12, T15) and Power Canal (T10, T13, T14, T171, T172, T173, T174)
- 3) Tailrace recapture location consisted of the two receivers within the tailrace (T17, T19)
- 4) Lower river recapture location at Montague (T18)
- 170 valid silver phased American Eel used
- 164 detected (recaptured) within impoundment
- 101 detected within the ‘project’
- 106 detected within the tailrace
- 10 detected at lower river

3.3.5-Downstream Passage of American Eel (2-Year Study)

CJS Estimated Arrival (survival) Rates ϕ

Parameter	Estimate (%)	Standard Error (%)	95% Confidence Interval	
			Lower Limit (%)	Upper Limit (%)
1: (ϕ) Release - Impoundment	1.0	0	1.0	1.0
2: (ϕ) Impoundment - Project	0.69	3.6	0.61	0.75
3: (ϕ) Project - Tailrace	0.91	2.8	0.85	0.97
4: (ϕ) Tailrace - Montague	0.31	110.36	0.0	1.0

CJS Estimated Recapture Rates p

Parameter	Estimate (%)	Standard Error (%)	95% Confidence Interval	
			Lower Limit (%)	Upper Limit (%)
5: (p) Impoundment	0.96	1.4	0.92	0.98
6: (p) Project	0.87	3.3	0.79	0.92
7: (p) Tailrace	1.0	0	0.99	1.0
8: (p) Montague	0.31	110.42	0.0	1.0

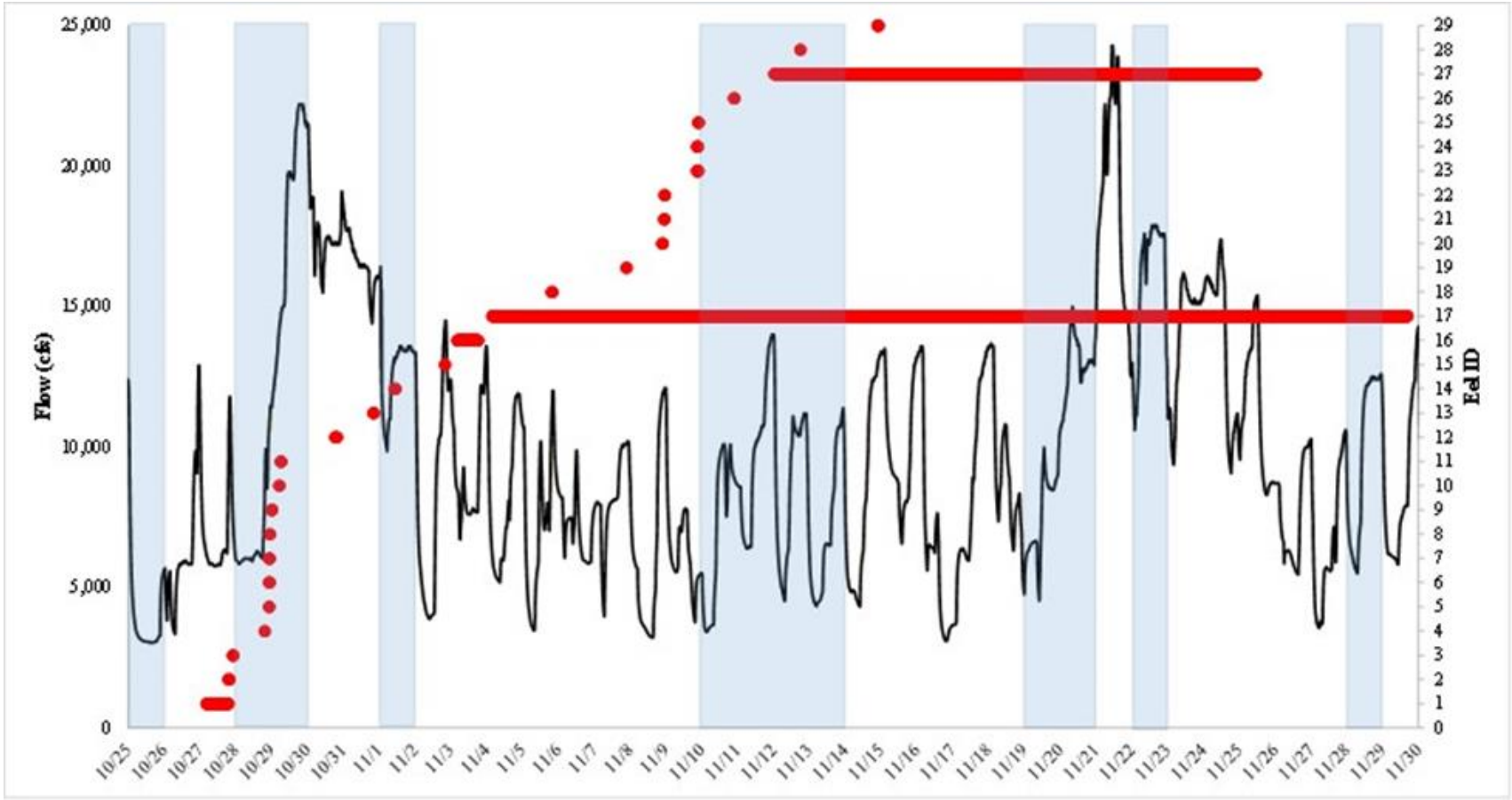
CJS estimates of arrival from release through the tailrace are 62.8% (1.0 * 0.69 * 0.91), which is very close to the raw count estimate of 62.4% (106/170). Therefore we have high confidence in the ability of the model to estimate survival through this reach, however due to limitations of the model and poor recapture at Montague, we lose confidence at the last station.

3.3.5-Downstream Passage of American Eel (2-Year Study)

What happened at Montague?

- All recaptured eel in Cabot Station tailrace were alive with no tags reverting to 11 second mortality signal
- After noting time at which eel left tailrace, searched for detections downstream at Montague Wastewater using the full dataset.
- 76 of the 106 eel detected in the tailrace were also detected at Montague, however only 10 made it through false positive reduction
  - Remaining fish classified as false positive because they were only detected once with no other detections in series
  - Of those 76 eel, 19 had detections after they left the tailrace – plausible?
- Cox PH fit to fish that transition into unknown state.
  - Best model found that fish are 67 times more likely to go missing from the tailrace at night when it rains

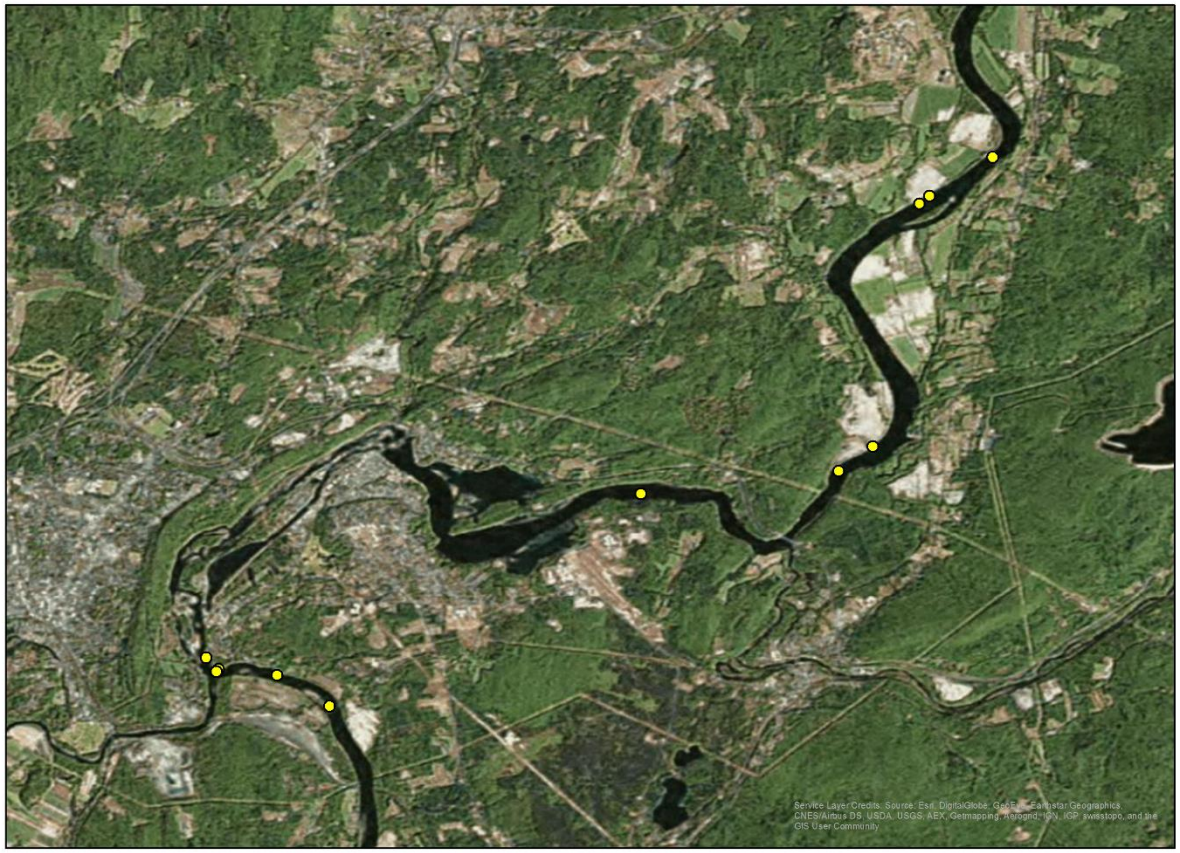
3.3.5-Downstream Passage of American Eel (2-Year Study)



3.3.5-Downstream Passage of American Eel (2-Year Study)

Mobile Tracking Mortalities

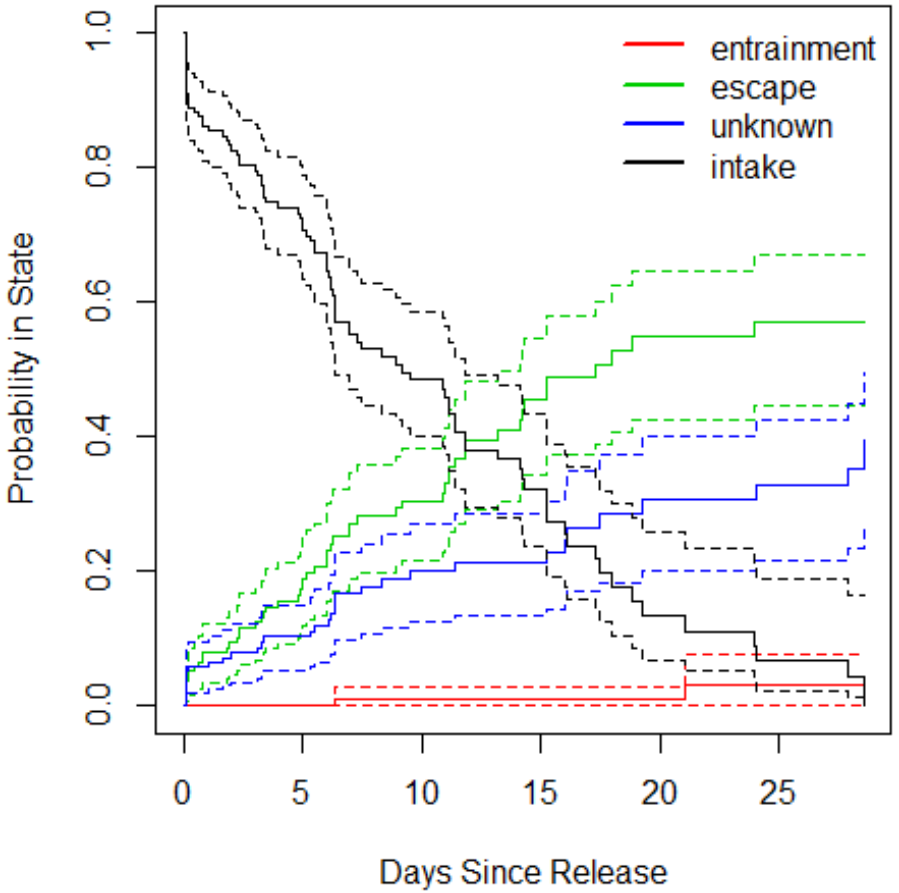
- 8 confirmed in impoundment
- 6 at or below Cabot Tailrace



3.3.5-Downstream Passage of American Eel (2-Year Study)

Entrainment at NMPS

- Fish are at risk of entrainment if they become attracted to the NMPS intake area (T3)
- Fish may transition from Shearer Farms (T1, T2) or Gill Bank (T5, T6)
- Modeled movement from the to the upper impoundment and CT River
- If a fish was last detected within the intake area before the end of the study, it was placed into an 'unknown' state
- Of the 170 valid American eel, 74 were attracted towards the intake, some more than once
  - 11 made 2 movements into the impoundment
  - 3 made 3 movements into the impoundment
- In total, 91 movements made from the intake
  - 55 escaped to the impoundment (55/91 = 60%)
  - 2 confirmed to have been entrained and detected at T4 (2/91 = 2%)
  - 34 transitioned into the unknown state (34/91 = 37%)



3.3.5-Downstream Passage of American Eel (2-Year Study)

Raw recapture counts within each reach by release cohort

Release Cohort	Intake	Impoundment	Entrainment	State-Unknown
TC	31	52	1	16
Lower Impoundment	11	48	1	3
Upper Impoundment	32	61	0	15
Sum	74	161	2	34

Descriptive statistics of event times (hours since release) from the NMPS intake to an absorbing state

Event	Min	25%	Median	75%	Max
Entrainment	153.3	241.3	329.3	417.3	505.3
Escape	2.2	50.2	131.3	267.6	575.5
Unknown State	2.3	10.1	138.7	261.6	685.0

3.3.5-Downstream Passage of American Eel (2-Year Study)

Cox PH output for time-to-impoundment

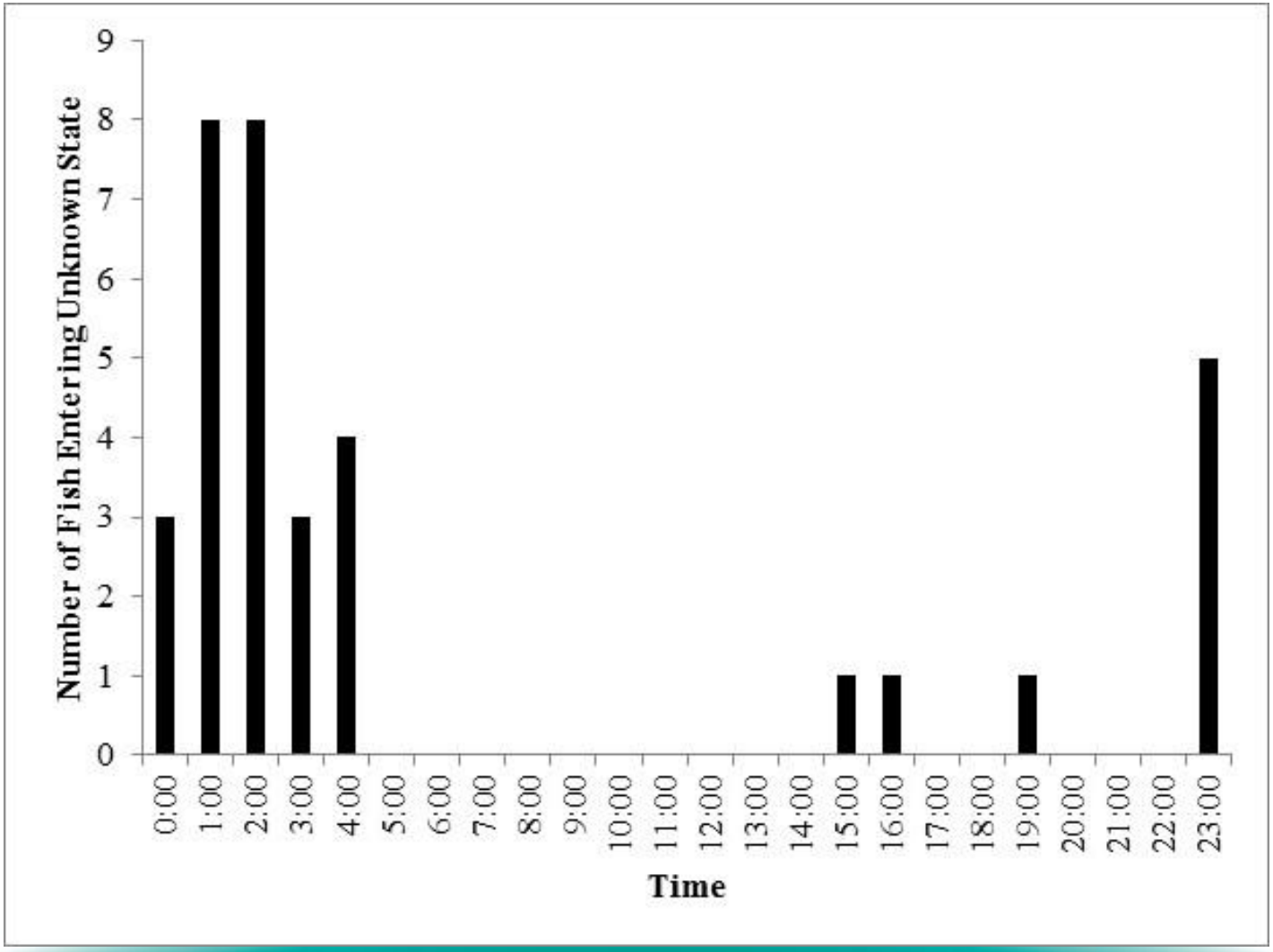
Model Number	Covariates	AIC	LR test	Hazard Ratio	SE	p	(+/-)
1	Rain (in)	822.13	0.06	2.86	0.54	0.051	(0.99,8.21)
2	NMPS ops (kcfs)	843.51	0.91	0.99	0.02	0.91	(0.93,1.06)
3	Diurnal (day)	822.92	<0.001	0.20	0.43	< 0.01	(0.08,0.46)
4	Night:Rain (in)	**818.97**	0.01	5.19	0.55	0.003	(1.74,15.43)
	Day:Rain (in)			0.29	1.53	0.42	(0.01,5.95)

Cox PH output for time-to-unknown state

Model Number	Covariates	AIC	LR test	Hazard Ratio	SE	p	(+/-)
1	Rain (in)	467.60	0.11	3.33	1.68	0.09	(0.81,13.58)
2	NMPS ops (kcfs)	**409.06**	<0.001	0.68	0.05	<0.001	(0.62,0.75)
3	Diurnal (day)	470.75	<0.001	0.05	1.01	0.003	(0.01,0.37)

3.3.5-Downstream Passage of American Eel (2-Year Study)

Were all fish that transitioned into the unknown state entrained?



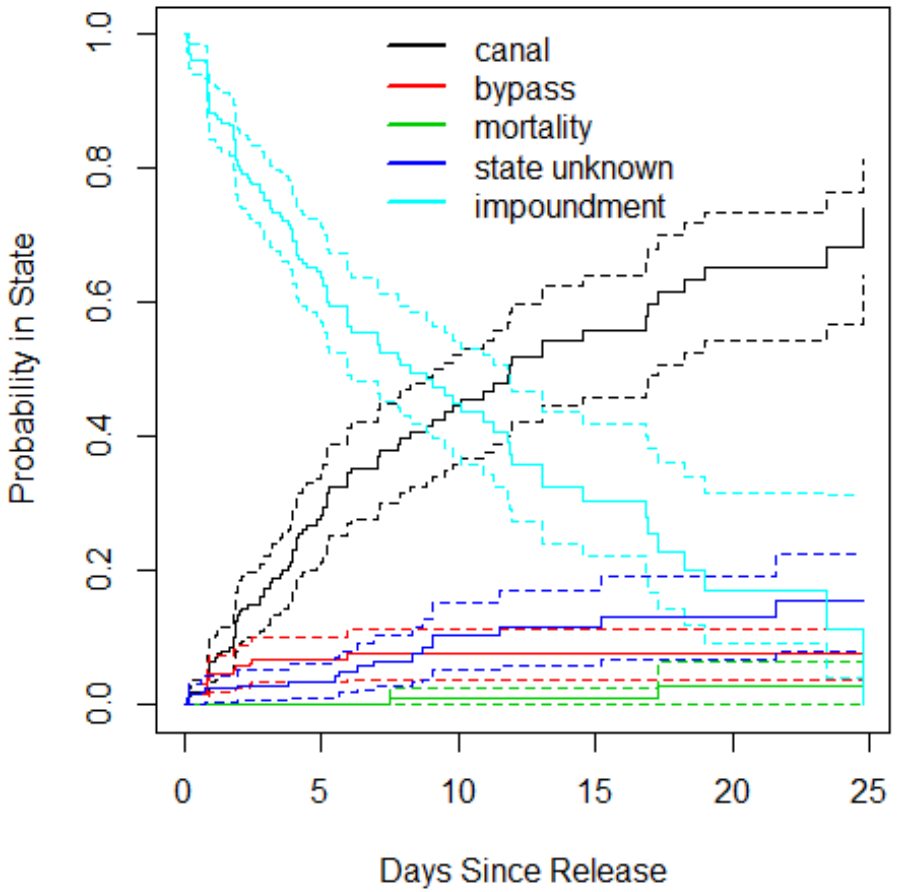
3.3.5-Downstream Passage of American Eel (2-Year Study)

Assessment of Passage at Turners Falls Dam

- Once arriving at TFD, fish can either pass through the gatehouse and into the power canal or they can pass over bascule gates and into bypass reach

- Some fish were found dead during mobile tracking, and some were never seen again (unknown state and presumed dead)

- Of 127 viable fish from all release cohorts,
  - 88 chose the canal (88/127 = 69%)
  - 16 chose the bypass (13/127 = 10%)



3.3.5-Downstream Passage of American Eel (2-Year Study)

Raw recapture counts within each reach by release cohort

Reach	TransCanada	Upper Impoundment	Lower Impoundment	All Cohorts
Impoundment	39	43	45	127
Canal	29	25	34	88
Bypass	2	7	4	13
Mortality	0	1	1	2
Unknown State	6	8	5	19

Descriptive statistics of event times (hours since release) from the TFI to an absorbing state

Event	Min	25%	Median	75%	Max
Canal	2.75	43.83	97.58	198.0	593.50
Bypass	20.10	21.11	32.67	53.83	143.50
Mortality	179.6	238.4	297.1	355.8	414.6
Unknown State	2.76	16.86	135.8	212.8	518.1

3.3.5-Downstream Passage of American Eel (2-Year Study)

Cox PH output for time-to-canal

Model Number	Covariates	AIC	LR test	Hazard Ratio	SE	p	(+/-)
1	Rain (in)	1647.84	0.001	4.18	0.42	< 0.001	(1.18,9.55)
2	Canal Flow (kcfs)	1678.07	< 0.001	1.11	0.03	< 0.001	(1.05,1.17)
3	Spill Flow (kcfs)	1683.06	0.004	1.10	0.02	< 0.001	(1.04,1.15)
4	Diurnal (Day = 1)	1636.65	< 0.001	0.10	0.42	< 0.001	(0.04,0.23)
5	Day:Rain (in)	**1634.166**	<0.001	0.11	1.55	0.172	(0.01,2.52)
	Night:Rain (in)			8.57	0.42	<0.001	(3.76,19.55)
6	Day: Canal Flow (kcfs)	1635.18	<0.001	0.85	0.07	0.02	(0.74,0.98)
	Night: Canal Flow (kcfs)			1.11	0.02	<0.001	(1.05,1.18)
7	Day: Spill Flow (kcfs)	1635.73	<0.001	0.76	0.26	0.292	(0.45,1.27)
	Night: Spill Flow (kcfs)			1.47	0.03	<0.001	(1.37.1.57)

3.3.5-Downstream Passage of American Eel (2-Year Study)

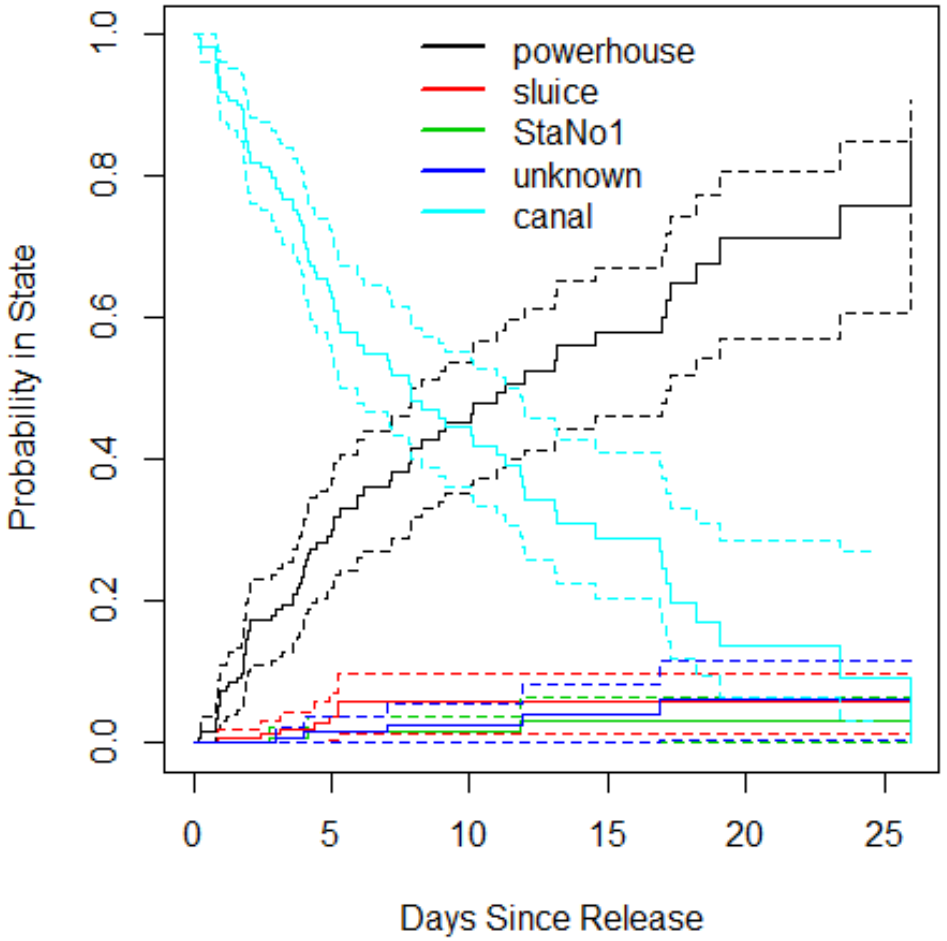
Cox PH output for time-to-bypass

Model Number	Covariates	AIC	LR test	Hazard Ratio	SE	p	(+/-)
1	Rain (in)	304.06	< 0.001	24.6	0.704	< 0.001	(6.19,97.76)
2	Diurnal (day)	305.29	< 0.001	0	3,772	0.996	(0, inf)
3	Spill Flow (kcfs)	313.82	0.003	1.19	0.04	< 0.001	(1.10,1.29)
4	Canal Flow (kcfs)	321.19	0.24	0.91	0.08	0.254	(0.78,1.07)
5	Rain: Spill Flow	300.38	< 0.001	2.18	0.14	< 0.001	(1.67, 2.86)
6	Day: Rain (in)	**295.71**	< 0.001	0.0	400	0.55	(0, inf)
	Night: Rain (in)			39.9	0.69	< 0.001	(10.3,155)

3.3.5-Downstream Passage of American Eel (2-Year Study)

Assessment of Passage Route through Canal

- Fish can pass via the Cabot Station Powerhouse, downstream bypass sluice or the Station No. 1 Powerhouse
- Final detection at T171, T172 or T173 followed by subsequent detections at T17 or T19 indicate passage through Cabot
- Final Detection at T174 with subsequent detections at T17 or T19 indicate passage via sluiceway
- Final Detection at T13 or T14 followed by detections at T15 indicate passage through Station No. 1
- Of 87 viable fish from all release cohorts
  - 72 passed via Cabot Station (72/87 = 83%)
  - 7 passed via sluiceway (7/87 = 8%)
  - 3 passed via Station No. 1 (3/87 = 3%)
  - 5 passed into tailrace via unknown route (5/87 = 6%)



3.3.5-Downstream Passage of American Eel (2-Year Study)

Raw recapture counts within each reach by release cohort

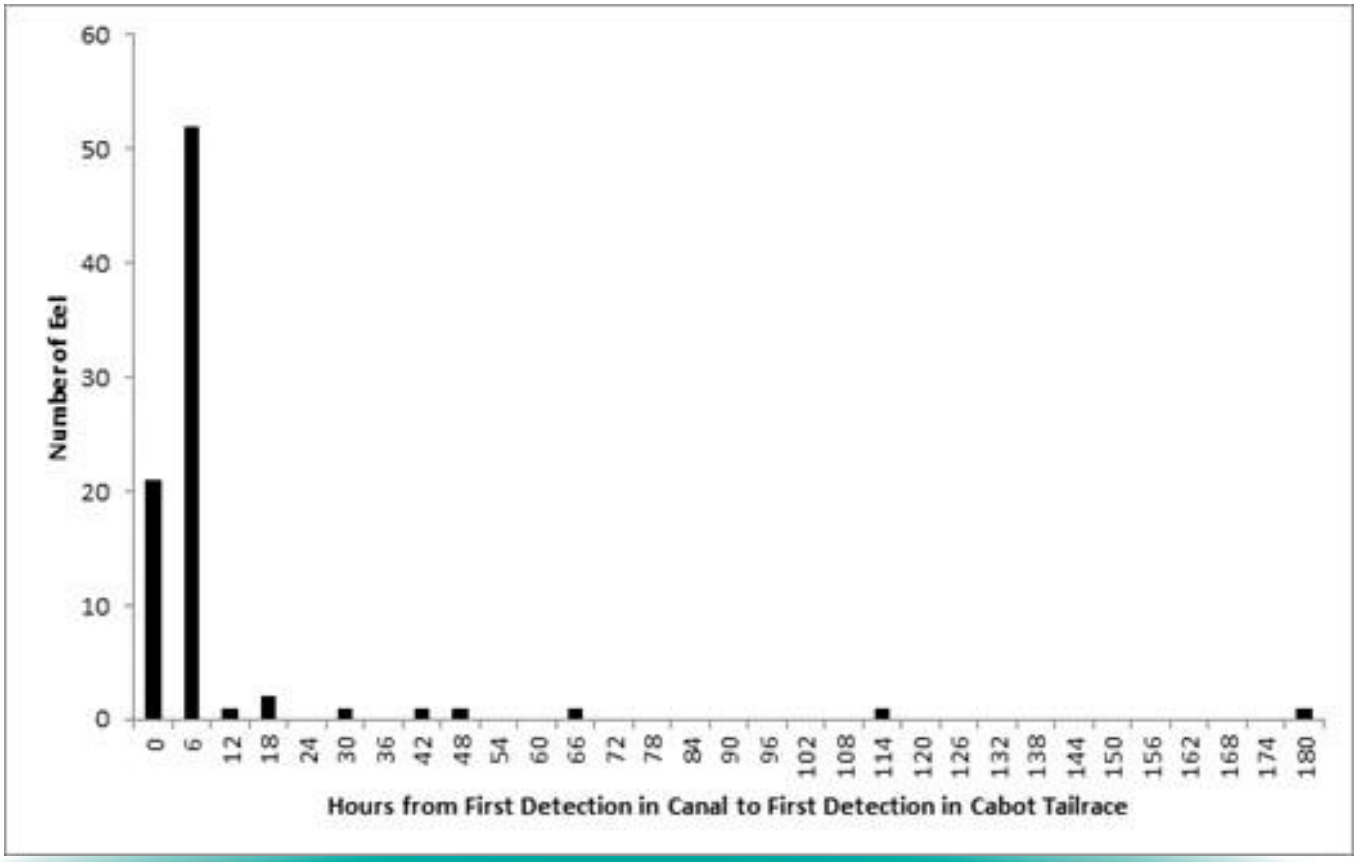
Route	TC	Upper Impoundment	Lower Impoundment	All Cohorts
Cabot Powerhouse	22	24	26	72
Downstream Bypass	4	0	3	7
Station 1 Powerhouse	2	0	1	3
Unknown Route	1	1	3	5

Descriptive statistics of event times (hours since release) from the Canal to an absorbing state

Event	Min	25%	Median	75%	Max
Cabot Powerhouse	4.71	44.14	96.37	191.50	622.80
Downstream Bypass	21.96	66.44	104.90	121.80	125.90
Station 1 Powerhouse	66.52	82.72	98.92	191.50	284.20
Unknown Route	70.83	94.98	169.10	285.00	404.20

3.3.5-Downstream Passage of American Eel (2-Year Study)

Histogram of durations for all fish within the canal. The durations in hours were calculated between the first detection in the canal and the first detection within Cabot Tailrace. It appears that as fish are motivated to move in the impoundment and into the canal that most migrate through in one event, majority of durations are 6 hours or less



3.3.5-Downstream Passage of American Eel (2-Year Study)

Cox PH output for time-to-powerhouse passage

Model Number	Covariates	AIC	LR test	Hazard Ratio	SE	p	(+/-)
1	Diurnal (Day = 1)	914.51	<0.001	0.10	0.52	<0.001	(0.04,0.29)
2	Canal Flow (kcfs)	913.39	<0.001	1.28	0.04	<0.001	(1.18,1.39)
3	Delta Canal Flow (1000 ft^3/s^2)	949.31	0.15	<0.001	116	0.13	(0.00,1.1*10^{22})
4	Day: Canal Flow (kcfs)	**895.57**	<0.001	1.01	0.08	0.94	(0.86, 1.18)
	Night: Canal Flow (kcfs)			1.26	0.04	<0.001	(1.16, 1.36)

3.3.5-Downstream Passage of American Eel (2-Year Study)

Turbine Survival Test Hi-Z Tag Study

Summary of 1-hour and 48-hour survival rates and 90% CI (+/-) for each study site.

Station	Number Released	1-hour Survival Rate (90% CI +/-)	48-hour Survival Rate (90% CI +/-)
Cabot Station Unit 2	50	98 (3.3)	96.0 (4.6)
Station No. 1 Unit 2/3	30	62.1 (14.8)	62.1 (14.8)
Station No. 1 Unit 1	30	90.0 (9.1)	90.0 (9.1)
Bascule Gate 1 (combined)	95	86.8 (5.8)	82.9 (5.9)
1,500 cfs	35	88.2 (4.0)	88.2 (4.0)
2,500 cfs	30	85.7 (7.4)	85.7 (7.4)
5,000 cfs	30	86.2 (10.5)	86.2 (10.5)
Bascule Gate 4 (combined)	95	90.5 (4.9)	88.4 (5.4)
1,500 cfs	35	88.6 (8.7)	82.9 (10.5)
2,500 cfs	30	90.0 (9.1)	90.0 (9.1)
5,000 cfs	30	93.3 (7.6)	93.3 (7.6)
Combined Controls	25	100	100

3.3.5-Downstream Passage of American Eel (2-Year Study)

Conclusions

- Potential for entrainment at NMPS, Cox PH states that fish are more likely to transition into the unknown state at night when pumping flow is greatest – follow the flow
  - 69% of the of the released eels were expected to arrive in either the Bypass Reach or Cabot Power Canal.
- Eel are motivated to move at night when it rains, and appear to continue migrating through flood pulse
- Fish overwhelmingly choose canal (69%) and overwhelmingly pass via Cabot Powerhouse (83%) – follow the flow
  - They do so relatively quickly < 6 hours suggesting a single migratory event
- Hi-Z turbine test suggests high survival through Cabot Station with > 90% survival after 48 hours
- DIDSON count data did not find a seasonal peak

Process for Developing Sea Lamprey HSI Curves

Habitat Suitability Criteria (Kynard and Horgan 2013):

Velocity		Depth		Substrate	
Velocity (fps)	SI Value	Depth (ft)	SI Value	Substrate Class	SI Value
0.00	0.00	0.00	0.00	Detritus – 1	0.00
0.30	0.00	0.13	0.00	Mud/soft clay – 2	0.00
1.28	0.34	0.46	0.50	Silt – 3	0.00
2.26	1.00	0.79	1.00	Sand – 4	0.04
3.25	0.86	1.12	1.00	Gravel – 5	1.00
4.23	0.30	1.44	0.60	Cobble/Rubble – 6	0.50
5.22	0.12	1.77	0.40	Boulder – 7	0.02
6.20	0.08	2.20	0.20	Bedrock – 8	0.00
6.23	0.00	2.30	0.00		

Kleinschmidt Study Spring/Summer 2015:

Mean Velocity = 1.76 fps Range = (0.82 to 2.99)

Mean Depth = 2.98 ft Range = (1.53 to 4.59)

Dominant Substrate = Cobble/Gravel

Process for Developing Sea Lamprey HSI Curves

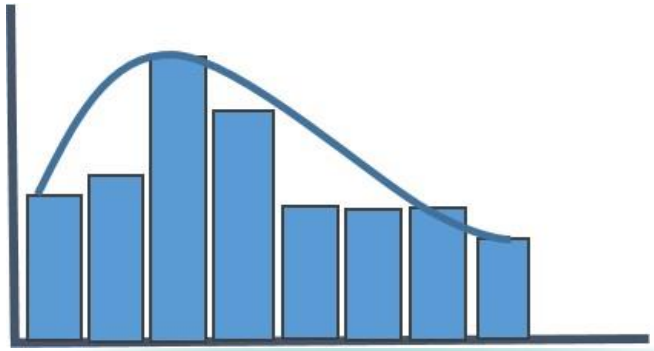
For sea lamprey spawning habitat suitability criteria for the PHABSIM model, there is interest in modifying the HSI curves, using observed data from the sea lamprey spawning study.

1. Propose to Develop Type II Utilization Curves
    a. Based on frequency analysis of fish observed and habitat variables measured.

2. Frequency curve is fit to a histogram then normalized so peak of the curve is 1.

3 Resulting function represents the probability of occurrence of variable given presence of fish.

4. Provide the new HSI curves to the stakeholders for their review.



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Power Resources

Developmental Resources

3.8.1-Operations Model

Study Goals and Objectives:

- To develop a baseline model of the Connecticut River Basin – specifically the reach from the Wilder Project to the Holyoke Project – which includes the following hydropower facilities:
  - TransCanada's Wilder, Bellow Falls, and Vernon Hydroelectric Projects,
  - FirstLight's Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project Project and
  - Holyoke Gas and Electric's Holyoke Hydroelectric Project

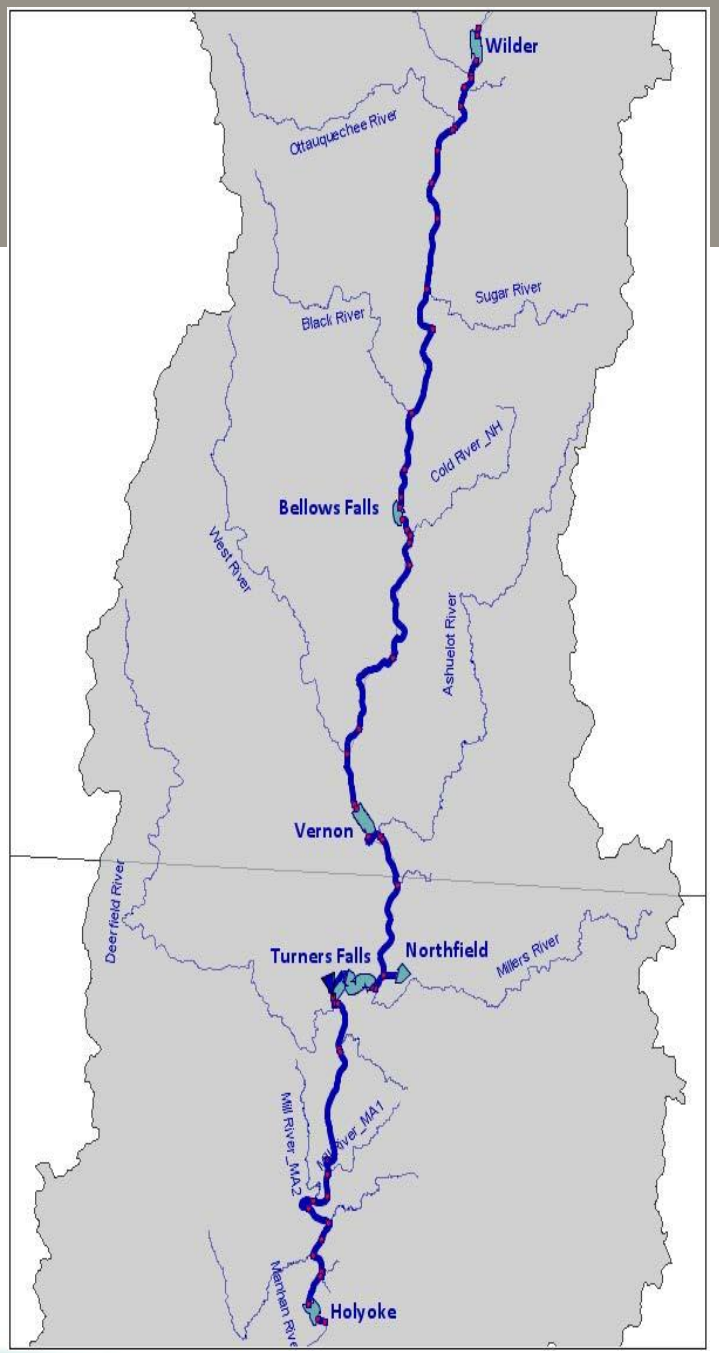
- The model will be used to determine the impact on hydropower generation and economics due to potential alternative modes of operation. Potential alternative modes of operation could include minimum bypass flows, changes in Turners Falls Impoundment (TFI) fluctuations, etc.

- Flow data generated from the model will be used to inform other studies, notably the instream flow study (habitat time series).

3.8.1-Operations Model

Model Development:

- Subset of Connecticut River Basin model
  - TransCanada Projects: Wilder, Bellows Falls, and Vernon
  - FirstLight Projects: Northfield Mountain and Turners Falls
  - Holyoke Gas and Electric Projects: Holyoke
- Model Updates
  - Physical (e.g. project configurations, reach routing)
  - Engineering (e.g. stage-storage-discharge rating curves, tailwater rating curves, power plant and pump capacities)
  - Operations data (e.g. pool fluctuation and flow release limitations)
- Data Collection (e.g. flows, WSELs)
  - USGS (gage observations and CRUISE simulation)
  - USACE (Connecticut River Basin model simulation)
  - FirstLight and TransCanada (observations)



3.8.1-Operations Model

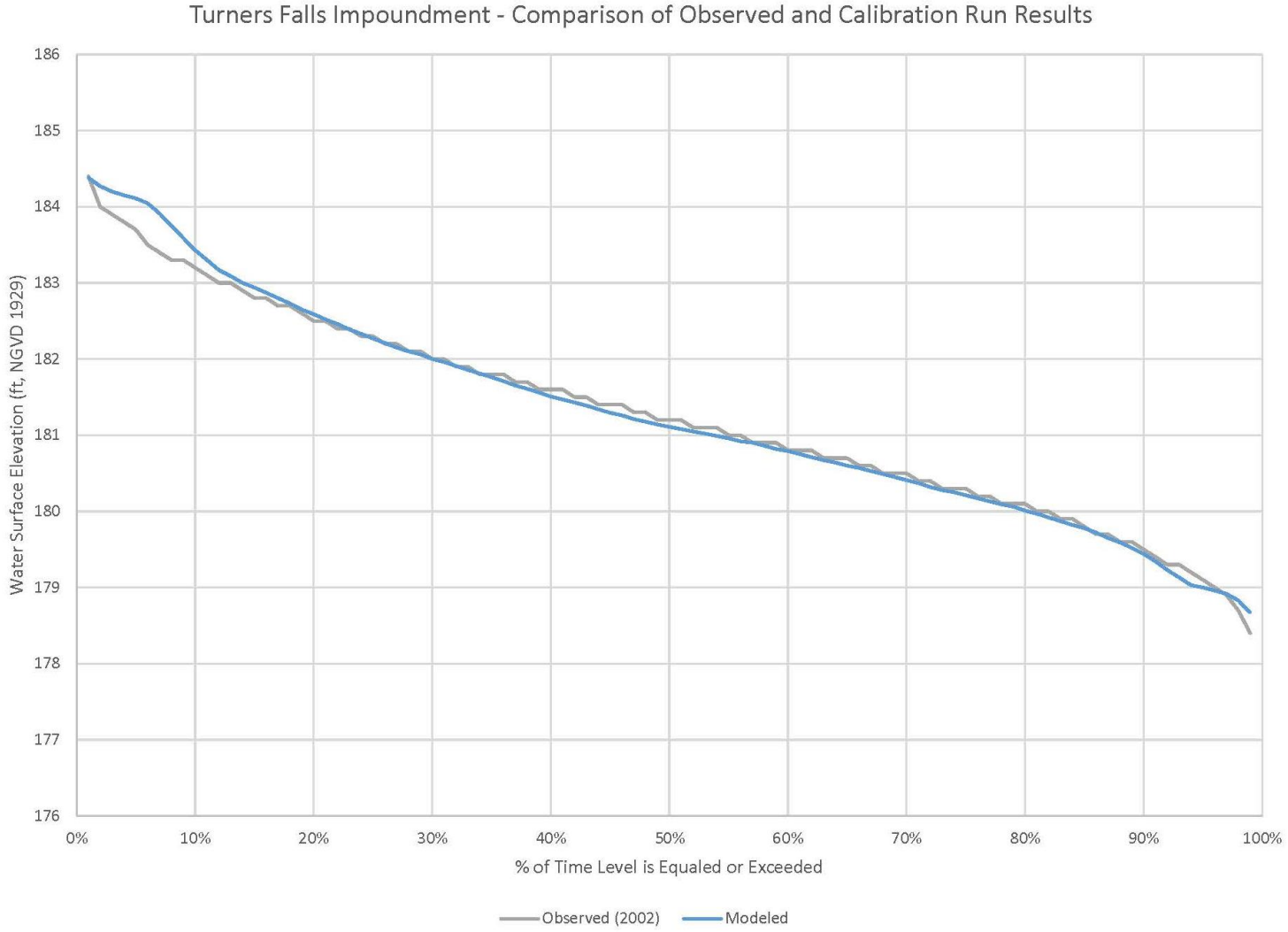
Model Calibration:

- Evaluated using calendar year 2002
  - Within available period of record for simulated flow data (USGS and USACE)
  - Flow duration curve at USGS Montague Gage generally representative of period of record from 1975-2016

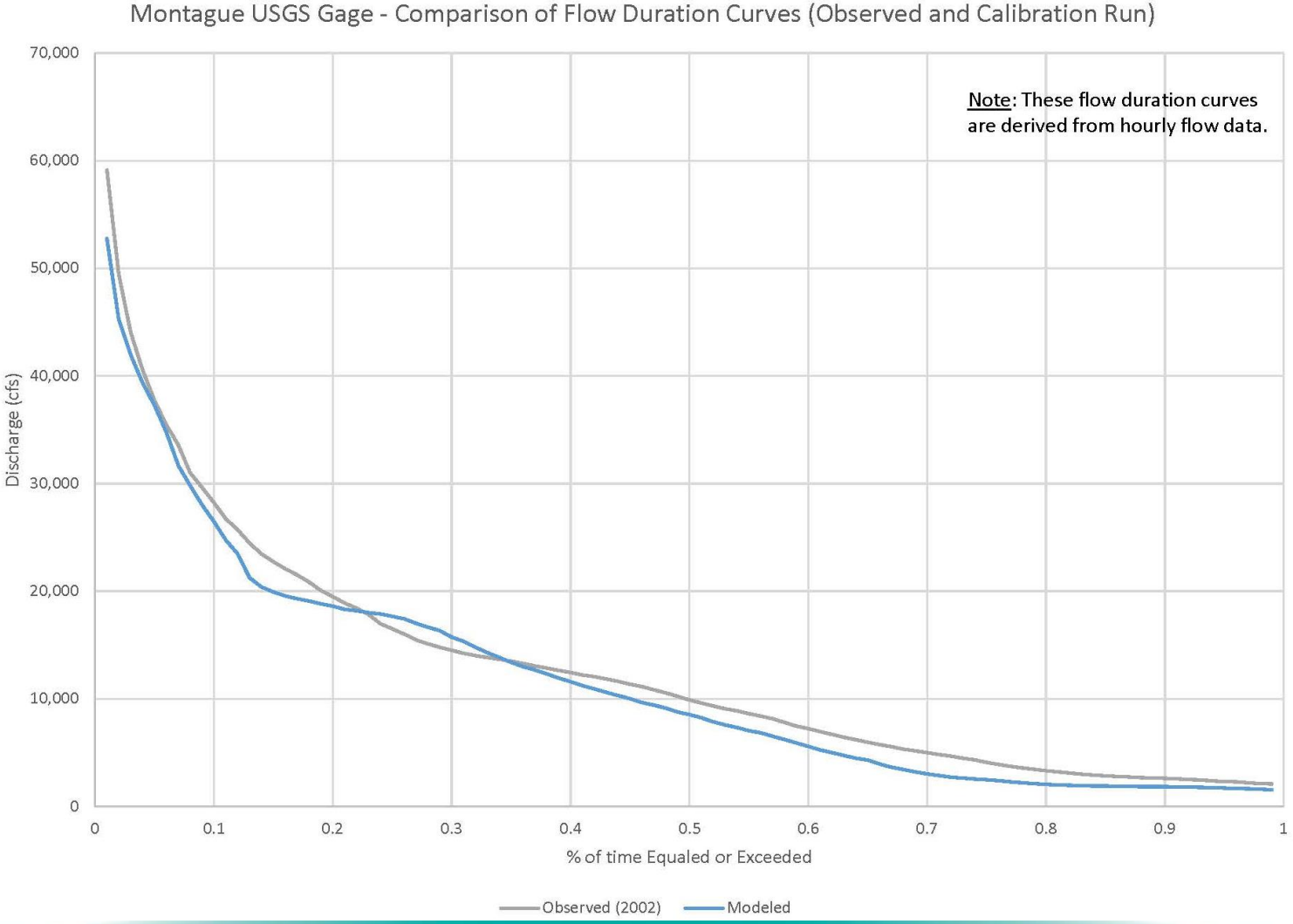
- Flow Inputs
  - Observed Vernon Discharge from TransCanada
  - Observed flows from Ashuelot, Millers, and Deerfield Rivers (all USGS gaged rivers)
  - Simulated flow data from USGS and USACE (only downstream of Turners Falls Project)

- Operations Data
  - Unit capacity and efficiencies consistent with machines circa 2002
  - Observed pumping and generation schedule for Northfield Mountain from 2002
  - Reservoir imbalance based on 2002 data

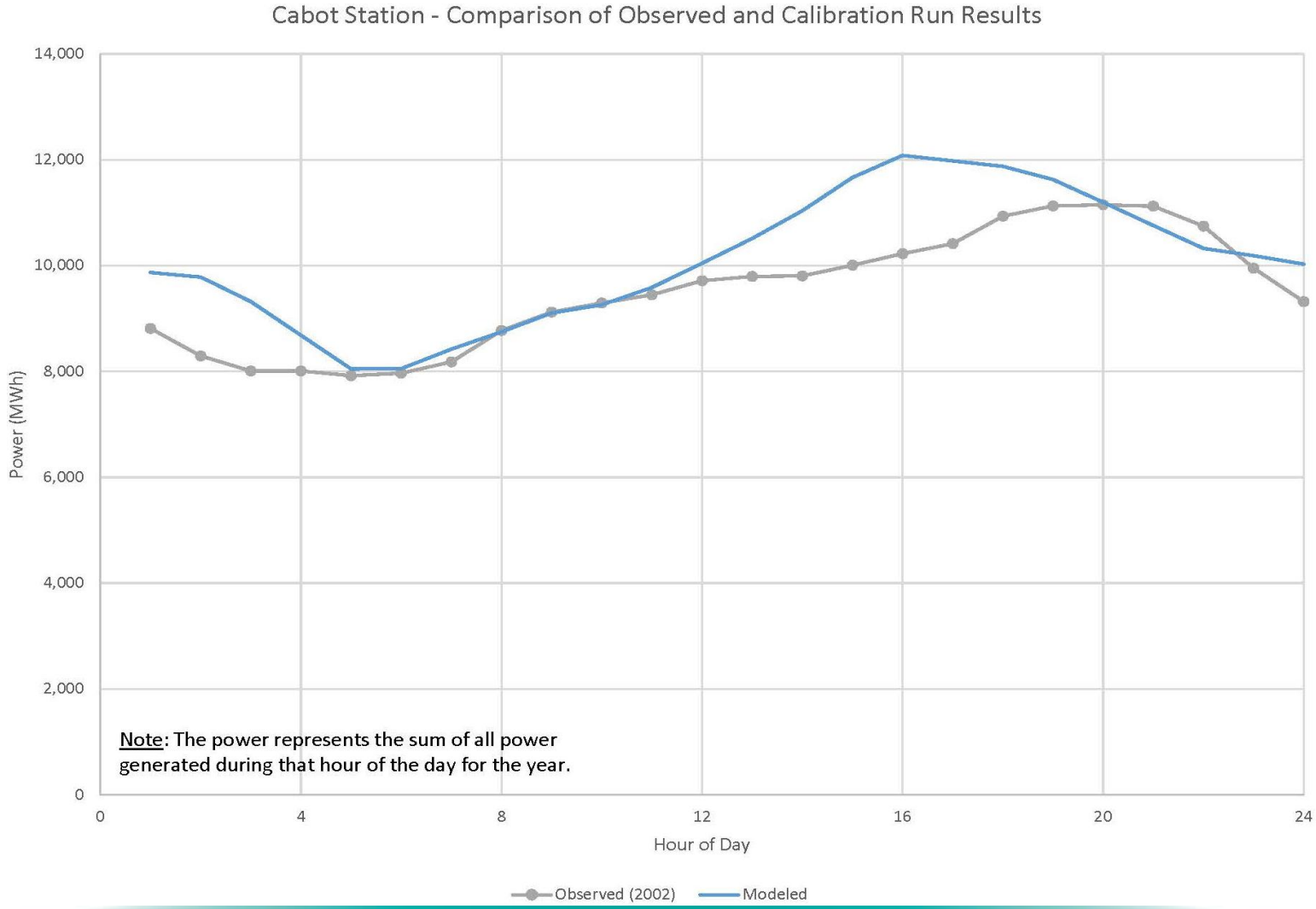
Calibration Results: TFI Annual Elevation Duration Curve (2002)



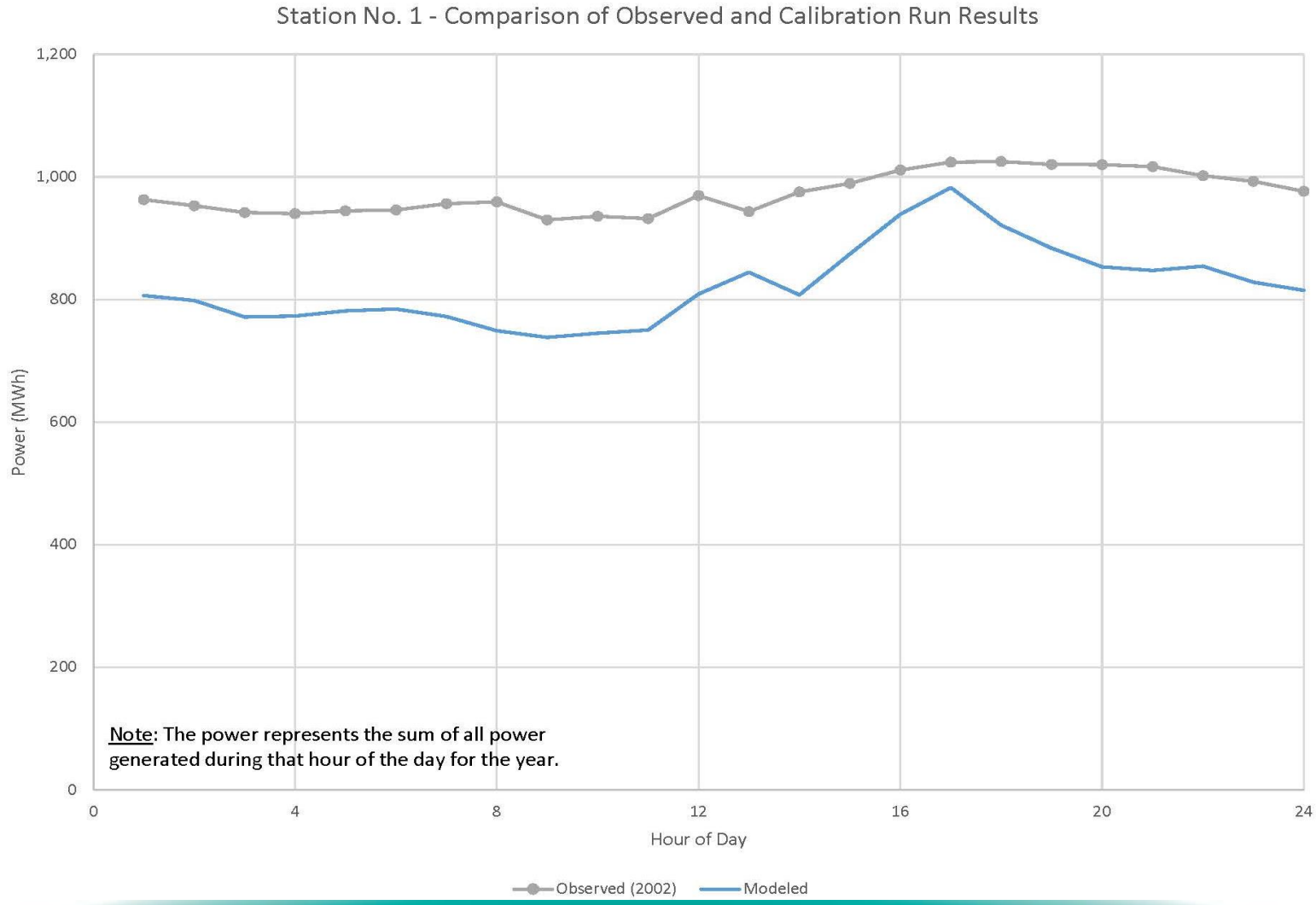
Calibration Results: Annual Flow Duration Curve at Montague Gage (2002)



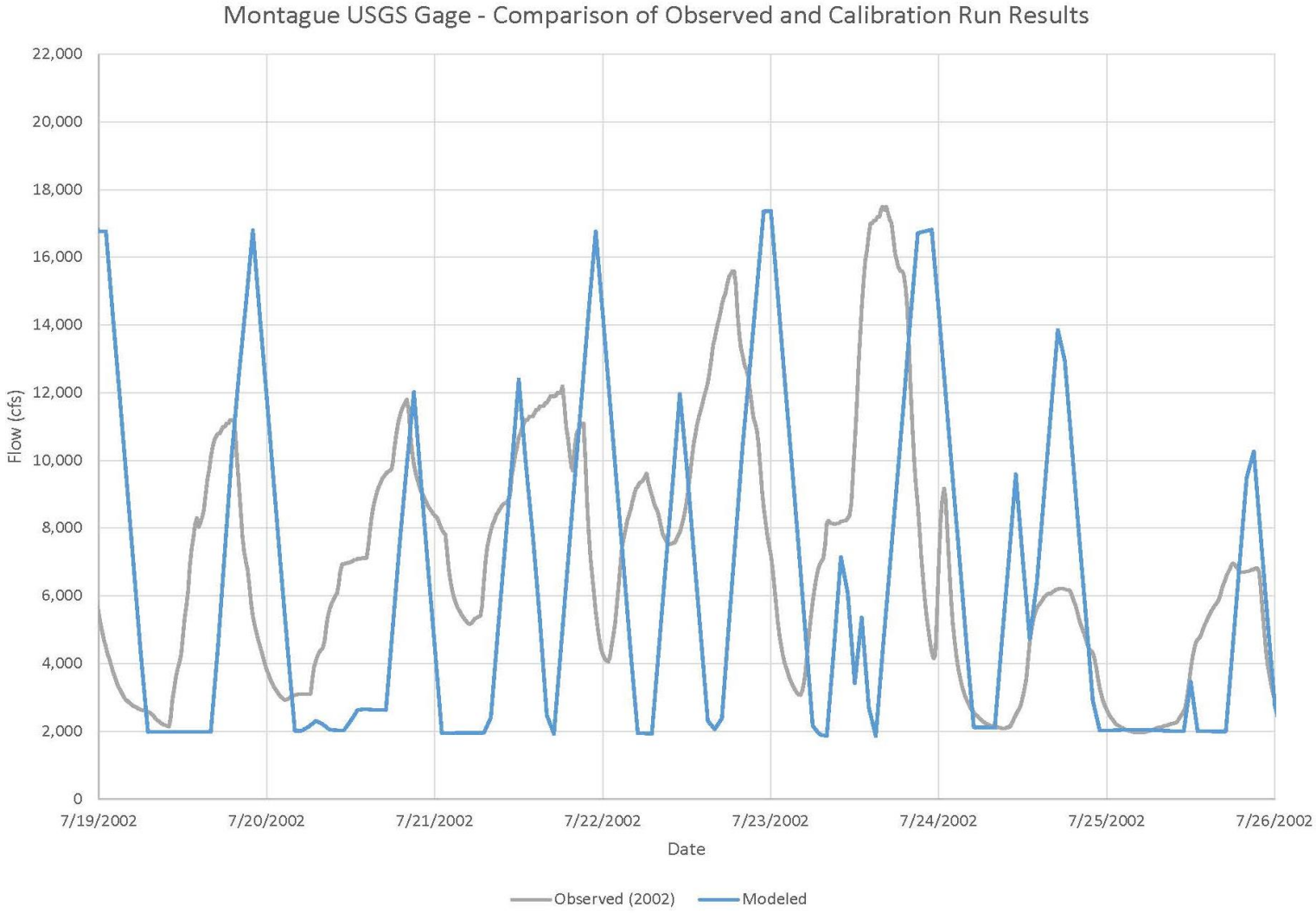
Calibration Results: Cabot- Timing of Generation during Day



Calibration Results: Station No. 1- Timing of Generation during Day



Calibration Results: Magnitude of Flows at Montague Gage

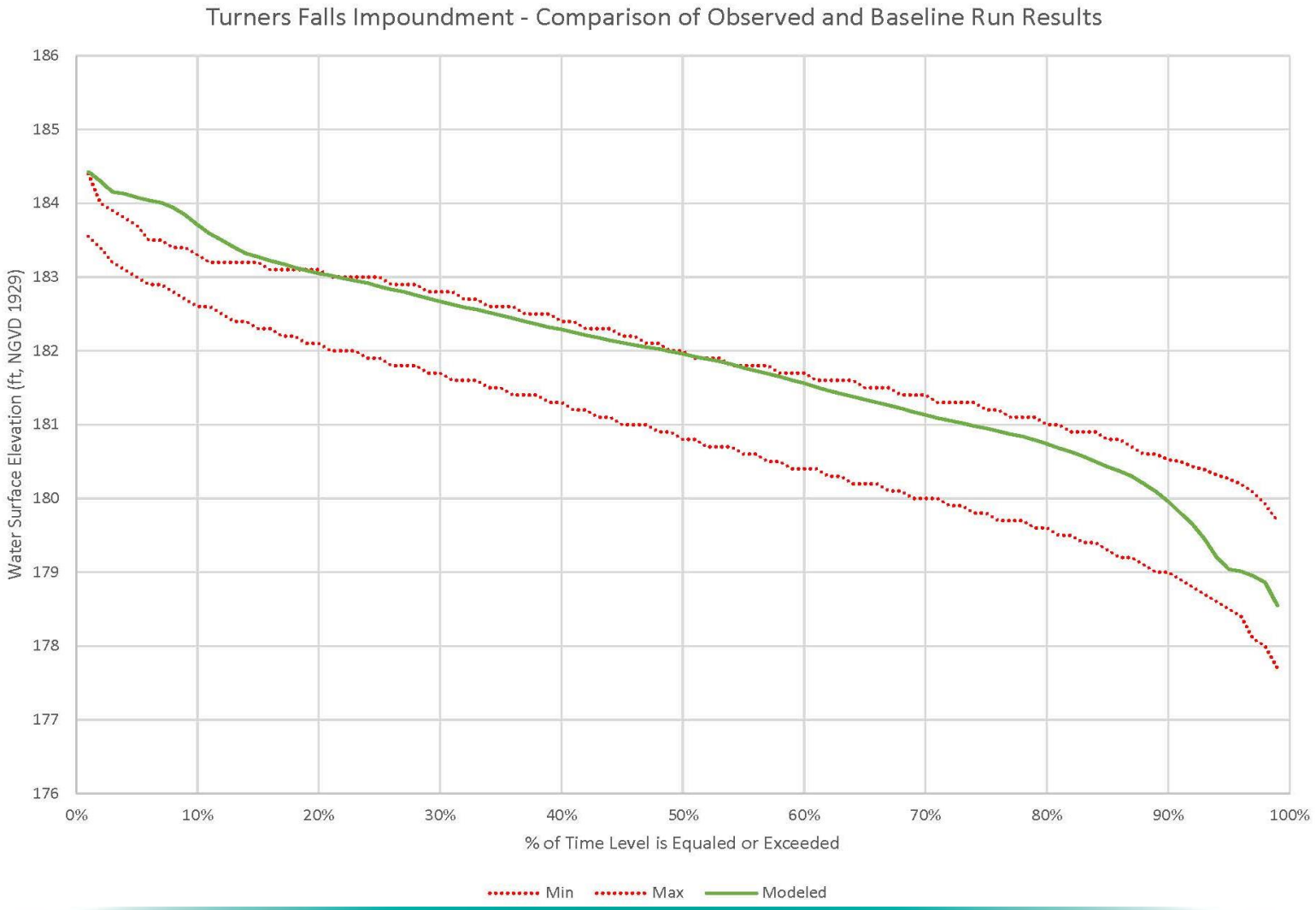


3.8.1-Operations Model

Calibration Results:

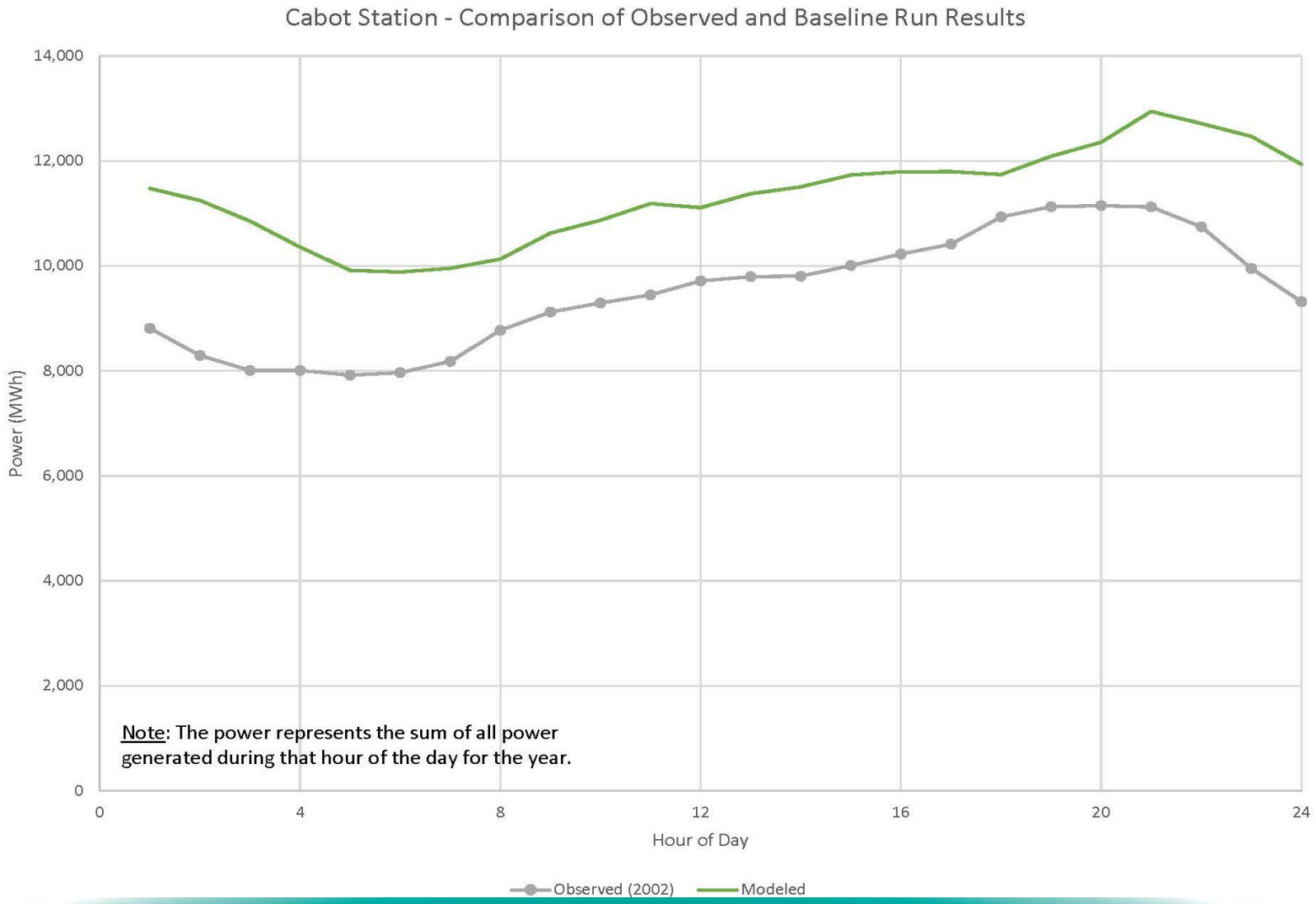
Project	Station	Observed Generation (MWh/yr)	Modeled Generation (MWh/yr)	Difference
Northfield Mountain	Northfield Station	1,327,953	1,294,774	-2.5%
Turners Falls	Cabot Station	228,123	242,179	+6.2%
	Station No. 1	23,368	19,730	-15.6%
Total		**1,579,444**	**1,556,682**	**-1.4%**

Baseline Results:



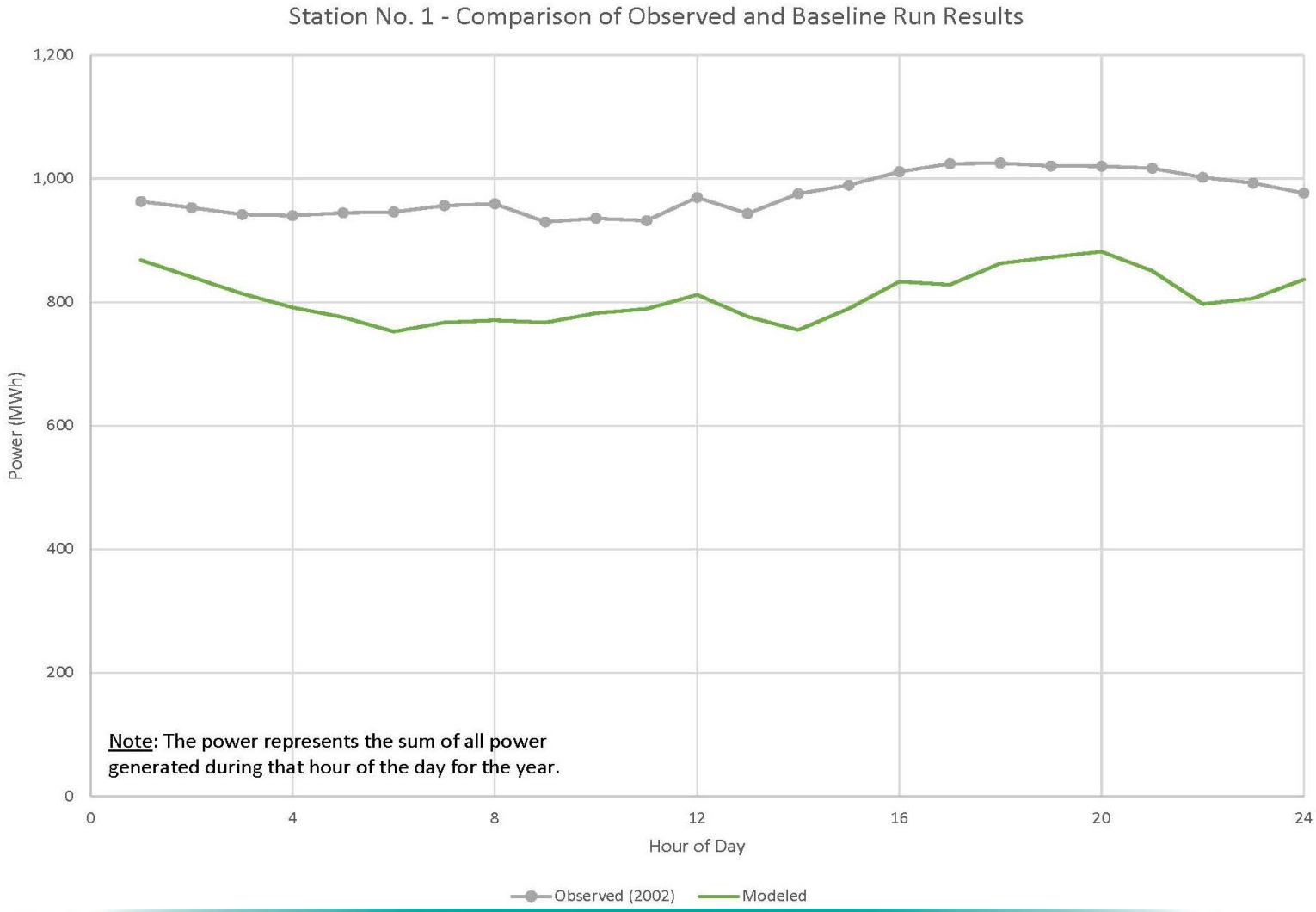
3.8.1-Operations Model

Baseline Results:



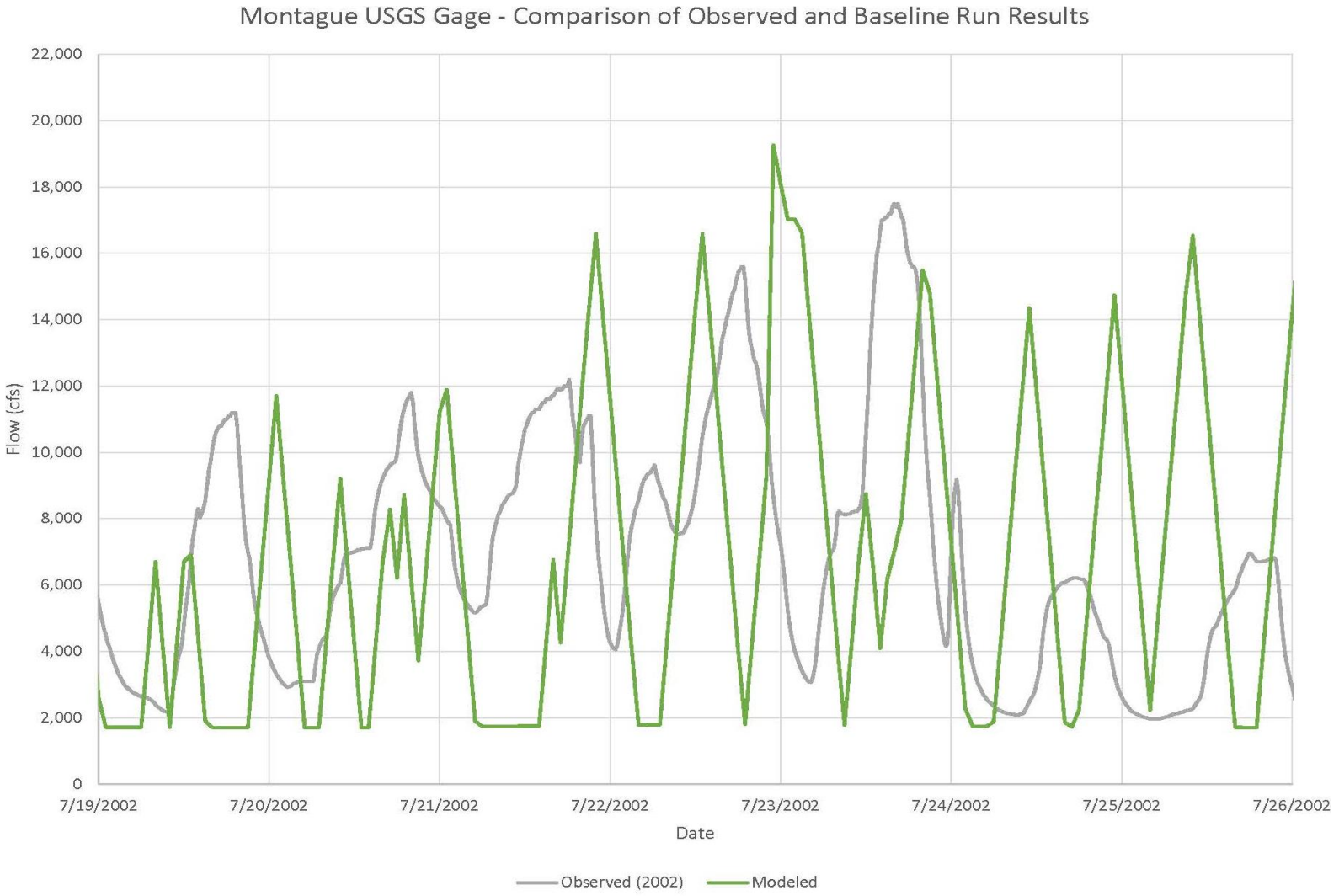
3.8.1-Operations Model

Baseline Results:



3.8.1-Operations Model

Baseline Results:



3.8.1-Operations Model

Baseline Results:

Project	Station	Modeled Generation (MWh/yr)
Northfield Mountain	Northfield Station	923,968
Turners Falls	Cabot Station	272,045
	Station No. 1	19,420
Total		**1,215,433**

3.8.1-Operations Model

Production Runs:

- Modifications to the baseline model may be made to evaluate the effects on generation, water surface elevations, and flows of a new operating regime
- The model may also be used to address stakeholder comments on other studies
- Changes to the FirstLight model necessary for completing future potential production runs could require that the calibration and baseline runs be reanalyzed.

3.8.1-Operations Model

Discussion:

- An existing model was modified to better simulate the operations of the Turners Falls and Northfield Mountain Projects
- Model calibration to calendar year 2002 provided acceptable agreement in TFI water surface elevations, as well as timing and total generation output
- A baseline run representing current operations provided results within the expected range
- The model may be used for future potential production runs